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A System Dynamic Energy Economic Assessment Model for Road Transportation

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Abstract *– The road transport sector is highly dependent on conventional energy resources that account for approximately 20% of a country's primary energy. This figure will certainly increase in the upcoming years due to the growth in population, leading to an increase of vehicles in the country, therefore increasing the consumption of fuel. Limited, poorly managed public transportation and the increase in the number of registered cars has led to an increase in emissions produced that contribute to environmental factors including air pollution and noise, as well as carbon dioxide (CO_2), and other greenhouse gases. This paper evaluates the economic impact of implementing energy efficiency strategies in the transportation sector using a system dynamic model and associated scenario analysis that can be applied to Bangladesh. Transportation data was collected and analyzed using Stella, a visual programming language for system dynamics modeling, to develop the energy economics evaluation model. Hence, the economic effect of various alternative scenarios for emission reduction and fuel consumption enhancement was identified and evaluated. It was estimated that the economic savings that would be achieved by adopting the 70/30 and 50/50 scenarios on private vehicles for the year 2027 were $74, 800, 00 and $124,700,000 respectively. Therefore, a significant reduction of approximately 60.35% is expected in financial terms. This demonstrates that along with emission and fuel consumption reduction, the proposed strategies will also achieve substantial financial savings.*

Keywords *– Bangladesh, economic evaluation, emissions, energy efficiency, road transport, system dynamics.*

1. INTRODUCTION

Worldwide, 98% of the energy consumption by transport is based on oil [1] that makes the transport sector heavily dependent on the price and availability of oil with consequent environmental impact. To achieve economic savings from fuel consumption policymakers introduce interventions targeting domestic oil prices when international oil prices rise. This allows domestic oil prices to correspond to global market prices. Freezing gasoline prices goes against encouraging public transportation use. Demand for public transportation may increase if oil prices increase, especially if the public transportation system is accessible and well established [2]. Thus, increasing gasoline prices via taxes or user fees can be methods adopted to incentivize public transportation [3]. Any country wishing to achieve emission reductions and economic savings should address the feasibility of these measures. Environmentally approachable and sustainable road transport is a key feature of the Bangladesh transport policy from 2013 [4]. The following literature gives a bird's-eye view of the existing literature about road transport research.

Economic development is another factor in the growth of road transportation. This in turn increases energy consumption, however; enhancing energy efficiency can reduce transportation energy consumption, and pollutant emissions [5]. Chapman [6] assessed new technologies, including alternative transport fuels, to decrease the dependence on petroleum, and suggested that technological innovation is expected to be the only solution to the climate change problem. Wang *et al.* studied the present practical developments of dynamic traffic assignment (DTA) models in environmentally sustainable road transportation applications in 2018. Gasoline prices and national fuel tax policy changes also affect road transportation energy consumption to certain extent. Financial credit and employment implications of policies influencing road transportation energy consumption in China have been studied. An increased energy utilization rate can reduce road transportation energy consumption and pollutant emissions, as can the price of gasoline and national fuel tax policy changes [7].

Ansari *et al.* [8] carried out a review study that analyzed the development of continuous approximation (CA) models for transportation, distribution, and logistics problems to synthesize current innovation and to recognize present research gaps. They focused on major principles and key results from CA models. Asadabadi and Miller-Hooks [9] studied the problem of optimal continuing transportation investment planning to shield from and alleviate the effects of climate change on roadway operations. The solution proposed by Asadabadi and Miller-Hooks enables the estimation of options relating to where, when, and to what level to make infrastructure investments. Yıldız *et al.* [10]

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developed a technique to optimize the location and capability of charging stations to assure the ease and speed of charging electric vehicles in urban areas and evaluated the electric vehicles demand in the transportation sector.

Factors including government policies, economic growth, employment, energy consumption, and environmental impact have been put into the system, and their interactive relationships were studied. It was found that road transportation energy consumption was affected by both market conditions and government policies [10], [11]. Based on the recommendations derived from J. Chai's study, the Chinese government should enhance and develop buses as public transportation to resolve city congestion and to encourage green transport. He suggested the government introduces strategies to discourage purchasing of private vehicles, such as strengthening the automobile credit market regulation, improving the control of automobile credit funds, managing private car parking, collect congestion charges and plan low emission zones and travel times. Road transportation energy consumption in China is expected to reach around 226181.1 ktoe by the end of 2015, and about 347,363 ktoe by 2020, [12].

Sun *et al.* [13], evaluated the coordinated development of economic, social, and environmental benefits taking four Chinese autonomous municipalities as examples, realizing the construction of urban public transportation infrastructure will cause a revolution in urban living. This will most importantly increase the flow of population, which will raise the urbanization rate, increase urban employment, leading to urban social development and progress. "Transportation infrastructure is an important basic condition of regional economic development. It generally confirms the universal knowledge that one of the basic functions of transportation infrastructure is promoting economic development. Also, the urban public transportation infrastructure has proven to be an effective way of tackling environmental problems, which were brought by the expansion of urban scale and the use of private transport".

