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Forecasting Co_2 Emissions from Fuel Consumption with Machine Learning Approaches

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ABSTRACT
African countries are the main of the importers of used vehicles from Japan and Europe, some countries install the regulations for limitation of poorest quality vehicles, and such regulations are often poorly enforced, due to corruption. The old cars have higher CO_2 emissions and are dumped on us because they are no longer considered as fit for the roads in their countries of origin, many of those used cars are being used for commercial, public transportation, and are causing roads accident which increases deaths rate in African roads as different consulted reports stated. To understand the relationship between the CO_2 emissions, vehicles imported annually, the amount of fuel consumed, and other parameters that make the huge volume of data need advanced methods such as machine learning techniques in data analysis to showcase the issue in Eastern, Southern and Western African countries and then predict the emission of CO_2 in these countries in case the situation remains the same as it is nowadays which is the main objective of this study. In this study, we are mainly aim at assessing the past and current, and predicting CO_2 emissions in Africa. The output indicated that the LR has the ability of predicting the CO_2 emission from solid fuel with MAPE with meaningful error rates at 1.024% and 1.901% for predicting AES and USA respectively and when predicting CO_2 emission from liquid fuel with LR, findings present the 2.36% and 2.85% for MAE when predicting Japan and USA emissions; For solid fuel are well predicted by SVM with MAPE at 1.28%, 4.28%, and 1.43% consecutively for AES, AWC, and EU.
Keywords: CO_2, used vehicles, Machine learning, WEKA, Forecasting

I. INTRODUCTION

The market for cars and commercial vehicles is growing rapidly but for the most part is supplied by imports of used vehicles. A number of countries are putting plans in place to expand production. (Anthony, B. et al, 2017). Importation of cheap secondhand vehicles from Japan is big business across many African countries whose citizens cannot afford new ones. The United Nations Environment Program (UNEP) said in an October report that Africa accounts for about 40% of all vehicles exported from major automobile manufacturing hubs such as Japan, Europe and the US (Tawanda, 2020).

Between 2015 and 2018, the European Union, Japan, and the United States exported 14 million used vehicles worldwide with 40 percent of which went to African countries; this is aligned with the low prices of these vehicles that create high demand for them in Africa and other developing regions, but there is a trade-off to the low cost: They are often poor quality and would fail roadworthiness tests in exporting countries (Payce, 2020).

The European Union which accounts for over half of global exports sent a majority of its used cars to countries across west and north Africa. It is the latest indicator of a long-running trend which sees African countries dependent on importing used cars mainly from Europe and North America to keep up with growing middle-class demand, especially given the gaps in local production (Yomi, 2020).

British broadcasting corporations (McGrath, 2020) wrote that: “four out of five poor quality vehicles exported from Europe, Japan and the US were sold to poorer countries, with more than half going to Africa. Experts say that up to 80% failed to meet minimum safety and environmental standards in exporting countries. As well as causing accidents, these cars make air pollution worse and contribute heavily to climate change. Many of the vehicles have also been tampered with to remove valuable parts.”

Many second-hand vehicles shipped to Africa from Japan are believed to have failed, or were about to fail, pollution tests there, according to the U.N. Environment Program. But in many parts of Africa such regulations are often poorly enforced, and rampant corruption ensures that used

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vehicles can slip by any controls. The old cars have higher emissions and are dumped on us because they are no longer considered as fit for the roads in their countries of origin, many of them are being used for commercial transportation," he said of the imports (Chanchal, 2020). Vehicle emissions are a prime source of small particulates and nitrogen oxides, which cause urban air pollution; countries have to stop exporting vehicles that are no longer roadworthy, and fail environment and safety inspections while importing countries must adopt up-to-date regulations (Duncan, 2021).

Based on these proofs and findings from various reports on used vehicles imported in developing countries it is found that these poor quality used vehicles are the main cause of more road accidents, a report of (Duncan, 2021) stated that: "Africa has the world's highest road traffic fatality rates with 246,000 deaths occurring annually, a number projected to rise to 514,000 in 2030, according to the World Health Organization"; additionally to these fatality and loss in population deaths, the used vehicles are sources of air pollution by emission of CO_2 through fuel combustion.

