Energy Consumption from Transport Sector and CO₂ Emission: A Case of Kandahar City

Wais Khan, Naqibullah Karger

ABSTRACT

This paper is concerned with the prospective estimation of energy consumption in the transport sector. To determine the long-term energy consumption targets for transport in Kandahar city. Later on CO₂ emission is calculated based on energy consumption in transport sector of Kandahar city from year 2017 to 2020 and the amount of emission is forecasted till 2030. Upon conducting this research it is found out that transport demand has increased during the last few years due to change in population growth and GDP. As a result, traffic congestion, road accidents, parking problems and air quality are worsening. In addition to those, lack of proper transport management system, public transport infrastructure and insufficient road capacity are adding growing energy demand and environmental problems of Kandahar transport sector. In order to avoid such problems, this research is conducted to focus on the energy demand and CO₂ emission only in transport sector of the Kandahar city.

This study has focused on energy demand and emission of CO₂ from passenger transport sector of Kandahar city from 2017 to 2020. If there is no policy intervention, energy demand can reach from 5.5 TJ in 2017 up to 14.8 TJ in 2030. Again gasoline passenger vehicles contributes the most in energy demand and emission. CO₂ emission can reach from 381 Thousand metric tons in 2020 up to 860.9 Thousand metric tons in 2030.

Out of all vehicle types of transportation, private cars are responsible for 26% of energy share, motorbikes consuming the most and reaching up to 35%.

Keywords: CO₂ Emission, energy consumption, energy demand, energy reduction, Kandahar.

I. INTRODUCTION

In the International Energy Outlook 2016 (IEO2016) reference case, transportation sector delivered energy consumption increases at an annual average rate of 1.4%, from 104 quadrillion British thermal units (Btu) in 2012 to 155 quadrillion Btu in 2040. The share of oil in total final consumption falls from over 90% of transport demand in 2018 to around 80 %by 2050in BAU )Business As Usual, 40% in Rapid and just20 %in Net Zero .The main counterpart is the increasing use of electricity, especially in passenger cars and light and medium-duty trucks, along with hydrogen, biofuels and gas. The share of electricity in end energy use in transport increases to between30 %and 40% by2050 in Rapid and Net Zero. Transportation energy demand growth occurs almost entirely in regions outside of the Organization for Economic Cooperation and Development (OECD), with transportation demand roughly flat in OECD regions—largely reflecting different expectations for economic growth in developing regions compared with developed regions [1].

Human activities are closely dependent on the usage of several forms and sources of energy to perform work. Transportation accounts for approximately 25% of world energy demand and for about 61.5% of all the oil used each year. Land transportation accounts for the great majority of energy consumption. Road transportation alone is consuming on average 85% of the total energy used by the transport sector. This trend is not however uniform within the land transportation sector itself, as road transportation is almost the sole mode responsible for additional energy demands over the last 25 years. Passenger transportation accounts for 60 to 70% of energy consumption from transportation activities. The private car is the high and dominant mode but has a poor energetic performance, although this performance has seen substantial improvements since the 1970s, mainly due to growing energy prices and regulations. Only 12 percent of the fuel used by a car actually provides momentum. There is a close relationship between rising income, automobile ownership and distance traveled by vehicle [2].

The issue of transportation and the environment is paradoxical in nature since transportation conveys substantial socioeconomic benefits, but at the same time transportation is impacting environmental systems. From one side, transportation activities support increasing mobility demands for passengers and freight, while on the other, transport
activities are associated with growing levels of environmental
effectualities [2].

Afghanistan is landlocked and mountainous country in
Central Asia and is counted a Middle Eastern country in the
world. Transport in Afghanistan is limited and in the
developing stage. Much of the nation’s road network was built
during the 1960s but left to ruin during the 1980s and 90s
wars. New national highways, roads, and bridges have been
rebuilt in the last decade to help increase travel as well as
trade with neighboring countries. In 2008, there were about
731,607 vehicles registered inside the country, which serve
29 million people [3].

