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Research paper

The Prediction of Energy Consumption Using Multivariate Regression and Artificial Neural Network Models: Transport in the GCC

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Abstract

Knowing how energy consumption correlates with transport sector in GCC can offer crucial strategies for planning and implementing policies in this sector. Therefore, an accurate prediction of energy consumption in transport and precise planning in energy consumption so as to effectively control the energy demand in the transport sector is crucial. Air pollution and public health are two of the most vital environmental issues. Urbanization, economic development, the growth of population, transportation, and energy consumption are viewed as the common factors that cause air pollution in towns and cities. The goal of this study is to use multiple liner regression (MLS) and artificial neural network (ANN) models for the prediction of energy consumption for the transport sector in GCC. Data on how energy is used in the transportation sector was incorporated as the output variable of predictive models. Moreover, this paper will discuss how advanced technology can come in to solve problems related to transport in the GCC.

Keywords: *Artificial Neural Network Models, Energy Consumption, multiple liner regression, Multivariate Regression Models*

1. Introduction

The transport sector is growing rapidly in the Middle East. According to numerous reports, the fuel efficiency of public and private transport is extremely low. The average energy consumption per vehicle is so much more than the average which prevails in those countries without fuel subsidies. With numerous energy subsidies getting rid of the incentives for public and private transport to economize on the consumption of energy (for example, by choice of public transport, choice of number of trips, and choice of vehicle, the Middle East countries waste huge revenue incomes on ineffective modes of transport.

It is particular to note that in different Arab countries, transportation policies have been put in place and have shown success in offering better standards of living for the citizens as well as low environmental impact. Fuel consumption in the transport sector can be controlled in two ways, either by implementing advanced technology to improve the gasoline economy of cars, or reduce the total distance travelled by vehicles (Jacobson & King, 2009). Furthermore, there are vital strategies that are involved in offering sustainable transport and they fall into the following categories: fuel/vehicle technological changes, demand management, and vehicle/road operations improvements (Deakin 2001).

This study provides a background review of how energy is consumed in transportation sector in the GCC along with the analysis of energy consumption and different transport behaviors in the transport sector using multivariate regression and artificial neural network models.

2. Background

The energy consumption in the transport sector is growing rapidly when compared to other sectors. Consequently, there has been an increased need to establish ways of modeling the energy consumption in the transport sector. Despite transport sector playing a huge role in determining the energy consumed, the energy consumption is this sector has received no or little attention. This is due to inadequate resources and awareness to conduct researches, huge number of stake holders, and complexity to carry out studies for various variables and elements in the transport sector. There is need for empirical models and field studies to explain and analyses to determine the past, current and future energy consumption level in the transport sector in the GCC.

Therefore, so as to support energy consumption related policies and research, energy demand models are needed on multiple liner regression and ANN methods. These models help in getting accurate results of the amount of energy consumed in the transportation sector. The models have the benefits of being simple and easy to understand. They also have the ability to estimate and predict energy consumption and potential technology that can help control the rate of consumption.

Clean air is considered to be top of the requirements list for the well-being of humans, plants, and animals. However, in the process of economic development, the pollution of the atmospheric air has steadily grown to become a significant health hazard with the main driving forces being urbanization, economic development, and growth of population, transportation and energy consumption. Being exposed to air pollutants is a menace that is increasing as the days go by due to the contaminants diversifying thus causing adverse effects on many people. It is therefore crucial for researchers to carry out studies to monitor how both secondary and primary air pollution precursors behave and help in the establishment of understanding into their impact on the environment.

Activities that are human-related usually the emission of primary pollutants like airborne chemicals that include non-methane hydrocarbons (THC) and methane (CH4), heavy metals, carbon monoxide, carbon dioxide, hydrogen sulfide, nitrogen oxide (NO) and Sulphur. Their subsequent interaction with the environment and the reactions of photochemical in the atmosphere causes secondary pollutants which include the Ozone (O3). Many studies have indicated that the primary characteristic for pollution in urban areas is the oxidation of both NO2 and SO2 with the conversion leading to them being either particulate nitrates or particulate sulfates. The transformation of the particulate nitrates adversely affects the formation of the ozone because they are oxidized into nitric acid. The particles that come from such particles cause effects that is deleterious to both flora and fauna, reducing the visibility rate and also precipitation acidification.

Kuwait city is based in the eastern part of the Kuwait state along the shore of the Arabian Gulf. The capital houses most government headquarters and offices and acts as the economic, cultural and political center. Crude oil is viewed to be the primary energy source for the city and also the principal generating commodity as it accounts for 50 % of the GDP, 79% of the government income and 98% of the export revenues. The Gross Domestic Product Per Capita for the city is at about 17000 dollars since 2000. Transportation is a necessity and is needed for comfort especially in summer due to its close and hot nature. The season goes for about seven months with temperatures reaching about 50 ºC. The difference between the Wet Bulb Temperature and the Dry Bulb Temperature in summer is usually high thus reflecting both the hot and dry nature of the weather (Amir Alhaddad, 2015). The last four decades have seen the Kuwait state experiencing the rapid growth rate regarding its infrastructure and socio-economic activities. Arterials and urban freeways that transcend over hundreds of kilometers have been constructed to ease transport and boost the subsequent development of the socio-economic sectors. The population has risen to over 3 million and the fleet of vehicles is at about 1 million with an expectation of the number increasing.

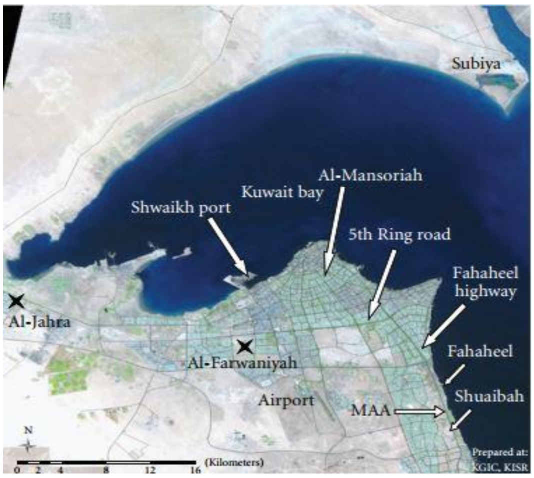

Fig. 1: Model representation of the City Of Kuwait, (Khan, 2010)

This surge in the population and the traffic has led to Kuwait experiencing the increase in the length of the trip, the frequency of the trip and also excess emissions into the atmosphere resulting from the quality of the air outside being a significant cause for concern. The elevation of NHMC concentrations in the area has to adhere to the set limits by the Kuwait Environment Public Authority which suggests that any activities that are oil-related are deemed to be contributors to the pollution menace. A survey conducted by the World Bank in over 100 cities in both non-industrial and industrial cities indicated that the air in the urban area was unhealthy. The results showed that about 30% of the surveyed cities had high concentrations of Sulphur dioxide which came from power plants which passed the set guidelines and that the remaining 70% had high levels of Nitrogen Oxide that were caused by urban traffic.