Supported by the above literatures, this research is about assessing the impact of cars in air pollution through CO_2 emissions from solid and liquid fuel consumption (% of total), for the Eastern, Southern, and Western Africa regions, and predicting the quantity of gas to be emitted in the coming years if African authorities do not ban the import of used vehicles from the EU, Japan, and US using deep learning approaches.

From various researches, the data scientists are trying to run from the past to predict the future using data mining techniques; some of the datasets analyzed are those related to the transportation in Africa, where different data were collected to understand the situation of vehicles imported from western countries towards low-income countries such as African, south American, and west Asian countries where these vehicles contribute to the pollution of the air in these countries.

Research like (Ayetor, G.K., 2021) in their paper examine the present and future vehicle regulations in various countries in Africa and their effect in curbing used vehicle import, new vehicle sales, and production. The investigation includes providing detailed data for used vehicle import into Africa from 2015 to 2019.According to (Marco, 2021), in his work presents a simple but significant application of a ML approach, the Support Vector Machine (SVM) to the estimation of CO_2 emission from electricity generation. The CO_2 emission was estimate in a framework of Cost-Effectiveness Analysis between two competing technologies in electricity generation using data for Combined Cycle Gas Turbine Plant (CCGT) provided by IEA for Italy in 2020. Both and many other researchers are struggling to tackle on the emission of CO_2 in global view and considering various aspects of causes to this problem but they are not thinking about the used vehicles sold to Africans from developed countries as the cause of the air pollution in these developing countries.

That why this study is under process from which it is proposing the application of deep learning techniques in data analysis to showcase the issue in Eastern, Southern and Western African countries and then predict the emission of CO_2 in these countries in case the situation remains the same as it is nowadays.

The main objectives of this study are aligned with the topic, below are the cited objectives:

- Assessing the CO_2 emission from fuel (solid and liquid) consumption in the Eastern, Southern, Central, and Western regions
- Predicting the quantity of CO_2 emission from solid consumption by learning the dataset with SVM and Linear regression models to find which model is fitting the most on the dataset

II. LITERATURE REVIEW

To assure the significance of this study, below works were reviewed to identify their gaps and weaknesses that may be addressed by this research.

An Approach for Predicting CO_2 Emissions using Data Mining Techniques, a research paper by (Douglas, K. and Hazael, P., 2017); researchers indicated that CO_2 is projected to continuously increase based on simulation and use SMOreg algorithm as data mining tools relying on historical data. Predicated emission values for both transportation and manufacturing sector show a continuous domination of these two sectors regarding carbon emission. Research has shown that the main contributing factors to climate change are greenhouse gases and carbon dioxide (CO_2) is the main greenhouse gas contributing to climate change; Further research, provides evidence that 80% of total CO_2 emissions globally come from fossil fuel combustion. The second question was to find out which sector had the highest contribution of emissions and lastly make predictions for the next five years regarding the rate of carbon emission for each sector.

This paper above does not tackle properly to the role of data mining in the determination of CO2 emission from the various sources and how

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they pollute the air; they only run a single algorithm to train the dataset and they didn't show how built model performance has been evaluated; to contribute to these weaknesses, in this current study, data on CO2 emission from both solid and liquid fuel consumption (% in total) for the Eastern, Southern, and Western regions, will be collected to form a dataset; to analyze and mine the dataset, I suggest two machine learning algorithms, LM and SVM, to be compared over the built dataset, then their performance will be evaluated using Root Mean Square Error (RMSE), the Mean Average Error (MAE) and the Mean Average Percentage Error (MAPE) parameters.

Forecasting CO_2 emissions from energy, manufacturing and transport sectors in Pakistan: Statistical Vs Machine learning methods, a research by (Hakeem, U. R. et al, 2017). The purpose of this study is to evaluate the performance of statistical and machine learning methods for forecasting CO_2 emissions from energy, transport and manufacturing sectors of Pakistan and provide sector wise CO_2 mitigation strategies. CO_2 emissions from the energy sector account for 60% of global emissions, however, due to diverse national energy structures, the share of these emissions varies from country to country.

Box–Jenkins models are known as ARMA (Auto-Regressive Moving Average) and ARIMA (Auto Regressive Integrated Moving Average) are the combination of AR (AutoRegressive) and MA (Moving Average) models are used to analyze data and provide the results for the research; The results show the increasing trend in CO_2 emission from energy, manufacturing and transport sectors in Pakistan which causes the significant problems if the government fail to respond sector related issues appropriately.

