Evaluation of Pakistan's Current Petroleum Supply Chain and Proposals to Enhance its Transportation Efficiency

By

Muhammad Habib Khan

(00000330221)

A thesis submitted in partial fulfillment of

The requirements for the degree of

Master of Science

In

Transportation Engineering

Department of Transportation

National Institute of Transportation Risalpur

National University of Sciences and Technology

Islamabad, Pakistan

(2022)

This is to certify that the

Thesis titled

Evaluation of Pakistan's Current Petroleum Supply Chain and Proposals to Enhance its Transportation Efficiency

Submitted by

Muhammad Habib Khan

Has been accepted towards the partial fulfillment

of the requirements for the degree

of

Master of Science in Transportation Engineering

_____

Dr. Muhammad Jawed Iqbal,PhD.PE.

Associate Professor and Head of Department

Department of Transportation Engineering

National Institute of Transportation (NIT), Risalpur

National University of Science & Technology (NUST)

Islamabad, Pakistan

DEDICATION

I dedicate this Research to my Parents,

and my beloved daughter and niece.

ACKNOWLEDGEMENT

I am thankful to Almighty Allah, who gave me strength to complete my research. I would like to pay debt of gratitude to my advisor Dr. Jawed Iqbal, for his fathomless guidance, valuable time and encouragement, to complete my research work. I am also extremely grateful to the committee member Dr. Sarfraz Ahmed for his sincere guidance to complete my research work. I owe my special thanks to Engineer Malik Kamran Shakir for assisting me throughout my course and research work. I pay my earnest gratitude with sincere sense of respect to my parents, brothers and wife, for their unending support, encouragement, prayers and patience. In the end I express my heartfelt love for niece; Umama Danin and daughter; Ayesha Siddiqa.

ABSTRACT

Pakistan is a developing country with economic issues that need to be addressed in order for the country to progress and prosper. Imports and exports decide the economic growth of a country. Unfortunately, Pakistan's economy greatly depends on imports in various sectors especially the energy sector. POL (petroleum, oil, lubricants) comprises major part of Pakistan's Energy sector imports. Pakistan imports **70% of its MOGAS and 35% of its HSD** total consumption. Transportation of petroleum products within the country entails significant cost along with varying degree of risks. Presently Pakistan POL supply chain is primarily based on road transportation with 69% share, pipeline share is 29% and railway share is only 2%. If Pakistan continues with the same pattern future forecast of traffic and POL demand shows that it will fail Pakistan road infrastructure in the near future.

The primary options for POL transportation include Pipelines, Vessels, railroads and road tankers world over. Pipelines are considered best for transporting POL, Vessel/Barge the cheapest and rail transport is also very efficient due to its load carrying and routing flexibility. However, each of the mode of transportation have its inherent pros and cons. The most efficient system for a country will be decided based on its Geography/Topography, existing transportation infrastructure, Economic activity, and Demography. White Oil Pipeline (WOP) and Mahmoodkot-Faisalabad-Machike (MFM) are the two major pipelines in Pakistan, their capacities were utilized 28.6% and 31.3% respectively, which are under optimum utilization. Underutilization of pipeline and Railways (which are preferred mode of transportation worshortlyn enhanced transportation of POL through road network. Therefore, present POL supply chain in Pakistan is enhancing cost of transportation as well as ri,sks/hazards.

This research aims to develop a long-term solution by fully exploiting pipeline capacity and the untapped potential of Pakistan railway's. Model-I considers 20% share of Oil movement through Railways, results reveal that it can save PKR 30 billion, save PKR 5.17 million per mile per year in maintenance costs, and reduce the movement of around 8,000 vehicles. Model-II considers using existing pipelines at full capacity, with the railway still accounting for 20% of the total share, results reveal that it can save PKR 63.6 billion, save an extra PKR 5.21 million per mile per year in maintenance costs, and reduce the movement of around 6,000 vehicles. In addition to Model-II considerations, Model-III consider Machike-Tarujabba pipeline is built and used at full capacity, results

reveal that it can save PKR 97 billion, save an extra PKR 3.89 million per mile per year in maintenance costs, and reduce the movement of around 6,000 vehicles. Thus; based on the data analysis carried out in this study, Model-I be adopted immediately with progressive adoption of Model-II and Model III to enhance POL supply chain and reduce associated risks/hazards in Pakistan.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

