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10th October, 2018

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Subject: Submission of FINAL Reports on Technical Studies on "Climate Change and Urbanization" Under Research Collaboration between GCISC and NED University of Engineering and Technology, Karachi, duly funded by HEC.

In continuation of the Draft reports submitted on 17th August, 2018, and since no comments are received to date, we are pleased to submit the two Final Reports as attached:

a. Energy Efficiency in Public Transport for City of Karachi, Pakistan

b. A Strategy of Enabling Pakistan's Construction Industry to Climate Friendly Buildings

Prof. Dr. Mir Shabbar Ali

REPORT 1

Energy efficiency in Public Transport for City of Karachi, Pakistan

Team Leader

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Project Team

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Research Collaboration between GCISC and NED University of Engineering and Technology, Karachi

Energy efficiency in Public Transport for City of Karachi, Pakistan

FINAL REPORT
OCTOBER 2018

Report Contents

Sections:

1. Background & Challenges:

Many cities of developing countries are experiencing rapid growth of motorized transportation. This is leading to severe congestion, which, in turn, is reducing productivity. Road accidents have been increasing. Transport emissions have become a major contributor to severe air pollution and greenhouse gas emissions. The main cause of these problems has been the increasing preference for personal motor vehicles for commuting to work and getting around the city. In many countries, urban development practices have worked in favor of such preference, leading to urban sprawl. Thus, remedial measures have to focus on reversing the preference for such modes of travel, shifting to public transport, cycling, or walking, and building and retrofitting cities to minimize the need for private automobiles.

The quality of urban transport systems is an important determinant of cities' livability and economic efficiency and, unfortunately, these systems are encountering several challenges. Severe congestion, deteriorating air quality, increased greenhouse gas emissions, increased incidence of road accidents, and increased fuel costs are threatening the health and well-being of residents as well as the economic efficiency of cities.

Air pollution is estimated to cause 800,000 deaths in urban areas every year and transport accounts for around 14 percent of human-created greenhouse gas emissions. The transport sector's share of petroleum consumption went up from 45 percent of the world's oil production in 1973 to 61 percent in 2007. Road transportation accounted for 81 percent of this consumption. International crude oil prices fluctuated significantly in the past, impacting the balance of payments of oil importing countries. From 2000 to 2013, inflation-adjusted average crude oil prices increased 2.5 times. In addition, road crashes caused 1.2 million deaths worldwide annually, making road accident deaths among the highest causes of death in the world.

The most important factor contributing to the above problems has been the rapid increase in the use of private motor vehicles. For instance, in the six largest cities in India, the population doubled between 1981 and 2001, but the number of motor vehicles increased eight times over the same period. Between 2000 and 2013, car ownership in China increased more than six times. Similar trends are seen in other fast growing economies. Increased income levels and the availability of cheaper personal vehicles, coupled with increased travel distances and inadequate public transport systems, have made the personal motorcar an increasingly attractive travel option.

Efforts to deal with the problems associated with increasing travel demand have tended to largely focus on expanding the capacity of roads and public transport. Unfortunately, this has not been enough. Increasing road capacity may help alleviate the problem in the short term, but, over the long term, as long as the number of motor vehicles continues to increase, roads will not only remain congested—there will be even more traffic. This is not the solution, nor is increasing the capacity of public transport by adding more vehicles, as this does not necessarily encourage a shift from personal motor vehicles. Energy efficient cities require a paradigm shift in urban land use and transport planning.

2. Problem Statement:

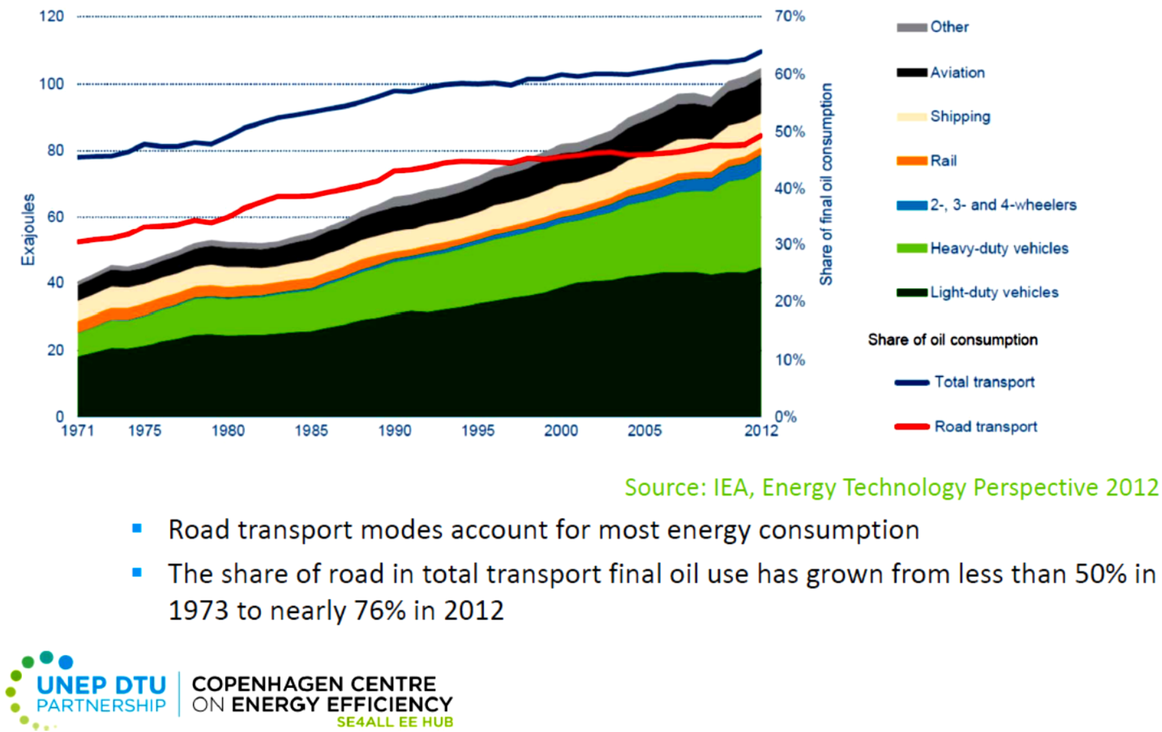


Figure 1 World Transport Energy Use (1971-2012)

Transport is strongly linked with economic activities. Economic growth triggers transport demand for the facilitation of movement of people and goods. Transport connects the economic activities and increases access to markets and services. Transport is a key to enhancing integration to global economy.

Today, the transport needs have changed drastically. Personal mobility today is a major energy-consuming activity. Mobility of individuals has increased by many folds and is expected to continuously increase in the future. New patterns of trade and businesses have evolved. The road networks within the countries and beyond the borders have increased. Freight transport has grown rapidly and is expected to continue to do so in the future.

A long period of economic growth has translated into declining poverty and significant improvements in human development in the region. A large number of people continue to migrate to the urban areas from the rural areas of the country. This has resulted in the rapid growth in demand for transport in the urban areas. However, the region requires improvement in transport infrastructure.

The transport sector is a huge consumer of energy; it is indeed the largest consumer of petroleum-based fuels, accounting for 20% of global final energy consumption and 60% of total oil consumption. More than one third of the total greenhouse gas emission comes fromthe transport sector.

All transport modes have shown substantial increases in activity, which in turn has resulted dramatic surge in energy demand. Along with the growth of industrial, commercial and transport sectors, people are using energy at unprecedented rates. Demand for energy in all the sectors in the region is expected to grow significantly in the future. All modes of transport are expected to grow significantly and the road transport (passenger and freight), in particular, will continue to dominate overall transport energy and oil use in the region although air travel and shipping too are expected to grow substantially.

To unleash the economic potential, every country is in a paradoxical situation between the economic growth and depleting energy resources. The consequent energy security and greenhouse gas emission implications of oil-dominated transportation imply that reducing the fuel used in this sector should be one of the highest priorities for all.

The total final energy consumption in the SAARC region in the year 2010 was 570 Million. Tonnes of Oil Equivalent. The final liquid fuel consumption in the region in the year 2010. was 135 Million Tonnes of Oil Equivalent.

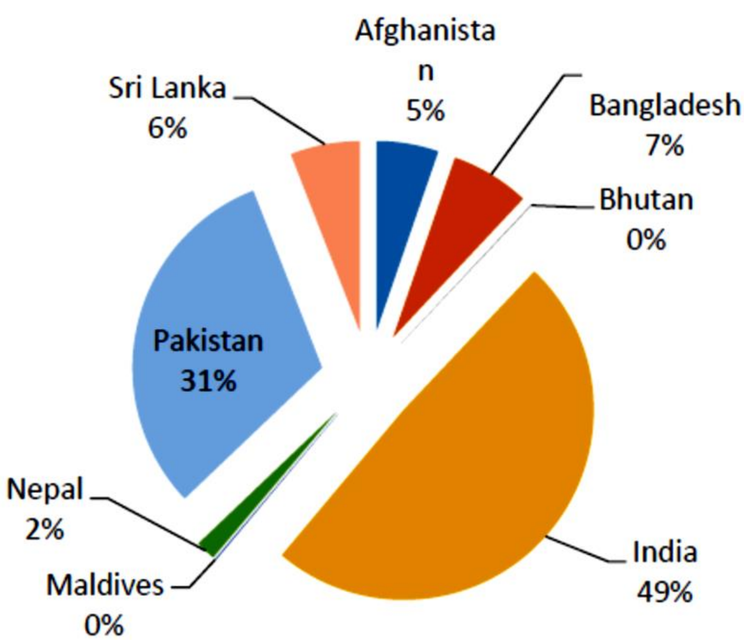


Figure 2 Energy Consumption in SAARC Region

Objectives & Scope:

- Identification of Existing energy Efficiency status for Public Transport in Karachi.
- Assessment of Policy deficiencies and Areas of Intervention.

Methodology & Analytical Approach:

- Data collection from Stakeholders; including travel indicators and past studies.

- Review of National, International reports and case studies.

Study Outputs :

- Review of Karachi Public Transportation Issues in relation with Sustainable Urban Transportation concept.
- Review of Energy consumption of Public Transportation operating in Karachi.
- The path towards an Energy Efficient Transportation system; Policy level Recommendations.

Abbreviations

TRACE	Tool for Rapid Assessment of City Energy
KWH	Kilowatt Hour
ESMAP	Energy Sector Management Assessment Program
KPI	Key Performance Indicators
GDP	Gross Domestic Product
HOV	High Occupancy Vehicle
EV	Electric Vehicles
CA	City Authority
ICE	Internal Combustion Engine

3. Karachi: The Current Situation

Karachi presently is among the top ten largest cities of the world. By 2020 its population is expected to touch 27 million from 15 million in 2005. The number of housing in 2005 was about 2 million and it would increase to nearly 4 million. Even at decreasing average annual growth rate, the increase in absolute terms is extremly high and will put heavy pressure on the physical, infrastructure, financial and institutional systems of the city.

Around 40% of Karachi population lives below the poverty line. The conditions of the deprived section and its economic well being are therefore a major concern, as these impact the environment and growth potential of the city. Roughly around 75% of the city household falls in the category of poor and low income group while 25% constitutes the high and middle income group.

The economy of the city is growing fast at the growth rate of 6-7% per annum. The main economic sectors contributing to the city's GDP are; trade and commerce, manufacturing, transport, including ports, real estate, construction and services.

Karachi; Pakistan biggest city contributes more than half of the total Federal tax revenue. Being a port city, the location of Karachi gives it a comparative advantage over other cities as most of Pakistan international trade passes through its port, making it the financial and business centre of the country. Of the city total labour force, 37% are employed, out of which 64% are employed in the services sector while the rest, 36% are in the industrial sector.

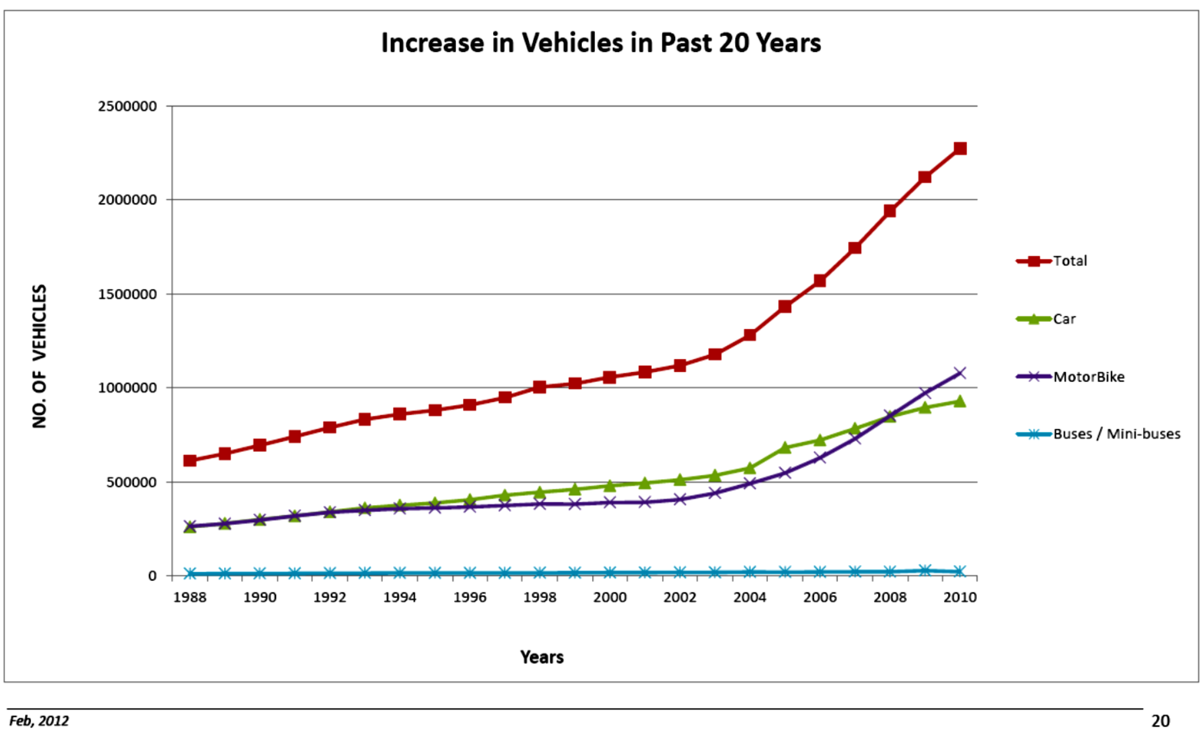


Figure 3 Vehicle Registration Trend

Karachi and mostly so called Pakistani cities depend on private transport for their mobility needs. However, by far the major share of investment and attention has been in channelling public funds to private transport through major road construction projects, with inadequate consideration of the needs of vulnerable groups like (two wheelers, pedestrians or of women and children).

Karachi has a complex traffic network with a large number of total private vehicles contributing to large traffic jams. There are a total of 2.6 million vehicles in Karachi. The number of private motor vehicles in Karachi grew by 9% in 2013, adding 280 vehicles per day to the already high number of private vehicles. The large number of vehicles leads to immense traffic congestion causing time loss, energy/economic loss and poses health hazards. The traffic congestion cost of Karachi in 2013 was estimated at US $ 688 million per annum, which is nearly 2% of the total revenue of Pakistan. To attend to the transport problem of Karachi the local government authorities introduced signal free corridors investing huge amount from the public exchequer but these measures have little impact or improvement in traffic or transport in Karachi.

Of 24 million trips taken every day in Karachi, public transport deemed to provide 50-60% of all trips, para-transit (taxis, qingqis, rickshaws) and private cars account for about 20% of the trips. Pedestrian trips represent about 20% of all the trips.

As mentioned above the public transport is privately owned and is operated on designated routes. The public transport is energy inefficient and uncomfortable for the passengers. There is a huge gap between number of seats available and the passengers, as indicated by the current passenger seat ratio of 1:34. The public transportation is mostly utilized by population below the poverty line. More than 40% of the total private bus fleet is nearly 20 years old with poor mechanical condition thus making it energy inefficient and contributes to GHG Emissions.

4. Karachi Transport Sector Diagnostics-Application of TRACE model

The diagnostic study framework is based on the inclusive growth which not only generates economic opportunities, but also ensures equal access to these by all members of a society. Growth is considered inclusive only when all members of the society are allowed to participate in and benefit from the growth process on an equal basis, regardless of their individual circumstances. An inclusive growth development strategy concept is anchored on three pillars:

- By creating and expanding economic opportunities through sustained growth,
- broadening access to opportunities for all members of a society, and
- Minimum well-being of the population through the adequate provision of social safety nets.

In order to cater these society growth incentives, this report aims at improving the energy efficiency of public transportation sector in Karachi. Public transportation sector in Karachi is improving day by day by planning new and energy efficient transport for the users, yet much work is still required in order to bring the Pakistan up to the rank of developed countries.

INTRODUTION TO TRACE 2.0:

This report is based on the implementation of Tool for Rapid Assessment of City Energy – TRACE 2.0 in Karachi. The Tool for Rapid Assessment of City Energy (TRACE) was first developed in 2008 by ESMAP (Energy Sector Management Assistance Program)'s Energy Efficient Cities Program which seeks to help cities expand their municipal services through energy efficiency.

It was designed to give city authorities a quick and easy way to assess their energy use and to identify cost-effective and feasible measures they can take to improve energy efficiency in a variety of public sectors including lighting, water and wastewater, buildings, transportation, and power and heating.

TRACE 2.0 is an enhanced decision-support tool designed to help cities quickly identify underperforming sectors; evaluate improvement and cost-saving potential; prioritize sectors and actions for energy efficiency (EE) intervention; and model potential interventions. It covers eight sectors: municipal buildings, residential buildings, commercial buildings, water and waste water, passenger transport, public lighting, solid waste, and power and heat.

TRACE 2.0 consists of three modules: a sector assessment module which compares key performance indicators (KPIs) among peer cities, and prioritize sectors that offer the greatest potential; a recommendations module which functions like a "playbook" of tried-and-tested EE measures and helps select locally appropriate EE interventions; and a results and analysis section which presents results in a user friendly manner TRACE 2.0 is the improved version of TRACE which was implemented in over 65 cities around the globe, and led to over US$ 250 million in investments in city energy efficiency and renewable energy. The data on energy consumption and expenditure used to calculate the KPIs for the TRACE 2.0 analysis in this report are for the reference period July 2014-June 2015. Some of the data comes from different sources provided by government entities, utilities, and national statistics. When such data was not available the KPIs were calculated based on expert estimates.