Researchers used statistical ARIMA and ARMA models to analyze the insights from data, this led them to create/build statistical models instead of machine learning models, which are both distinct. As defined by (Piatetsky, 2019), the Statistical modelling is a method of mathematically approximating the world, it means that statistical models contain variables that can be used to explain relationships between other variables while Machine Learning is the use of mathematical and or statistical models to obtain a general understanding of the data to make predictions by teaching the computer to learn like humans. In this current study, I will use machine learning approaches to understand the dataset insights and be more helpful compared to using the statistical techniques of data analysis.

Machine Learning in Estimating CO_2 Emissions from Electricity Generation, a research by (Marco, 2021); This work presents a simple but significant application of a ML approach, the Support Vector Machine (SVM) to the estimation of CO_2 emission from electricity generation. The CO_2 emission was estimate in a framework of Cost-Effectiveness Analysis between two competing technologies in electricity generation using data for Combined Cycle Gas Turbine Plant (CCGT) provided by IEA for Italy in 2020. Respect to other application of ML techniques, usually developed to address engineering issues in energy generation, this work is intended to provide useful insights in support decision for energy policy.

The researcher tackled on the prediction of CO_2 emitted from the energy production plants using data for Combined Cycle Gas Turbine Plant (CCGT); SVM model has been chosen for dataset training, and if you continue to read his work report you find that the performance of the built model indicated that the CO_2 emission will continue to increase but he is not précising the quantity and in which period he is projecting the emission.

To have revive the same experience of predicting the CO_2 emission, but here we are collecting data on fuel consumptions, in three selected African regions and through the application of machine learning algorithms I expect to come with insights that may be helpful for decision makers on the use of imported used vehicles from the developed countries to the developing countries including African countries.

Partially concluding, various researchers are conducted on predicting the CO_2 emissions from different causes like green gases, energy, etc. but it is rare to see a research considering the fuel consumptions in developing countries especially in Africa with the main cause, the used vehicles imported by this continent population. The current study will tackle on the assessment of current and past situation of CO_2 emissions from fuel (solid and liquid) consumption in Eastern, Southern, and Western African regions using machine learning approaches.

III. RESEARCH METHODOLOGY

Research approaches

This study is an analytical research, where data are collected and arranged using a tabular dataset for facilitating their analysis; this involves a quantitative approach, such that data from World bank database on developing countries especially on CO_2 emission from fuel consumptions considering three African regions; and data had to

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be counted, arranged and attributed by numerical values and then analyzed.

Describe geographical area of the population

As specified in the scope of the study the geographical area to be considered is limited to three African regions to be noted, Eastern, Southern, and Western Africa. In these continental sides, the air pollution is a matter as other remaining parts of the world; as of (Yat, 2019), Africa holds the world's largest source of desert dust emissions and produces approximately a third of the Earth's biomass burning aerosol particles; the analysis of satellite imagery by Greenpeace reveals that the world's deadliest air pollution spot on the planet is in South Africa, with its eastern province Mpumalanga being the largest single area infected by deadly nitrogen dioxide.

Researchers used visibility to estimate the pollution increase in Addis Ababa (Ethiopia), Nairobi (Kenya), and Kampala (Uganda). The significant visibility decrease found estimated that air pollution had increased by 62% in Addis Ababa, 162% in Kampala, and 182% in Nairobi (Munyaradzi, 2020).

As the discussed above, it is shown that 40% of used cars exported from EU, Japan, and US were sold to Africa, and these vehicles emit high percentage of CO_2 which contribute to the air pollution.

Data collection methods

For an analytical data mining study, data is a collective term used to define results of a statistical study, survey or investigation. Here, data are to be classified as numerical (quantitative). Depending on the manner how data are collected, this study uses secondary data to be downloaded from the World bank database.

Data are about CO_2 emission from the fuel (solid and liquid) consumption, two indicators for air pollution are extracted in a downloaded CSV file, when the file is downloaded the needed data will be prepared to eliminate the unnecessary data and deal with the missing values so that we can have to analyze the data in convenient way that leads to the responses of the questions addressed by the study.