FOTCO	Fauji Oil terminal & Distribution Co. Ltd
GoP	Government of Pakistan
KPK	Khyber Pakhtunkhwa
MOGAS	Motor Gasoline
HSD	High Speed Diesel
PR	Pakistan Railways
NHA	National Highway Authority
JICA	Japan International Cooperation Agency
NTRC	National Transport Research Centre
KAR	Karachi
WOP	White Oil Pipeline
MFM	Mahmoodkot-Faisalabad-Machike Pipeline
MTT	Machike-Thallian-Tarujabba
PACRA	Pakistan Credit Rating Agency Limited
POL	Petroleum Oil Lubricants
PSC	Petroleum Supply Chain
TJB	Tarujabba
MCK	Machike
MMK	Mahmoodkot
FO	Furnace Oil
PSO	Pakistan State Oil
PQ	Port Qasim
ARL	Attock Refinery Limited
PRL	Pakistan Refinery Limited
NRL	National Refinery Limited
MCR	Mid Country Refinery
PARCO	Pak Arab Refinery Company Limited
PAPCO	Pak Arab Pipeline Company Limited
WOP	White Oil Pipeline
MFM	Mahmoodkot-Faisalabad-Machike
KMK	Karachi -Mahmoodkot

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 STUDY BACKGROUND

When it comes to safe, timely and efficient transportation oil industry stands out all over the world. The hurdles and hazards involved with POL transportation are well known, but Pakistan Oil industry use most expensive, unsafe and prone to disruptions model. Oil possess the largest share in Pakistan energy consumption and its consumption is not central it spreads throughout the country (Ministry of Planning development & Special Initiatives 2021). Moreover, neither the spread of refineries is uniform nor the imports are at multiple places so huge quantity of POL needs to be transported over a large distance. This transportation of POL products not only increases consumption further but also pose an extra load on Road and Railways. Pipelines of Pakistan are neither used at their full capacity nor they cover the whole country area and with the degradation of Pakistan railways performance roads are loaded to an extent which have caused multiple problems for road sector. The road sector felt an exponential increment in maintenance cost, high number of accidents and an incremental degradation of road service and its level of service. Further with traffic growth and demand growth of POL products will further worse the situation in the near future.

1.2 PROBLEM STATEMENT

Pakistan doesn't produce enough MOGAS and HSD for its consumption, hence they are imported. Being common man's fuel not only the import is of concern, POL transportation also creates additional challenges and poses risks. In Pakistan we have the worst scenario of moving 96% of our freight through roads which is not only detrimental to roads but also a major cause of fatal accidents (Pakistan 2016). POL transportation is also majorly done through roads, 69% of total oil consumption was moved through roads in 2019-20 (Ministry of Planning development & Special Initiatives 2021). Not only the road transportation is three times costlier as compared to pipelines but the problems it creates further are unbearable, 2030 forecast of Pakistan freight and public traffic growth shows that it will be almost impossible for Pakistan's existing infrastructure to bear the growth.

The growth in freight and public will also result in increase of POL demand. To cater the future problem intermodal transport and other policies should be opted and other efficient ways for POL transportation should also be explored.

1.3 RESEARCH OBJECTIVES

The main objectives of this research study are;

- To analyze current POL transportation supply chain management of Pakistan.
- Formulation of framework for POL transportation, considering cost effectiveness, safety and best practices adopted by progressing economies.

1.4 SCOPE AND LIMITATION

The scope of this research study is limited to Pakistan supply chain and MOGAS and HSD transportation is its main concern. This study will have its impact on the Petroleum supply chain directly and will also have positive impacts on other industries as Petroleum industry affects all.

Use of Optimized model will help Pakistan to save revenue and reduce congestion and accidents on roads. The optimized model will also reduce the maintenance cost of roads and will also help it to cope with future demand.

The research findings will provide some significant insight for all the stakeholders including the government agencies to look for best possible mode of passenger and especially freight transportation.

One of the major hurdle while performing this study was lacking of statistical data and the unwilling ness of organizations or people involved to share the required data. However, efforts were made to convince them and analyze on the most accurate data.