The network includes 12,350 kilometers of paved roads and
29,800 kilometers of unpaved roads, for an approximate
total road system of 42,150 kilometers as of 2006. Traffic in
Afghanistan is right hand. The Afghan government passed a
law banning the import of cars older than 10 years [4].

Kandahar is the second-largest city in Afghanistan, with a
population of about 1,337,183 (2018) with growth rate of
2.80% [5]; Kandahar is located in south of the country at an
altitude of 1,010 m above sea level. The Arghandab River is
the largest river in Kandahar which runs along the west of the
city.

Kandahar has an international airport and extensive road
links with Lashkar Gah and Herat to the west, Ghazni and
Kabul to the northeast, Tarinkot to the north, and Quetta in
neighboring Balochistan to the south. Kandahar has a
subtropical arid climate characterized by little precipitation
and high variation between summer and winter temperatures.

Commuters of the city use the public bus system (Milli Bus),
taxicabs and rickshaws. Private vehicle use is increasing,
partially due to road and highway improvements. Large
dealerships are importing cars from Dubai, UAE [6].

Afghanistan's Registered Motor Vehicles was reported at
1,572,663 Unit in Dec 2015 [7]. Total roadways are 42,150
km out of which 12,350 km are paved and well-constructed and
is 84th comparison to the world. Transport infrastructure is
mainly flexible pavement, with 76.8% of roads for all
seasons, and 19.1% of roads for some seasons. Kandahar has
107,800 vehicles (including three and two wheelers) both
registered and unregistered [8].

A. Problem Statement

Afghanistan is a South Asian country which is included in
the reform process. Being a developing country, it does not
have much of renewable technologies and highly depends on
fossil-fuels.

Recently, due to tremendous growth of vehicle population
in Kandahar has caused many problems which have not been
prepared to tackle such as traffic congestion, increasing road
accidents, parking problems, stagnant public transportation
system. Hence these growth causes increase in fuel demand
and within fuel demand increment, CO2 emission increases
and causes air pollution.

Emission from the growing population of vehicles is
deteriorating the air quality, and the trend would likely to
continue in the future. Habitants of Kandahar city are longing
for better public transport such as Bus Rapid Transit (BRT)
or Mass Rapid Transit (MRT), or better road infrastructure
because of the poor vehicle condition and poor management
of public transport sector [9].

Since lack of management of traffic rules, no road
maintenance and old vehicles in the city could play major role
in causing more air pollution.

However, local government is facing many challenges to
solve such problems mentioned above, long term and short-
term preventive measures and policies are necessary to
combat all the challenges. In order to develop policies and
programs, it is necessary to have information on the transport
demand and respective energy usage at the end use levels
such as passenger vehicles, buses, taxis and other vehicles.
This study will provide necessary basement that will help in
dressing issues and challenges facing in the transport
sector. Forecast of transport demand from 2021 to 2030 will
help to provide guidelines and indications for the likely and
future development potentials in the transport sector of
Kandahar city.

B. Objectives

In view of energy transition’s central role to climate change
mitigation that builds on the two pillars of energy efficiency
and renewable energy, the objectives of this paper are:

- To estimate energy consumption from transport sector in
Kandahar city from year 2017 to 2020
- To analyze CO2 emission and its intensity into different
vehicle types

C. Background

In Kandahar city, the use of energy, its types and the
limited access to necessary energy have become very
essential issue for the Transportation sector as well as other
sectors. The burning of fossil fuels to deliver energy is the
major donor to extra carbon in the atmosphere which is the
cause of global warming. Accordingly, increasing climate
change is one of the main challenges that should be measured
and taken care of by the companies from the transportation
sector [10].