Timilsina and Shrestha [14] did a comprehensive study of climatic change in Asia, focusing on the transportation sector. They pointed out the need to identify key factors that drive CO_2 emission so that the preparation of policies and strategies will be much easier. The transport sector contribution to the total national CO_2 is continuing steadily for Bangladesh according to their study. They stated that, even though the rail system was a vital mode of transportation in Bangladesh, the road transportation sector is contributing a lion's share in the CO_2 emission.

Alam *et al.*, [15] analyzed the future energy requirements for Bangladesh based on Long-range Energy Alternatives Planning (LEAP). They identified that the imported energy demand from the transportation sector will increase by more than 10 times in a span of 25 years as per the Business as Usual (BAU) scenario.

The United States Agency for International Development (USAID), [16] in one of their studies reported that for the road transport sector, GHG emissions are approximately 14% for Bangladesh. According to them, the transport sector energy consumption reduction has to be a major priority, to reduce GHG emissions as well as to achieve significant reduction in fuel consumption. In their report, the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) feature are noticeably reinforced.

Ahmad *et al.*, [17] estimated the major GHG emissions – CO_2, N_2O, and CH_4 from transportation in Bangladesh. In addition, by using a co-integrating econometric model, they projected the future transportation performance for the country. According to their study, the road transportation sector in Bangladesh is currently undergoing a phenomenal change and the likely GHG emission growth rate in the projected study period is more than 17% per year. Rahman [18] emphasized the importance of public transportation in Bangladesh and the need to decrease emissions as well as fuel consumption to significantly reduce the national transport energy consumption.

The referred literature emphasized the importance of developing the transportation infrastructure to reduce dependence on private vehicles and to encourage the use of public transportation facilities. Decreasing climate change in Asia can be achieved by giving precedence to the transportation sector, and by studying the future energy requirements for Bangladesh and GHG emissions produced by the transportation sector. Therefore, this study is a vital topic for Bangladesh transportation sector. However, it was noticed that no studies on this subject was previously carried out in any of the Gulf Corporation Council (GCC) countries or in Bangladesh, despite the fact they all struggle with limited and poorly managed public transportation systems. Through this study, authors are trying to fill the above gap by developing an economic model and analyzing the associated benefits by demonstrating the results in one of the GCC countries, Kuwait. The referred literature emphasized the importance of developing the transportation infrastructure to reduce dependence on private vehicles and to encourage the use of public transportation facilities. Even though Kuwait is not a highly industrialized country, the per capita CO_2 emission stands among the top ten countries in the world, and the transportation sector accounts for 14% of the share [3]. The backbone of Kuwait's economy is the export of oil, which provides 80% of the country's income [2]. However, the recent increase in the internal consumption of oil is very alarming, as it consumes 24% of the oil produced in the country. As the above figure is mainly distributed between power generation and transportation sectors [19], any reduction in the transportation sector's fuel consumption will not only improve the country's rank in the per capita CO_2 emission but also will enhance Kuwait's oil reserves. These factors show the importance of this study for the region. Hence, a detailed study was carried out to identify the impact of the reduction of private vehicles on the environmental parameters, specifically CO_2 emission. The main contribution of this study and novelty are as follows:

- A System dynamic modeling (SDM) methodology is suggested to identify the fuel consumption reduction and associated emission reductions, so as to develop a suitable public transportation system.
- In this study, the authors predict the possible growth rate of GHG emission, especially CO_2, until 2027, along with the projected number of vehicles, which is not performed previously in the GCC region.
- The results are based on the three different scenarios carried out in this study. This can be used as a reference for calculating the impact on associated parameters in other sectors.
- The economic benefits and the associated environmental gains are predicted as the major outcomes of this study. It will be thought-provoking to the policymakers to consider a category, which was not previously studied.

To carry out this study, a detailed methodology based on system dynamic modeling (SDM) is developed. The methodology consists of two parts. In the first part, various parameters such as the type of vehicles, daily distance covered, average fuel consumption, etc. are collected through a survey. In the second part, the actual analysis of the data through system dynamic modeling to measure the impact of the pollutants such as CO, CO_2, HC, and NO is done. Data are collected for one year. The methodology is presented below.

2. METHODOLOGY

The economic benefits are evaluated by using the following methodology, as illustrated in Figure 1. Data on transportation in the study area were collected, from various sources such as the Ministry of Interior (MOI), Ministry of Electricity and Water (MEW), statistical books, relevant literature as well as from other government sources. In addition to this, the project team collected data using a survey consisting of 17 questions, which was distributed to participants. The present population of the study area was collected, and the population growth for the next ten years was forecast. The number of commercial and non-commercial vehicles in the study area between the years 2006 to 2017 were also collected. The data collected were screened and verified for the correctness and accuracy. The sampling plan used was simple stratified cluster sampling to give equal opportunity for all sectors of data.