1.5 ORGANIZATION OF THESIS

The thesis is organized in six chapters, chapter wise discussion is as under

a. **Chapter 1: Introduction**. This chapter briefly discuss the problem statement, scope of study, research objectives and organization of dissertation.
b. **Chapter 2: Overview of Pakistan Oil Industry**. This chapter of dissertation discusses the reliance of Pakistan energy demand on oil, sector wise consumption of oil, consumption of oil in past and now, refineries, local production vs imports, oil depots, Oil Manufacturing companies and their respective shares and IFEM

the mechanism through which the rates of HSD and MOGAS remains flat throughout the country.

c. **Chapter 3: Research Methodology**. This part of dissertation discusses the research methodology adopted to complete this study and methods for analysis of obtained data.

d. **Chapter 4: Analysis of Current Practice and Model Development**. This part discusses the possible Models Pakistan can adapt to optimize its POL supply chain. Model-I proposes that share of Pakistan railways increased from 2% to 20%. Model-II proposes that pipelines are used at their full capacity with share of PR remains same as 20%. Model-III proposes the construction of Machike-Thallian-Tarujabba Pipeline completed. Model-III is analyzed for 2030 and Model 4 to cater future problems is developed. Model 4 proposes further increase in railway share or construction of new pipelines.

e. **Chapter 5: Conclusions and Recommendations**. The final part of dissertation discusses the conclusion from the results and give suitable recommendations for POL supply chain.

1.6 SUMMARY

The introductory chapter discusses the Oil industry importance in the growth and development of a country, afterwards in the Problem statement section the loopholes of Pakistan petroleum supply chain and their possible solution were discussed. Objectives of this study are discussed in Research objectives section and finally the section Organization of thesis discusses the roadmap of this dissertation.

CHAPTER 2
OVERVIEW OF PAKISTAN OIL INDUSTRY

2.1 INTRODUCTION

Pakistan a country in the south Asia, fifth most populous country in the world needs energy to pace its growth and fulfill its population needs. It is blessed with energy resources by nature such as coal, crude oil, natural gas and water resources. But still the country is not self-sufficient in energy sector and like its neighboring countries it imports crude oil, refined oil, LNG, LPG and other energy resources. Pakistan has huge reserves of coal and its rivers have the capacity to generate electricity and natural gas is abundant. But with time natural gas reserves are diminishing at a faster rate and the reliance on the oil resources and imports is increasing. This chapter will introduce about Pakistan Oil industry its working strategies, involved stake holders and their relationships.

2.2 OIL AS THE MAIN SOURCE OF ENERGY

Pakistan existing energy mix shows that country highly relies on expensive fuels like oil and gas instead of coal and hydel. Gas has a share of 46% in energy supply and oil has 3 % share while the stats of energy consumed reveals that oil has 32% share and gas has 31% share. The stats of energy consumed shows that more than half of energy consumed is from oil and gas, but this chapter will specifically focus oil.

2.2.1 Pakistan Oil Production

Pakistan domestic oil production remained flat in the range of 70 to 77 BBL per day for last two decades but the demand is increasing continuously. The production almost remains flat as in FY 2013-14 4.07 MTOE were produced and in the FY 2017-18 this production increased to 4.72 MTOE which not a significant change (commision 2020).

Table 2. 1 Domestic Fuel Production

Energy Product	2013-14	2014-15	2015-16	2016-17	2017-18
Oil (including LPG)	4.07	4.26	4.46	4.67	4.72
Gas	31.44	33.09	31.56	30.86	30.89
Coal	1.64	1.88	2.15	2.45	12.82
Total indigenous supply	37.15	39.23	38.17	37.98	48.43

Note: Units Million Tons of Oil Equivalent

Source: Planning Commission (commision 2020)

2.2.2 Oil Share in Energy Mix

Till 1980s the oil share in the national energy consumption was more than 50%. The country was very much reliant on the oil for energy needs. This share was reduced, but instead of transferring this load to renewable resources the whole load was taken by natural gas sector. As the policy adopted was not sustainable Pakistan faced a huge energy crisis in first two decades of twenty first century. Now country is looking for other energy resources, it is building daMOGAS, establishing nuclear power plants and taking other necessary measure but now the natural gas resources are depleted to a level where now country faces shortages especially in winter season. In 1986 the oil contribution was 52% and natural gas contribution was 26%. These share were slightly decreased to 51% and 24% respectively in 1990 (PIDE 2021).