The Ozone (O3) gas is viewed to be an excellent example of the indication of the interaction that occurs between the primary pollutants and the surrounding environ and also the upshot of the atmospheric photochemical reactions. These interactions lead to the formation of secondary pollutants like the one mentioned above. The conversion rate of both NO3 and NO affects the creation of the ozone and also determines the absorption of the NO into the atmosphere. NO3 particles are formed in the atmosphere as a result of the oxidation of the Nitrogen Oxide to the Nitric Oxide (HNO3) (Braglia., 2002). Data retrieved from some monitoring stations indicated that there was a slight increase in the concentrations of CH4, NOX, SO2, O3 and CO and the primary source of pollution was traffic in the urban centers and oil refineries in the rural areas.

2.1. Literature Review

A study conducted by AbdulWahab (1996) presented a model that was based on statistics and that which was able to forecast the precursor concentration of the ozone level and other parameters that relate to the meteorological settings during the day at the Shuaiba Industrial Area, Kuwait. The data were collected from December 1994 through a mobile monitoring station, and the study used some regression models that aimed at the determination of the relation that exists between some independent variables and the ozone layer. It explained that any precursor concentrations in the atmosphere were related to solar radiation, the speed of the wind and the level of the ozone. The temperature relationship of the ozone was also presented, and it was found out that it correlated negatively with temperatures going above 27 degrees.

A comparison of the concentrations of Nitrogen Oxide in the town of Jamshedpur in India was made by the use of an ISCST model which predicted Nitrogen Oxide emissions from domestic, vehicles or industries. The results showed that the contributions were as follows: 8% from local sources, 52 % from industrial causes and 40 from cars (Sivacouma Richard, 2001). Braglia (2002) evaluated the efficiency of 7 oil refineries to the Italian environment by use of the data envelope model over four years which considered the emission of the primary pollutants as the function of the processed oil.

The trends that exist in the ambient concentrations of S04, NO3, NO, and SO2 were analyzed and studied by Hunova (2004). The case study was conducted in the rural site near the Czech Hydro Meteor Institute, and the results showed that the concentrations in the Nitrogen Oxide reduced in 5 /14 stations while the remaining locations didn't indicate any change in the trend. This decrease was also witnessed in the wet deposition of both Nitrogen and Nitrogen Oxide at about 10%.

The concentrations of the ambient Nitrogen Oxide also decreased by 30%. In the year 2005, two air qualities in two Greek Coastal cities were studied by (A. Nelly, 2005). The study revolved around the emission of SO2, CO, NO, NO2 and O3 gases into the atmosphere. The data collected were compared and analyzed to evaluate the rising of air past the set EU values. The results showed that there was the high concentration of the ozone levels that were above the set standard for plants but favourable to humans in both Volos and Patras city. The levels of O3 in both towns were low during the week but high over the weekends. The SO2 and NO levels were lower in Volos compared to Patras. This supported the theory that purports that the O3 effect in the weekend is caused by the amalgamation of the Volatile Organic Carbons and the Nitrogen Oxides emissions during the weekends.

Research by K. Simkhada (2005) in the Bishnumati area in Kathmandu which is usually the end target for pollution. The pollutants collected were Nitrogen Oxide, Sulfur Oxide, and PM10. The levels in the corridor sites were viewed to be extensive, and they were categorized as hazardous and harmful. Open combustion of the solid waste was said to be a massive contributor to the pollution. A study on the emissions of gas in the Arabian Gulf was later conducted by El Fadel (2005) on two delineation plants. The ISCST3 model was used in the assessment of the concentrations of the SO2 with the results showing that some receptors being susceptible to health standards.

A study was also conducted on the use of a mathematical model to allow for the investigation of just how efficient the sites that monitor gas emissions were in Kuwait(Nassehi). The model used was the ISCST3 model to identify any temporal and spatial variations of the Sulphur oxide in residential areas (Grivas,2006).Grivas (2006) implemented a model that combined artificial neural networks, metrological and timescale variables that were used in the predicting the level of PM10 in the city of Athens on an hourly basis. The data used was collected over a span of 2 years, and the analysis showed that the model was the preferable option in the yielding of any acceptable probabilities.

Steadman (2006) made a model assessment of the air quality in the United Kingdom from the year 2005 to the year 2010 with comparisons being made to the data collected from 2004 and 2005. The air quality predictions for the year 2005 worked in alignment with the recent measurements and assessments from various contemporary models. Zhou (2007) ran an analysis of air pollutant data that was provided to them by the Guangzhou Monitoring station for a period that ranged from 1987 to 2007. This data includes variations between the NO2 and SO2, prominent pollutants, the air quality characteristics and the particulates of CO and PM10. The final result showed that CO was one of the highest rated contaminants in the Guangzhou town although the concentrations had gone down in the years building up to the study.

According to an assessment by Ettouney (2007), the state of the atmospheric pollution in the Arab Gulf can be assessed by use of a model that emitted and dispersed the gases CO, NO and SO2. The estimation of the emission of the gases was done on an hourly basis for oil refiners, oil fields, power plants, and vehicles. The estimates used to come as a function that represents the overall number of vehicles and the distance travelled by each car, the rating of every power plant according to its usage and the capacities of production by the refineries and the oil fields. The study incorporated the use of the ICST model in the imitation of the dispersion of the gases CO, NO and SO2 in 2004. The predictions that were used in the model were derived from data collected from two locations in Kuwait with errors ranging from the annual maximum and averages at (-6% to 17.7%) and (-12.0% to +27%) respectively. The final results indicated that the S02 prediction with the most substantial error was in the town of Umm ALhyman.

A comparison of the performance of both ISCST3 and CALPUFF models was conducted by Lingjuan Wanga (2006) with the study indicating that the first model was preferable compared to any other due to its ability to make predictions on downwind odor concentrations. Gurjar (2008) conducted an evaluation and ranking of megacities according to their particle emissions, trace gases and the quality of ambient air. The assessment was done by use of the emissions of Carbon Monoxide per unit surface area, capita and year. The study indicates that they further put the megacities in a particular order with the ambient levels of the pollutants, NO2, SO2 and suspended particles being considered. They later proposed an index which examined the combination of the three primary contaminants in alignment with the guidelines set forth by the WHO regarding the quality of air. The highest ranked cities included Karachi, Cairo, Beijing, and Dhaka.

A study assessment by Özden (2008) on the quality of air in Turkey considered the use of only five air pollutants for the paper which included NMVOCs, O3, NO2, PM, and SO2. Data was collected from the local emission inventories showing the origin of the pollutants in the region. The different peaks and falls during the seasonal activities led to the changes in the quality of the air temporarily and were used in the study. The development of a forecast system that was tailored to air pollution by use of neural networks was done by Maria Guadalupe Cortina (2010). This model analyzed various CO, PM10 and SO2 concentration levels in 4 days and the outcome indicated that the use of a single day as the input parameter into the system led to the provision of forecasts that had high accuracy.