| TABLE I: POPULATION AND NUMBER OF HOUSEHOLDS IN THE
<p>| DISTRICTS OF KANDAHAR CITY [8] |
|-----------------------------|------------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Districts</th>
<th>Total Population</th>
<th>Registered Houses</th>
<th>Unregistered Houses</th>
<th>Total Number of Houses</th>
</tr>
</thead>
<tbody>
<tr>
<td>District 1</td>
<td>131,390</td>
<td>6532</td>
<td>4100</td>
<td>10,632</td>
</tr>
<tr>
<td>District 2</td>
<td>70,000</td>
<td>2277</td>
<td>10,000</td>
<td>12,277</td>
</tr>
<tr>
<td>District 3</td>
<td>115,000</td>
<td>6500</td>
<td>4000</td>
<td>10,500</td>
</tr>
<tr>
<td>District 4</td>
<td>60,000</td>
<td>5100</td>
<td>1800</td>
<td>6900</td>
</tr>
<tr>
<td>District 5</td>
<td>51,000</td>
<td>2800</td>
<td>2000</td>
<td>4800</td>
</tr>
<tr>
<td>District 6</td>
<td>70,000</td>
<td>651</td>
<td>4144</td>
<td>4795</td>
</tr>
<tr>
<td>District 7</td>
<td>80,000</td>
<td>1000</td>
<td>3494</td>
<td>4494</td>
</tr>
<tr>
<td>District 8</td>
<td>75,000</td>
<td>1600</td>
<td>3693</td>
<td>5293</td>
</tr>
<tr>
<td>District 9</td>
<td>135,000</td>
<td>15,000</td>
<td>13,000</td>
<td>28,000</td>
</tr>
<tr>
<td>District 10</td>
<td>67,000</td>
<td>5600</td>
<td>6191</td>
<td>11,791</td>
</tr>
<tr>
<td>District 11</td>
<td>135183</td>
<td>15740</td>
<td>0</td>
<td>15740</td>
</tr>
<tr>
<td>District 12</td>
<td>91731</td>
<td>10681</td>
<td>0</td>
<td>10681</td>
</tr>
<tr>
<td>District 13</td>
<td>82075</td>
<td>9557</td>
<td>0</td>
<td>9557</td>
</tr>
<tr>
<td>District 14</td>
<td>101387</td>
<td>11805</td>
<td>0</td>
<td>11805</td>
</tr>
<tr>
<td>District 15</td>
<td>72420</td>
<td>8432</td>
<td>0</td>
<td>8432</td>
</tr>
<tr>
<td>Total</td>
<td>1,337,187</td>
<td>103275</td>
<td>52,422</td>
<td>155,697</td>
</tr>
</tbody>
</table>

Kandahar city is divided into fifteen districts and
population of the city is estimated in the Table I, reaching up
to 1.3 million. Even though the population is growing day by
day.

The transport infrastructure in Kandahar is mainly flexible
pavement, with 76.8% of roads in the province able to take
car traffic in all seasons, and 19.1% able to take car traffic in spring and summer seasons.

Commuters of the city use the public bus system (Milli Bus), taxicabs, Zaranges, and auto rickshaws as a public transport. Private vehicle use is increasing, partially due to road and highway improvements. Large dealerships are importing cars from Dubai (UAE) and Japan [1].

Kandahar city has a public bus system that takes travelers on daily routes to many destinations throughout the city or outside of the city. Besides the buses, there are yellow taxis that arrange for both private and line services in the city. Private cars are on the growth in Kandahar city, and there are several showrooms selling mostly second-hand vehicle and some new vehicles imported from United Arab Emirates or Japan. Some other traditional methods of ground transports are also used in Kandahar city, like bicycle and animal transportation [3].

Table II shows the number of private cars, taxis, trucks, buses, rickshaws, Zaranges, and motorbikes in Kandahar city. The numbers of registered vehicles were provided by the Department of Traffic in Kandahar city and the number of unregistered vehicles is based on survey and suggestions from the Traffic Department of Kandahar city.

| TABLE II: THE NUMBER OF AUTOMOBILES IN KANDAHAR CITY [8] |
|---|---|---|---|
| No | Vehicles | Registered | Unregistered | Total |
| 1 | Private Car | 16,000 | 4,000 | 20,000 |
| 2 | Taxi | 6,350 | 0 | 6,350 |
| 3 | Truck | 3,500 | 0 | 3,500 |
| 4 | Bus | 350 | 0 | 350 |
| 5 | Van | 800 | 0 | 800 |
| 6 | Tractor | 450 | 200 | 650 |
| 7 | Rickshaw | 2,120 | 2,300 | 3,150 |
| 8 | Motorbike | 13,000 | 58,000 | 71,000 |
| 9 | Zarange | 0 | 2,000 | 2,000 |

The number of private car and motorcycles are more than the government’s registered vehicles in the city.