Data analysis

To achieve the objectives of this study, a framework that consists of steps set up as follow: Problem defining, Data collection, Data pre-processing, Data mining and Forecasting, and Discussion of results. When the dataset is loaded into WEKA to be processed by fulfilling the objectives of the study.

From WEKA environment, there are two configurations' panels Basic and Advanced configurations. Both panels give the user the ability to configure the parameters for a specific selected learning algorithm, where under Basic configuration, it is chosen to use the set-up Number of time units to forecast, Time stamp, Periodicity, and Perform evaluation; while for the Advanced configuration, there are other panels such as Base learner, Lag creation, Periodic attributes, Overlay data, Evaluation and Output.

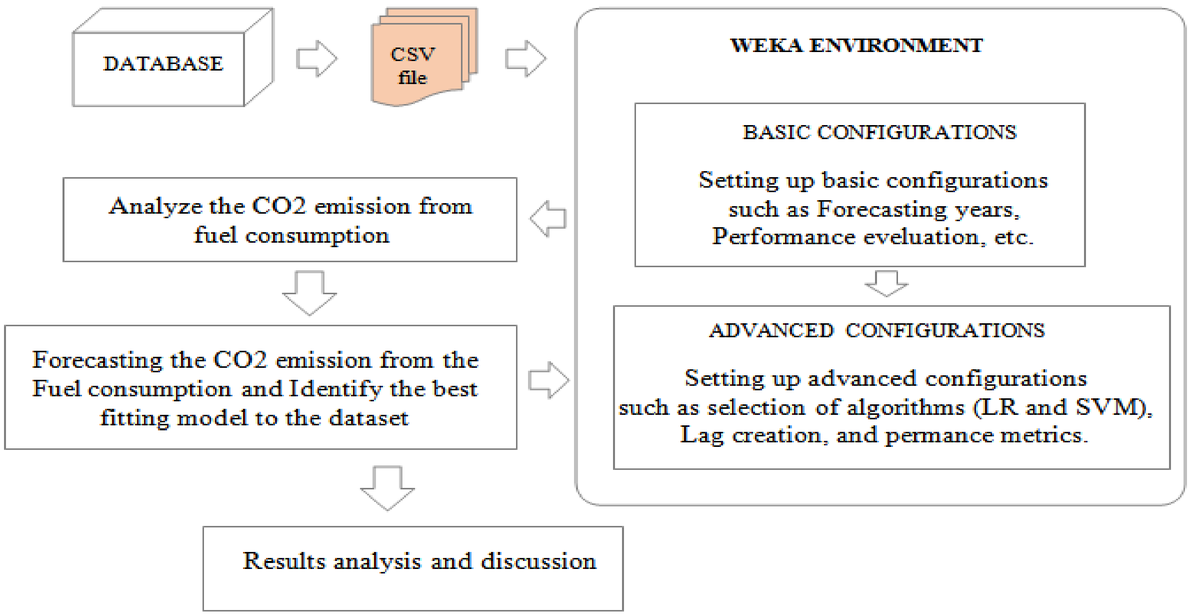

Figure 1 - Conceptual framework

Machine learning

Machine learning (ML) is the field of artificial intelligence (AI) that provide methods to learn from data over time creating algorithms not being programmed to do so (Marco, 2021).

WEKA 3.8.3 Forecast Package encounters various built in active algorithms such as Multilayer Perceptron (MP), Sequential Minimal Optimization (SMOreg), Linear Regression (LR), and Gaussian Processes (GP), SVM, etc. In this study two of these built-in algorithms, Linear Regression and Support Vector Machine, will be learnt with the dataset to determine which one is the most accurate to be used for forecast scenario.
To evaluate the accuracy of the forecasts from the algorithms trained with the dataset under this study, the Root Mean Square Error (RMSE), the Mean Average Error (MAE) and the Mean Average Percentage Error (MAPE) will be used.

LM and SVM were chosen, in this study, for the sake of simplicity in models to be built; moreover, Linear Regression is a great tool to analyze the relationships among the variables, and it handles overfitting pretty well using dimensionally reduction techniques, regularization, and cross-validation. SVM is very helpful method if researcher does not have much idea about the data because it can be used for the data that is not regularly distributed and have unknown distribution, outliers have less influence in SVM Algorithm, and can be robust, even when the training sample has some bias. With these consents, I chose to use both models in this study to mine my dataset to study the emission of CO_2 from fuel consumption.