Saleh M. Al-Alawia (2008) later devised models that were used in the prediction of O3 concentrations in the city of Kuwait. The subsequent data used in the three models were collected in the summer season (Matthew Lorbera, 2000). The models included a hybrid system between the artificial neural network and the principal component regression, the PRC alone and the ANN alone (Matthew Lorbera, 2000). The final results indicated that the hybrid system was the best method of forecasting the accuracy of the O3 concentrations with the ANN and PCR models following suit (Matthew Lorbera, 2000).Another study by Pfeiffer (2009) incorporated the use of diffusive sampling measurements and the ANN in the calculation of the spatial distribution of Nitrous Oxide in Cyprus. The results from the study indicated that "average distribution maps of NO2 were generated by the artificial neural network without any glitches whatsoever".

A revised proposal on the AQI by L. Zhen (2011) was based on the combination of the effects of pollutants on the public health by use of an entropy function. The revised index was designed with a basis on the air pollutants that were collected from different air monitoring stations in China's capital city. Through the comparison of the revised API and the existing ones, the values that were generated at both plants were indicative of high levels of the concentrations and thereby rendered more information pertaining the pollution crisis.

A review of the study conducted on Thessaloniki, the second largest Greek city, was redone in the year 2012with the timeline running from 2003 to 2008. The data collected was used in the computation of air quality indices that were different by nature. The EMMA indices were considered to be the first Air Quality indices ever to be devised, and they were based on individual pollutants while the second technique incorporated the combination of the contaminants. They later included the collected indices with a focus being on the effects caused by pollution to humans. Results obtained indicated that in the cases where the individual pollutants acted alone, the air quality was viewed to be wrong while when the contaminants were mixed, the air quality became problematic (P. Kassomenos, 2012).

Limanond, Jomnonkwao, and Srikaew (2011) created a feed-forward neural network (FFNN) model and log-linear model based on GDP, number of the registration vehicles, and population as independent vehicles. They created two log-linear models. One described energy demand in the transport sector in terms of GDP. These models accounted for 95 percent of variability of energy demand in the transport sector. The ANN models incorporated the social-economic variables as the input and projected energy demand in the transport sector as the output. The results derived from these models were projected for 2010 to 2030.

Moreover, Murat and Cylan (2006) examined the current and future energy demand in the transportation sector using social-economic variables and ANNs. The models included the FFNN derived by the back propagation algorithms. The social-economic variables used were the yearly average vehicle kilometres, the population and Gross National Product. Data derived from these models were grouped into 6 partitions and the one that offered the minimum error was chosen as the superlative network architecture.

Jin-ming and Xin-heng (2009) used the ANN models to compare China's energy consumption from the trend extrapolation. The ANN models incorporated in this research were very accurate.

Geem (2011) incorporated the Artificial Neural Network model in estimating the energy consumed in the transportation sector. Geem incorporated various independent variables including the number of passengers, number of vehicle registrations, oil price, population and GDP. The ANNS models were compared to MLS models. The Artificial Neural Network models' results were in terms of R2 and RMSE, when linked to multiple linear models.

In recent years, due to the increase of fuel prices in the global marketplace and environmental problems, concerns about the energy demand in the GCC are growing, particularly in the transportation sector. The increase in demand of energy in the transport sector has been attributed to the technological and economic changes witnessed in the past 2 decades. The increases in vehicles have contributed to the increase in energy consumption damaging the environment.

2.2. Methodology

The method of emission used was theISCST3 model which provided alternatives from different origins which could be used in the presentation of a typical industrial source complex. Its performance has been studied by some researchers like (Braglia., 2002), (Amir Alhaddad, 2015), (Saleh M. Al-Alawia, 2008)and (R.S. Ettouney, 2010). Both the CALPUFF and ISCST3 models under-predicted the rates of emission from the various sources. The ISCST3 model was used in this study in the prediction and measurements of the VOCs, CO, NO and the SO2. The values were derived from the hourly averages over a period of twenty-four hours in a day. I combine two dispersion models to predict the concentrations of the hydrogen cyanide.
These models include the AERMOD software and the ISCST3. The monitoring stations in every town generated the samples used in the study with the results indicating that there was an over prediction in the levels of Hydrogen Cyanide in the area as shown by Arslan Saral (2009).The AERMOD software however under predicted the levels of cyanide in the area with an average of about 0.76 (Matthew Lorbera, 2000). This led to the modeling of a dispersion model that dealt with both emissions of hydrogen sulfide and the volatile organic compounds (Matthew Lorbera, 2000).Combining both the ISCST3 and dispersion model led to the prediction of high concentrations of hydrogen sulfide, methyl mercaptan and ethyl mercaptan which exceeded the set thresholds of the study. The air-quality dispersion Gaussian model was also used in the prediction of both polychlorinated dibenzofuran and dibenzodioxin concentrations in the soil and the air. The results indicate that the values used in the forecast were with a factor of 10. Thus they were considered to be reasonable due to the uncertainties that revolved around the study like the reactions of dioxins, weather data and the rate at which the stacks are emitted (Matthew Lorbera, 2000).

2.3. Theoretical principles

2.3.1. Artificial Neural Network

The ANN model can be described as a huge number of neurons which jointly perform task that even computers have not been able to match. It can also be defined as a regression method that presents high nonlinearity between dependent and independent variables. Others say that it is a data-processing system which has specific performance properties that are in common with the biological neural networks. There are input, hidden and output layers. These are data processing nodes. In the ANN model, traffic data can be entered into the model as both dummy variables and binary values. This way, it offers a solution to engineering problems especially in the transportation sector.

The explanation on how ANN and MVR was used was however lacking. Add how ANN and MVR was use.

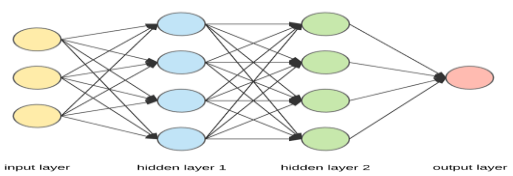

Fig. 2: Data processing nodes

2.4. Discussion

The variations in the temperature are plotted in the second figure with the data collected varying from 10 degrees to 52 degrees in three sets of measurements. The profiles of the heat are regular with the changing norms whereby the maximum will occur in the evening. The third figure shows an analysis of the emission patterns in the area where there are oil refineries in the state of Kuwait with the wind varying from 1 to 9 meters per second in three sets of measurements. The results show that wind rises during the afternoon which is caused by a rapid spike in the land temperature that leads to the rising of any adjacent air mass.
This causes the sea breeze occurrence. The speed of the wind decreases until midnight when the heat on land is low then the temperature at sea thus creating a land breeze, increase in the speed of the wind and also air turbulence (Amir Alhaddad, 2015). The fourth figure shows the rising of the wind in three study sessions that bring us to the conclusion that April experiences more turbulent wind conditions compared to July and January (Amir Alhaddad, 2015). The climate change condition in April results in the movement of wind speeds towards the same direction (Amir Alhaddad, 2015).