The total fuel consumption in the transport sector can be estimated by considering daily average fuel consumption by the vehicles obtained. The total yearly fuel oil consumption by private cars is calculated by finding the average from the 30 cars daily fuel consumption and then by using the (1).

\[ y_c = A_d \times C \times 310 \]  
\[ y_c = \text{Yearly fuel consumption by cars} \]  
\[ A_d = \text{Average fuel consumption per day per car} \]  
\[ C = \text{Total number of cars} \]  

There was a public bus transport before 2009 in Kandahar city. Around 30 buses were in service in Kandahar city, and were finished until it is now recently put into the service for public, and also some buses are used for school students or mass movement in some occasions. Because of poor public transport, the residents use more private cars or taxies. The motorbikes consume the second highest portion of the fuel in the city almost every household owns at least one motorbike [11].

The lack of management of public transportation has formed many problems in the city. If the city of Kandahar had a good and appropriate public transportation system there would be no need for this enormous amount of private cars and motorbikes in the city.

II. METHODOLOGY OVERVIEW

There are quite a number of approaches to estimate travel demand in terms of passenger-km or vehicles-km travelled in the literature. The most commonly method applied is econometric approach. It is strongly believed that population and per capital income are the main two drivers for travel demand.

A. Energy Demand

Stock of vehicles, their utilization pattern and the average efficiency greatly effect energy demand. Two common approaches to estimate transport energy demand are the identity approach and the structural approach.

The identity model considers the demand for a transport fuel to be equal to the product of vehicle utilization rate and total stock of the vehicles. One common example of identity approach is:

\[ F = (C \times U)/SC \]  

Where,

- \( F = \text{fuel consumption (litters)} \)
- \( C = \text{number of cars} \)
- \( U = \text{car usage annually (km/year/car)} \)
- \( SC = \text{specfic fuel consumption (km/liter)} \)

Reference [11] also adopted this approach to estimate past trend of transport energy demand. General approach is to use the simplified assumption of car usage and specific fuel economy (static in nature) while the car ownership is estimated using an econometric model [12].

B. Field Survey

The field survey is conducted to estimate occupancy factor, average specific fuel consumption and vehicle kilometer of travel by different vehicle types in Kandahar. The targeted points to be conducted are gas stations, parking lots, bus terminals and random drivers in the city.

Truck (Heavy Duty) and other category such as ambulance, fire-fighter vehicles, and hearses are not considered. The reasons are as follow:
- Truck (Heavy Duty): mainly used for freight transport across cities
- Other categories: whatever remains are put inside other category and the number are relatively small.

Sampling method is carried out using Yamane’s formula

\[ n = \frac{N}{1+N d^2} \]  

Where:

- \( n = \text{sample size} \)
- \( N = \text{population size} \)
- \( d = \text{level of precision} \)

By using Yamane’s formula of sample size with sampling error 5%, a confidence coefficient of 95% and \( P=0.5 \) (level of maximum variability), take \( d = 0.05 \) [13].
In other words, this means that, if a 95% confidence level is selected, 95 out of 100 samples will have the true population value within the range of precision specified earlier. There is always a chance that the sample you obtain does not represent the true population value.

Gasoline Passenger Cars: It refers to the gasoline passenger vehicles, mostly in Kandahar such types of vehicles are used.

Diesel Passenger Cars: It refers to the diesel passenger vehicles which are few compared to Gasoline passenger cars.