METHODOLOGY OF TRACE:

This program consists of three principal components:

I. an **energy benchmarking** module which compares key performance indicators (KPIs) among peer cities
II. a **sector prioritization** module which identifies sectors that offer the greatest potential with respect to energy-cost savings, and
III. An **intervention selection** module which functions like a "playbook" of tried-and-tested energy efficiency measures.

The steps in the TRACE analysis for determining public transportation energy efficiency are as follows:

A. Collection of Candidate City Energy Use Data

Step 1 of the TRACE analysis involves the gathering of data related to the public transport situation in the city, the governing bodies and jurisdiction handling the innovations made in public transport, the present economic conditions, population, growth rate, the type of fuel used for public transport and energy consumption of public transportation. All the calculations for the unknown values used in this report are based on the TRACE 2.0 manual and justified estimations.

KPI
Meters of High Capacity Transit
Meters of High Capacity Transit per 1000 People
Transportation Non-Motorized Mode Split
Public Transportation Mode Split
Public Transport Energy Consumption per Passenger km
Public Transport Energy
Passenger Kilometers
Meters of Bike Lanes
Meters of Bike Lane per 1000 people

DATA REQUIREMENTS FOR TRANSPORT MODELLING

Baseline data requirements

1. vehicle stock determination by mode and technology

2. Defining the transport activity by mode and technology (total travel by mode (pkm/tkm) or vehicle mileage)

3. Energy intensity by mode and technology – e.g. vehicle fuel consumption

4. Fuel characteristics – e.g. carbon intensity, sulfur content

5. Understanding historic development and the driving forces
   - Driving force behind vehicle ownership – e.g. income, population density
   - Driving force behind vehicle use – mileage, load factors vs. income, fuel prices

B. Analysis of City Energy Use against Peer Cities

The city performance is compared with a range of peer cities through benchmarking—selected by the city based on population, climate, and human development—to determine their performance in the sector to be analyzed. The benchmarking process provides an overview of energy performance so that the city can evaluate its relative rankings against peer cities in the sector. The Relative Energy Intensity (REI), or in simpler terms the percentage by which energy use in a particular sector could be reduced, is calculated using a simple formula. The formula looks at all of the cities that are performing better on certain KPIs and estimates the average improvement potential. The reliability of the final results depends on higher the number of cities in the database.

C. Assessment and Ranking of Individual Sectors

During the initial city visit, a number of meetings and interviews are conducted to collect additional data across city departments and agencies, augmenting benchmarking results with contextual information. At the end of the first phase, a prioritization process takes place to identify sectors with the greatest technical energy savings potential. Energy costs are also weighed, as is the ability of city authorities to control or influence the outcome. Priority sectors are reviewed in detail in the second phase.

D. Ranking of Energy Efficiency Recommendations

TRACE contains a playbook of over 60 tried and tested energy efficiency recommendations in each of the sectors.

Recommendations are evaluated according to five different factors: *finance; human resources; data* and *information; policy, regulation* and *enforcement;* and *assets and infrastructure*. This step helps cities better assess potential measures that are within its capacity to implement effectively. TRACE then allows recommendations to be plotted on the basis of two attributes in a 3x3 matrix (energy savings potential and first cost), with an additional filter that enables the user to sort recommendations based on the speed of implementation.

Recommendations in each priority sector are quantitatively and qualitatively evaluated based on key data, including institutional requirements, energy savings potential, and co-benefits. The recommendations are supported by implementation options, case studies, and references to tools and best practices.

E. Report Preparation and Submission

A Final City Report incorporates the various sections outlined above along with the review of the findings and recommendations by city authorities. The intention of the TRACE report is to identify, together with the city, high-priority and near-term actions to improve the energy efficiency and overall management of municipal services.

SCENARIOS ANALYSIS:

Scenarios are alternative opinions of the future used to explore the implications of different sets of assumptions and to determine the degree of robustness of possible future developments.

The analysis of different energy scenarios is a suitable means to visualize possible energy futures as well as analyzing a complex dynamic system with many interdependencies. In this study on improvement of energy efficiency in Karachi's public transport sector, instead of telling policymakers and senior energy leaders what to do, in order to achieve a specific policy goal, the project in hand will allow them to test the key assumptions that they decide to make to shape the energy of tomorrow. This tool which is based on a scenario analysis for the future development until the year 2030 can be used by the investors to evaluate which are likely to be the most dynamic areas and real game-changers of tomorrow

There are three scenarios used in this sector analysis; current, low and high. In the current scenario the data from the present situation is used.

CASE 1: BAS(e) Scenario

The BAS scenario assumes a continuation of current government policies, making adjustments where necessary to project them forward to 2030 and to implement what are considered to be more realistic options in light of recent economic conditions. This scenario presumes that most governments' plans and targets will be realized, without judging the likelihood of their being achieved.
As transport activities are interrelated with the income level of the population and the overall GDP of a country, the future transport demand was forecasted with the average annual growth of income and GDP on the basis of elasticity that these variables have with transport demand.

Transport activities and the energy intensity of each technology were used to calculate the energy consumption.

CASE 2: MASSTRAN Scenario

In mass transit scenario, for calculating the energy efficiency, it is assumed that the public transport is comprised by Bus Rapid Transit for which the construction work has already been started in the metropolis. It is assumed that it would be fully operated until the year 2030.

CASE 3: FUELEFF Scenario

This scenario is based on the assumption that the mass transit will be equipped with electricity as the fuel. This would be analyzed for year 2030.

KARACHI PUBLIC TRANSPORT SECTOR DIGONOSTIC

These steps are further evaluated for determining public transportation energy efficiency in Karachi city as follows:

CASE 1: BAS SCENARIO

City KPIs and Data

The KPIs related to public transportation are investigated through the interviews and meeting with government officials and through literature review. Below is the table showing the values of KPIs with the associated units.

In Karachi there is no bike lane so this data cell is left empty. The data on mode split is taken from Malik 2004. All the other data are assumptions, and calculations.

KPI	Value	Units
Meters of High Capacity Transit		Meters
Meters of High Capacity Transit per 1000 People		Meters/1000 people
Transportation Non-Motorized Mode Split	0.5	%
Public Transportation Mode Split	0.23	%
Public Transport Energy Consumption per Passenger km*	1.74	MJ/passenger km
Public Transport Energy		MJ
Passenger Kilometers		Km
Meters of Bike Lanes		Meters
Meters of Bike Lane per 1000 people		Meters/1000 people

*****Divide the total energy consumption (in megajoules) by the total passenger distance travelled by public transit (in kilometers). The passenger distance is usually calculated by multiplying the number of unlinked passenger trips by the average length of the trips.

Peer Benchmarking

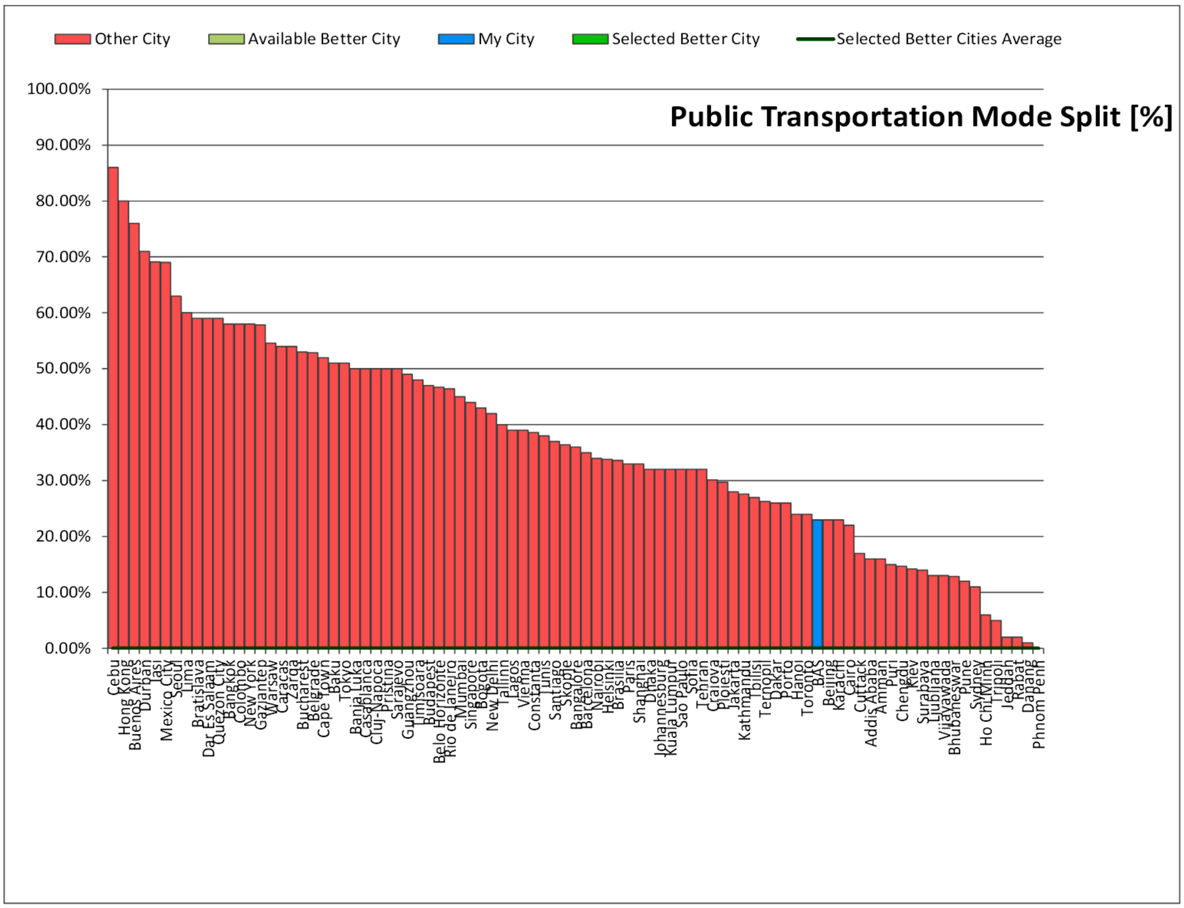
This involves the comparison of KPIs of public transportation of Karachi with the peer cities. On the basis of this comparison, the TRACE module will prioritize the recommendations for evaluating the energy efficiency of Karachi.

Meters of High Capacity Transit / 1000 People

As for Karachi, this indicator is invalid for the base line scenario as there is no high mass transit been developed in the city. Since mass transit program is being planned, this indicator would be incorporated in the upcoming scenarios.

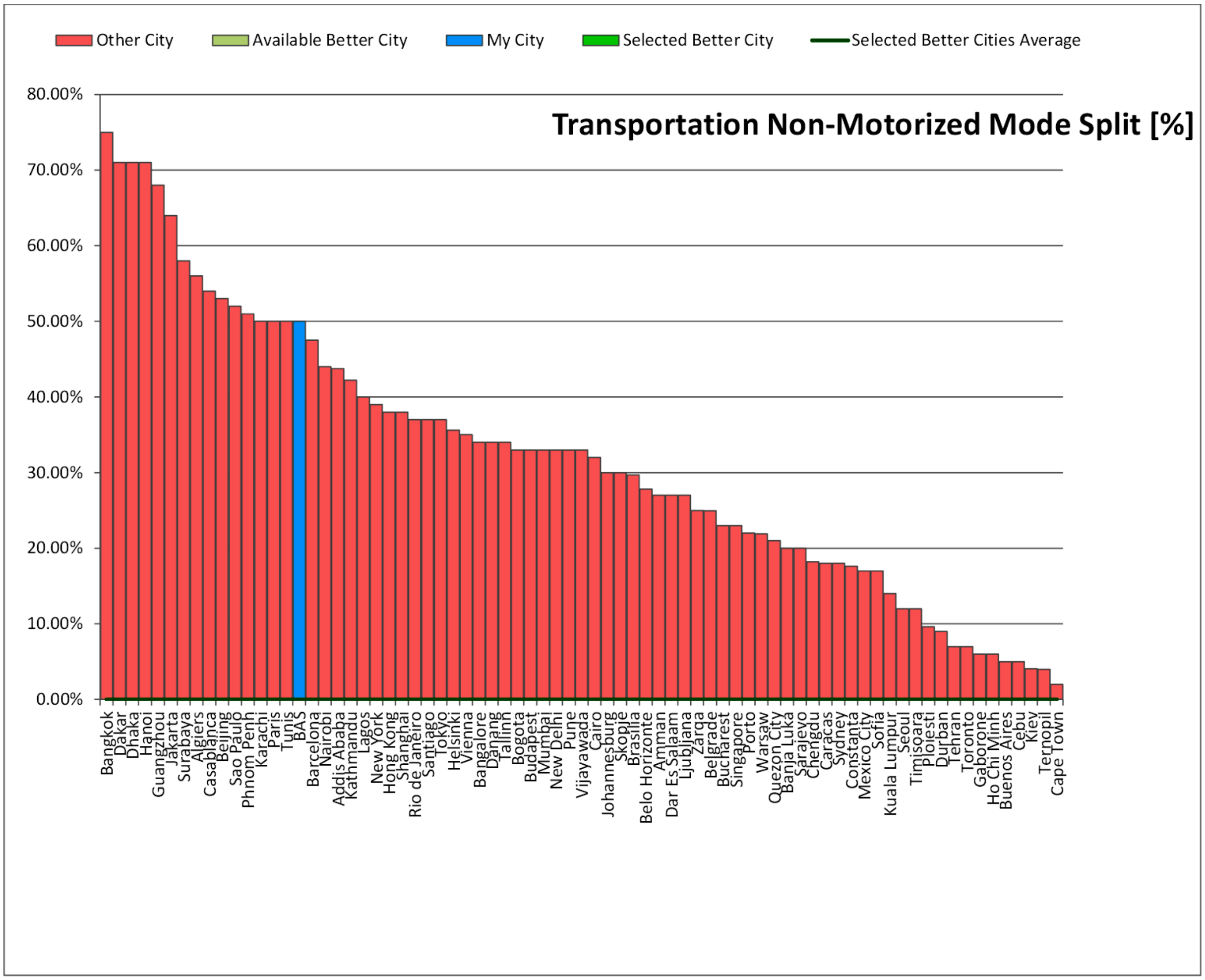
Public Transport Mode Split (%)

According to the TRACE analysis, 23% of the commuters uses public transport which places Karachi in the low end of the graph. The reason is that due to the lack of good conditions of the public transport, people usually travel by private vehicles especially motorcycles. Thus, more people use buses in Karachi than in Sydney or Cuttack and fewer than in Dhaka or Shanghai.



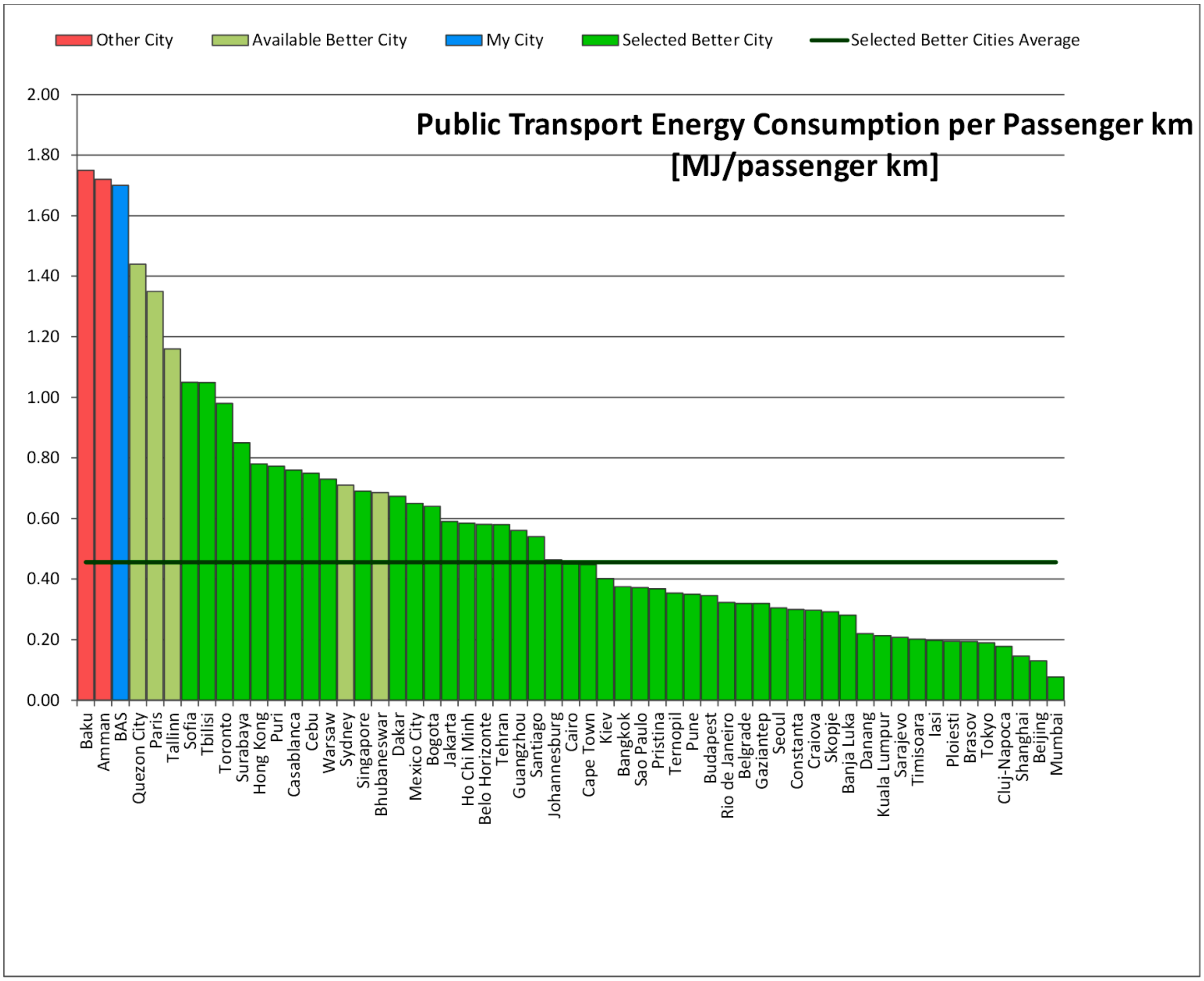
TRANSPORTATION NON-MOTORIZED MODE SPLIT (%)

In terms of transportation non-motorized mode split Karachi is ranked at the upper part of the graph showing a good performance in the indicator. Karachi's non-motorized mode split comes out to be 50% which is quite high as compared to Tokyo or Bangalore but is lower than Hong Kong or New York. This is higher in Karachi due to high fares and bad conditions of public transport.