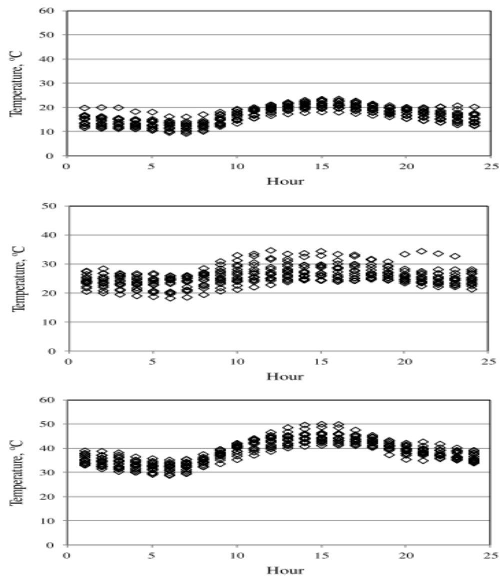

Fig 3: Temperature Variations in the three measurement sets.,(Amir Alhaddad, 2015)

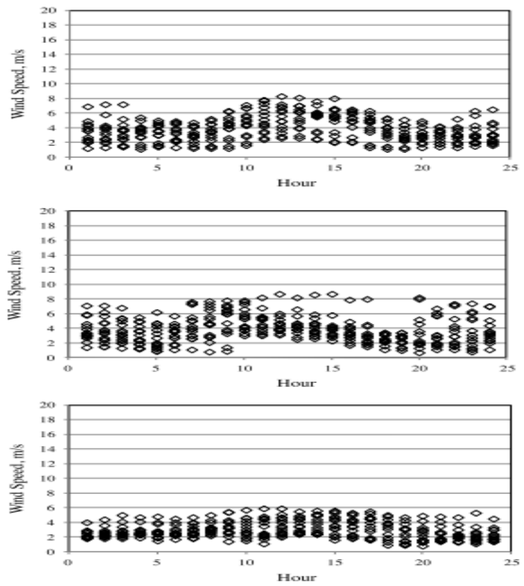

Fig 4: Wind Speed Variation in the three measurement states,(Amir Alhaddad, 2015)

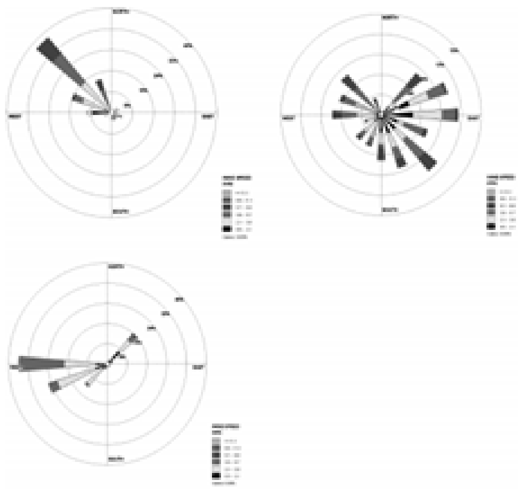

Fig 5: Graphs representing rising winds in 3 data sets,(Amir Alhaddad, 2015)

2.5. Air Pollution Data Analysis

The data collected for the analysis of air pollution is plotted in the figures following this section. The data sets vary between 5 and 25 ppb with most concentrations being high which was as a result of the emission rates that were caused by both the Shuaiba and the Ahmadi refineries. Divergent opinions can be noted with regards to previous studies conducted with this one showing the SO2 base concentration in the three data sets. The discerning of the diurnal variations in two sets was difficult to assess which helped in the explanation on why there has been the passing of emission regulations for refineries that differ from the ones used during the conducting of previous studies. The data from the Nitrogen and Carbon oxide emissions are represented in figure 8 and six respectively. Nitrogen Oxide Patterns indicate variations in a bi-diurnal manner especially during the evenings and subsequent morning hours. The find correlates with the Carbon Oxide results which are caused by the increment of traffic in the area or the use of heavy machinery. These results are evident in the works of Abdul Wahab (1996), whereby the daily variations in the Carbon Oxide emissions are consistent with the way the other photochemical components react. We have recorded similar patterns with Nitrogen Oxide and NMHC.

Table 1: Annual Excess of NHMC, (Socan Statistics)

csb.gov.kw

Annual Excesses of NMHC (ppm) by the Station

2015-2006

المحطة	عدد التجاوزات الساعية / نسبة التجاوز					Number of Hourly Excesses / Ratio of Excesses					Station
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
المنصورية	6805	5805	6267	6296	7077	5447	5753	6858	6838	8040	Mansoria
	81.67	81.86	78.17	75.27	83.63	65.47	66.69	82.81	86.09	97.73	
القرين	-	-	-	-	-	6020	3243	6118	7161	8132	Al-Qurain
						95.48	82.14	95.8	89.5	93.77	
الرقة	7394	7280	6928	6191	5915	4920	7168	7655	-	-	Reqa
	89.8	85.74	89.26	82.77	77.34	82.52	85.86	90.01			
الجهراء	4034	1300	2866	2702	4284	7156	3235	5467	4573	8641	Al-Jahra
	49.42	16.56	34.72	34.71	51.63	85.57	38.85	63.58	56.25	99.72	
علي السالم	6979	7650	8516	7648	7211	6950	7541	7501	7843	8167	Ali Al-Salem
	84.4	91.28	98.69	93.97	88.23	88.56	92.52	91.19	99.08	100	
المطلاع	-	-	2140	3793	3097	4785	6907	4284	7221	8668	Al-Mutla
			59.73	51.73	38.86	66.84	83.26	88.95	89.48	100	
الرميثية	6518	5987	6127	7659	6434	7616	6942	7207	6826	7714	Rumeithiya
	79.92	69.22	72.85	90.18	79.35	92.38	81.64	86.35	85.98	92.44	
الفحيحيل	7279	7667	7212	6919	7326	6855	7297	7832	6997	7871	Al-Feheheel
	84.87	89.89	83.47	82.65	84.15	80.08	84.89	91.28	90.55	93.6	
الشعيبة	-	-	-	-	3583	3174	95	-	-	2199	Shuaiba
					52.18	39.6	14.89			33.6	
سعد العبدالله	-	-	-	-	1891	7427	7653	6211	7577	8125	Saad Al-Abdullah
					88.65	85.31	92.63	93.74	94.84	97.74	
الشويخ	-	-	-	-	-	3076	3728	4004	4808	2777	Shuwaikh
						50.18	45.34	47.16	61.46	35.81	
السلام	-	-	-	-	-	1195	1982	5267	7714	7909	Al-Salaam
						97.15	75.91	89.99	95.47	94.18	