To ensure the quality of data collected based on the survey, statistical tools such as coefficient of variation, standard error, standard deviation, etc. were determined. The population growth will lead to an increase in vehicles, consequently producing an alarming increase in CO, CO_2, HC, and NO emissions. This was then projected for the next ten years using System Dynamic Modeling (SDM) growth rate to estimate the private vehicle population. The fuels that were considered in the study are petrol and diesel. The projected number of vehicles was then used to carry out three different scenario analyses. The do- minimum (base case) scenario- where the number of cars operating in the future is projected using SDM. Based on the existing growth rate, the amount of fuel consumed by the private car transport sector and the corresponding emission levels have been simulated. The system dynamic model applicable to the interaction of the social sector, fuel, and energy sector, environmental sector, and their impact on the overall road transport sector in terms of economics and atmospheric pollutants were developed.

2.1 System Dynamic Model Development

The system dynamic model (SDM) applicable to the economic evaluation of the road transport sector was developed. The various parameters considered for building the SDM are presented below in figure 1. POP - Total Population, BR - Birth Rate, DR - Death Rate, IMR - Immigration Rate, OMR – Out-Migration Rate, BN - Birth Normal, DN - Death Normal, IMN - Immigration Normal, OMN – Out-Migration Normal. In this segment, population of the base year, birth rate, death rate, immigration, and outmigration are considered.

The size of the population is predisposed by both the net birth rate and the net migration rate. The net birth rate equals the total number of births per year, minus the total number of deaths. Likewise, the net migration rate equals the number of immigrants minus the number of out-migrants. The number of births and deaths in addition to net immigrants can be defined as a percentage of the yearly population. Thus, the population model can be defined as stated below:

$$\text{Population}(t) = \text{Population}(t-dt) + (\text{Birth\_Rate} + \text{Immigration\_Rate} - \text{Death\_Rate} - \text{Out-Migration\_Rate}) * dt \quad (1)$$

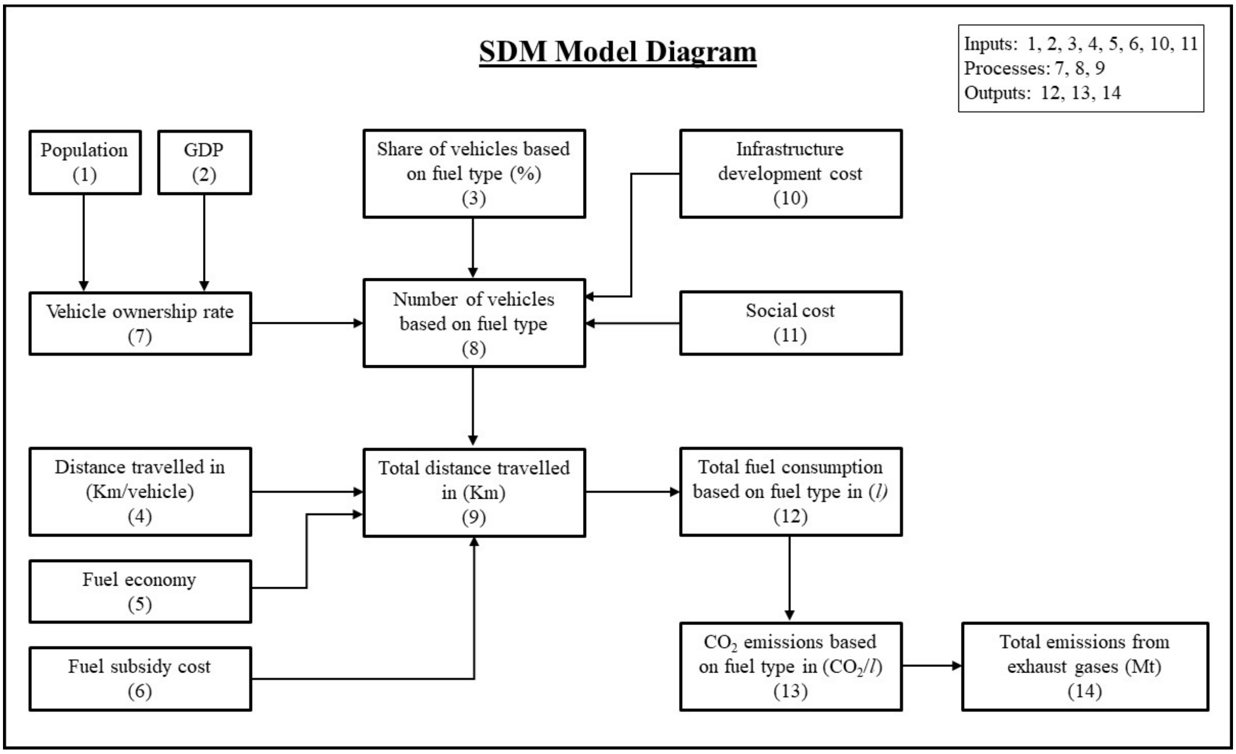

Fig. 1. Model diagram of system dynamic parameters for the energy economics assessment for the transport sector.