ENERGY CONSUMPTION MJ/PASSENGER KM

With an energy consumption of 1.748 MJ/passenger-kilometer, the public transport system in Karachi is at the high energy intensive part compared to cities with similar Human Development Index. The available cities with better fuel consumption are Sydney and Bhubaneswar. Karachi should lower its energy consumption in the public transport sector.



SAVING ESTIMATES BASED ON PEER CITIES

The energy spending calculated by virtue of TRACE based on the given data has come out to be 10% which shows that Karachi has to take steps in order to achieve higher energy saving estimates.

SECTORAL ENERGY SPENDING

According to a report, the estimated cost over ten years for Karachi's urban transport was predicted to be 5.5 million to 6 million.

CITY AUTHORITY CONTROL:

The City-District of Karachi governed by elected municipal administrations responsible for infrastructure and spatial planning, development facilitation, municipal related activities and control, besides education, health, transport and communication, and investment promotion. Public transportation and mass transit are the most important function being undertaken by the CDGK.

RECOMMENDATIONs from application of TRACE model

After the saving potential of BAS scenario was calculated, the recommendations identified by TRACE were presented and discussed with local public administration officials in Karachi. The following are the recommendations that could be adopted by the city government in order to improve the public transportation energy condition of the city.

Non-Motorized Transport Mode

ATTRIBUTES

Energy Savings Potential (kWh)

50,000

CAPEX or First Cost ($)

$1,000,000.00

Speed of Implementation (Years)

2.00

Co-benefits

Reduced carbon emissions

Improved air quality

Enhanced public health & safety"

DESCRIPTION

Benefits of non-motorized transport include improved air quality and user health, lower noise pollution, lower operating costs for users and providers, and lower infrastructure requirements along with zero operational fuel consumption cost.

IMPLEMENTATION OPTIONS

Implementation Activity and Methodology
Pedestrianization
Inclusion of cycle/ walking routine dedicated lines in the road network plan and reservation of right of way for cycling and walking requires good drainage and proper lighting and shading. Involves feasibility study and research of probable take-up from origin and destination surveys, existing mode splits, and subsequently designs networks to suit commuting patterns of neighborhood.

Microcredits
Microcredits available to bicycle owners as increased cycle ownership can have significant financial benefits to low-income workers so they do not depend upon expensive, inefficient and infrequent public transport.
Rental Programs
Bicycle rental programs which provide bicycles on demand for a fee that involves tariffs which encourages usage and security procedures to avoid theft. Branding of bicycle creates revenue for local authority.
Public awareness Programs
Increasing public awareness of non-motorized modes in streets by termination of motor vehicles result in removal of noisy and pollutant vehicles as well as creating street markets opportunities.

ACTIVITY

Monitoring

After the implementation of a recommendation, its effectiveness and advancement should be monitored in order to accurately understand its value over the longer term. A target should be defined to measure the level of acceptance over a time scale. A monitoring plan should be defined including information sources identification, validation of monitoring equipment or process, record keeping protocols, establishment of performance indicators, a daily, weekly or monthly schedule for measurement activity, responsibilities assignment for each aspect of process and finally establishment of reporting and review cycles.

Key Measures

• Perform road surveys by using traffic counters on roads and cycle lanes for determining the number of cycles.

• Determine the mode share of people travelling in the area or city.

CASE 2: MASSTRAN SCENARIO:

In this scenario, the energy efficiency is determined taking mass transit in the form of Bus Rapid Transit into consideration.

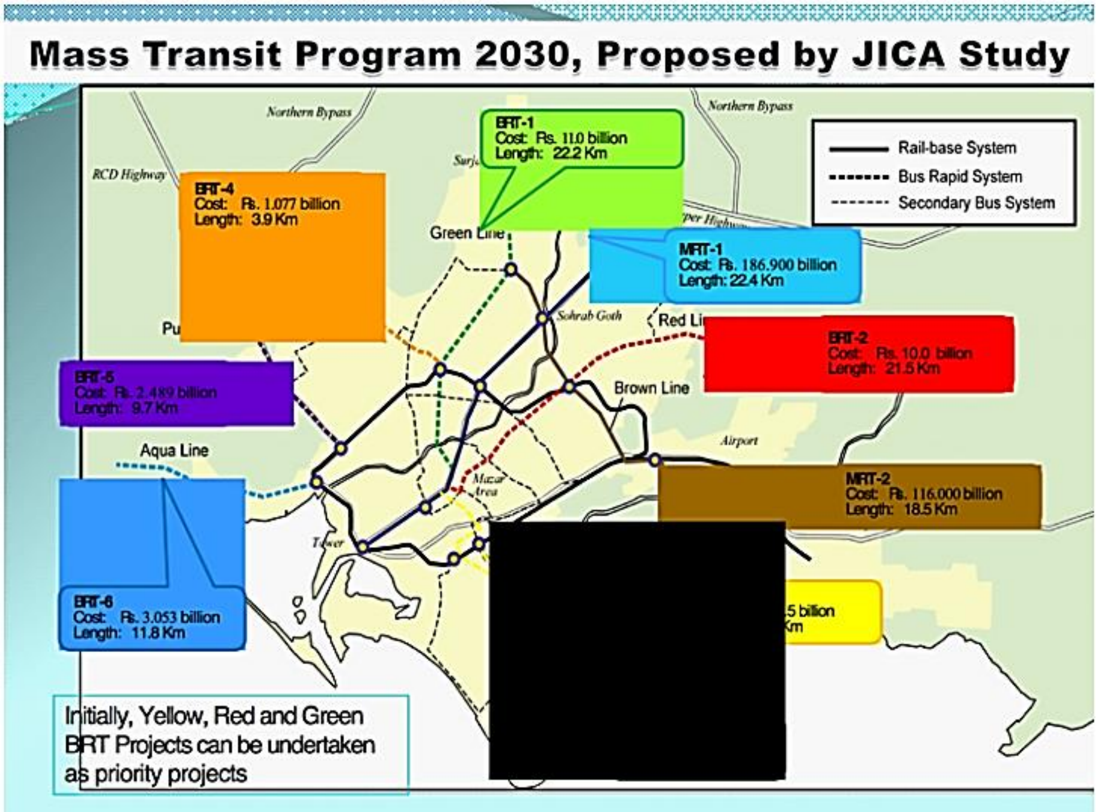


Figure 4 Karachi Mass Transit Routes

Source: JICA study

Green Corridor

1) BRT bus (nos): **100**
2) Corridor length (km): **21**
3) Passengers (per annum): **58,400,000**
4) Share of emissions of the total carbon offset potential (60,672 tCO_2eq): **17%**
5) Impact (2017-2030): **PKR 116 m/yr**

Orange Corridor

1) BRT bus (nos): **25**
2) Corridor length (km): **4**
3) Passengers (per annum): **14,600,00**
4) Share of emissions of the total carbon offset potential (60,672 tCO_2eq): **3%**
5) Impact (2017-2030): **PKR 89 m/yr**

Blue Corridor

1) BRT bus (nos): **100**
2) Corridor length (km): **53.93**
3) Passengers (per annum): **58,400,000**
4) Share of emissions of the total carbon offset potential (60,672 tCO_2eq): **43%**
5) Impact (2017-2030): **PKR 116 m/yr**

Red Corridor

1) BRT bus (nos): **100**
2) Corridor length (km): **21.5**
3) Passengers (per annum): **58,400,000**
4) Share of emissions of the total carbon offset potential (60,672 tCO_2eq): **17%**
5) Impact (2017-2030): **PKR 116 m/yr**

Figure 5 Karachi Mass Transit Design Parameters

Source: ALI DEHLAVI WWF-PAKISTAN 25.07.2016, Karachi

City KPI's and data

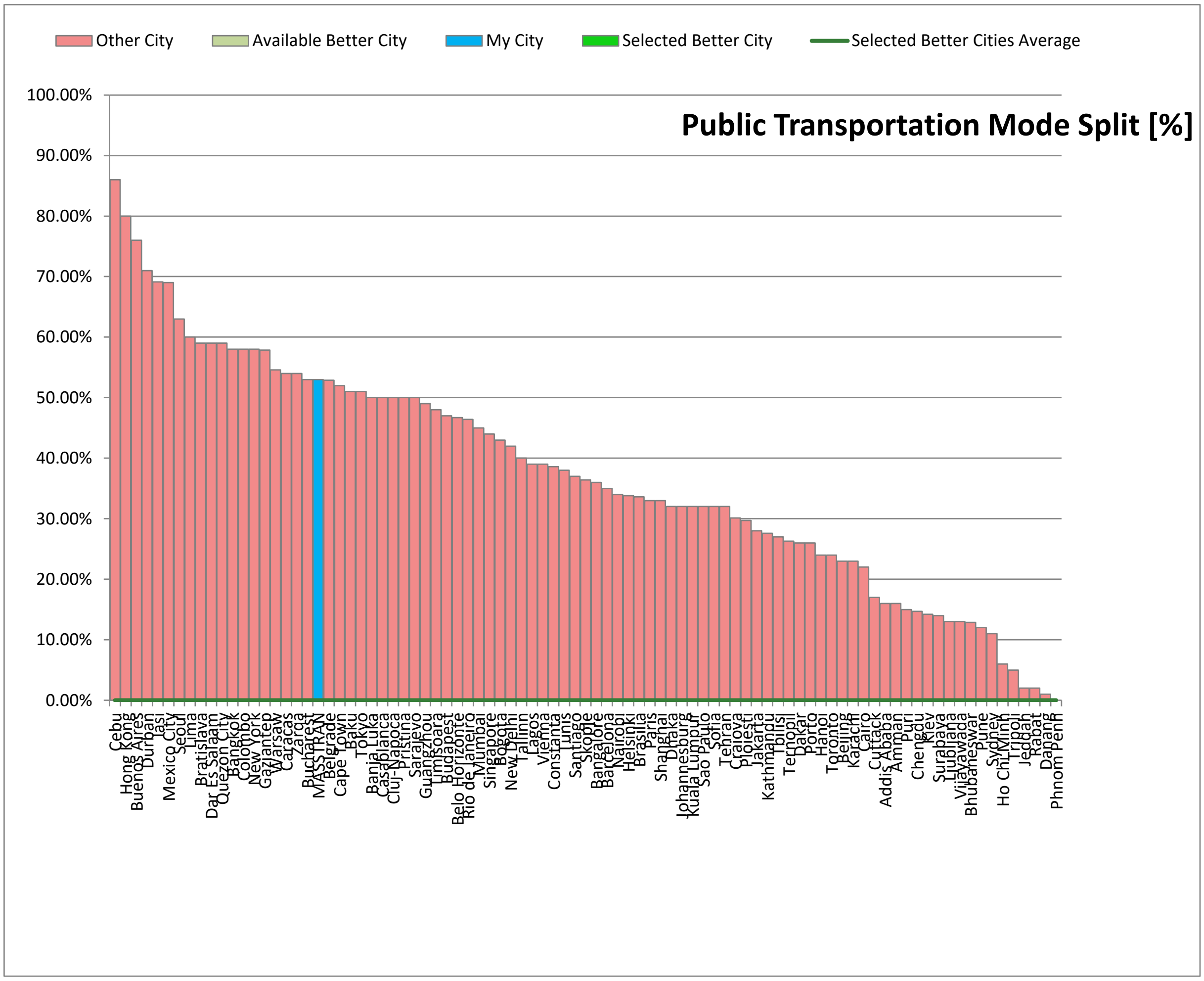
The values of meters of high capacity transit are calculated according to the above figure values. Mode split values are assumed to increase as more people would travel in BRT while due to the alarming security and safety problems on the roads, the lack of policy and planning for pedestrians/cyclists, and the encroachment on footpaths non-motorized transport are less being used by middle and lower income groups. Public transport energy is taken from Delhi data.

*Divide the total length of high-capacity transit (in meters) by total population (in thousands).

KPI	Value	Units
Meters of High Capacity Transit	100,430	Meters
Meters of High Capacity Transit per 1000 People*	4.73	Meters/1000 people
Transportation Non-Motorized Mode Split	0.12	%
Public Transportation Mode Split	0.53	%
Public Transport Energy Consumption per Passenger km	**0.30**	MJ/passenger km
Public Transport Energy	48,000,000,000	MJ
Passenger Kilometers	353,320,000	Km
Meters of Bike Lanes		Meters
Meters of Bike Lane per 1000 people		Meters/1000 people

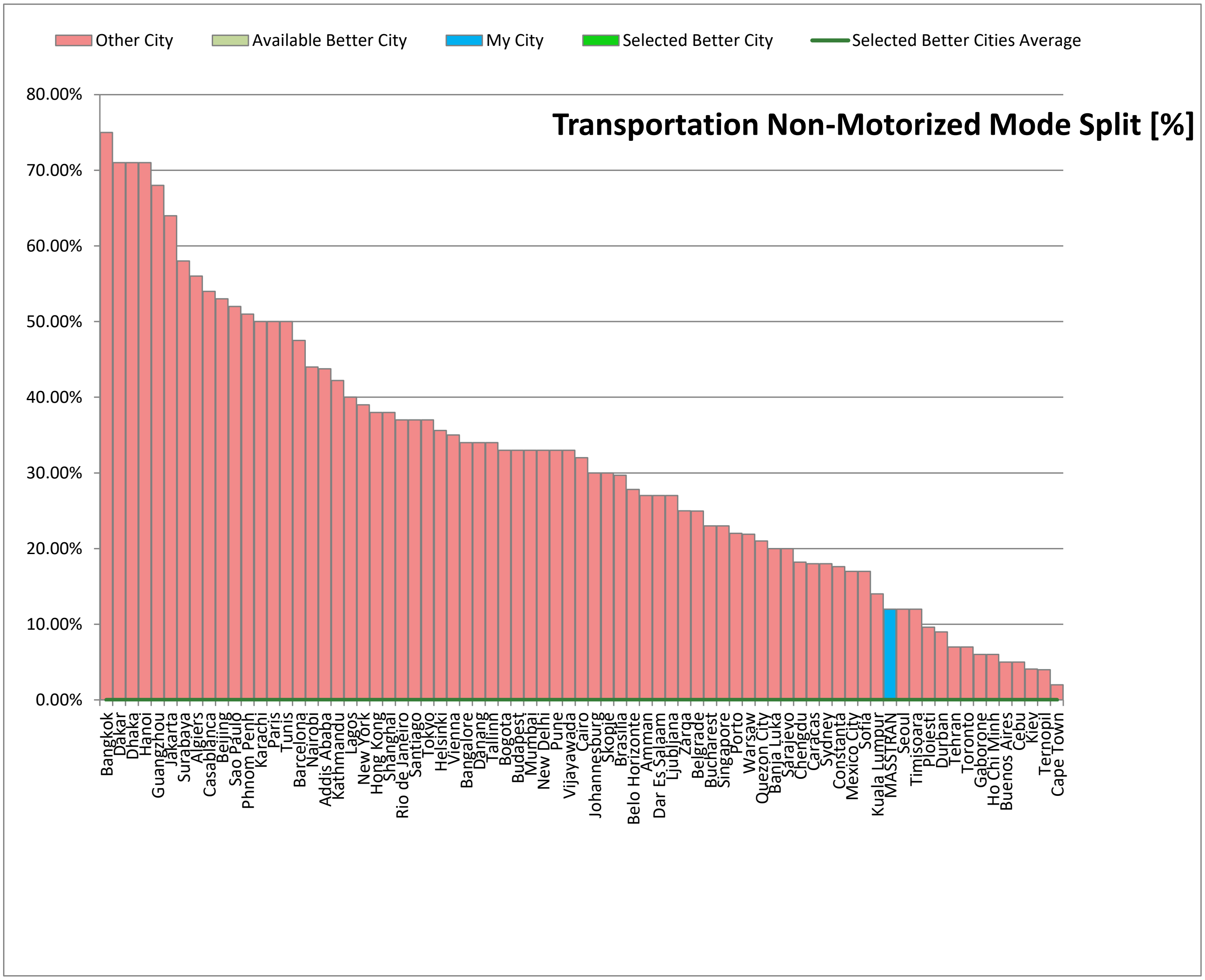
PEER BENCHMARKING

By the use of BRT, Public transport mode split has now been placed on the higher place of the chart in comparison to cities like Belgrade, Cape Town and Tokyo. Due to its efficiency in condition and less fuel consumption, more people will use BRT as public transport.