المصدر: الهيئة العامة لل Source: Environment Public Authority (EPA)

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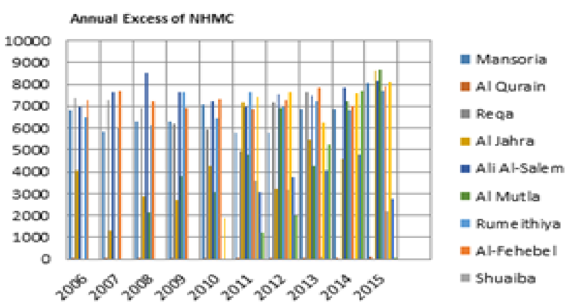

Fig 6: Annual Excess of NHMC

The chart above indicated that on hazy days and in the morning, the hydrocarbons reached a high level. Case example, on hazy days in a number of years, ethane decreased to a point of -30% in the morning and then subsequently increased to about 37% in the evening. The pattern formed which diurnal was showed that emission that emanates from vehicles is because of the increase in traffic volume which occurs in the morning and evening.

Low levels in the afternoon can be attributed to the OG reaction that goes in tandem with the increase in mixture height on the planets boundary layer. The average emission of the NHMC in most days was high thereby leading to the dilution of the air pollutants due to strong ventilation. A marker for the evaporation of gasoline, the i-Pentane gas, can however be seen to spike in most afternoons on hazy days. The temperature rate that is exhibited in most afternoons makes it easy for the solvent that contains the Pentane gas to evaporate. Others gases like benzene, ethane, toluene, propene and ethane account for about 72%-84% of NHMC gases with the concentrations being greater on days that is hazy. This goes ahead to lay a strong foundation to the theory that most diurnal variations occur on hazy days compared to normal days due to traffic volumes.

Table 2: Annual Excesses of CO, (Socan Statistics)

csb.gov.kw

Annual Excesses of CO (ppm) by the Station

2015-2006

المحطة	عدد التجاوزات الساعية / نسبة التجاوز					Number of Hourly Excesses / Ratio of Excesses					Station
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
المنصورية	-	-	-	-	-	-	-	-	-	-	Mansoria
القرين	-	-	-	-	-	-	1	-	-	-	Al-Qurain
							0.024				
الرقة	-	-	-	-	-	-	-	-	-	-	Reqa
الجهراء	-	-	-	-	-	-	-	-	-	-	Al-Jahra
علي السالم	-	-	-	-	-	-	-	-	-	-	Ali Al-Salem
المطلاع	-	-	-	-	-	-	-	-	1	-	Al-Mutla
									0.014		
الرميثية	-	-	-	-	-	-	-	1	-	-	Rumeithiya
								0.012			
الفحيحيل	1	-	-	1	-	-	1	1	1	-	Al-Feheheel
	0.011			0.012			0.012	0.012	0.013		
الشعيبة	-	-	-	-	-	-	-	-	-	-	Shuaiba
سعد العبدالله	-	-	-	-	-	-	-	-	-	-	Saad Al-Abdullah
الشويخ	-	-	-	-	-	-	-	-	-	-	Shuwaikh
السلام	-	-	-	-	-	-	-	-	-	-	Al-Salaam

المصدر: الهيئة العامة لل Source: Environment Public Authority (EPA)

لم يتم قياس الملوث في - The Pollutant Not Measured in the Above Fixed Station

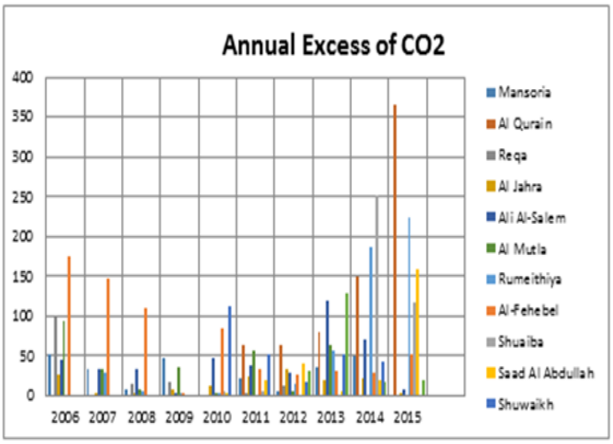

Fig 7: Annual excess of CO2

The carbon emissions logged into the system indicate a positive coefficient that is persistent of about 0.70 significant at a percentage level of 1 thereby showing that the carbon emissions from previous years affected the final readings in the carbon emissions of 2015. The increase in GDP per capita was at a coefficient of about 0.27 with a 1% level of significance. This means that every time the GDP increases then the emissions per capita increase also. The increased use of fossil fuels by oil refineries in the various areas led to the increase of the coefficient value to about 1.03 with a note being made on the fact that Kuwait was one of the countries that contribute to about 35% of the world's oil exports thereby it releases about 50% more emission.

Table 3: Annual Excesses of H2S, (Socan Statistics)

csb.gov.kw

Annual Excesses of H2S (ppb) by the Station

2015-2006

المحطة	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Station
	عدد التجاوزات الساعية / نسبة التجاوز					Number of Hourly Excesses / Ratio of Excesses					
المنصورية	-	-	-	-	-	1	6	7	-	-	Mansoria
						0.013	0.07	0.082			
القرين	-	-	-	-	-	11	1	-	-	-	Al-Qurain
						0.164	0.023				
الرقة	1	-	2	-	-	-	7	14	-	-	Reqa
	0.012		0.024				0.082	0.164			
الجهراء	-	-	-	-	-	-	48	-	-	-	Al-Jahra
							0.567				
علي السالم	1	-	-	-	-	2	-	-	-	-	Ali Al-Salem
	0.012					0.027					
المطلاع	-	-	-	-	1	-	-	-	3	-	Al-Mutla
					0.024				0.04		
الرميثية	-	-	-	-	-	-	2	1	1	-	Rumeithiya
							0.025	0.012	0.013		
الفحيحيل	2	-	-	1	-	-	1	2	-	-	Al-Feheheel
	0.023			0.012			0.012	0.023			
الشعيبة	-	-	-	-	77	9	-	-	-	-	Shuaiba
					1.121	0.112					
سعد العبدالله	-	-	-	-	7	36	55	36	-	-	Saad Al-Abdullah
					0.317	0.413	0.657	0.543			
الشويخ	-	-	-	-	-	-	-	-	-	-	Shuwaikh
السلام	-	-	-	-	-	-	-	2	-	-	Al-Salaam
								0.034			

المصدر: الهيئة العامة للبيئة — Source: Environment Public Authority (EPA)

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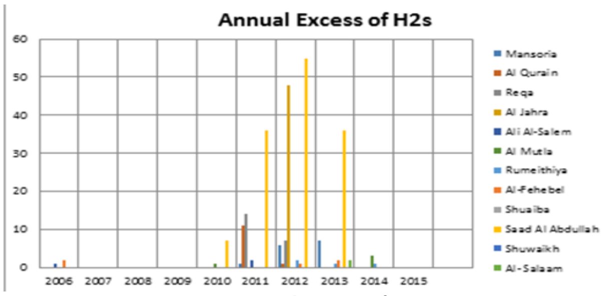

Fig 8: Annual Excess of H2S

Hydrogen sulfide on the other hand, denoted with the formulae (H2S), was recorded highly in the Al Jahra and Saad Al Abdullah stations respectively. The Saad Al Abdullah city is known to be Kuwait's first smart city and therefore the emissions carry at 6.23 ppm while the lowest value was at Shuwaikh which was at 1.31 ppm.