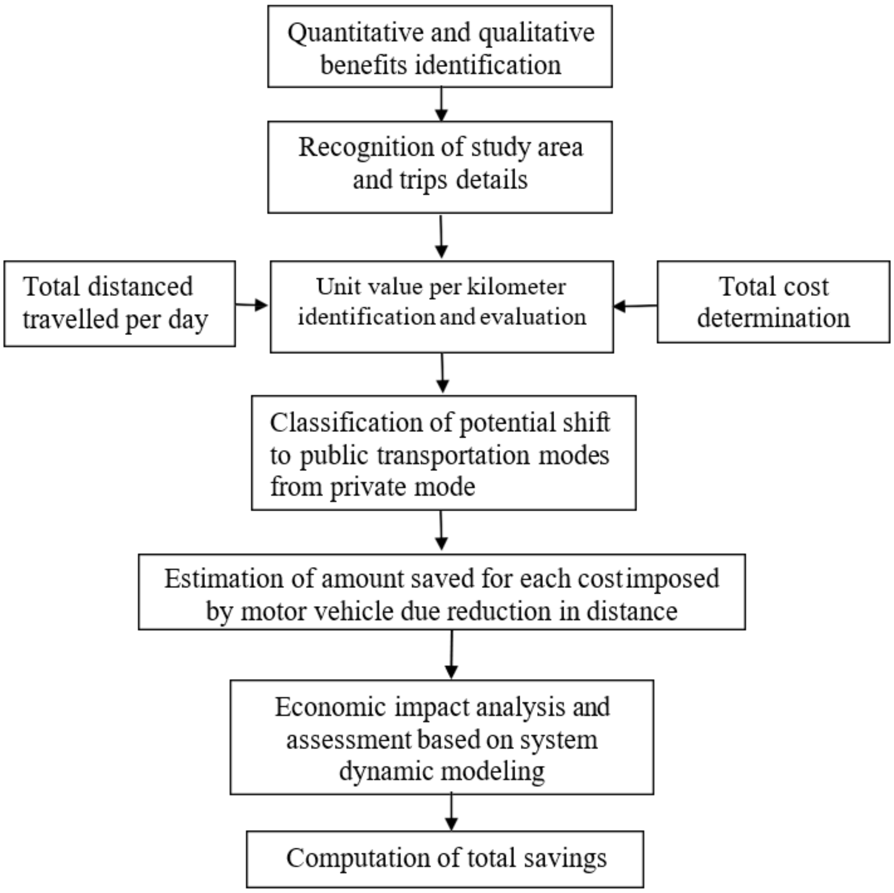

Fig. 2. Flow diagram showing the system dynamic modeling methodology.

The base year population for the study area is taken as 2,217,258 as per the data available from the government. The Birth Rate is inspired by the number of births per 1000 Population, Birth Rate Normal, and Initial Population. Birth Rate is established by multiplying the Birth Rate Normal by the population. Birth Rate Normal is expressed in terms of several births per 1000 of the population. The population growth rate is taken as 3.44 [20] in the year 2017 and is expected to reach 2.63 in the next ten years. The death rate normal is described as the number of deaths for every 1000 population. It is expected to be 2.2 per 1000 population as per data and is expected to reduce further due to improved health services that would be fundamental to the study area. In the study area, the total immigrant population was 1,375,468 in 2000, whereas it was 2,931,401 in 2015. This implied that there is high migration to the study area every year, by which the immigrants comprise of nearly 69% of the total population. Figure 2 depicts the flow diagram explaining the system dynamic modeling methodology and Figure 3 presents the system dynamic model developed for the energy economics assessment for the transport sector.