IV. RESULTS AND DISCUSSION

In this study, three datasets were formed, firstly Mortality caused by road traffic injury (per 100,000 population), secondly CO2 emissions from liquid fuel consumption (% of total), and then CO2 emissions from solid fuel consumption (% of total) for five regions: Eastern, Southern, Western, and Central African, European Union, Japan, and USA. From the experiments conducted the following findings were drawn.

a. Data visualization

Considering five regions in this study, it is shown that the quantity of CO_2 emitted in East and Southern African (AES) region is higher with 64.91% compared to other regions, whereas for USA is the least one with 25.58% respectively in 2011 and 2019; for Western and Central African (AWC) region CO_2 emission was in annual average of 0.96% of total from liquid fuel consumed, while for Japan and European Union (EU) the average annual quantity was on 36.45% and 34.13%. From this situation, we conclude that as the quantity of CO_2 emission from consumption of liquid fuel in Eastern and Southern African regions are the highest in the studied data it is aligned with the imported vehicles in the regions where the literatures indicated that Kenyans and Ugandans imported used vehicles between 2010 and 2015 even if some measures were taken to reduce those kind of vehicles in the region.

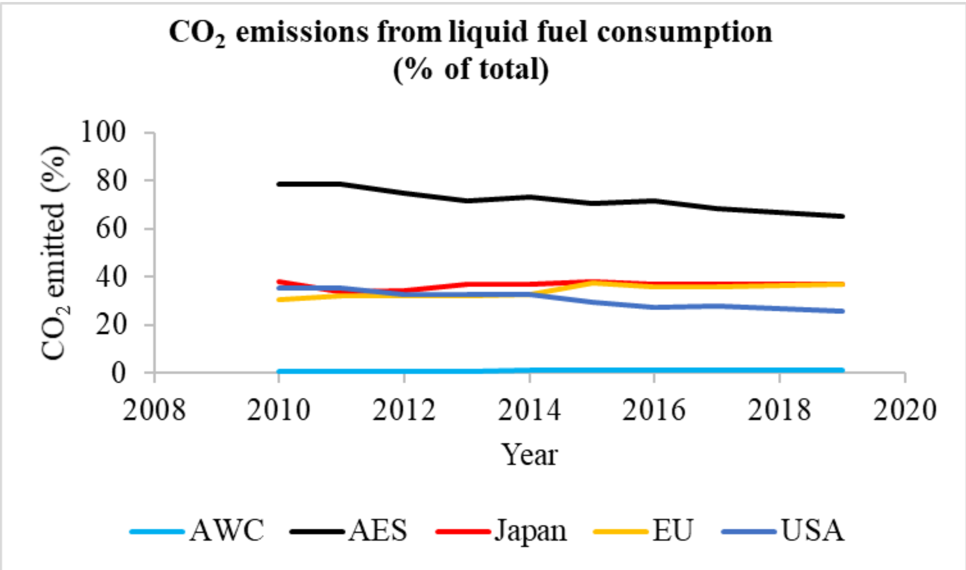

Figure 1 - Emission of CO_2 from liquid fuel consumption.

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Apart from that it shown that the quantity of CO_2 emitted in the developed world, United states, EU, and Japan is least compared to the African regions, just because the vehicles imported by Africans are no longer in use in those countries, means that in those developed countries only new cars are allowed with a restriction on service ages where mainly cars with more than five years are no longer accepted; such that those cars are hard to repair as well as they are emitting a pollutant gases such as CO_2 on a high rate.