Table 4: Annual Excess of NO2, (Socan Statistics)

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Annual Excesses of NO2 (ppb) by the Station

2015-2006

المحطة	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Station
	عدد التجاوزات الساعية / نسبة التجاوز					Number of Hourly Excesses / Ratio of Excesses					
المنصورية	143	50	70	180	540	237	664	700	87	87	Mansoria
	10.142	0.606	0.856	2.179	6.317	2.731	7.697	8.3	1.1	1.09	
القرين	-	-	-	-	-	269	342	643	352	26	Al-Qurain
						4.032	7.963	10.18	4.45	0.3	
الرقة	587	926	423	73	297	315	19	134	-	-	Reqa
	7.955	13.212	5.464	0.902	3.577	3.693	0.221	1.613			
الجهراء	11	58	74	104	117	1	5	16	2	36	Al-Jahra
	0.126	0.664	0.874	1.204	1.345	0.012	0.059	0.206	0.027	0.44	
علي السالم	10	-	-	88	28	156	294	558	525	192	Ali Al-Salem
	0.118			1.074	0.351	1.942	3.664	6.759	6.75	2.56	
المطلاع	-	-	19	-	34	4	1	2	11	68	Al-Mutla
			0.533		0.848	0.051	0.012	0.042	0.15	0.79	
الرميثية	90	2	98	517	950	584	782	243	105	57	Rumeithiya
	1.06	0.023	1.14	5.975	11.526	6.903	9.226	2.887	1.37	0.67	
الفحيحيل	24	4	26	320	312	375	1229	1960	750	238	Al-Feheheel
	0.275	0.047	0.301	3.718	3.595	4.287	14.314	23.021	9.93	2.75	
الشعيبة	-	-	-	-	29	24	-	-	125	18	Shuaiba
					0.433	0.309			1.52	0.23	
سعد العبدالله	-	-	-	-	72	105	452	81	88	358	Saad Al-Abdullah
					3.526	1.211	5.382	1.222	1.09	4.14	
الشويخ	-	-	-	-	-	13	7	32	64	8	Shuwaikh
						0.184	0.081	0.379	0.81	0.1	
السلام	-	-	-	-	-	284	434	668	116	309	Al-Salaam
						21.242	15.028	11.527	1.44	3.94	

المصدر: الهيئة العامة للبيئة — Source: Environment Public Authority (EPA)

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Being one of the primary pollutants in the state of Kuwait, Nitrogen Oxide was shown to be the highest at a value of 41.24 ppb at the Al Qurain station in the year 2013 but it has decreased significantly. Low concentrations were recorded in the Shuwaikh station at 0.32 ppm.

Table 5: Annual Excesses of SO2, (Socan Statistics)

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Annual Excesses of SO2 (ppb) by the Station

2015-2006

المحطة	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Station
	عدد التجاوزات الساعية / نسبة التجاوز					Number of Hourly Excesses / Ratio of Excesses					
المنصورية	6	3	-	-	-	-	2	8	2	-	Mansoria
	0.072	0.036					0.023	0.094	0.025		
القرين	-	-	-	-	-	-	-	-	-	-	Al-Qurain
الرقة	14	2	-	-	-	-	78	10	-	-	Reqa
	0.171	0.028					0.918	0.117			
الجهراء	6	1	3	7	6	-	7	4	7	-	Al-Jahra
	0.069	0.012	0.035	0.089	0.069		0.083	0.047	0.09		
علي السالم	1	-	-	-	-	-	-	1	-	-	Ali Al-Salem
	0.012							0.012			
المطلاع	-	-	-	-	1	-	-	-	1	-	Al-Mutla
					0.024				0.012		
الرميثية	2	-	2	-	9	1	-	1	3	-	Rumeithiya
	0.024		0.024		0.108	0.012		0.012	0.04		
الفحيحيل	60	18	4	15	39	5	30	147	51	8	Al-Feheheel
	0.688	0.208	0.046	0.176	0.471	0.057	0.349	1.712	0.67	0.094	
الشعيبة	-	-	-	-	312	67	-	-	169	192	Shuaiba
					4.598	0.837			2.02	2.47	
سعد العبدالله	-	-	-	-	-	7	35	20	7	2	Saad Al-Abdullah
						0.08	0.418	0.302	0.087	0.023	
الشويخ	-	-	-	-	-	1	1	1	-	1	Shuwaikh
						0.014	0.012	0.012		0.013	
السلام	-	-	-	-	-	3	-	15	9	-	Al-Salaam
						0.224		0.257	0.112		

المصدر: الهيئة العامة للبيئة — Source: Environment Public Authority (EPA)

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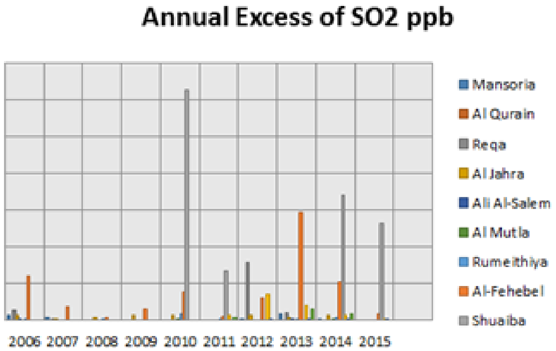

Fig 9: Annual Excess of SO2

The maximum concentration of the Sulfur Dioxide was shown at 10.21 ppm in the sampling station of Rewa while the lowest was at Rumeithiya with the value being 0.39 ppm.