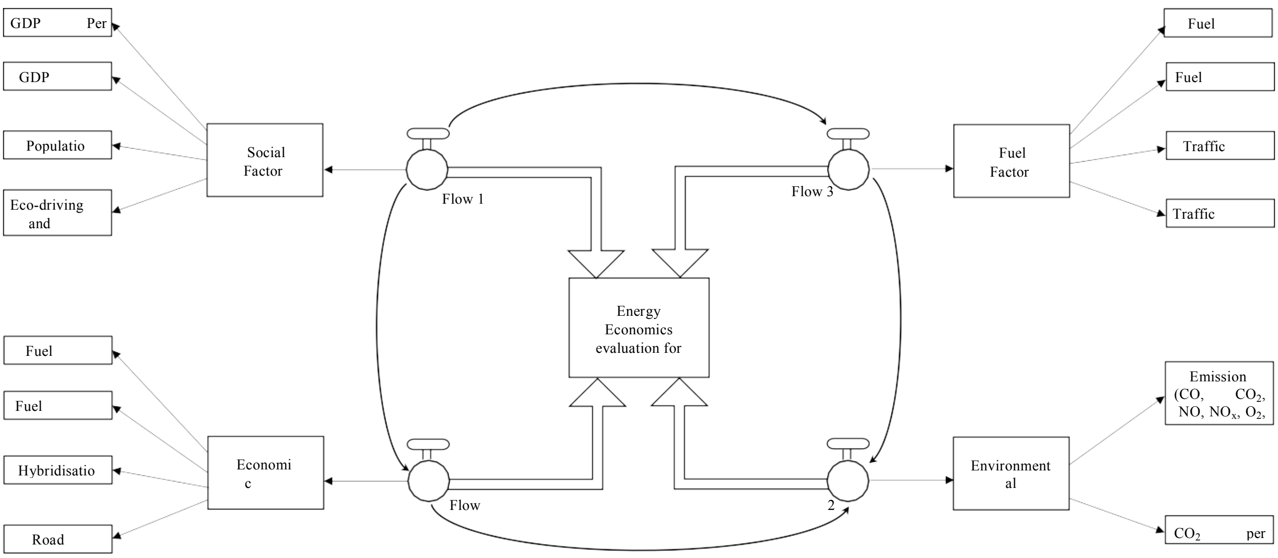

Fig. 3. System dynamic model for the energy economics assessment for the transport sector.

3. MODEL RESULTS AND SCENARIO ANALYSIS

Among the three scenarios analyzed in this study, the do- minimum (base case) scenario, where the assumption is, the normal situation. Scenario II, the 50:50 scenario, which is replacing 50% of private vehicles with public transport facilities, and scenario III, the 70:30 scenario where 30% of the cars on the road will be replaced with public transport. The effect of the road transport sector is considered in two major fields – fuel consumption or energy requirement and GHG emissions. Hence, the outcome was investigated for these two fields in the below three scenarios.

3.1 Do-Minimum (base case) Scenario

Under the base case scenario, it is assumed that the prevailing patterns will remain in the future. The current vehicle exhaust emissions (base case) were derived from the measurements taken during the one-year study. To measure the concentration of CO, CO_2, HC, and NO in vehicle exhaust emissions, two types of tests were applied: the first type in which, the vehicle is in a state of idle, and the second type in which, the vehicle is in the state of accelerating. This data was projected using population increase to forecast emissions until the year 2027.

Based on the number of vehicles operating in the study area for the year 2015, the number of cars until 2027 is estimated, and CO, CO_2, HC, and NO emissions expelled from the cars' exhaust is calculated for each year. Hence, the major emission parameters of CO, CO_2, HC, and NO in terms of parts per million (ppm) and fuel efficiency parameters such as fuel consumption of vehicles were identified for the present scenario. Based on this, the forecasted values till 2027, including the CO_2 per capita are identified and presented in Table 6. The existing growth rate, the amount of fuel consumed by the private car transport sector, and the corresponding emission levels have been simulated. This is presented in Table 1. Table 2 shows the estimated annual cost of fuel while applying the do-minimum scenario.

Table 1. Predicted emissions based on private vehicle population.

Year	Population forecast	Forecasted vehicle population	Emissions (x 10^6) (ppm)				Metric tons per capita
			CO	CO_2	HC	NO	CO_2 per capita
2016	4411124	1708589	2910.43	246173	74.2285	137.134	55807.25
2017	4590028	1798615	3530.22	253640	88.9292	310.979	55258.92
2018	4791651	1894360	4145.04	262549	64.8367	433.847	54793.06
2019	5002837	1996133	5398.84	288882	108.715	475.841	57743.67
2020	5222177	2105223	4614.69	304877	87.4339	327.515	58381.13
2021	5448511	2220438	4435.94	325862	79.0747	315.311	59807.47
2022	5672497	2340437	4972.92	335459	100.92	397.148	59137.75
2023	5890626	2464412	5409.41	352921	106.133	454.917	59912.32
2024	6108252	2594971	5796.45	372564	108.997	484.076	60993.56
2025	6322733	2734216	6128.28	394823	118.39	490.694	62445.07
2026	6553190	2880854	6234.48	415845	119.379	488.722	63456.81
2027	6801274	3035658	6555.37	437952	125.747	522.103	64392.57

Table 2. Prediction of the estimated annual cost for fuel consumption.