The share of each resource in national energy consumption for year 1986 and 1990 is shown in Figure 2.1

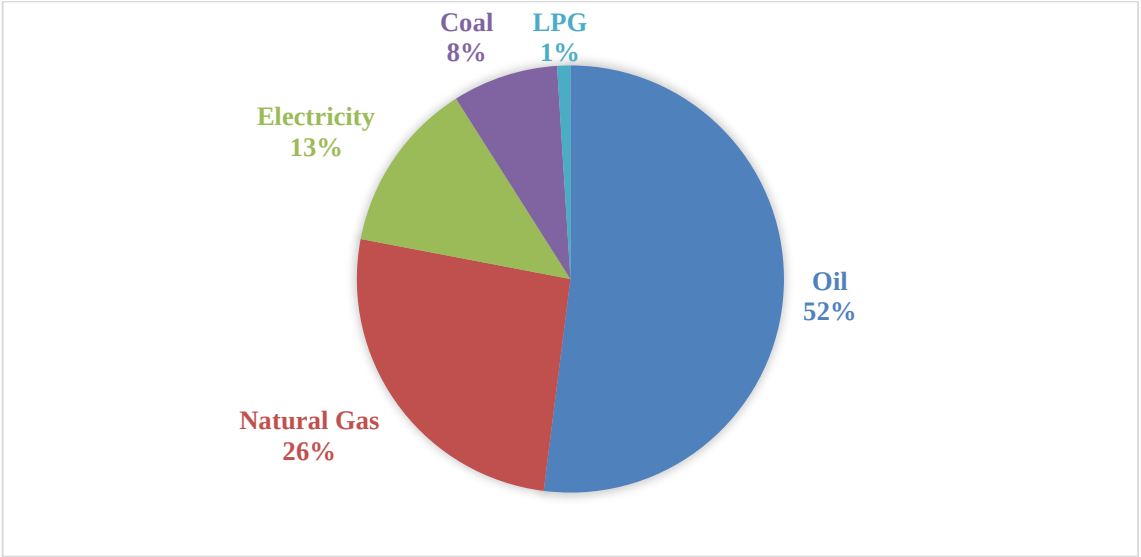

Figure 2. 1 Primary Energy Consumption (1986)

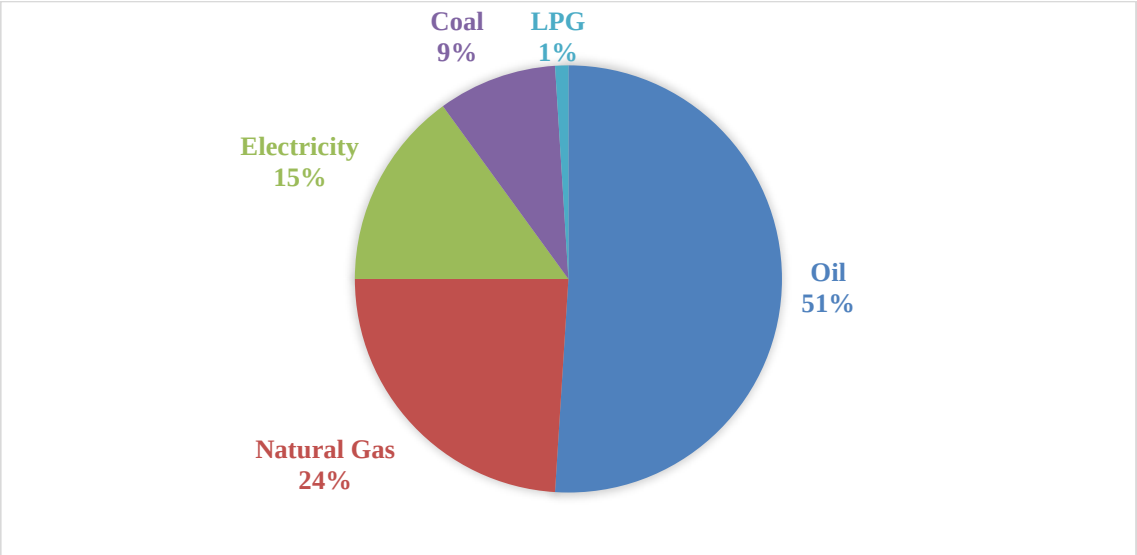

Figure 2. 2 Primary Energy Consumption (1990)