### TABLE III: SAMPLE SIZE BY YAMANE FORMULA WITH 5% ERROR

<table>
<thead>
<tr>
<th>Types of Vehicles</th>
<th>Number of Vehicles</th>
<th>Percentage</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Car</td>
<td>20,000</td>
<td>18%</td>
<td>74</td>
</tr>
<tr>
<td>Taxi</td>
<td>6350</td>
<td>6%</td>
<td>23</td>
</tr>
<tr>
<td>Track</td>
<td>3500</td>
<td>3%</td>
<td>13</td>
</tr>
<tr>
<td>Bus</td>
<td>35</td>
<td>0%</td>
<td>1</td>
</tr>
<tr>
<td>Van</td>
<td>800</td>
<td>1%</td>
<td>3</td>
</tr>
<tr>
<td>Tractor</td>
<td>650</td>
<td>1%</td>
<td>2</td>
</tr>
<tr>
<td>Motorbike</td>
<td>3510</td>
<td>3%</td>
<td>13</td>
</tr>
<tr>
<td>Rickshaw</td>
<td>71000</td>
<td>66%</td>
<td>262</td>
</tr>
<tr>
<td>Zarange</td>
<td>2000</td>
<td>2%</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>108,160</td>
<td>100%</td>
<td>398</td>
</tr>
</tbody>
</table>

### C. Travel Demand Forecasting

Past trend of passenger travel (km) is estimated by the following:

\[
\text{Travel demand (t)} = \sum_{i} V_i (t) \times VKT_i (t) \times \text{occupancy factor} (t) \times \text{utilization factor} (t)
\]  

\[
\text{Travel demand (t)} = \text{passenger travel demand in passenger km for t year}
\]

\[
V_i (t) = \text{vehicle population of t year}
\]

\[
VKT_i (t) = \text{the average vehicle kilometer traveled by vehicle type i in year t}
\]

\[
\text{Occupancy factor} (t) = \frac{\text{passengers}}{\text{vehicle for t year}}
\]

The annual travel demand for 2020 is taken as a base year demand and with the growth rate the pass-km travel demand is projected which’s unit is passenger-km [14].

### D. Energy Demand Estimation

Energy demand by fuel type is estimated using the following equation:

\[
\text{Energy demand (t)} = \sum_{i} V_i (t) \times VKT_i (t) \times F_i (t) \times \text{utilization factor} (t)
\]  

\[
\text{Energy demand (t)} = \text{energy demand by fuel type in GJ}
\]

\[
V_i (t) = \text{vehicle population of t year}
\]

\[
VKT_i (t) = \text{the average vehicle kilometer traveled by vehicle type (i) in year t}
\]

\[
F_i(t) = \text{fuel economy of vehicle type i. [15]}
\]

### E. Survey result of annual VKT and fuel economy by vehicle types

Table IV represents the survey result of annual vehicle kilometer travelled and fuel economy by vehicle types. The term “passenger vehicles” is used to follow the same set of categories defined by vehicle registration types in Kandahar.

![Annual Average km Travel per Vehicle Type of 2020](image1)

**Fig. 1.** Annual average km travel per vehicle type of 2020.

![Average Fuel Economy by Vehicle Type of 2020](image2)

**Fig. 2.** Fuel economy by each vehicle type of 2020.

The energy demand estimated in terms of Giga Joule (GJ) is shown in Fig. 3. The total energy consumption is about 5,490 TJ in 2020. It has been found that total energy demand increased from 2017 to 2018 and dropped back in 2019 and then increased back in 2020 due to the vehicle population variation and covid-19 pandemic.
Fig. 3. Total energy demand in GJ in Kandahar from 2017 to 2020.

Fig. 4. Annual travel demand passenger traveled per vehicle from 2017 to 2020.

Fig. 5 shows the energy share of different passenger transport vehicles in Kandahar city by vehicle type for year 2020, in which motorbike has the highest demand as per its population. And the least demand passenger vehicles are Bus and diesel van.

Fig. 6 shows the CO₂ emission from 2017 to 2020.

Fig. 7 shows the CO₂ emission share of different vehicle types in 2020.

Fig. 8 shows CO₂ intensity of modes in year 2020 in which diesel van, Private car, and motorbike has the highest intensity of CO₂. But Bus, Zarange, and Rickshaw are in the least intensity of CO₂ emission.