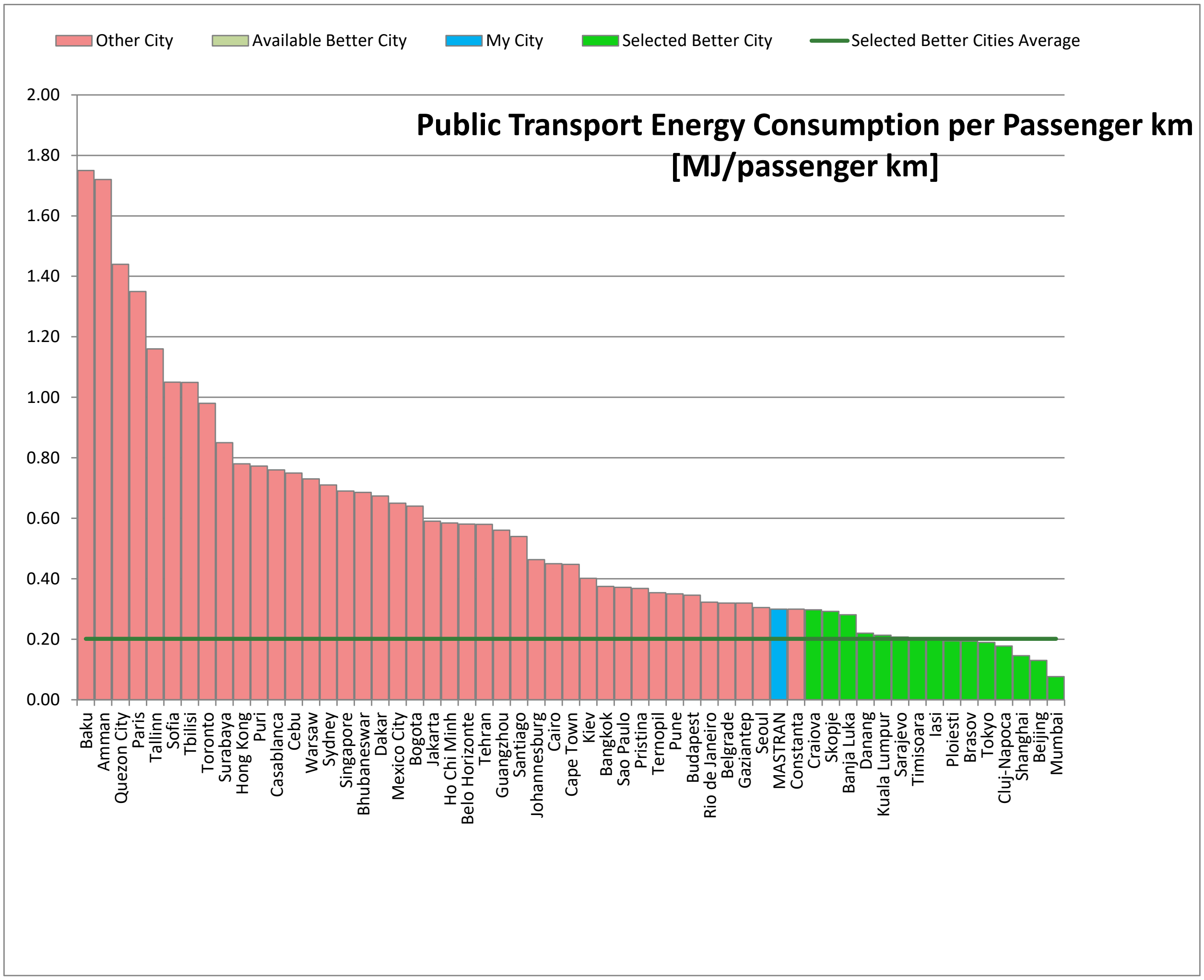
TRANSPORTATION NON-MOTORIZED MODE SPLT

As shown from the graph, the non-motorized transportation mode split has decreased as compared to the baseline scenario. This is due to the alarming security and safety problems as the pedestrians besides being exposed to air and noise pollution, are also the largest group of victims of road accidents. Besides, the absence of policy and planning for pedestrians/cyclists, and the encroached/ill maintained footpaths are some of the main reasons of low usage of non-motorized transportation in Karachi.



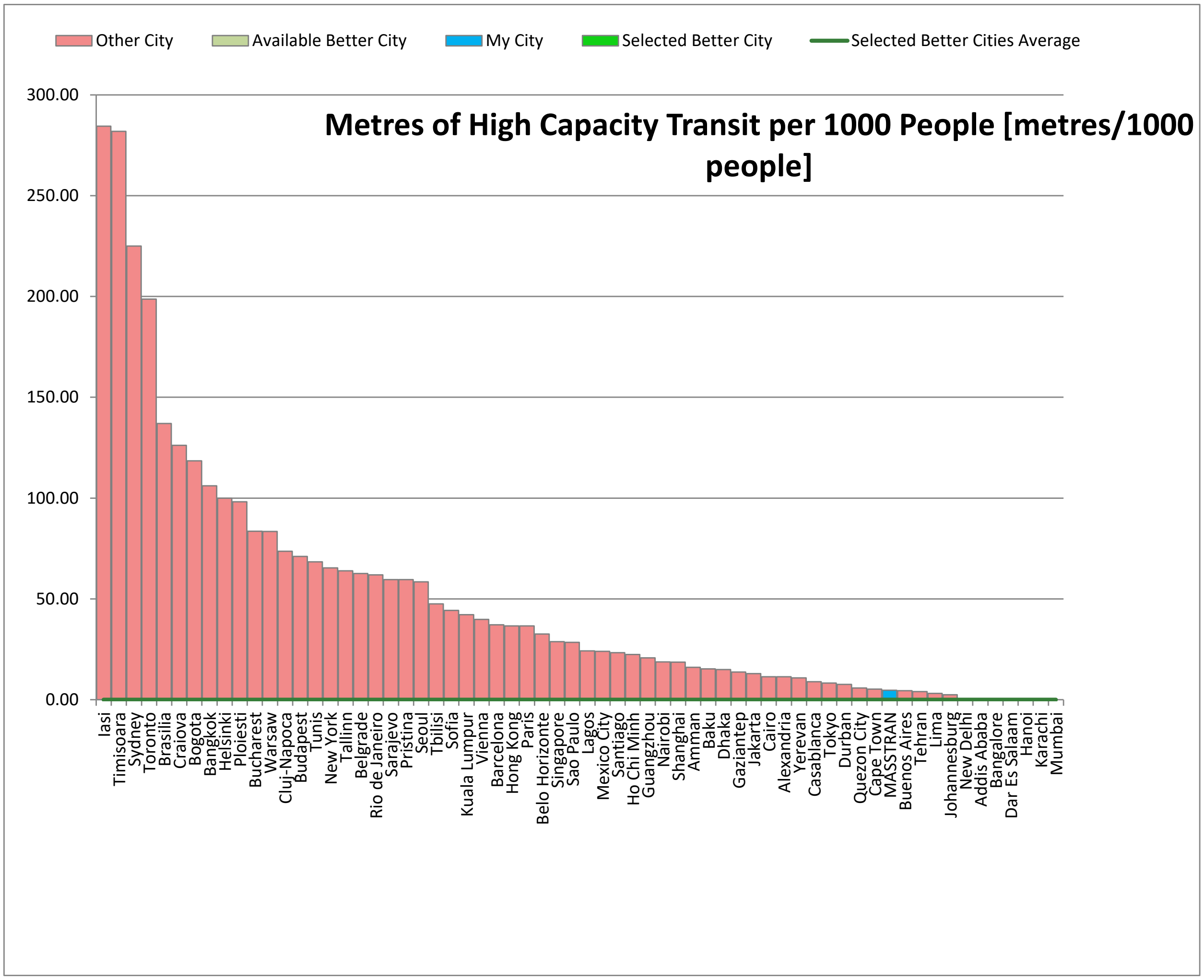
PUBLIC TRANSPORTATION ENERGY CONSUMPTION PER PASSENGER KM

As it is seen from the graph the public transport energy consumption of Karachi in the mass transit scenario is 0.30MJ/pkm which is ranked in the lower part of the graph along with Belgrade and Gaziantep. As the city has a lower energy consumption in comparison to Cairo or Johannesburg, the opportunities for increased public transit are gradually increasing with BRT innovative.



METERS OF HIGH CAPACITY TRANSIT/1000 PEOPLE

In this case another energy efficiency indicator is used as high capacity in the form of BRT is involved. For the indicator of meters of road of high capacity transit, the graph is showing city is at the lower end greater than Tehran and Johannesburg but it should improve to come in comparison to Shanghai or Amman.



SAVING POTENTIAL:

The saving potential that the software has calculated in the light of the above condition is 7%. This manipulates that BRT would be an efficient means to save overall transportation energy of the city through modal shift from private vehicles to mass transit and non -motorized transport.

In addition to the expansion of the public transport networks, there is a need to better manage and control the use of private and public vehicles which can negatively impact traffic congestion, energy consumption, and air quality. In parallel, city managers must continue to pay attention to improving the quality of public transport service, especially for the popular and well-used BRT system.

Another key area for the city is non-motorized transport, which includes the improvement and expansion of pedestrian routes.

SECTOR RECOMMENDATION

After the saving potential of MASSTRAN scenario was calculated, the recommendations identified by TRACE were presented and discussed with local public administration officials in Karachi. The following are the recommendations that could be adopted by the city government in order to improve the public transportation energy condition of the city.

Public Transportation Development

ATTRIBUTES

Energy saving potential

50,000 KWh/annum

First Cost

$1000, 000.00

Speed of implementation

2 years

Co-benefits

Reduced carbon emissions
Improved air quality
Enhanced public health & safety

IMPLEMENTATION OPTIONS

Implementation Activity and Methodology
Flow Optimization
By changing the route patterns of drivers either technically by traffic signaling or by provision of information. Drivers are provided with route switching options, clear directional validation to destinations, or to nearest available car parks This minimizes congestion and journey length. The crimes can also be reduced by messaging systems.
Regulatory
Establishment of high occupancy vehicle (HOV) lanes induces car sharing potential. Achieving a minimum number of users is vital, as insufficient use results in reduced available road space and increased congestion. An effective enforcement and penalty system is also important as the lane will otherwise attract an unacceptably high level of non-HOVs, reducing effectiveness

DESCRIPTION

Development or improvement of the public transport system and adoption of measures to increase its accessibility and use is important for achieving lower emissions per capita than private cars, and has the prospective to provide equitable transport network. A reduction in the number of private vehicles on roads can lower emissions and improve air quality.

ACTIVITY

Monitoring

Monitoring includes measuring the progression and effectiveness of recommendations in order to determine their value over the longer term. The level of progress is measured against a well-defines target over a definite timescale. A monitoring plan is designed which should not be necessarily much complicated covering the flowing aspects: information sources identification, validation of monitoring equipment or process, record keeping protocols, establishment of performance indicators, a daily, weekly or monthly schedule for measurement activity, responsibilities assignment for each aspect of process and finally establishment of reporting and review cycles.

Key Measures

Some suggested measures that relate specifically to this recommendation are as follows:

- •Perform surveys of public transport passenger numbers.
- •Determine mode share of people travelling in area or city.

CASE 3: FUELEFF SCENARIO

City KPIs and Data

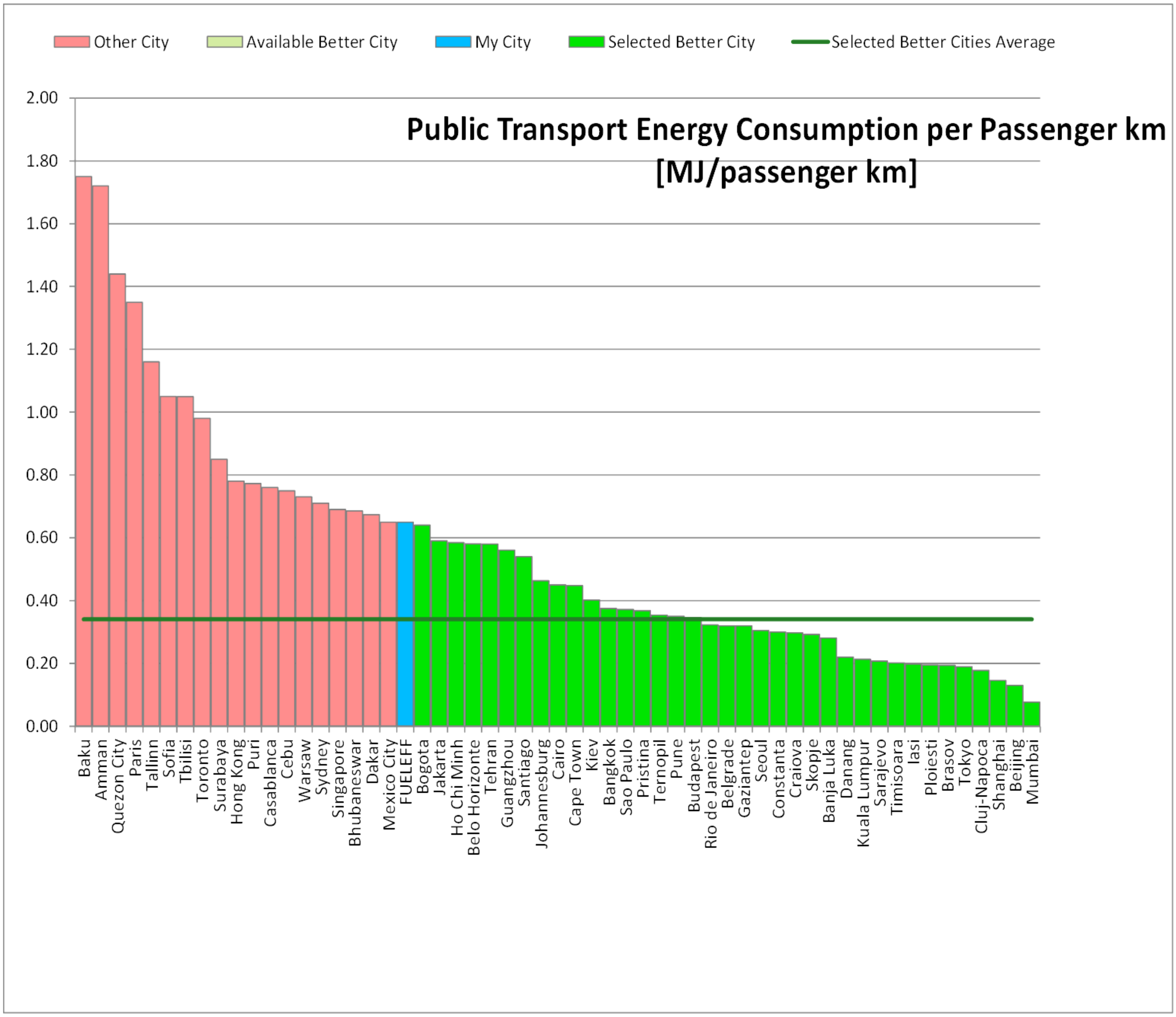
As this scenario is assumed for the year 2030, the public transport mode split and non-motorized mode split would be further improved. It’s assumed that the electric buses would travel approximately 280 km once fully charged. Public transport energy consumption per passenger km is assumed to be that of urban electric train based upon Carpenter (1994) Potter (2000) and Roy, Potter and Yarrow (2002).

KPI	Value	Units
Meters of High Capacity Transit	280,000	Meters
Meters of High Capacity Transit per 1000 People	13.20	Meters/1000 people
Transportation Non-Motorized Mode Split	0.53	%
Public Transportation Mode Split	0.6	%
Public Transport Energy Consumption per Passenger km	**0.65**	MJ/passenger km
Public Transport Energy		MJ
Passenger Kilometers		Km
Meters of Bike Lanes		Meters
Meters of Bike Lane per 1000 people		Meters/1000 people

Peer Benchmarking

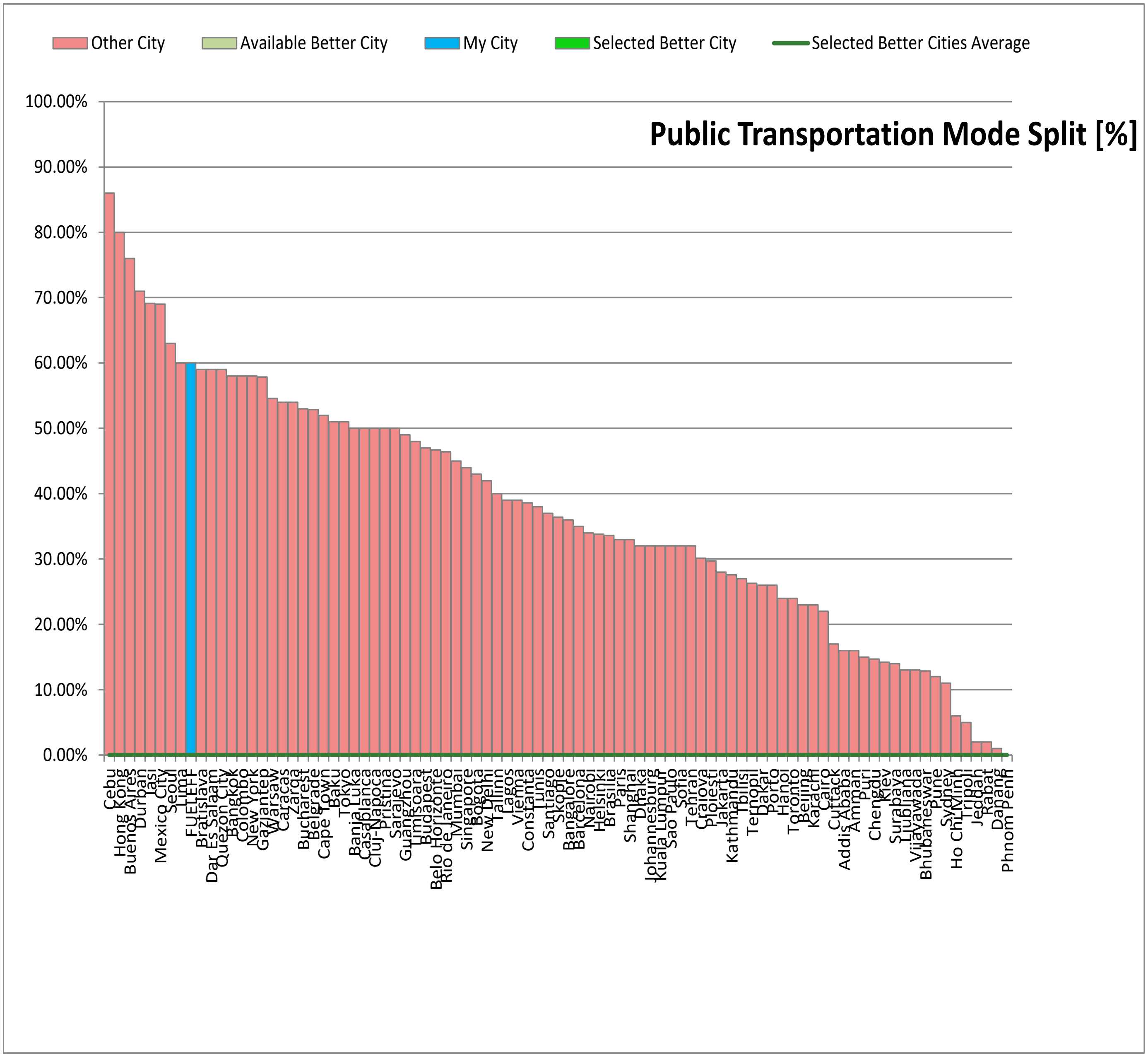
Public Transport Energy Consumption MJ /Passenger Km

Here as seen from the graph, this value is paced in the middle part of the graph along with Jakarta and Bogota indicating that with this energy consumption, Karachi would be in the ideal place in the world with lower energy consumption as compared to other more developed countries such as Toronto and Paris.