This trend of highly reliance on oil and natural gas continued up to 2000. However, the natural gas consumption was increased with a significant percentage, and oil share in the consumption decreased. In 2000 oil share in total energy was 47% and that of natural gas was 32%. After 2000 the country seen a drastic change as the CNG sector was allowed to use natural gas without any restriction. Due to such non sustainable policies oil share dropped from 47% to 28% and the natural gas share was increased from 32% to 43%. Electricity, coal and LPG share was not disturbed significantly (Islamabad 2021). The corresponding shares of each resource in year 2000 and 2010 is shown in the Figure 2.3 and 2.4

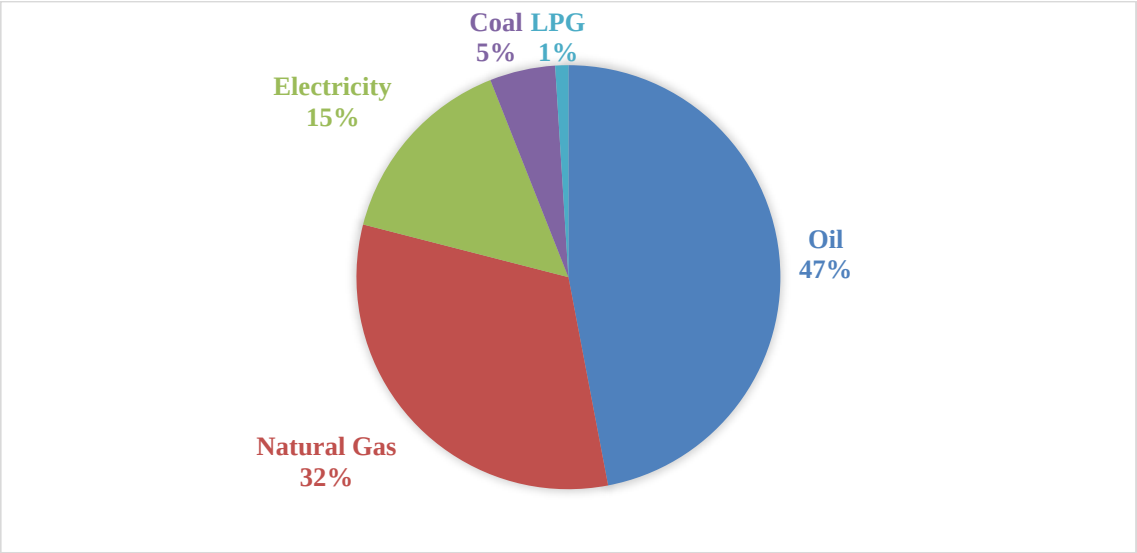

Figure 2. 3 Primary Energy Consumption (2000)