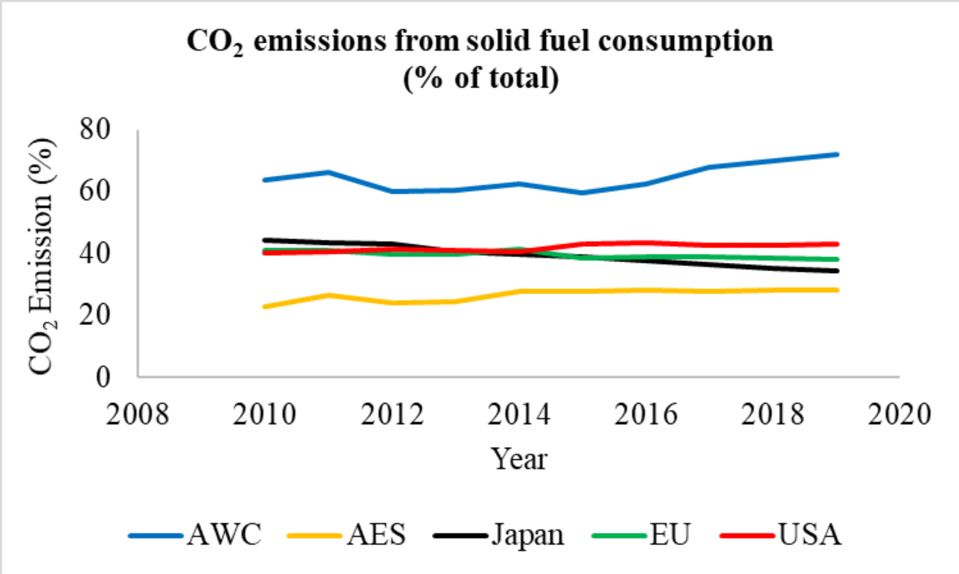

Figure 2 - Emission of CO_2 from solid fuel consumption.

The above figure, shows how the situation how CO2 is emitted from the consumption of solid fuel which is not far from the situation of CO2 emitted from the liquid fuel as well as the African regions data still the highest compared to the developed countries those selected to be used in this study; the data indicated that generally the whole regions emit the CO2 at 42.31% of the total emission from the solid fuel, with the Western and Central African (AWC) region to send in the air a total of 64.44% annually as average, on this parameter the Eastern and Southern African (AES) region deliberate the least value with an average of 26.49% annually. The developed world is the most deliberating a highest CO2 percentage emitted from the solid fuel consumption as it is indicated with annual average of 39.36%, 39.51%, and 41.75% for Japan, EU and USA respectively.

By concluding, we say that the findings are correct due to the fact that the solid fuel is set of other energies generators such wood, charcoal, peat, coal, hexamine fuel tablets, dry dung, wood pellets, corn, wheat, rye, and other grains used normally for producing energy in industries; the counties such as USA and Japan are the ones with strong industries and are using these sources of energy at highest level.

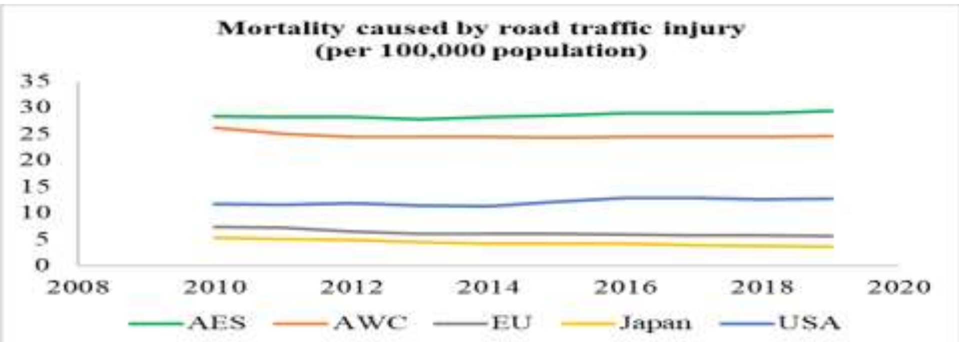

Figure 3 - Mortality caused by road traffic injury (per 100,000 population)

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The above results as plotted in this figures, were about showcasing the mortality caused by traffic injury with main cause of roads accidents; in this figure data indicated that the AES regions are the most vulnerable countries with traffic deaths where only 2019 marks 29.38 per 100,000 population, 26.22 for AWC in 2010, whereas the annual average of both AES and AWC were 28.58 and 24.68 of death per 100,000 population which are higher compared to the developed countries where EU, Japan, and USA marked consecutively 6.21, 4.33, and 12.1 as mortality rate per 100,000 population.