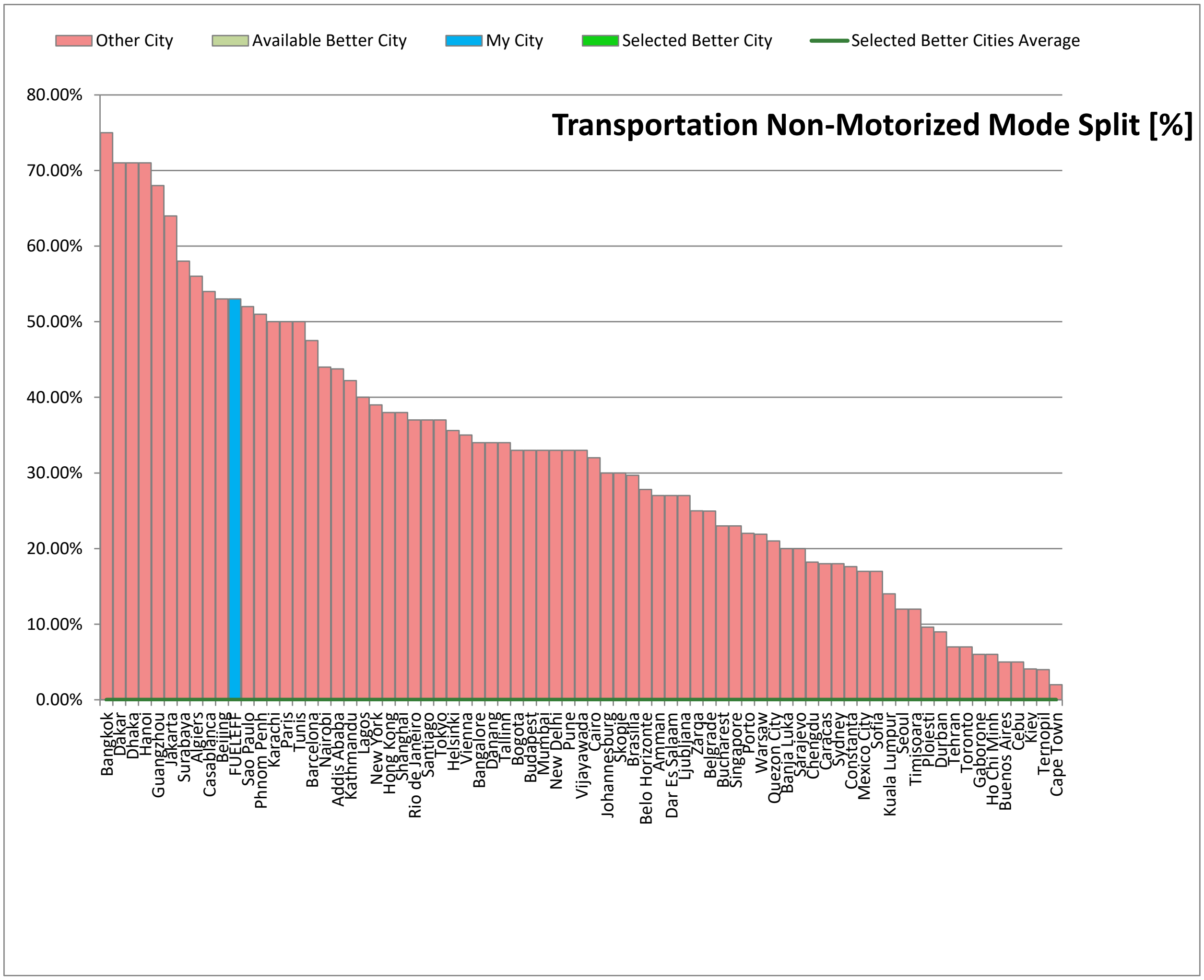
Public Transportation Mode split %

As seen from the graph, this percentage places Karachi in the high end of the TRACE database with comparable cities. Thus, more people use buses in Karachi than in New York or Colombo, but fewer than in Hong Kong or Mexico City. With the advent of high efficiency public transport, mode split of Karachi would come in pace of developed countries.



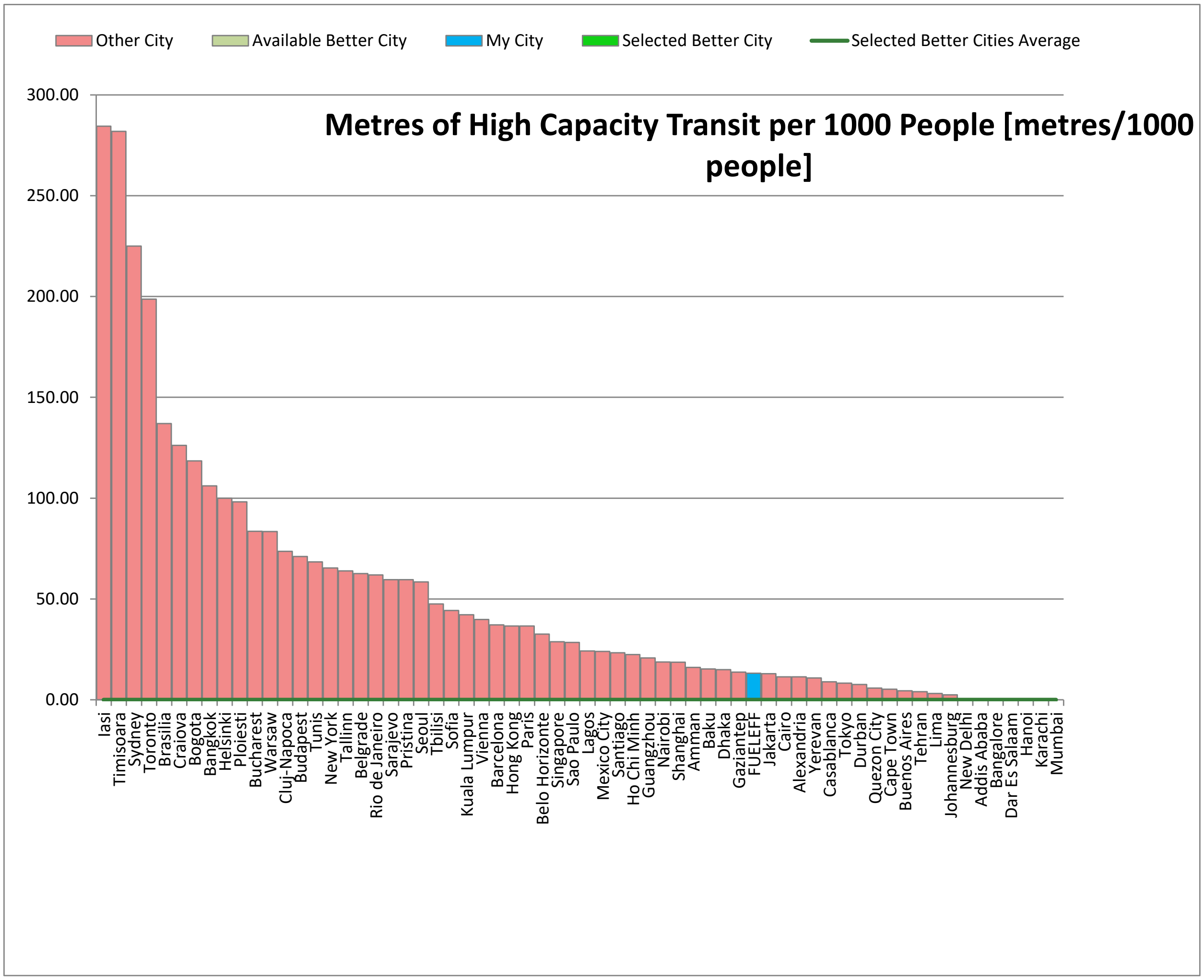
Transportation Non-motorized Mode split %

This also places Karachi in the higher range in graph along with the cities of Beijing or Casablanca. This leads to the fact that in the future years, safer road environment, lesser road accidents and pollutant free transport, non-motorized mode split is going towards higher end.



Meters of High Capacity Transit/1000 People

Karachi is placed in the lower end of the graph because due to low economic condition, there could be less meters of high capacity transit that can be operated. If the length is increased, the city can be placed in the higher end of the graph along with Paris or Singapore.



Saving Potential

According to the TRACE, the saving potential calculated in the light of the above condition is 48%. This deploys that the use of electric buses would be an efficient means to save overall transportation energy of the city through modal shift from private vehicles to mass transit and non -motorized transport.

In addition to the expansion of the public transport networks, there is a need to better manage and control the use of private and public vehicles which can negatively impact traffic congestion, energy consumption, and air quality. In parallel, city managers must continue to pay attention to improving the quality of public transport service, especially for the popular and well-used BRT system.

Another key area for the city is non-motorized transport, which includes the improvement and expansion of pedestrian routes.

SECTOR RECOMMENDATION

After the saving potential of FUELEFF scenario was calculated, the recommendations identified by TRACE were presented and discussed with local public administration officials in Karachi. The following are the recommendations that could be adopted by the city government in order to improve the public transportation energy condition of the city.

Deployment of Electric Vehicle Charging System

After the saving potential was calculated, the recommendations identified by TRACE were presented and discussed with local public administration officials in Karachi. Six recommendations have been chosen together with the city managers, and these are discussed in more detail in the sections below.

ATTRIBUTES

Energy saving potential

4500 KWh/annum

First Cost

$450 to $1,000 per Level 2 charging point for homeowners
$15,000 to $18,000 per Level 2 charging station
$45,000 to $100,000 per DC fast-charging unit

Speed of implementation

1 year

Co-benefits

Decrease oil consumption
Increase energy security
GHG emissions reduction and pollutants
Improve city's image

DESCRIPTION

Electric vehicles (EVs) are electricity powered and have great potentials to transform the transportation sector. Comparing with internal combustion engine (ICE) vehicles, electric vehicles have potential to cut oil consumption, increase energy security, and reduce Greenhouse gases emissions. Cities should work with utilities, charging equipment manufacturers, automakers, major employers and business owners to expand charging infrastructure.

Energy Efficiency Implementation Options

Energy Efficiency Implementation Activity and Methodology
Use of regulatory influence in city
Assessment of existing charging stations by experienced staff. Study is conducted to determine the cost of installing charging infrastructure and equipment. Use of regulatory influence (for example, standards for charging infrastructure, permitting process, planning) to create an environment by establishing standards for charging infrastructure, streamline permitting process, planning infrastructure network.
Provide Incentives for local business for charging infrastructure
Provision of financial incentives to charging utilities. Coordination with business owners to reach agreements of quality, location, payment mechanism and regulations.
Development of pilot programs in focused areas.
Launch pilot programs, test and demonstrate business models so that the program reach the private sector.
Begin a public campaign
Educate the public about the benefit, awareness, and accessibility of charging stations. Use of advertisement to offset the cost of the station installation and its operation.
Evaluation of program results
The effectiveness of the program is evaluated by measuring the economic benefits, the reduction in car trips number, the amount of gasoline consumption decreased, pollution

ACTIVITY

Monitoring

Monitoring the progression and effectiveness of recommendations, once implemented, is fundamental to an accurate understanding of their value over the longer term. Where the City Authority (CA) implements a recommendation, Key Performance Indicators (KPIs), should be defined to track performance and a target (or set of targets) should be defined to ensure the expected progress over a given timescale. At the same time a monitoring plan should be designed. The monitoring plan does not need to be complicated or time consuming but should, as a minimum, cover the following aspects: identification of information sources, identification of performance indicators, a means of measurement and validating measuring equipment or processes, record keeping protocols, a schedule for measurement activity (daily, weekly, monthly etc.), assignment of responsibilities for each aspect of the process, a means of auditing and reviewing performance and finally, establishment of reporting and review cycles.

Key Performance Indicators

- Cost per charging station
- Number of charging station
- Charging station lifespan
- Charging capacity in KWh
- Fee payment to use a charging station

Sector Analysis Outcome

Due to the increase in the urbanization, private vehicle ownership is rising causing more emission of greenhouse gases which ultimately influence public health. Also, with the lack of proper law and order situations the citizens are facing security problems in terms of vehicles and road use. The public transport is facing many challenges due to its detreating condition and long trips which forces the people to adopt private transport which is consequently affected by the income and economic conditions of the people. The city authority should develop plans to upgrade its public transportation system plan and consider low economic, user friendly, and environment friendly modes so that the purpose of transportation is achieved at its fullest scale.

The initial assessment using TRACE 2.0, indicates that besides the development of adequate infrastructure and purchase of energy efficient buses, public transport sector can be improved and upgraded by implementing some soft interventions. However, a more detailed analysis is required to assess costs and opportunities in order to address the issues with regard to fuel efficiency and congestion.

5. Field study

Estimation of different parameters of transportation system are vital to understand its impact on the future development. Transportation system is the backbone of economic cycle of country by providing support from domestic to freight movement. Numbers of methods, techniques are used to analyze the system which helps to make it efficient and up to mark. Parameters which were discussed in literature review would help to understand the integration of transportation system in whole urban environment. One of the important considerations is the energy use in different sector of urban environment. To manage the energy production and supply at whole, it must be necessary to have the energy consumption record of different sectors.

This research projects aims to established different energy parameter to understand the energy consumption in public transportation of Karachi. This will lead to compare our Public transportation system with developed cities and helps to make it more efficient.

There are many cases for sustainable transportation system in developed countries. A study conducted in Egypt by R.M.R Hussein that define sustainable transport as the use of renewable resources, reducing consumption of non-renewable resources, minimizing carbon emissions on all transport modes and also the production of noise. The smart sustainable transport is also considered as the transport which reduces the consumption of fuel, minimizing carbon emissions and improving the safety. The transport can be improved by reducing private vehicles and moving towards public transport and newly vehicles.

Energy efficiency is needed in transportation system because transport consumes a large amount of global energy. Energy efficient transport gives vast possibility for minimizing the demand both for oil and for energy in general. Many countries are working to reduce energy consumption of transportation system as International Energy Agency (IEA) estimates that advanced Technologies and alternative fuels such as hybrid vehicles, electric vehicles, and fuel cell vehicles can reduce the energy intensity of transportation system about 20 to 40 percent by the year 2050 that would result in minimizing share of fossil fuels need.

Purpose of Project:

Karachi city is a most appropriate study area because it hosts millions of public masses and largest vehicle population in country, fastest developing metropolitan, and greatly motorized inner-city. The study main purpose is to identify the current existing status of energy efficiency and assessment of the policies which are likely to be deficient in the city. The project would look over the interventions of the areas.

Field Data Collection Methodology:

The study project mainly consists of data collection through survey and analysis of data for estimation of energy consumption parameter in public transportation of Karachi. Existing bus routes in Karachi are approx. 160 including Buses, minibuses, coaches and others. Collection of data for all router is not possible in given time of project life, for the representation of complete public transportation system 10% route are selected from all areas of Karachi which are in total 18 routes. In every selected route there are three observations which make around 60 data sets for analysis and estimation. Figure 1: shows the number of routes and its trip length of one direction.

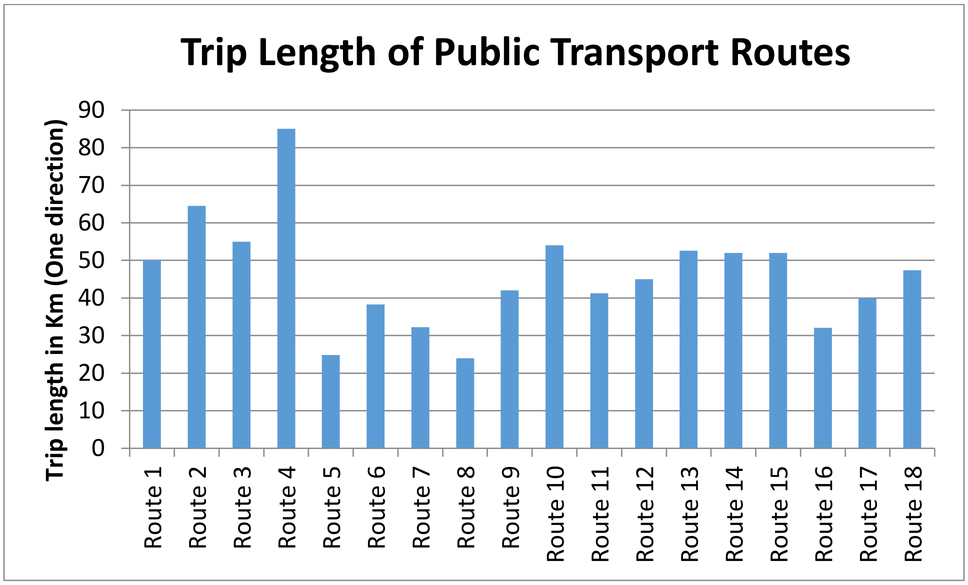


Figure 6: Number of public transport routes and trip length

Route Selection:

Karachi is the Capital of Sindh province. It comprises of large number of public transports which is also known as public transportation or public transit. In Karachi city the numbers of public transport routes are approximately 160 that consist of large buses, Mini buses and coaches respectively (KMC 2012). The public transport runs throughout the city approximately covering every area of the city, from which many running from one district to the other and charging on per trip.

Buses/ Mini buses:

Route: 1

Ittehad Town → New Saeedabad Police Training School → Hub River Road → Traffic Police Kiask → Philips Company → Polytechnic, S.I.T.E Police Station, Bhawani Chall → Frontier Mor → Badar Chowk → Orangi No. 4 → Orangi No. 5 → Metro Cinema → Banaras Chowk → Abdullah College → Board Office → Bank Qtrs → Ziauddin Hospital → Moosa Colony → APWA Girls College → Karimabad → Naseerabad → Telephone Exchange → Water Pump → City Garden → Moti Mehal → N.I.P.A Chowrangi → Safari Park → Gulistan-e-Jouhar → Abdullah Apartments → Jouhar Square → Golden City → Pehlwan Goth Old Area → Safoora Goth.