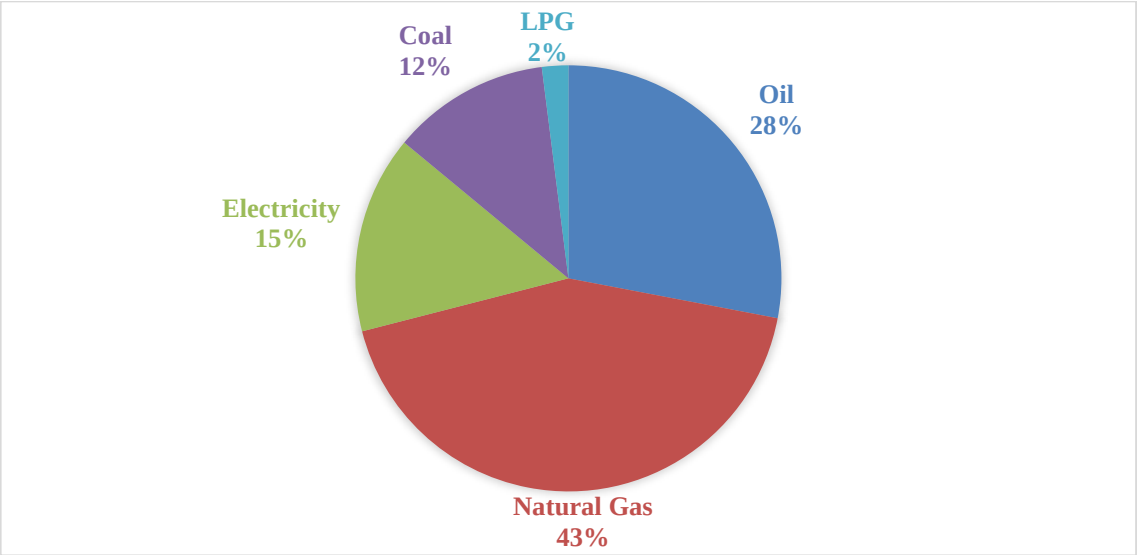

Figure 2. 4 Primary Energy Consumption (2010)

After 2010 government established coal power plants and utilized it for energy production. The share of coal was increased to 19%, oil and natural gas percentage share was reduced to 31% each. The corresponding share in 2020 is shown in Figure 2.5

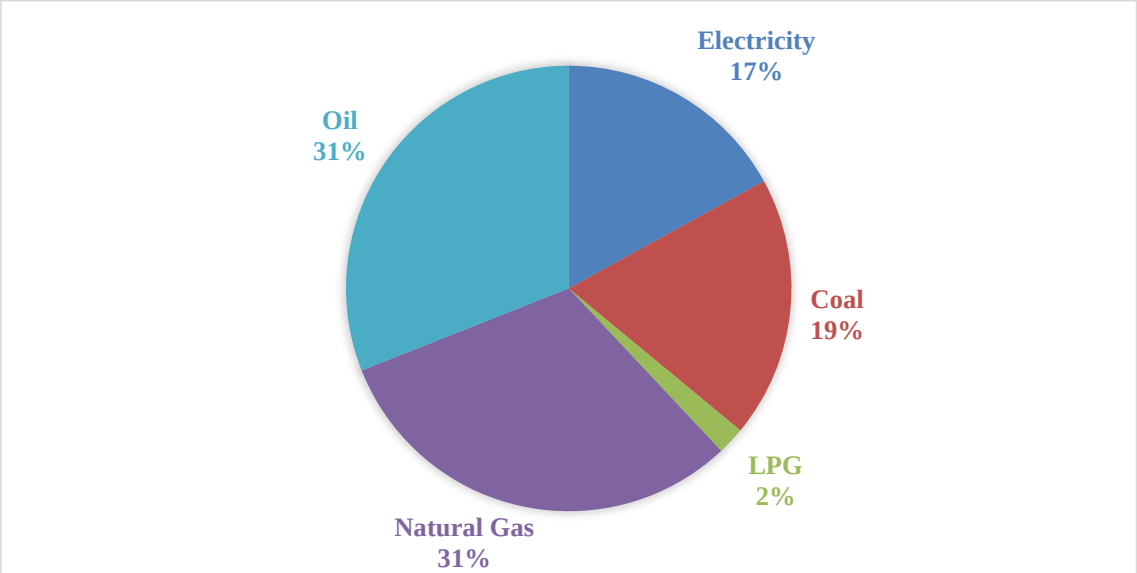

Figure 2. 5 Primary Energy Consumption (2020)

2.2.3 Share of Gas vs. Oil in Energy Mix

The consumption shows a significant change as in past and now Pakistan used its gas reserves at their full capacity so now the reserves are at the point of end so the depletion in the reserves is also evident from the consumption as it is also decreased. However, this decrease is covered by the oil sector as Pakistan has not develop system to

use hydel or coal energy sources as alternatives. In the past up to the 90s the oil sector was dominant in the energy mix from 90s to 2015 the gas sector dominated in the energy mix but with the depleting resources the trend again had reversed (Islamabad 2021).

2.3 OIL DEMAND

As discussed in previous section Pakistan historically relied on oil sector for its energy consumption. This reliance was reduced in the past years. The petroleum demand in FY 2019 was 19.2 MTOE. The consumption of oil demand had an upward trend up to the first year of new century but 2001 to 2006 it dropped down significantly due to use of natural gas. After 2007 it surged an upward trend again. The overall demand is declining but Pakistan will remain a net importer of oil as its refineries and local production can't fulfill its needs (Islamabad 2021, PIDE 2021).