Do-Minimum Scenario		
Year	Total volume of fuel consumption liter/month	Petrol Price X Total volume of fuel consumption (liter/month)
2016	391573870.5	46336241.34
2017	279374884.8	33059361.36
2018	294246716	34819194.73
2019	460258854.9	54463964.49
2020	583372659.6	69032431.38
2021	578322858.2	68434871.56
2022	510204409.9	60374188.51
2023	532636613.3	63028665.91
2024	587151647	69479611.56
2025	650984418.5	77033156.19
2026	689504480.8	81591363.56
2027	707447253.2	83714591.63

The number of private cars until the year 2027 is estimated based on the number of vehicles operating in Kuwait for the year 2015. CO, CO_2, HC, NO emissions expelled from the cars is calculated for each year. For do- minimum scenario, the results showed that the trips taken by private cars form a major share and the corresponding CO_2 per capita based on this has been estimated as 64,392.57 metric tons per capita for the year 2027 as shown in Table 1. Inevitably, with the increase in the number of vehicles, the fuel consumed increases. The demand for fuel by private vehicles reaches to approximately 391,573,871 liters per month in 2016. This figure is established by calculating the monthly fuel consumed by the participants in the survey using fuel efficiency details and monthly kilometers reading of surveyed vehicles.

The liters of fuel consumed in a month for each participant is then calculated using the equation:

$$\text{Liters of fuel consumed in a month} = \textit{(Fuel Efficiency/100) x (Monthly Kilometers Driven)} \quad (2)$$

This will give the monthly amount of fuel in liters consumed for each vehicle. The average liters for each month are computed, and then by projecting the current vehicle population to the year 2027, the growth in vehicles is forecasted, thereby, the amount of fuel consumed by vehicles in 2027 is calculated. Fuel consumed is established to be 707,447,253 liters per month in the year 2027. The average quantity of diesel consumed by buses in each month is multiplied by the computed number to determine the quantity of diesel consumed by buses in 2027. Based on the existing scenario, the monthly petrol consumption from vehicles in Kuwait is 400 million liters per month. The cost of fuel consumed by private vehicles is determined by multiplying the amount of fuel consumed monthly by the price of petrol. The average price of petrol is established to be $0.039/liter. This is the average of the three types of fuel, Super, Premium and Ultra that are being used in the study area. The cost of diesel is $0.031/liter. These numbers are multiplied by the corresponding quantity of fuel, and the total cost of fuel is established for buses and private vehicles.

3.2 50:50 Scenario

The second scenario is 50:50, which is replacing 50% of the operating vehicles with buses. The hypothesis considered is that one bus will replace 40 cars. This is shown in Table 3 below.

To achieve the 50:50 scenarios, 50% of the vehicles are replaced with buses. Introducing the metro in the country, and promoting utilization of the services by providing smooth, time-saving commutes can achieve this increase and act as an incentive for 50% of private vehicle owners to replace their daily private vehicle trips by public transportation. This reduces the increase of private cars by 50% by the year 2027 compared to the do-minimum scenario.

The total cost of fuel consumed monthly for both buses and cars are determined. The average quantity of diesel consumed each month (liters/month), was multiplied by the computed number of buses to determine the volume of diesel consumed by buses. Table 4 shows the savings yielded from the 50/50 assumption, the base case monthly cost of petrol was compared to the monthly cost of fuel for 50% of cars and 50% of buses. Savings of 45% were found to be achieved. The total cost of fuel for 2027 was $150,338,987 when this scenario was adopted, where else it was $274,809,891 in the do-minimum scenario, as shown previously in Table 3.

The total volume of fuel consumed by cars, based on this scenario, is 353,723,627 liters per month for the year 2027, which is half of the fuel consumption in do minimum scenario (707,447,253 liters per month). Also, a reduction of 50% is observed in fuel consumed by petrol-driven cars. Table 4 shows the expected savings from scenario II.

3.3 70:30 Scenario

The third scenario is 70:30, where 30% of the cars on the road will be replaced with buses. These two scenarios will further encourage the use of public transportation, decreasing the number of vehicles on the roads in Kuwait, consequently leading to an overall drop in fuel consumption. This, in turn, will reduce energy consumption and emission levels.

In scenario III, 30% of cars have been converted into buses, therefore, giving the 70:30 hypotheses, restricting the growth of cars for the year 2027. In this scenario, public transport has been developed and enhanced to encourage 30% of car owners to replace their daily private vehicle trips to utilize public transportation. This is shown in Table 5. The decrease in private cars leads to a reduction in fuel consumption, as displayed in Table 6. The total cost of fuel consumed in 2027 was $200,127,347 for scenario III, showing a 27% saving was achieved compared to $274,809,891 in the do-minimum scenario.

Adopting one of the presented scenarios can achieve vast financial rewards. This is illustrated below in Table 7. Implementing the simpler policy, the 70:30 hypotheses for the year 2019 can achieve savings of $48,587,794 and eventually savings of $74,682,541 for 2027.

Table 3. Predictions based on 50/50 scenario (Scenario II).