Route: 2

Safoora goth → Pehalwan goth → Gulistan-e-jouhar → Jouhar square → Rashid minhas road → N.I.P.A Chowrangi → Hassan square → Purani sabzi mandi → New town → Jail Chowrangi → Islamia college → Mazar-e-quaid → Numaish Chowrangi → M.A Jinnah road → Plaza → Jama cloth market → Tower → Mai kolachi road → Boat basin → kharkar Chowrangi → Bilawal house → Samundar kinara → Abdullah shah ghazi road → 26 street → Saudi embassy → kheyaban-e-hafiz → Sultan masjid → kheyaban-e-baharia → kheyaban-e-Ittehad → Qayyumabad → Crossing → Korangi → Korangi no.5.

Route: 3

Orangi town → Yousuf goth → Hub river road → Bukhramandi → Afridi chowk → Didgah mor → Jamia mehnodia → Orangi town → Saddiq akber colony → Sabri chowk → Urdu chowk → Orangi no 10 → Orangi no 4 → Orangi no 5 → Metro cinema → Banaras chowk → Abdullah college → Board office → kda chowrangi → Ziauddin hospital → Landhi kotal → Peoples Chowrangi → Buffer zone → Power house → Sohrab goth → Fazal mills → N.I.P.A Chowrangi → Safari park → Jouhar square → Pehalwan goth → Safoora goth.

Route: 4

Safoora Goth → Gulistan-e-Jouhar → University Road → N.I.P.A Chowrangi → Hassan Square → Sabzi Mandi → Shaheed-e-Millat Road → Tariq Road → Shahrah-e-Quaideen → Gora Qabristan → Korangi Road → Denfence mor → Punjab Colony → Gizri → Saudi Embassy → Abdullah Shah Gazi Mazar → Clifton, Boat Basin → Bilawal House → Mai Kolachi Road → Tower → Gulbai → Shershah → Habib Bank Chowrangi → Banaras → Qasba Colony → Mangopir.

Route: 5

Azam Basti → Corporation → Kala Pull → Jinnah Hospital, Saddar → 7th Day Hospital → Numaish Chorwrangi → Islamia College → Jail Road → New Town Police Station → Purani sabzi Mandi → Civic Centre → Urdu College → N.I.P.A Chowrangi → Safari Park → University Road → Safoora Goth.

Route: 6

Gulshan-e-Ghazi → Nai Abadi → Mohajir Camp No. 7 → Mohajir Camp No. 8 → Shershah → Gulbai → Agra Taj → Tower → Bolton Market → Jama Cloth Market → M.A Jinnah → Numaish Chowrangi → Khudadad Colony → Society Graveyard → Tariq Road → Bahadurabad → New Town → Purani sabzi Mandi → N.I.P.A chowrangi → Sachal goth → Muhammad khan goth**.**

Route: 7

Majeed colony → Gul Ahmed Textile Mills → Dawood Chowrangi → Quaidabad → Malir Halt → Natha Khan Goth → Drigh Road →Station → Dalmia Chowrangi → Gulshan Complex → N.I.P.A chowrangi → Gulshan Chowrangi → Sohrab Goth → Al-Asif Square → Jamali Pull.

Route: 8

Maymar complex → Al-Asif square → Water pump → Karimabad → Laloo khait → Tin hati → Guru mandir → Numaish Chowrangi → Saddar Empress market → Regal → Burns road → Jama cloth market → Light house → Bolton market.

Route: 9

Bhains colony No.12 → Bhains colony mor → Manzil Pump → Quaidabad → Malir Kala boat → Airport → Allama Iqbal college gate → Natha khan → Paf Karsaz → Awami market → Baloch colony → Nursery → Gora qabristan → Saddar Empress market.

Route: 10

Bhains colony → Dawood Chowrangi → Landhi → Korangi No.5 → Korangi No.6 → Crossing → Qayummabad → Tariq road → Nursery → Jail Chowrangi → Hassan square → N.I.P.A Chowrangi → Gulshan → Moti Mehal bakery → Water pump → Serena market → Bhutto colony.

Route: 11

New Sabzi mandi → Al-Asif → Maskan Chowrangi → N.I.P.A Chowrangi → Hassan square → Laloo khait No.10 → Petrol pump → Habib bank Nazimabad → Siemen's Chowrangi → Ghani Chowrangi → Shershah → Gulbai → Agra taj → Dockyard road.

Route: 12

New Sabzi mandi → Al-Asif → N.I.P.A Chowrangi → kala board → Safari park → Jail Chowrangi → Medical Chowrangi → Nursery → Taj Mahal hotel → Jinnah Hospital → Cantt Station → 3 Talwar → 2 Talwar → Bilawal House → Park Tower → Ziauddin hospital → Shireen colony.

Route: 13

Jawani Complex → Sachal Goth → Mausamyat → Pehlawan Goth → Jouhar Chowrangi → Jouhar Mor → Aladin park → N.I.P.A chowrangi → Civic center → Essa nagri → Laloo khait No.10 → Dak khana Laloo khait → Golimar → Habib Bank Chowrangi Bus stop → Banaras → Baloch colony → Manghopir → Sultanabad.

Route: 14

Itehad town → No.9 market → No.24 market → Mohajir camp → Shershah → Habib bank Nazimabad → Petrol pump → Laloo khait No.10 → Numaish Chowrangi → Saddar → Punjab Chowrangi → Gizri → DHA Shahbaz commercial → Misri shah ghazi → Do Darya.

Route: 15

Jungle school → Metroville → Habib bank → Jamia masjid makki → Saddar → Jinnah hospital → Kala Pull → Defence mor → Akhtar colony → Qayyumabad → Chamra chowrangi → Vita Chowrangi → Bilal Chowrangi → Singer Chowrangi → Murtaza Chowrangi → Mansehra colony → Future colony → Dawood Chowrangi → Gul Ahmed Textile Mill → Hospital Chowrangi → Majeed colony → Labour colony → Bhains colony.

Route: 16

Ahsanabad Gulshan-e-Maymar → Allah wali → Sindhi hotel → Godhra → Sohrab goth → Laloo khait → Guru mandir → Numaish chowrangi → 7day → Jama cloth → Bolton market → Tower → Keamari.

Route: 17

7A Surjani town → 4k → Nagan Chowrangi → Sakhi hassan Chowrangi → Board office → Nazimabad → Golimar → Guru mandir → Numaish chowrangi → 7day → Jama cloth market → Civil hospital → Bolton market → Tower → Mai kolachi bypass → Super market → 2 Talwar → Abdullah shah ghazi → Hyperstar Clifton.

Route: 18

7A Surjani town → Nagan chowrangi → Sohrab goth → N.I.P.A Chowrangi → Jouhar mor → Drigh road → Shahrah-e-faisal → Malir kala board → Landhi → Quaidabad → Dawood Chowrangi → Korangi No 5 → Korangi No 2.5 → Bilal Chowrangi → Godam Chowrangi.

Chingchi Rickshaw:

Route: 1

N.I.P.A Chowrangi → Jail chowrangi → Qayyumabad.

Route: 2

N.I.P.A Chowrangi → Hassan square → Saddar parking plaza.

Route: 3

N.I.P.A Chowrangi→ Gulshan Chowrangi → Ayesha manzil.

Route: 4

N.I.P.A chowrangi → Karachi university → Safoora.

Route: 5

N.I.P.A Chowrangi → Gulshan Chowrangi → lyari basti.

Route: 6

N.I.P.A Chowrangi → Jouhar mor → Jouhar Chowrangi.

Route: 7

7A Surjani town → Nagan chowrangi → Sakhi hassan Chowrangi → Ziauddin → Laloo khait → Tin hati.

Route; 8

Malir 15 → Malir kala board → Airport → Star gate → Drigh road → Aladin park → N.I.P.A Chowrangi → Gulshan Chowrangi → Sohrab goth → Shafiq mor → Nagan Chowrangi → Power house → Abdullah mor → Dil pasand → 7A Surjani town**.**

Data Collection:

Karachi city is the largest city of the Pakistan, comprising an area of 3,780 km^2(1,460 square mile). The population of Karachi city is 14.9 million according to the census conducted in the year 2017. The whole city is divided into 6 districts named as district Malir, district Central, district South, district East, district West and district Korangi. As for the proper representation of whole transportation system for Karachi city it is must to take the sample from every area, which is done in this project. The data of public transportation system is taken throughout the all districts of Karachi city covering the whole city transport that consists of buses, mini buses, coaches and Chingchi rickshaw. The data is taken through every area of the Karachi city.

Sampling:

As discussed Karachi is the largest metropolis city of Pakistan. It is not possible of cover all routes surveys with in limited resources. Total 18 routes were selected from all 6 district of Karachi among 160 routes 18 routes were selected for study. The sampling is done by two methods, the first method is survey data and the second is interview data. The data is collected by proper way as discussed below.

Survey data:

Survey data is collected by observing the whole situation of the Karachi transportation system. The data is observed by traveling in a different routes transport i.e. large buses, mini buses, coaches and Chingchi rickshaw from origin to destination. The number of people traveling in each type of transport is observed for several of each type, the route length, sitting capacity, time consumption everything was observed.

Interview data:

The interview data was collected by interviewing the driver, conductor, owner and the person who handle the whole system of them. Interview data was based on the proper questionnaire which consisted all of the related questions to the public transport such as how many trips per day, type of engine, number of persons per trip, sitting capacity, number of stops, route length per trip, CNG, diesel and petrol per trip and how much time is consumed per trip etc. The data interviewed from the driver and conductor was taken from the three persons of each.

Way forward:

Data that were collected through prescribed method later analyze with the estimation of different parameter. These parameters are representing energy consumption in public transport sector and important for estimation. In the result and discussion section the data were comparing with other data and also presented graphically.

6. Field Study Result and Discussion:

As discuss in the methodology about the collection of data. In this section we discuss the analysis of data and some estimation from collected data set. Initially the analysis was performed on compression of different parameter that were observed in data set for example passenger capacity, number of trips performed by individual vehicle of particular trip, trip length and etc. Later some mathematical calculation performs to estimate the fuel consumption per km, number of fuel unit per passenger, energy consumption per passenger per km and etc.

Analysis of Parameter:

Trip Length of Classified Public Transport:

One of the important consideration among parameter is the trip length of classified Public Transport is shown in figure below. This explains trip length of studies mode of public transportation i.e. Chingchi, Bus, minibus/coaches. The figure shows that the Chingchi rickshaw has an average trip length of 12.87 km, while the average trip length for buses has come 24.4 km and that for Mini buses / Coaches has come 48.96 km. The Trip Length of Chingchi rickshaw is small as compared to Buses and Mini Buses / Coaches which are used for the smaller routes and attract the people who have shorter trip length.

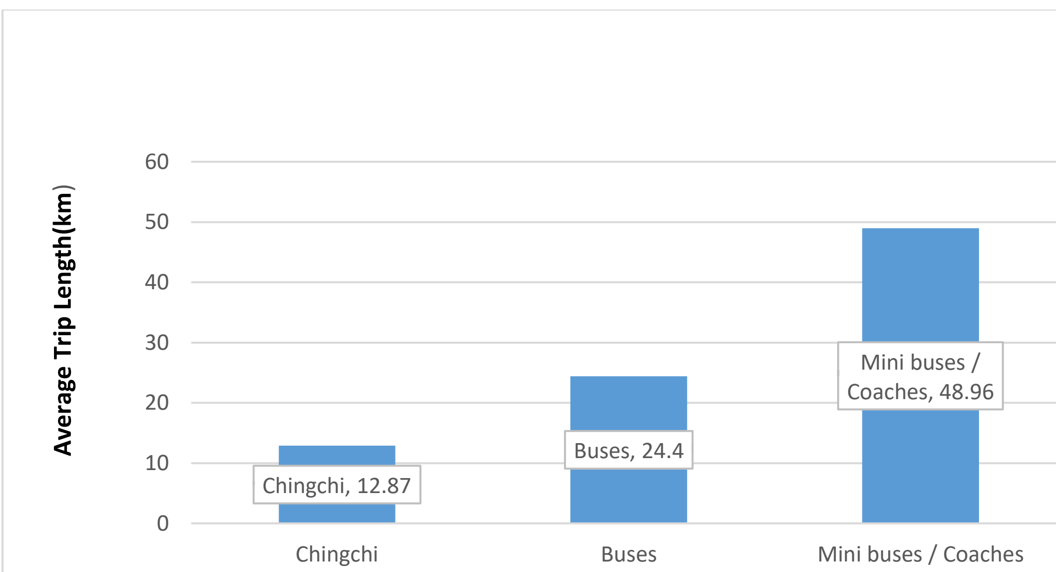


Figure 7 Trip Length of Classified Public Transport

Seating Capacity of Classified Public Transport:

Seating capacity of Public Transport varies according to the mode. Figure shown below describe the average seating capacity of classified Public Transport. According to the figure average seating capacity of Chingchi rickshaw is 8, that of Buses is 41.5 and Mini buses / Coaches is 28.75 respectively. The seating capacity depends upon the size of vehicle i.e. Buses are large in size as compared to Mini buses / Coaches so have more seating capacity and Chingchi are small in size to both so have comparatively less seating capacity.

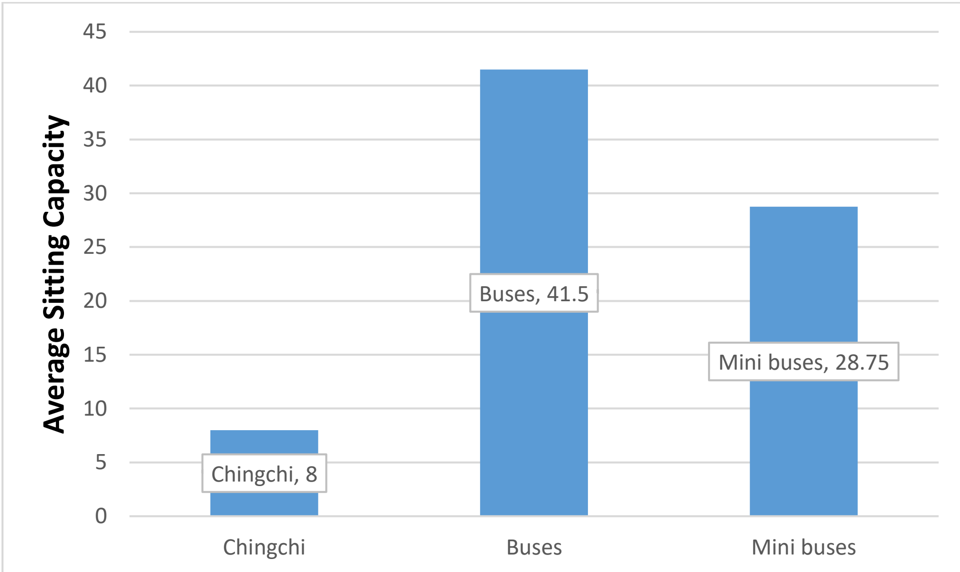


Figure 8 Seating Capacity of Classified Public Transport

Number of Trips by Individual:

Number of trips by individual vehicle type is dependent upon the route length on which they are operated. According to the graph shown below, average numbers of trips for Chingchi rickshaw, Buses and Mini buses / Coaches are came out 16.25, 7 and 4.75 respectively. The Chingchi routes are usually small as compared to Buses and Mini buses / Coaches that is the reason they cover a greater number of trips and having high frequency.

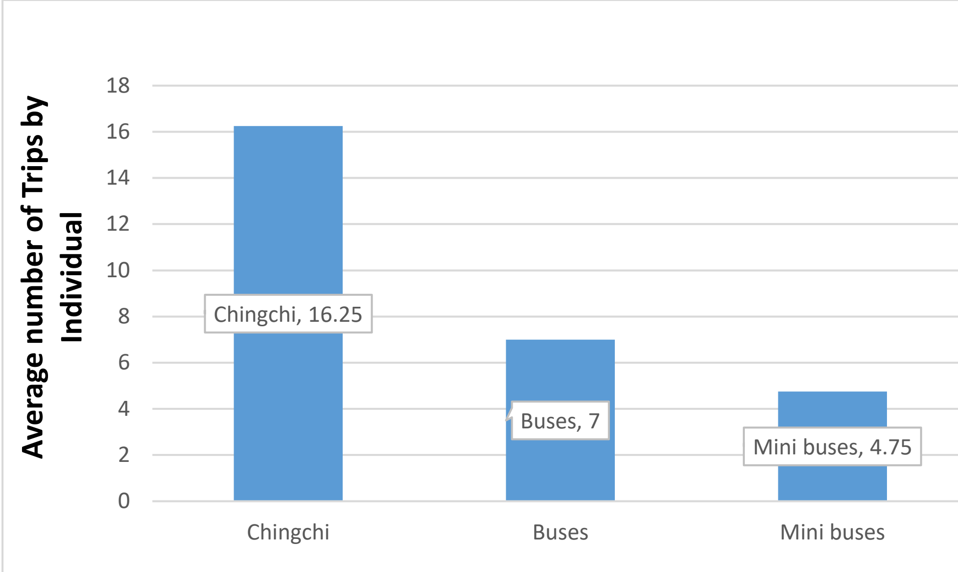


Figure 9 Number of Trips by Individual

Trip Length versus Number of Trips by Individual (Chingchi):

Compression of parameter trip length versus number of trips is shown in figure shown below. In the graph number of trips is shown on primary vertical axis and trip length is shown on secondary vertical axis. The Chingchi is operated on smaller route usually but in the data which we have collected there is a case in which Chingchi is covering long route that is from Malir to 7A Surjani town it's just because the frequency of Chingchi is more it takes less time to fill up as its seating capacity is low in comparison to the Buses and Mini buses / Coaches.