2.4 PRODUCT WISE CONSUMPTION OF PETROLEUM

The two most used petroleum products are High Speed Diesel (HSD) and Motor Spirit (MOGAS). The third in this list is Furnace Oil (FO), but the consumption of FO dropped significantly as the government changed its policy of using LNG and other cheap sources of energy. In FY 2019-20 Pakistan consumed 7.45 million tons of MOGAS and 6.63 million tons of HSD (OGRA Petroleum Industry report 2019-20).

2.5 LOCAL PRODUCTION VS. IMPORTS

MOGAS is imported in a greater quantity as compared to HSD. Pakistan oil demand in FY 2019-20 was, 7.5 million metric tons (MMTs), local production of MOGAS fulfils almost 30% of the total demand whereas 70% of the demand is imported, High Speed Diesel (HSD) demand was 6.7MMTs of which 65% was fulfilled from local refineries and 35% of the demand was imported (Commission report 2020).

As a net importer of POL products not only the quantity of import affects Pakistan, its timely, safe and cheap transportation is also a major challenge for a developing country. MOGAS being a common man fuel is imported in the largest quantity, and a considerable amount of HSD is also imported. The Figure 2.6 summarizes the discussion

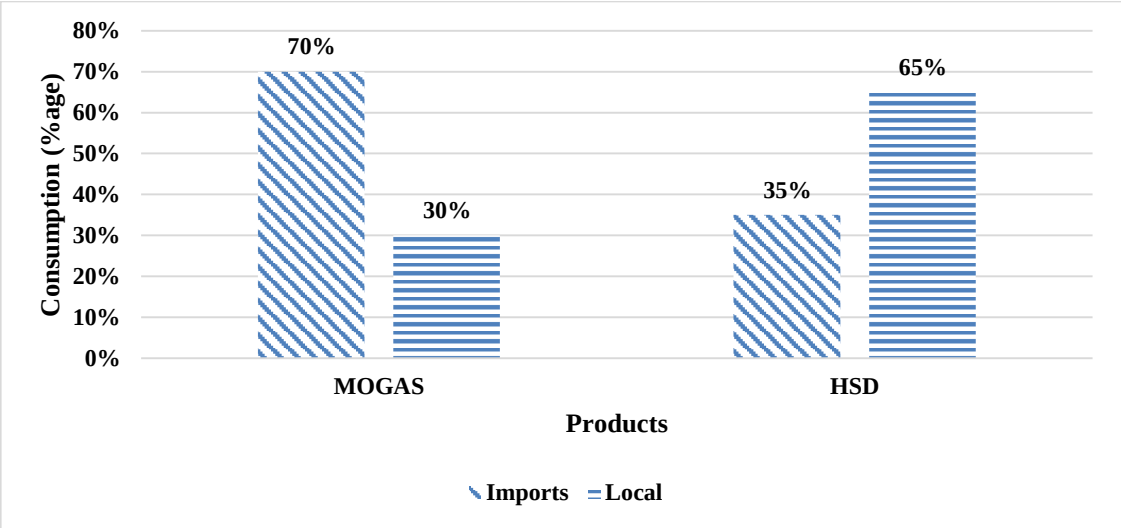

Figure 2. 6 POL Production VS Imports FY2019-20

Source: Petroleum Industry Report

2.5.1 HSD vs. MOGAS Imports

The consumption of MOGAS and its imports increased in the past however, the HSD does not follow a uniform trend. The imports of HSD decreased and that of MOGAS increased. The Figure 2.7 and Figure 2.8 shows the year wise consumption, local production vs imports from 2014-19