This is justified with different factors such as well-maintained roads, new vehicles, highly developed technology, advanced medical and health services, etc. where with all those factors allow the developed world to sustain their population life. On the African side the road is not even there, where are available are not maintained at all, above this we have the used cars that many of them are not maintained properly such that they may cause accident at any time and the owners themselves are poor which is hard to them to keep their vehicles healthy, in addition when an accident occurs it is hard to save the injured people due to poor health care facilities.

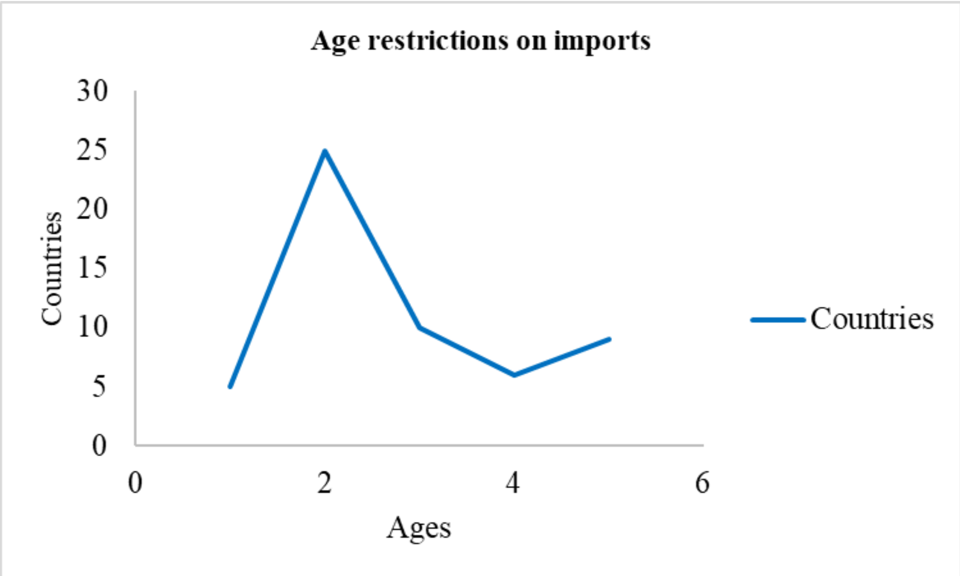

Figure 4 - Age restrictions on imports

Above, the figure presents the image of restrictions put in place by various countries on the African continent by ages of services for used cars to be imported; countries were classified into six categories: those banned completely used cars, those allows cars under 5 years, under 10 years, over 10 years of services but impose taxes, and others which did not care about these.

Findings show that 5 countries such as Morocco, and South Africa banned used cars, 25 countries such Angola, Algeria, Chad, Libya, and Mauritius tolerate vehicles with under 5 of services, 10 countries like Benin, DR Congo, and Eritrea allow those with 10 years and under; other 6 countries like Rwanda, Nigeria, Liberia, etc. impose taxes on vehicles more than 10 years of service and the remaining 9 countries did not impose any restriction on the import used cars.

This is aligned and can justify the rate of mortality from traffic accidents, and the CO2 emission from liquid and solid fuel consumption throughout the African continent.

b. Prediction of CO_2 emission

The predictions are conducted by training two selected Machine learning algorithms, LR and SVM, with dataset collected for understanding the impact of used vehicles on the African continent and CO_2 emission. Four experiments were conducted by training each algorithm with the dataset and evaluate their performance using three parameters, the Root Mean Square Error (RMSE), the Mean Average Error (MAE) and the Mean Average Percentage Error (MAPE).

For the first experiment with Linear regression, the output indicated that the LR has the ability of predicting the CO_2 emission from solid fuel with MAPE with meaningful error rates at 1.024% and 1.901% for predicting AES and USA respectively; while predicting AWC, EU, and Japan, the SVM marks 3.102%, 2.78%, and 2.84% with MAPE.

On the other side, second experiment, when predicting CO_2 emission from liquid fuel with LR, findings present the 2.36% and 2.85% for MAE when predicting Japan and USA emissions; the remaining are well predicted by SVM with MAPE at 1.28%, 4.28%, and 1.43% consecutively for AES, AWC, and EU.