Table 6: Annual Excess of 03

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Annual Excesses of O3 (ppb) by the Station

2015-2006

المحطة	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Station
	عدد التجاوزات الساعية / نسبة التجاوز					Number of Hourly Excesses / Ratio of Excesses					
المنصورية	52	34	7	46	-	21	6	36	50	7	Mansoria
	0.62	0.42	0.08	0.55		0.24	0.07	0.43	0.64	0.084	
القرين	-	-	-	-	-	62	42	79	149	365	Al-Qurain
						0.95	0.47	1.31	2.08	4.76	
الرقة	100	16	16	-	1	-	11	-	-	-	Reqa
	1.21	0.17	0.19		0.012		0.13				
الجهراء	27	3	1	8	12	33	32	20	21	2	Al-Jahra
	0.31	0.035	0.012	0.09	0.14	0.4	0.39	0.27	0.26	0.03	
علي السالم	45	31	34	3	47	38	28	120	70	8	Ali Al-Salem
	0.56	0.36	0.4	0.04	0.59	0.47	0.36	1.46	0.83	0.11	
المطلاع	-	-	65	6	56	3	35	7	32	95	Al-Mutla
			1.78	0.075	0.66	0.04	0.42	0.15	0.43	1.07	
الرميثية	28	5	1	-	2	-	15	57	187	225	Rumeithiya
	0.329	0.058	0.012		0.024		0.183	0.692	2.44	2.6	
الفحيحيل	174	148	109	3	85	32	26	31	28	51	Al-Feheheel
	1.99	1.7	1.25	0.035	1.15	0.37	0.304	0.36	0.37	0.6	
الشعيبة	-	-	-	-	6	5	-	-	252	117	Shuaiba
					0.09	0.06			3.05	1.56	
سعد العبدالله	-	-	-	-	2	19	40	8	18	158	Saad Al-Abdullah
					0.09	0.22	0.48	0.08	0.22	1.87	
الشويخ	-	-	-	-	-	102	51	17	51	42	Shuwaikh
						1.59	0.59	0.2	0.65	0.53	
السلام	-	-	-	-	-	-	31	129	16	19	Al-Salaam
							0.07	2.22	0.2	0.25	

المصدر: الهيئة العامة للبيئة — Source: Environment Public Authority (EPA)

لم يتم قياس الملوث في المحطة — - The Pollutant Not Measured in the Above Fixed Station

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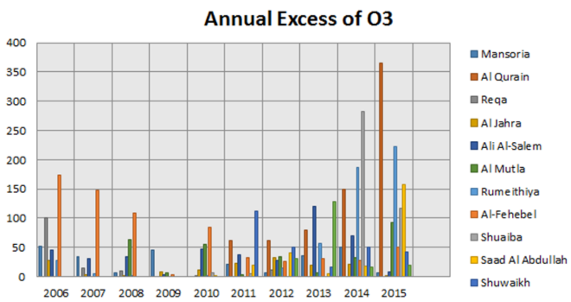

Fig 10: Annual Excess of O3

The ground level concentrations of O3 varied largely in the various stations with the lowest value being 0.03 at Al Fehebel and the highest value being in Al Qurain at 0.25 ppb.

Table 7: Annual excesses of NH3

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Annual Excesses of NH3 (ppb) by the Station

2015-2006

المحطة	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Station
	عدد التجاوزات الساعية / نسبة التجاوز					Number of Hourly Excesses / Ratio of Excesses					
المنصورية	-	-	-	-	-	-	-	-	-	-	Mansoria
القرين	-	-	-	-	-	-	-	-	-	-	Al-Qurain
الرقة	-	-	-	-	-	-	1	1	-	-	Reqa
							0.012	0.012			
الجهراء	-	-	-	-	-	-	-	-	-	-	Al-Jahra
علي السالم	-	-	-	-	-	-	-	-	-	-	Ali Al-Salem
المطلاع	-	-	-	-	-	-	-	-	-	-	Al-Mutla
الرميثية	-	-	-	-	-	-	-	-	-	-	Rumeithiya
الفحيحيل	-	-	-	1	-	-	-	1	-	-	Al-Feheheel
				0.012				0.012			
الشعيبة	-	-	-	-	1	-	-	-	-	-	Shuaiba
					0.015						
سعد العبدالله	-	-	-	-	-	-	-	-	-	-	Saad Al-Abdullah
الشويخ	-	-	-	-	-	-	-	-	-	-	Shuwaikh
السلام	-	-	-	-	-	-	-	-	-	-	Al-Salaam

المصدر: الهيئة العامة للبيئة — Source: Environment Public Authority (EPA)

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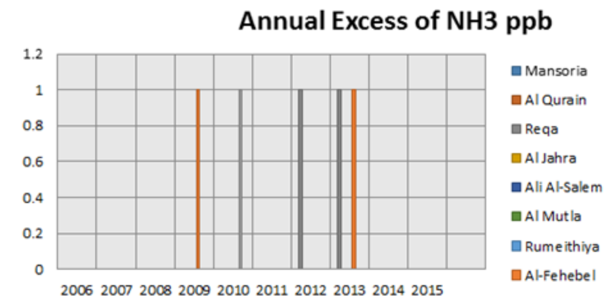

Fig 11: Annual Excess of NH3 ppb

The concentrations of NH3 were equal in two stations which are Al Qurain and Reqa respectively. This is attributed to the fact that Reqa has a landfill site nearby and Al Qurain is a station dominated by farming and animal husbandry which are the root causes of NH3 emissions to the air.

2.5.1. Problems

Figures notably, the GCC requires a structured technological framework to overcome the challenges facing the transport sector as parts of these challenges have been caused by global political and economic uncertainties.

First, there are fluctuations in the oil prices. GCC government has reduced investments and does not want to justify spending on transport infrastructure projects. Second, there is a higher mortality in the GCC region majorly caused by accidents. This translated to an economic loss is about 2.5 percent of the GDP among the GCC countries. Transportation carries have also led to the increase in the environmental costs (Bätzner, & Stephenson, 2017). The emission levels are higher than the world average of 1.03 tons of Carbon dioxide per capita. This can be broken down to 5.59 tons in Qatar, 4.12 tons in Saudi Arabia, 3.58 in Kuwait, 3.49 in the UAE, 3.16 in Oman and 2.44 in Bahrain. This means that the Arab countries should try decrease emission of CO_2 and meet its international and national commitments. Additionally, populations have significantly risen and thus require the upgrading of transport systems to take care of the rising transport needs. In addition, the economic development in the GCC region relies on efficient as well as reliable transport infrastructure in the transportation of goods and attraction of citizens. Drivers experience an average loss of eight working days per year due to congestion on the roads (Stephenson, & Bätzner, 2017).

2.5.2. Solutions

The GCC countries need to take advantage of both the current and emerging new technologies to help in the upgrading of the transportation systems in the region. Besides, the new urban challenges in the GCC area call for watertight justification in the investment in Smart Transport solutions. Tapping on different technologies, the GCC region can invest in advanced public transportation, congestion charging, smart parking, and traveler information systems. Smart Transport options will lead to an obvious reduction in the traffic levels. Smart Transport systems will also lead to attain the sustainability targets (Alshamsi, & Diabat, 2017). Previously, the sustainability levels were hard to achieve due to the environmental impact caused by petroleum-based modes of transportation increases. Investing in technology will also lead to the reduction in the commute times and make it easy for individuals to get to work thus enhancing the quality of life and ensure too a forward-thinking municipality where it will attain competitive edge over the neighbors. Furthermore, staying up to date with the advancing technology in electric and hybrid vehicles is effective in the control of energy emission. Therefore, transport must be made a priority in the GCC region by embracing automated vehicles besides rail systems which can travel at a higher speed. A sustainable future requires smart city planning and the transportation sector upgraded (Bayram, & Mohsenian-Rad, 2016).