Year	Number of Cars	50% of Cars	Convert 50% of Cars to Buses
2016	1708589	854295	21357
2017	1798615	899308	22483
2018	1894360	947180	23679
2019	1996133	998067	24952
2020	2105223	1052612	26315
2021	2220438	1110219	27755
2022	2340437	1170219	29255
2023	2464412	1232206	30805
2024	2594971	1297486	32437
2025	2734216	1367108	34178
2026	2880854	1440427	36011
2027	3035658	1517829	37946

Table 4. Expected savings from 50/50 scenario (Scenario II).

Year	Base Case - Monthly Cost of Petrol ($)	Monthly Diesel Consumption by Buses (50/50), (liter/month)	Diesel Price ($)	Monthly Petrol Consumption by Cars (liter/month)	Petrol Price ($)	Total Cost ($)
2016	152,107,978	22,956,150	7,159,024	195,786,935	76,053,991	83,213,015
2017	108,523,964	16,378,447	5,107,724	139,687,442	54,261,984	59,369,707
2018	114,300,971	17,250,313	5,379,623	147,123,358	57,150,484	62,530,107
2019	178,788,855	26,982,830	8,414,771	230,129,427	89,394,427	97,809,199
2020	226,612,761	34,200,419	10,665,624	291,686,330	113,306,382	123,972,003
2021	224,651,154	33,904,372	10,573,298	289,161,429	112,325,577	122,898,875
2022	198,190,350	29,910,905	9,327,910	255,102,205	99,095,173	108,423,084
2023	206,904,202	31,226,001	9,738,031	266,318,307	103,452,101	113,190,132
2024	228,080,722	34,421,963	10,734,711	293,575,824	114,040,361	124,775,072
2025	252,876,741	38,164,181	11,901,747	325,492,209	126,438,371	138,340,118
2026	267,839,971	40,422,433	12,605,998	344,752,240	133,919,985	146,525,983
2027	274,809,891	41,474,334	12,934,042	353,723,627	137,404,946	150,338,987

Table 5. Scenario III: 70:30- Private vehicle replacement with public transport systems.

Year	Number of Cars	30% of Cars	70% of Cars	Number of buses after converting 30% of cars
2016	1708588.92	512576.676	1196012.2	12814.417
2017	1798614.754	539584.4262	1259030.3	13489.611
2018	1894359.563	568307.869	1326051.7	14207.697
2019	1996132.838	598839.8515	1397293	14970.996
2020	2105222.841	631566.8524	1473656	15789.171
2021	2220438.327	666131.4982	1554306.8	16653.287
2022	2340436.858	702131.0575	1638305.8	17553.276
2023	2464411.941	739323.5824	1725088.4	18483.09
2024	2594970.579	778491.1736	1816479.4	19462.279
2025	2734215.974	820264.7922	1913951.2	20506.62
2026	2880854.134	864256.2403	2016597.9	21606.406
2027	3035657.703	910697.311	2124960.4	22767.433

Table 6. Predicted savings from 70/30 assumption (Scenario III).

Year	Base Case: Monthly Cost of Petrol Consumed by Cars ($)	Monthly Diesel Consumption by Buses (70/30) (liter/month)	Diesel Price ($)	Monthly Petrol Consumption by Cars (liter/month)	Petrol Price ($)	Total Cost ($)
2016	152,107,978	13,773,690	4,295,416	274,101,709	106,475,586	110,770,999
2017	108,523,964	9,827,068	3,064,634	195,562,419	75,966,776	79,031,410
2018	114,300,971	10,350,188	3,227,774	205,972,701	80,010,678	83,238,452
2019	178,788,855	16,189,698	5,048,862	322,181,198	125,152,199	130,201,060
2020	226,612,761	20,520,251	6,399,374	408,360,862	158,628,934	165,028,308
2021	224,651,154	20,342,623	6,343,979	404,826,001	157,255,807	163,599,785
2022	198,190,350	17,946,543	5,596,747	357,143,087	138,733,244	144,329,992
2023	206,904,202	18,735,601	5,842,819	372,845,629	144,832,941	150,675,759
2024	228,080,722	20,653,178	6,440,828	411,006,153	159,656,504	166,097,332
2025	252,876,741	22,898,509	7,141,048	455,689,093	177,013,718	184,154,769
2026	267,839,971	24,253,460	7,563,600	482,653,137	187,487,977	195,051,577
2027	274,809,891	24,884,600	7,760,424	495,213,077	192,366,922	200,127,347

Table 7. Projected financial savings by adopting the scenarios

Year	Savings from 70/30 scenario ($)	Savings from 50/50 scenario ($)
2016	41,336,980	68,894,964
2017	29,492,555	49,154,257
2018	31,062,519	51,770,864
2019	48,587,794	80,979,656
2020	61,584,457	102,640,759
2021	61,051,366	101,752,276
2022	53,860,359	89,767,263
2023	56,228,443	93,714,070
2024	61,983,390	103,305,647
2025	68,721,975	114,536,623
2026	72,788,390	121,313,987
2027	74,682,541	124,470,904