After obtaining the performance of our algorithms on the dataset, we cannot conclude that this or that algorithm is the best for predicting the future value of CO_2 emission from both solid and liquid fuel consumption; below are the CO_2 emission forecasts for coming years:

Table 1 - CO_2 emission from liquid fuel (% of total)

Year	AWC	AES	Japan	EU	USA
2020	74.1244	25.4382	32.9446	38.0357	41.5802
2021	76.8954	27.44	31.5906	38.7576	41.0437
2022	74.2775	27.9272	30.6964	38.2011	41.7853
2023	73.4546	27.2944	29.063	37.787	41.8812
2024	76.2989	29.2738	27.9009	38.9822	41.6179
2025	75.0008	30.0944	26.8049	37.6673	42.6206
2026	75.8222	30.4712	25.507	37.4083	43.4424
2027	80.0033	30.2772	24.2585	37.6664	42.828
2028	82.3428	30.4047	23.0658	37.2866	42.7269
2029	83.7811	31.0492	21.9292	37.0208	43.1258

The above figure presents the forecasts of CO_2 emission from liquid fuel consumption, the main findings indicate that for AWC the emission will increase from 2022 to 2026, the same for Japan will increase between 2021 and 2023. In the AES, the valuation of emissions will vary between 27.44% and 31.04%, means will make a little change on long of the time and insure the regulation of used cars imports in AES, same for EU with values between 37.02% and 38.98%.

Table 2 - CO_2 emission from solid fuel consumption (% of total)

Year	AWC	AES	Japan	EU	USA
2020	1.2586	65.6952	33.3733	34.1185	24.2572
2021	1.1937	61.9136	31.7621	35.5284	22.2647
2022	1.2554	59.4645	33.5967	35.4632	20.9237
2023	1.3477	58.9574	34.4103	35.5964	20.7142
2024	1.5061	59.286	32.8221	37.0636	18.8351
2025	1.6081	55.8208	33.7135	39.5788	16.2771
2026	1.6787	55.0163	34.3137	37.5784	15.9907
2027	1.6561	53.1821	33.9475	38.6638	16.1091
2028	1.781	52.2236	33.1854	39.8837	13.9384
2029	1.806	50.6778	32.1478	38.8654	12.4419

Regarding to the solid fuel consumption, the figure shows that for different set of data, there is an increase and decrease of CO_2 emission in quantity of fuel consumed, in the AWC there will be an increase from 2025 to 2029, and for AES from 2020 to 2022; a decrease will be for Japan between 2026 to 2029.

V. CONCLUSION

According to the Paris Agreement on Climate change, its goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels; to achieve this long-term temperature goal, countries aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate neutral world by mid-century.

Increases in atmospheric carbon dioxide are responsible for about two-thirds of the total energy imbalance that is causing Earth's temperature to rise, this CO2 emission comes to different human activities including agriculture activities, energy generation, fuel consumptions, etc. as confirmed by (Hannah, R. and Max, R., 2017), a changing climate has a range of potential ecological, physical and health impacts, including extreme weather events (such as floods, droughts, storms, and heatwaves); sea-level rise; altered crop growth; and disrupted water systems. The most extensive source of analysis on the potential impacts of climatic change can be found in the 5th Intergovernmental Panel on Climate Change (IPCC) report.

My contribution via this study was to reveal the relationship between used vehicles imported by African countries with the emission of CO2 specifically from the fuel consumptions between 2011 and 2020 and forecast the quantity of CO2 to be emitted in the coming ten years if African authorities do not change their policies of used cars trades.

The findings indicated that CO_2 emitted in East and Southern African (AES) region is higher with 64.91% compared to other regions, whereas for USA is the least one with 25.58% respectively in 2011 and 2019; for the solid fuel, Western and Central African (AWC) region to send in the air a total of 64.44% annually as average, on this parameter the Eastern and Southern African (AES) region deliberate the least value with an average of 26.49% annually. Whereas the annual average of both AES and AWC were 28.58 and 24.68 of death per 100,000 population which are higher compared to the developed countries where EU, Japan, and USA marked consecutively 6.21, 4.33, and 12.1 as mortality rate per 100,000 population.

For the first experiment with Linear regression, the output indicated that the LR has the ability of predicting the CO_2 emission from solid fuel with MAPE with meaningful error rates at 1.024% and 1.901% for predicting AES and USA respectively; on the other side, second experiment, the remaining are well predicted by SVM with MAPE at 1.28%, 4.28%, and 1.43% consecutively for AES, AWC, and EU.

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