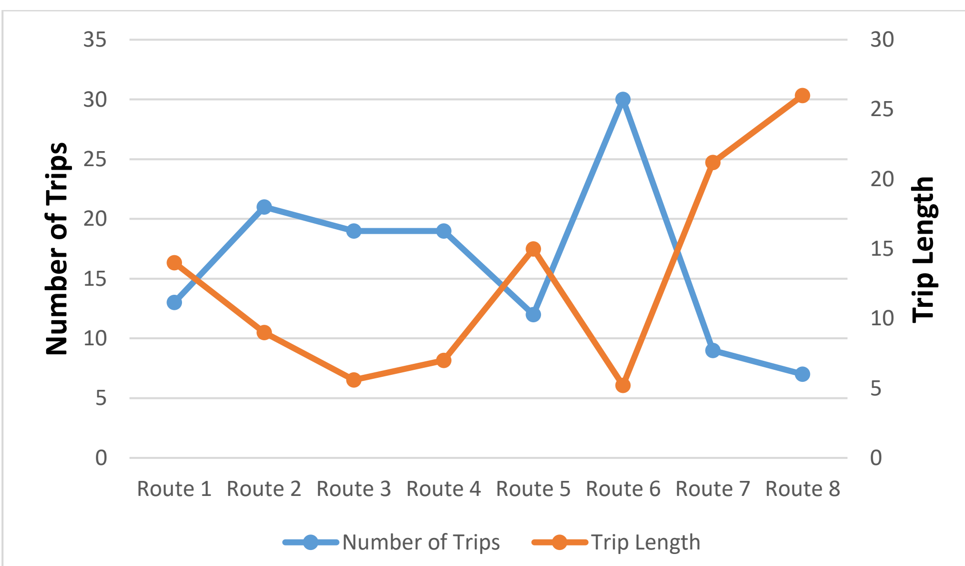


Figure 10 Trip Length vs Number of trips by Individuals for Chingchi

Trip Length versus Number of Trips by Individual (Buses / Mini buses / Coaches):

The trip length of Buses is less as compared to Mini buses / Coaches as shown in figure shown below. The reason is there large size and more engine power. The Buses are operated on fewer routes as compared to Mini buses / Coaches because their frequency is low; they consume more time to fill up by Passenger. However, that of Mini buses / Coaches is less than Buses.

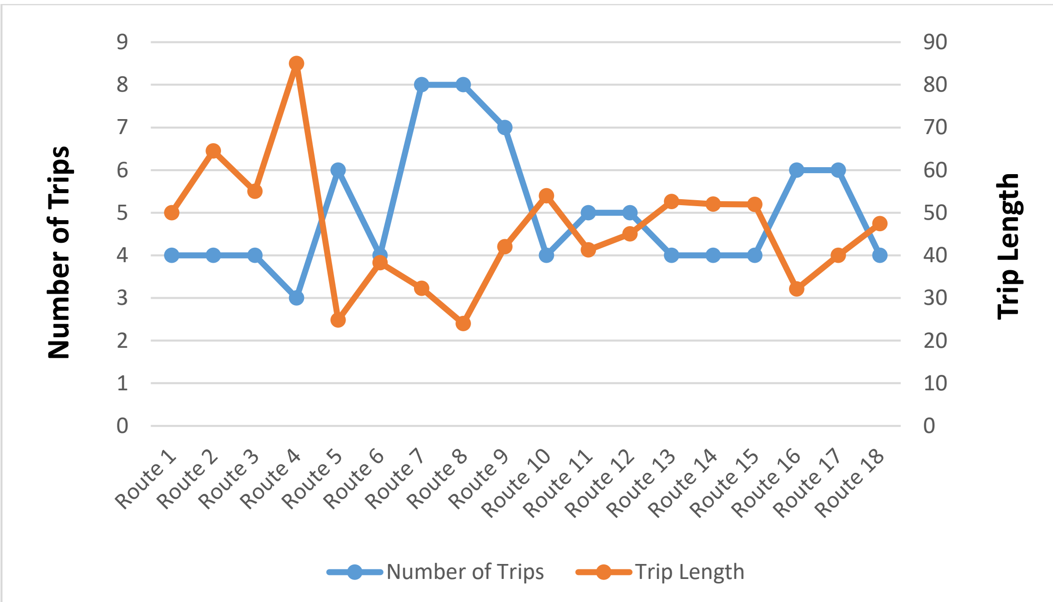


Figure 11 Trip Length vs # of trip by Individual for Bus/minibus/coach

Share of Fuel Oriented Engine in Public Transport:

Nowadays, the Public Transport is operated on CNG approximately, around all Buses and Mini buses / Coaches are shifted to CNG because Diesel fuel gives comparatively less mileage than CNG fuel and the price of Diesel is more than that of CNG. The Public Transporter can't afford Diesel in this situation which resulted towards the shift to CNG fuel.

Share of Diesel and CNG Engine in data collection		
Public Transport (Bus and mini bus)	54 CNG	3 Diesel
Total observation	57	

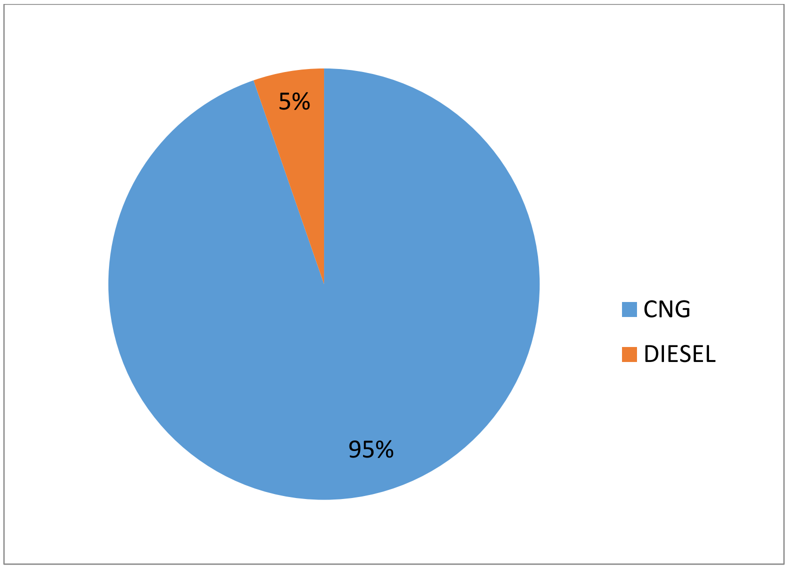


Figure 12 Share of Fuel oriented engine in Public Transport

Some of the estimation which was estimated through the data collection are number of fuel passenger of CNG and Diesel public transport see table below. In this calculation for CNG is came out to be 0.0825 Kg/passenger, for diesel 0.25 lit/passenger and 0.0835 Kg/passenger are came out for Chingchi Rickshaw.

Number of fuel unit per passenger		
Public Transport (Bus and mini bus)	0.0825 Kg/passenger (CNG)	0.25 lit/passenger (Diesel)
Chingchi Rickshaw	0.0835 kg/passenger (CNG)	

Public transport which includes bus/mini bus and coach are the under observation in the survey and the energy consumption per passenger per kilometer. The value of energy consumption for diesel public transport is 1.0635 MJ/Passenger/Km, for CNG Public Transport is 1.7488 MJ/Passenger/Km and 4.27 MJ/Passenger/Km.

Public Transport (Bus and minibus/coach) energy consumption /passenger/Km		
Public Transport (Bus and mini bus)	1.7488 MJ/Passenger/Km (CNG)	1.0635 MJ/Passenger/Km (Diesel)
Chingchi Rickshaw	4.27 MJ/Passenger/Km (CNG)	

Vehicle kilometer is the significant parameter in the estimations of traffic behavior. It shows the amount of kilometer covered by the individual mode. Table shown below describe the km calculated for Buses/mini buses/ coached under study area. It is estimated while having assumption that existing routes are 139 and every route and 60 buses. The value calculated to be 1.8 million Kilometer per day. It is not possible to calculate the vehicle KM for Chingchi because the routes are not registered.

Public Transport vehicle KM	
Public Transport (Bus and mini bus)	1.8 million km per day
For Chingchi Rickshaw routes are not registered	

Passenger per Trip of Classified Public Transport (Chingchi):

The Passenger per trip of Chingchi rickshaw is shown in the figure shown below. The Passenger per trip varies for Chingchi as it is operated on small route, those people prefer Chingchi whose destination is near and they have to cover small distance but there are some cases in which Chingchi covers a long route e.g. from Malir to 7A Surjani Town which length is 26 km as shown in figure. The reason is there high frequency as compared to Buses and Mini buses / Coaches they take less time to fill up by Passenger and save time.

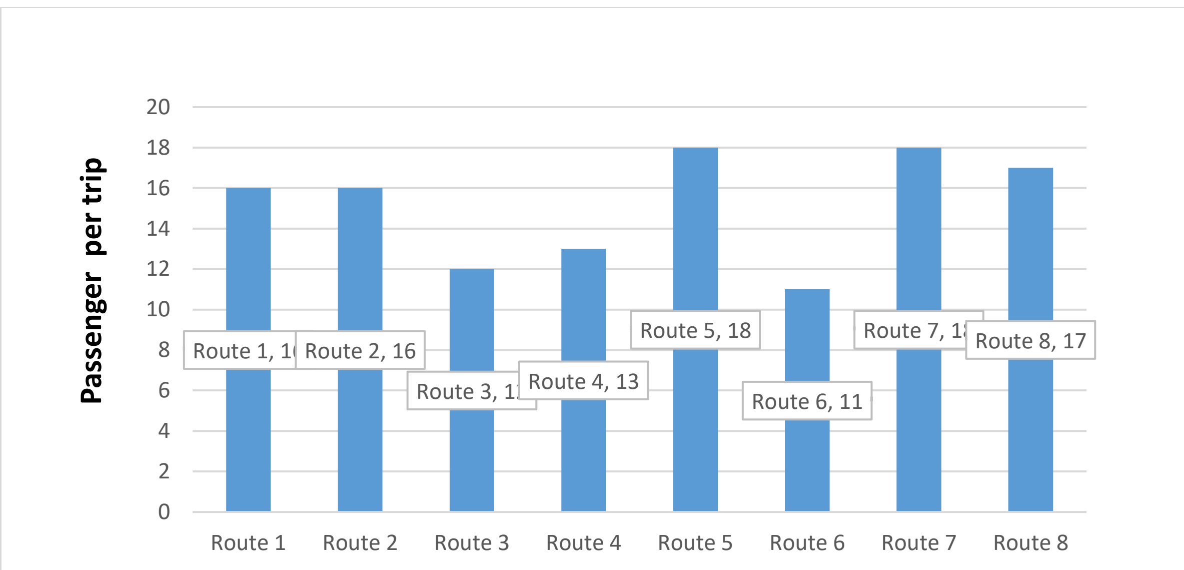


Figure 13 Passenger per trip for Chingchi

Passenger Per Trip versus Trip Length by Individual (Chingchi):

The Passenger per trip versus trip length is shown in figure below. The primary vertical axis shows the Passenger per trip while the secondary vertical axis shows the trip length for the Chingchi rickshaw.

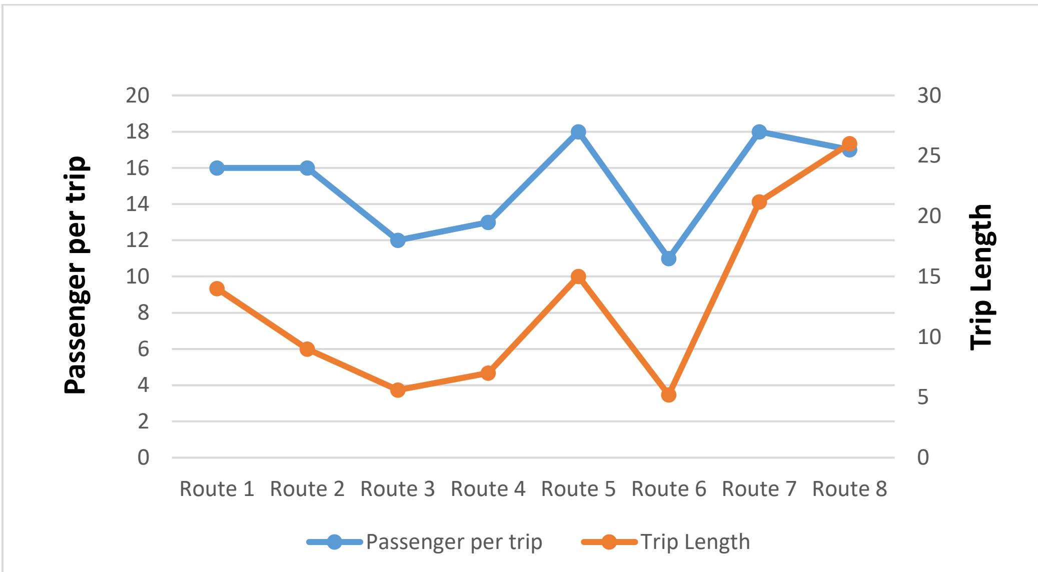


Figure 14 Passenger and Trip Length variation for Chingchi

7. Study Summary Conclusion and Recommendations

STUDY SUMMARY

Summary of Field data outputs

Passenger Per Trip of Classified Public Transport (Buses / Mini buses / Coaches):

Passenger per trip of Buses and Mini buses / Coaches is high, as they cover a long route. They Travel from one District to another in most of the cases. The Passenger that Travel through these modes are to go too far, there Travel distance is more and these modes charge comparatively less than that of Chingchi rickshaw. The Passenger who uses Buses and Mini buses / Coaches for traveling are long distance Traveler's and also small route Traveler's. Those who Travel long distance avoid to go via Chingchi rickshaw because in such a case they have to change twice to thrice Chingchi rickshaws which would cost more as well as difficulty to reach destination.

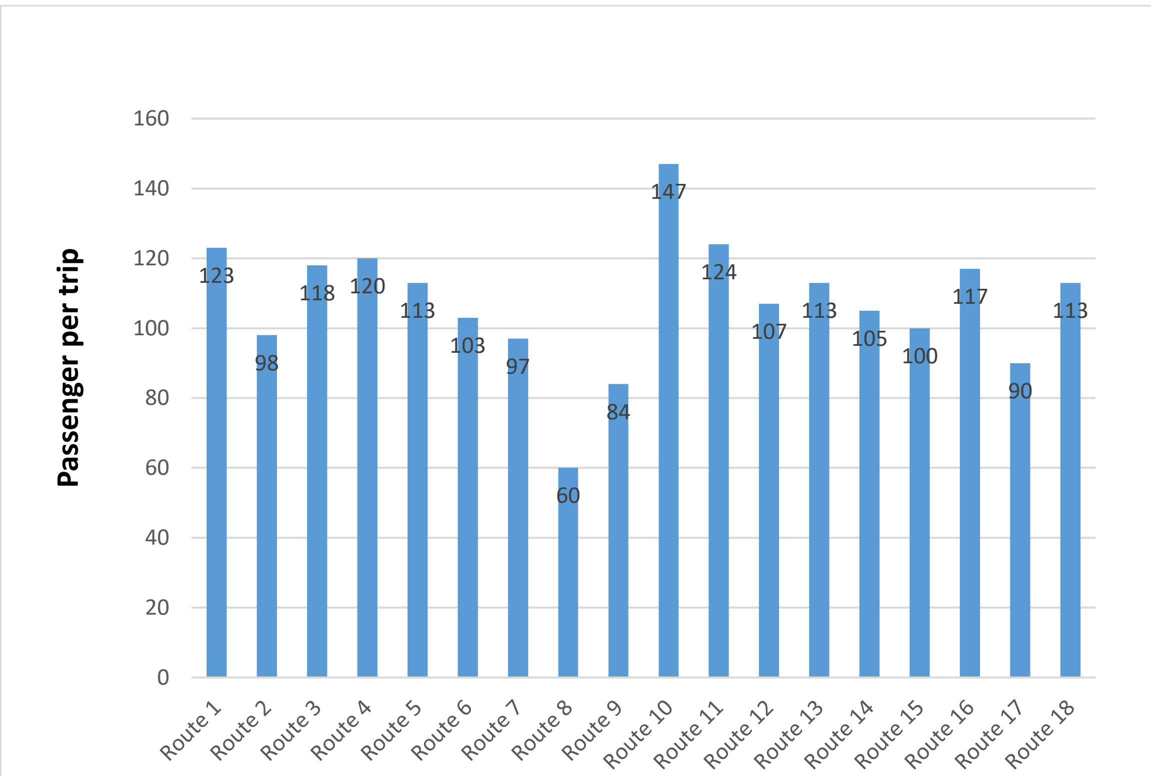


Figure 15 Passenger per Trip for Bus/Mini Bus/Coach

Summary of TRACE model

Energy Efficiency Implementation Options

a) Use of regulatory influence in city

Assessment of existing charging stations by experienced staff. Study is conducted to determine the cost of installing charging infrastructure and equipment. Use of regulatory influence (for example, standards for charging infrastructure, permitting process, planning) to create an environment by establishing standards for charging infrastructure, streamline permitting process, planning infrastructure network.

b) Provide Incentives for local business for charging infrastructure

Provision of financial incentives to charging utilities. Coordination with business owners to reach agreements of quality, location, payment mechanism and regulations.

c) Development of pilot programs in focused areas.