The same definition of legends is used for emission estimation (Gasoline passenger car and diesel passenger car). Fig. 6 shows the CO₂ equivalent emission by different modes and fuel type. Fig. 7 shows the emission share of the different vehicles type in year 2020 in which the highest amount of emission is from Taxi, Private vehicle and motorbike as their population number is high too.

III. CONCLUSION

This study focuses on analyses of energy and environmental implications of passenger transport in Kandahar from 2017 to 2020. It has been found that there is a dramatic increase in passenger transport energy demand between 2017 and 2018 but a slight decrease in the year 2019. The total energy is about 5.5 thousand TJ in 2020. The slow increment is due to nature of no change in car importing policy by the government. The motorbike, taxi and gasoline
private car take the highest (about 35%, 27% and 26% respectively) share of energy demand and bus and van has the lowest (about 0% and 1% respectively) of total energy demand. In term of MJ/pass-km, however, buses and vans contribute the most efficient energy intensity, followed by Zarange, and taxi. It is because the load factor is high and hence it becomes efficient although the vehicle technology and other aspects such as road conditions for energy efficiency can be worse. Similar structure and trends are found in CO2 equivalent emission. The total emission in year 2020 is 377.8 thousand metric tons. The highest is motorbike which emits (about 130.9 thousand metric tons) of CO2.

It has been observed that there is a shift in the quantity of buses which shifted from the 35 in (year 2017) to 12 in (year 2020). And there is a continuous increase in motorbike and auto rickshaws from year 2017 to 2020 in the average 6% and 13% respectively.

The highest percentage shares of energy demand are: 28% by motorbike, 26.4% by taxi, and 26.6% by rickshaw. And the lowest percentage share of energy demand are van and bus. It is estimated that the future trend in CO2 emission the increment will go up to 860.9 thousand metric tons in 2030. Passenger vehicles emit 4 times more than public bus.

For recommendation it is possible to construct and test some future possible scenarios from 2020 to 2030 to improve energy demand and emission of CO2. Institutional and policy barrier is the most important barrier to overcome, followed by financial barrier and land resource barrier for the alternative scenarios to implement. Legal barrier and human resource barrier are relatively the least important barriers to consider based on local stakeholders’ opinion. Among the three alternative scenarios, the most feasible scenario is fuel efficiency gain scenario, and institutional and policy barrier and financial barrier are the most important barriers to overcome.

IV. POLICY IMPLICATIONS

What likely to happen in the future can be summed up as follow: urban population trends of Kandahar will be growing, economic activities will be growing up and subsequently means for passenger transport sector will become a vital for survival of Kandahar residents, especially for increasing and maintaining the comfortability and reliability of public transport together with increasing number of passenger cars. More infrastructure development phases such as building overhead bridges and upgrading of those infrastructure regarding road transport will be coming out soon. As a result, compromising transport energy consumption per capita and emission per capita from passenger transport sector without affecting the development and the environment is the key factor for Kandahar.

Based upon past trends and future possible scenarios of this study, energy demand and emission of air pollutants will increase more in the future if there is no proper policy interventions applied.

There will be more gasoline passenger cars in the future and demand for gasoline and emission from gasoline engine will dramatically increase. Hence, government should consider proper plans and actions to control gasoline vehicles in term of setting up emission standard and fuel economy, especially for new importing vehicles. Giving some incentive such as smaller tax for smaller engine power sized vehicles over large engine power sized vehicles will be a good way to control. Such mechanism has been successful in other countries.

Efficiency gain scenario shows compelling result to reduce energy demand and air pollutants. Therefore, the government needs to consider all possible ways to improve the efficiency of the vehicle fleet. Methods include relieving traffic congestion, increasing road capacity, building overhead bridges, setting vehicle emission standards. This could be a challenge to implement all the possible methods. Land resource barrier can be the most important barrier to tackle for increasing road capacity and relieving traffic congestion to improve efficiency.

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CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

REFERENCES


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