3.4 Discussion

From the analyzed scenarios, by implementing the simpler policy, the 70:30 hypotheses for the year 2019, savings of $48,587,794 and $74,682,541 for the next ten years can be achieved. The economic savings adopting the scenarios on vehicles for the year 2027 were $74,682,541 and $124,470,904 respectively. Therefore, for the year 2027, a considerable reduction of approximately 60.35% is expected in financial terms. At the same time, it is evident that the projections of emissions until the year 2027 vary considerably, spanning around 9,133 metric tons per capita for the next ten years from 2018. This study adds to a notable and needed outlook on how innovative economic policy measures are vital that provide increased energy efficiency in the road transportation sector, and consequently help to downsize CO_2 emissions.

By the assessment of these scenarios, it can be identified that the fuel consumption and corresponding GHG emissions are the major parameters that affect the energy economics of any developing country. The average fuel consumption for a private car in Asia is approximately 10 liters per kilometers [17]. This is comparatively high in comparison with first world countries, for which the value is nearly 5-6 liter per kilometers. Hence, even by improving technology to increase efficiency in private vehicles used in the country, a realistic minimum of a 1% efficiency increase can be achieved in road transportation. This also includes the public transportation segment modes. If the study includes the latest hybrid vehicles and electric vehicles, which produce very low emissions, the energy economics enhancement will be much higher. In line with this, the use of compressed natural gas (CNG), alternative fuels like biodiesel, are other options that were not considered for this study, but are essential to consider in the future. Particularly CNG utilization in public transportation will result in a reduction of fuel consumption and GHG emission reduction.

The predicted population in the study area for the year 2027 is 6,801,274 and the corresponding vehicle population is 3,035,658. These numbers make the transport state of affairs in the study area extra perilous if suitable actions are not taken to restrain the swift surge in the population and corresponding travel and fuel demand. Contemplating the prevailing socio-economic circumstances, including the future energy demand and travel scenarios, developing countries should focus more on developing public transportation facilities including rail transportation. These energy-efficient mass transportation methods will restrict the use of small, private vehicles, which consume high quantities of fuel and emit considerable GHGs.

4. CONCLUSION

Public transport infrastructure development faces multiple barriers in many countries. Endorsing the harmonized development of socio-economic and environmental benefits of road transportation infrastructure is of immense significance to sustainable development. Since it is clear that the other energy-consuming sectors might not be able to compensate for emissions from the road transportation sector; the three scenarios that were evaluated here reveal the development of emissions portfolios that affect attaining and endeavoring environmental protection and climatic change.

The results of this study recommend that a well-tailored transportation policy suitable for each region/country have substantial effect on the national energy demand situation. Road transportation has been prioritized by the government in the previous decades and was improved by substantial investments in the road network. Presently the road transport in the region is dominant with the energy-intensive transportation systems, which are hugely dependent on private vehicles, and hence produce high GHG emissions and high consumption of fuel. It should be noted that the apprehensions about the diminishing quantity of natural resources, ambiguities in international and regional political scenarios and increasing fuel demand has triggered a swift surge of fuel prices that has caused an immobilizing effect on the economy. The road transport sector, which is, accountable for approximately 20-25% of collective general energy consumption, is a significant factor in this situation.

From a regional outlook, the economic evaluation indicates that future dynamics in the transportation energy demand is important as road transportation structure in the region is highly dependent on private vehicles. Developments that are taking place in the electric vehicle technology were not considered in the study. Once the electric vehicle technology is established, the present scenario will surely change. Similarly, the impact of mass mobility, especially the metro rail feasibility is another feature that needs to be investigated. When these two scenarios come into existence, there will be a total change in the present economic and emission characteristics.

Public sector - multi-modal transportation systems-bonding energy-efficient public transportation approaches with less private travel needs blend well with sustainable future. We understand the limitations of this research and suggest some ideas for future research in the same sector, such as multi-modal mass transit and electric vehicle inclusion. Even if energy efficiency features in the road transportation sector have numerous dimensions, this study relies on one dimension- energy economics, which is important.

Finally, this study is based on SDM and does not comprise concerns such as fuel demand price elasticity, economic change related to different scenarios, technological change of vehicles and use of alternative fuels in the vehicle. Moreover, this study does not assess likely choices such as travel demand management, vehicle capacity, and governmental regulatory opportunities. The methodology employed in this study has focused primarily on system dynamics and hence it is static in nature. Their implication can be augmented by incorporating demand dynamic interfaces, GHG emissions and related environmental implications, fuel price as well as international supply politics, which are likely to be included in upcoming studies.

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