Launch pilot programs, test and demonstrate business models so that the program reach the private sector.

d) Begin a public campaign

Educate the public about the benefit, awareness, and accessibility of charging stations. Use of advertisement to offset the cost of the station installation and its operation.

e) Evaluation of program results

The effectiveness of the program is evaluated by measuring the economic benefits, the reduction in car trips number, the amount of gasoline consumption decreased, pollution

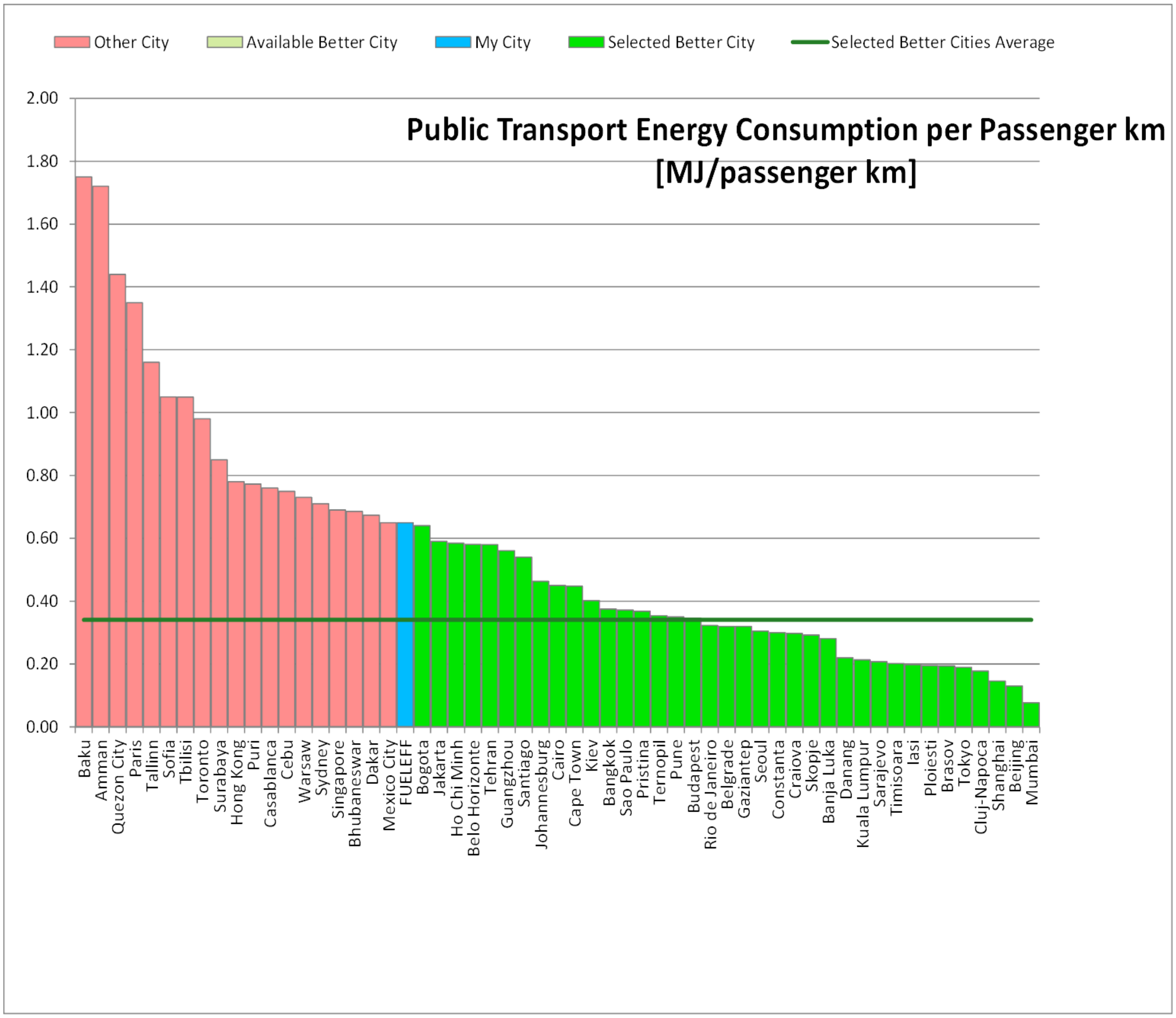


Figure 16 TRACER model output

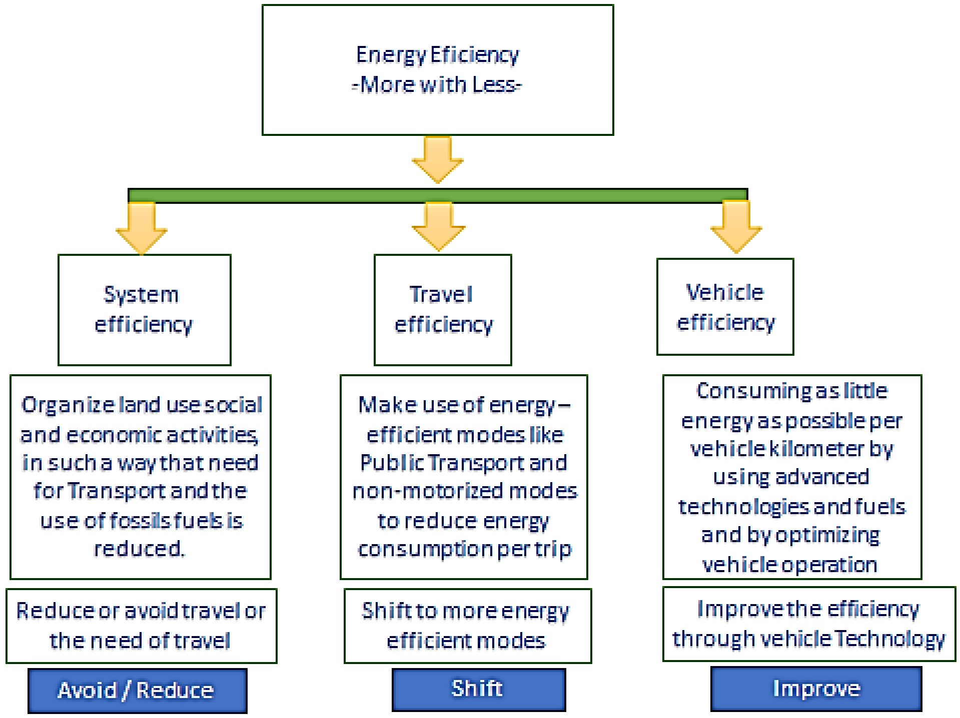
Summary of International Best practices

<u>Approaches to Reduce Energy demand in the road transport sector:</u>

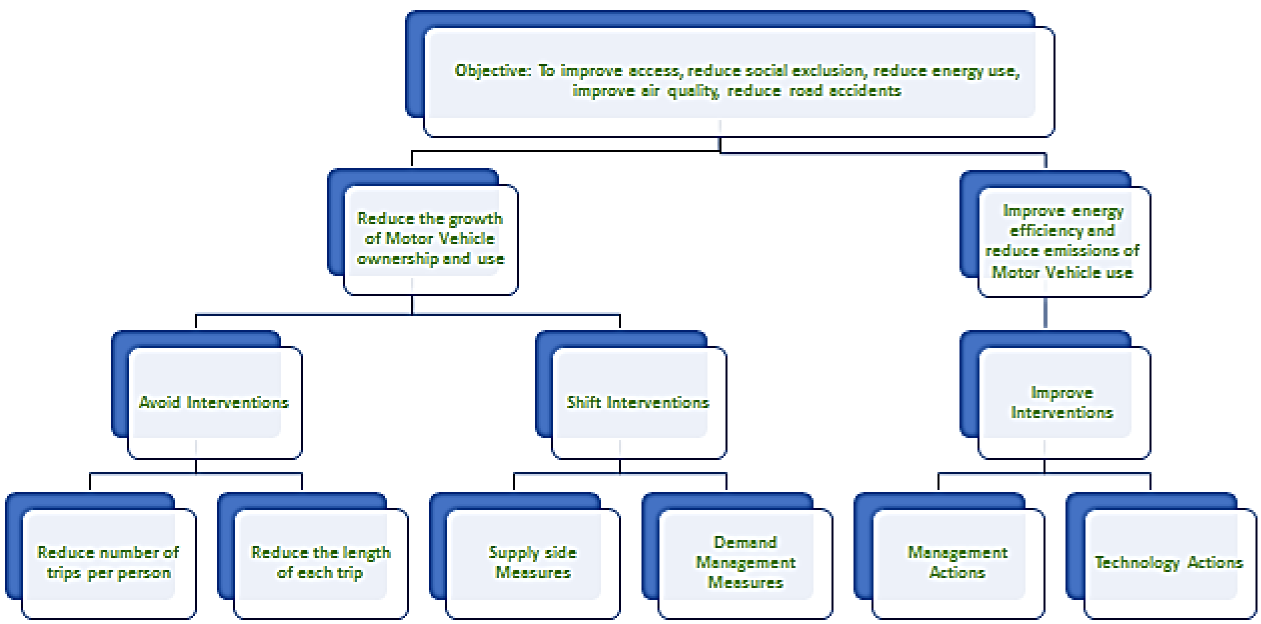
Three basic strategies exist to improve energy efficiency in road transportation,

- Avoid increased transport activity and reducing the current demand for transport.
- Shifting demand to more efficient mode of transport
- Improving the vehicles and fuels used.

These principles are usually known as ASI approach (Avoid, Shift & Improve) which provide the holistic framework for strategic action to encourage a sustainable transport system. Each strategy addresses a different level of energy efficiency; avoiding / reducing the demand for transport improves system efficiency; shifting demand increases travel efficiency; and improving vehicles and fuels will increase vehicle efficiency.



However to explore ASI approach another flow diagram is presented,



Avoid actions:

- "Avoid" actions seek to reduce the need for travel. Travel demand is the average number of trips that people make, multiplied by the average length of each trip. Therefore, travel demand can be reduced by decreasing the average number of trips that people need to make or by shortening the average length per trip or a combination of the two.
- Smart logistic

Shift Actions:

"Shift" actions seek to persuade people to move from personal motor vehicles to public transport or non-motorized modes. Such a shift is desirable because public transport and non-motorized modes occupy less road space, emit fewer pollutants, and consume less fuel than personal motor vehicles, on a per passenger/km basis.

Supply-Side Measures:

Supply-side measures seek to provide adequate public transport capacity to meet the demand. They also seek to enhance the convenience and attractiveness of public transport. The objective is to persuade people who have other options for travel to prefer this mode. Construction of mass transit systems, like metro rail and BRT, or enhancing the supply of buses contributes to enhancing public transport capacity.

- Construction of high-density commercial and residential complexes close to mass transit stations.
- Common fare cards and fare collection systems.
- Improved integration of different modes of transport.

Demand-Side Management Measures:

Demand-side measures primarily focus on reducing the use and/or discouraging the ownership of personal motor vehicles. Fiscal and physical measures to discourage use include;

- Increasing the fuel tax so that gasoline becomes more expensive
- Levying a road user fee or a congestion charge for using personal motor vehicles in certain parts of a city
- Increasing parking charges for personal motor vehicles
- Reducing the number of parking spaces available, thus deterring the use of personal vehicles
- Reducing road capacity by allocating preferential road space to public transport and non-motorized modes
- Implementing car-free days when people are not allowed to use cars in certain parts of a city

- Designating some core city areas as “pedestrian zones” so that people are discouraged from using their personal vehicles

Measures to discourage ownership include:

- Increasing vehicle registration charges significantly to increase the cost of ownership
- Limiting the right to purchase a car by requiring a permit to buy a personal motor vehicle, such as the “Certificate of Entitlement” scheme in Singapore
- Increasing the purchase tax of a personal motor vehicle so that the cost of the vehicle goes up.
- Requiring the demonstration of an owned parking space before a person can buy a car.

Improve Actions:

Improve actions seek to reduce the negative impacts of whatever motor vehicle use is inevitable. There are two types of actions that can be taken: (i) management measures and (ii) technological measures.

Management Measures:

- ECO Driving
- Management measures primarily seek to improve traffic flow along heavy demand corridors so that time and fuel are not lost in idling. A series of measures can be adopted to improve traffic flow:
- Improve the quality of the road surface as poor roads lead to slow movement at suboptimal speeds
- Improve road and intersection design so that vehicles move smoothly with few barriers
- Use synchronized traffic light signaling to reduce vehicle idling at intersections along a corridor
- Segregate slowly and fast-moving vehicles into separate lanes so that slower vehicles do not adversely impact the faster moving ones (e.g., separate lanes for cycles and public transport systems, good sidewalks.

Technological Measures:

Technological measures work to improve fuel and vehicle efficiency, meaning that a vehicle consumes less fuel for the same distance travelled or emits fewer pollutants for the same amount of fuel consumed.

The automotive industry has improved design techniques to make vehicle bodies more aerodynamic and the use of lighter materials reduces fuel consumption. In addition, a number of steps have been taken to impose stringent emissions standards for cleaner fuel, such as the removal of lead from gasoline and the reduction of sulfur levels in diesel.

Also, the use of cleaner fuels has gained momentum in many cities. An emphasis on Compressed Natural Gas (CNG) as a motor vehicle fuel and the use of electric vehicles are both important steps in this direction.

Cleaner fuels for transportation sector:

Due to the damaging impacts of fossil fuels burning, there is global interest in developing sustainable biofuel production to reduce the impacts of climate change and global warming. Biomass is considered as a source of biofuels-renewable energy production. The Pakistan's current estimated population is 185 million and it is expected to be doubled in the next 36 years. The Pakistan's energy demand is about 120 MTOE (million tons of oil equivalent), while the current supply is 99 MTOE with a sort fall of 21 MTOE. The current estimated oil import is around 346,400 barrels/day. The major portion of energy demand is met by fossil fuels, which are non-renewable resource, causes climate change in the world and also its finite reserves would not last for more than 50 years. Moreover, the target set by Alternative Energy Development Board to introduce 10 % blended biodiesel fuel with conventional diesel by 2025 to mitigate the emissions of toxic gases into the atmosphere.

For the sustainable development in the renewable energy sector with less dependence on imported fossil fuels and to mitigate the accumulation of carbon dioxide emissions into the atmosphere from anthropogenic sources (human induced sources) causing climate change and global warming issues. The importance of alternative renewable biofuels has been realized in the last few decades in Pakistan. The non-edible vegetable seed crops such as: Jatropha (rattan joot), pongamia (sukh chan), castor (arand) and eruca sativa (tara mera), are the potentially suitable crops that can be cultivated on marginal land, with regard to the favourable climatic conditions of Pakistan for its growth. The approximate oil content present by % weight in jatropha seed is 37%, pongamia 30%, castor 40% and eruca sativa 35%. The maximum oil yield from jatropha, pongamia, castor and eruca sativa is 1892, 1430, 1413 and 1750 litres/hectare/ year respectively. The government incentives would encourage the farmers to get their earnings and create job opportunities based on utilizing their idle land productive. These incentives would help farmers to cultivate those non-edible crops on marginal land to get their earnings and also it open job opportunities in this sector. It was observed that planting 1000 saplings of jatropha in one hectare yields around 1.5 tonnes of seeds per year. It is expected to create one job for each four hectares of cultivation of non-edible crops on marginal land.

Biodiesel is a clean renewable fuel having positive energy balance meaning that biodiesel yields 4.56 units of energy for every unit of fossil energy consumed over its lifecycle. Similarly, it has a closed carbon cycle that the CO_2 released when biodiesel is burned is absorbed fully by those plants that are growing through photosynthesis. Then these plants are processed and used to produce clean biofuel again. Another potential feedstock to produce biodiesel in Pakistan is *Azadirachta Indica* commonly known as neem and is native to the Indian subcontinent including

Pakistan. Its fruits and seeds are the source of neem oil and it is fast growing and evergreen tree that can reach a height of 15-20metres (49-66ft) in a year with an oil yield content of 35-45 % by weight. Neem oil can be used as a non-edible source for biodiesel production. The blended biodiesel fuel can be used in the transportation sector to reduce the emissions of carbon monoxide and particulate matter into the atmosphere. Therefore, for the sustainable development in the country in the field of renewable energy sector, the neem biodiesel can be used in Pakistan in future as an alternate fuel in automobiles with less toxic emissions to protect the health and the environment.

Based on the above-mentioned facts, the Department of Environmental Engineering, NED University took an initiative to conduct research on alternative fuels such as biodiesel for transportation sector and solar dried bagasse from sugar industry to produce power generation. The department's biodiesel laboratory has testing facilities to measure different physical and chemical properties of biomass derived biofuels. Furthermore, gas analyzer is also used to measure the emissions of these biofuels from stationary and mobile sources. As an output of this research work, yielded research journal publications at the local and international levels. But still there are many research gaps needs to be investigated and improved such as the cold flow properties of neem biodiesel, biodiesel producing real time viscosity measurement and combustion and emissions characteristics of biodiesel fuel etc.

STUDY CONCLUSIONS

Comprehensive Approach

The set of initiatives mentioned above can be taken in singularity; however, they are integrated set which works toward sustainable and efficient mobility. The figure below explains how these initiatives are linked and connected. In order to produce best results, it is prudent take up the issues in the comprehensive, holistic and integrated manner, approach that combine supply-side measures with demand-side management to integrate transport planning with land use planning, environmental planning, energy planning and other dimensions, as well as to accommodate the needs of a variety of people particularly vulnerable sections such as the old aged, women, children and the physically disabled.

STUDY RECOMMENDATIONS

Karachi is growing rapidly; the growing economy is leading to growth in the energy demand and hence leading to increase in vehicle ownership. Pakistan is being the importer of fossil fuel / petroleum needs to review and work aggressively towards energy efficient system and needs to follow Reduce-Shift-Improve policy.

- ✓ Fuel economy of the vehicle is dependent on driving behavior; Driving training centers needs to be established which not only caters Safe Driving but also Energy Efficient driving, as a matter of fact Safe Driving is Energy Efficient driving.

- ✓ Karachi needs to develop innovative projects for enhancing the capacity of public transportation. Presently work is being carried out on the BRT system which will relieve some pressure; however, Study to explore drainage / sea water as a medium for public transportation is needed.
- ✓ Modal Shift measures explained above needs to be adopted, making use of energy efficient modes like public transportation and non-motorized modes to reduce energy consumption per trip and not the least discouraging the use of private cars.
- ✓ Government & Non-governmental actors need to put more fund in R&D for the development of alternate source of Fuel e.g. Solar/ Electric / Hybrid / Bio Fuels. The wonderful work carried out by NED University in the realm of Bio-Fuels should be supported to catalyze the project and full-scale production comes in effect.
- ✓ Levying high fuel taxes on more than 1000 CC private cars and utilizing the fund for Mass transport projects.
- ✓ The City needs to conduct traffic survey periodically and energy consumption data in different modes of transport by vehicle & fuel type. Transport energy Efficiency indicators like Passenger Transport energy use per capita (MJ/person), private individual mobility (Pkm/capita) and some others needs wide sets of accurate data for developing realistic scenarios and minimizing assumptions.
- ✓ Application of AI (Artificial Intelligence) and VI (Virtual Reality) in Energy Efficiency modelling can highly enhance the system performance.

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