2.6. Result of Study

2.6.1. Multivariate Linear Regression

ANOVA

Analysis of variance is utilized in the analysis of the effects of more and independent variables on the dependent variables. The table below shows the results of different clusters and transport behaviors in the GCC region.

Table 7: Results of different clusters and transport behaviors in the GCC region.

Number of clusters	Share of private motorized modes		Public transport use		Bike use	
	F	n2	F	n2	F	n2
1	15.36***	.007	.077***	.000	1852.64***	.415
2	277.54***	.296	178.99***	.145	200.69***	.200

It is, therefore, important for the government in the GCC regions to come up with alternative modes of transport such as and car and bike sharing and congestion easing.

2.6. Result of the Neural Network

To get the results of the future demand of energy in the transportation sector, the MATLAB neural network tool was used. This toolbox incorporated the 6 equations to give accurate results. All models with three and four parameters showed accurate results in terms of Root Mean Squared Error (RMSE), R^2:

$$R^2 = \frac{\left(\sum XY - n\bar{X}\bar{Y}\right)^2}{\left(\sum X^2 - n\bar{X}^2\right)\left(\sum Y^2 - n\bar{Y}^2\right)} \quad (1)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n}} \quad (2)$$

Furthermore, since the R^2 values are above 0.950, these models are effective. The results in table 8 proves that there is improvement when the values of energy consumption are estimated using the artificial neural network in comparison to the multiple linear regression models. The data used to get these results were divided in 3 categories 25 data points that were used for training, four data points that used for validation, 21 points predicted to get results of the future energy consumption demand. The results of the test period from the ANN and MLR models are displayed in the table below.

Table 8: Results of the test period from the ANN and MLR models

Method	Error	Model 1	Model 2	Model 3
ANN	R2	0.9962	0.9840	0.9798
cMLR	R2	0.9930	0.9930	0.9890
	RMSE	20.3059	145.8258	187.6521
Method	Error	Model 4	Model 5	Model 6
ANN	R2	0.9910	0.9955	0.9923
	R2	0.9858	0.9931	0.9935
MLR	RMSE	24.3806	161.2944	42.0043

Detailed The ANN models display accurate performance in predicting the energy consumption when compared to MLR models. Both models provide accurate prediction; the improvement in ANN models proves that ANN Models offers advantages which are apparent when predictions are done over long periods.

2.6.1. Evaluation of the Models

Multiple Linear Regressions (MLR)

The MLR model is a statistical formula that involves incorporating relationship between two or more variables using equations which relates to the variable of interest to a series of independent variables. In this analysis, the initial point is defining the independent and dependent variables which are vital in explaining the response behavior. (E) Energy Consumption is the dependent variable. Other parameters used in the multiple linear regression include

- Large to small engine sizes (ES)
- Public to private car ration (PP)
- Gasoline fuel cost (G$)
- Income Level (IL)
- Number of vehicles (V)

Equation (3) that represent the suggested multiple liner regression model is:

$$(E) = \mu 0 + \mu 1(V)t + \mu 2(IL)t + \mu 3(G\$)t + \mu 4(PP)t + \mu 5(ES)t + \varepsilon t \quad (3)$$

This formula is a simple illustration of how to calculate the energy consumption with the listed variables. Below is another model (ANN Model), though a little more complex compared to the above-mentioned.

2.6.2. ANN Model

This part of research focuses on the ANN and multiple liner regression models to forecast the energy consumption within the transportation sector in GCC. This study incorporates various variables such as number of passengers, registered vehicles, oil price, and GDP to structure a transportation model of GCC.The study uses 6 equations, and each equation is based on some of the mentioned variables mentioned below.

Table 9: Variables applied in each model

Method	GDP per Capita	Population	Nominal Oil Price	Total number of registered vehicles	Annual vehicle Transport Amount
1	X	X			X
2	X			X	X
3			X	X	X
4		X	X		X
5	X		X	X	X
6	X	X	X	X	X

This table lists the variables applied in the 5 equations. The equations are first creating using the multiple liner regression method. The equations used are:

Table 10: Multiple liner regression method equations

$y1 = \beta 1\ x1 + \beta 2\ x2 + \beta 5\ x5 + \beta 0$	(4.1)
$y2 = \beta 1x1 + \beta 4\ x4 + \beta 5\ x5 + \beta 0$	(4.2)
$y3 = \beta 3\ x3 + \beta 4\ x4 + \beta 5\ x5 + \beta 0$	(4.3)
$y4 = \beta 2\ x2 + \beta 3\ x3 + \beta 5\ x5 + \beta 0$	(4.4)
$y5 = \beta 1x1 + \beta 3\ x3 + \beta 4\ x4 + \beta 5\ x5 + \beta 0$	(4.5)
$y6 = \beta 1x1 + \beta 2\ x2 + \beta 3\ x3 + \beta 4\ x4 + \beta 5\ x5 + \beta 0$	(4.6)

In this 6 equations, energy consumed is prevented by the variables y1 to y6, the indicators of regression are x1 to x5, whereas β0 to β5 represents coefficients of regression.

5. Conclusion and Recommendations

This paper concurs with previous studies conducted for the investigation of dispersion, air pollution and photochemical mechanisms in the city of Kuwait. There was a difference in the results derived from the various pollutants found in Mansoura, Al Qurain, Reqa, Al Jahra, Ali- Al Salem, Al Mutla, Rumeithiya and Al Fehebel. The areas that were affected by substantial emissions of pollutants were the ones close to the oil refineries in the area. With comparison being made to the set international air quality limits, we can deduce that the atmospheric condition in the town of Mansoria ignored the limits with only Sulphur Oxide being the lowest.

The concentrations of O3, NO, and SO2, are all below the set international standards in most of the towns although the emissions of NHMC in all cities is high due to the availability of small-time industries that aren't regulated as expected by the law. We highly recommend that the oil refineries and other power-generating sectors to ensure they perform measurements that aim at the minimization of emission rates in the study areas. This will help guide future researchers and studies on pollution dispersion and patterns.

Since the ANN model is a blackbox model and it has hidden trends implicitly and explicitly variables, it becomes hard to illustrate the uniform results. However, there are factors which might have been captured in the model which can explain the results such as public transportation become popular while change the modes of transportation and the delivery of freight become effecting using optimal logistic methods. An increase in energy consumption in the transport sector of the GCC has been displayed by ANN. Moreover, improved economic conditions might make the Artificial Neural Network methods to revise the prediction upward in terms of energy consumption.

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