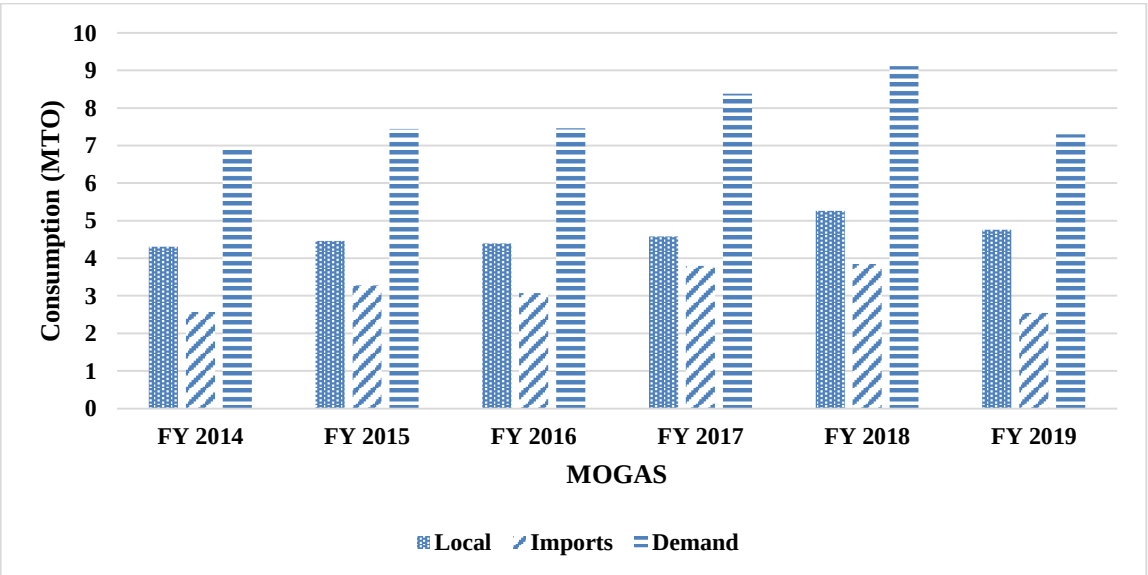

Figure 2. 7 MOGAS Consumption (Million Tons)

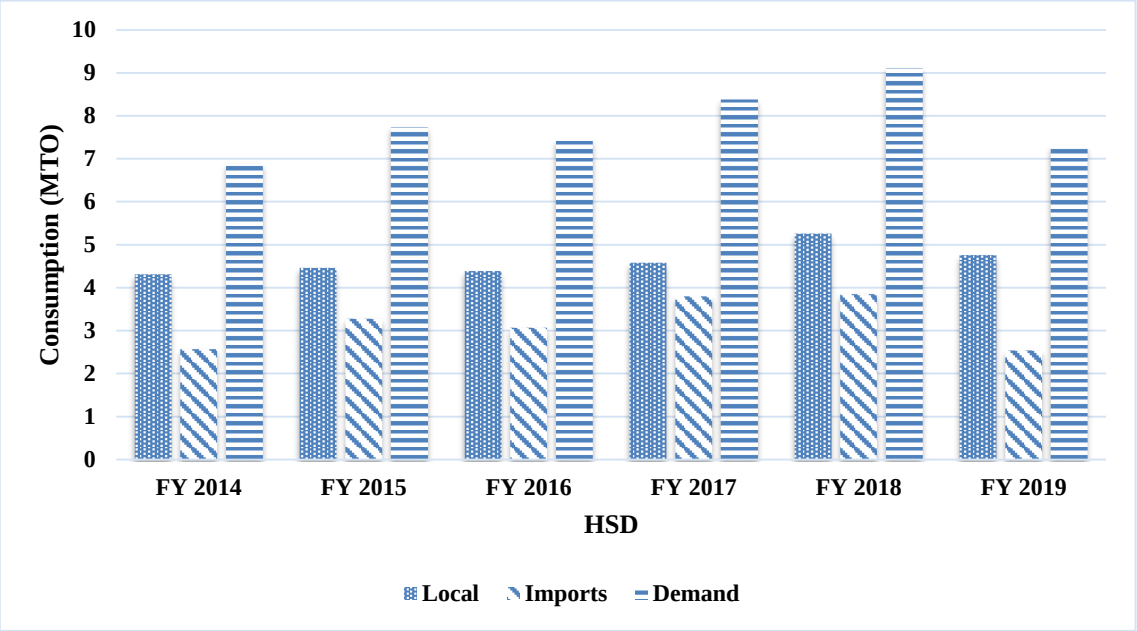

Figure 2. 8 HSD Consumption (Million Tons)

2.5.2 Pakistan Crude Oil Imports Country Wise Share

Pakistan imports its oil import from various countries. UAE holds the largest share in countries from which oil is imported. Pakistan imports POL products majorly from UAE, Qatar and other gulf countries as shown in the Figure 2.9

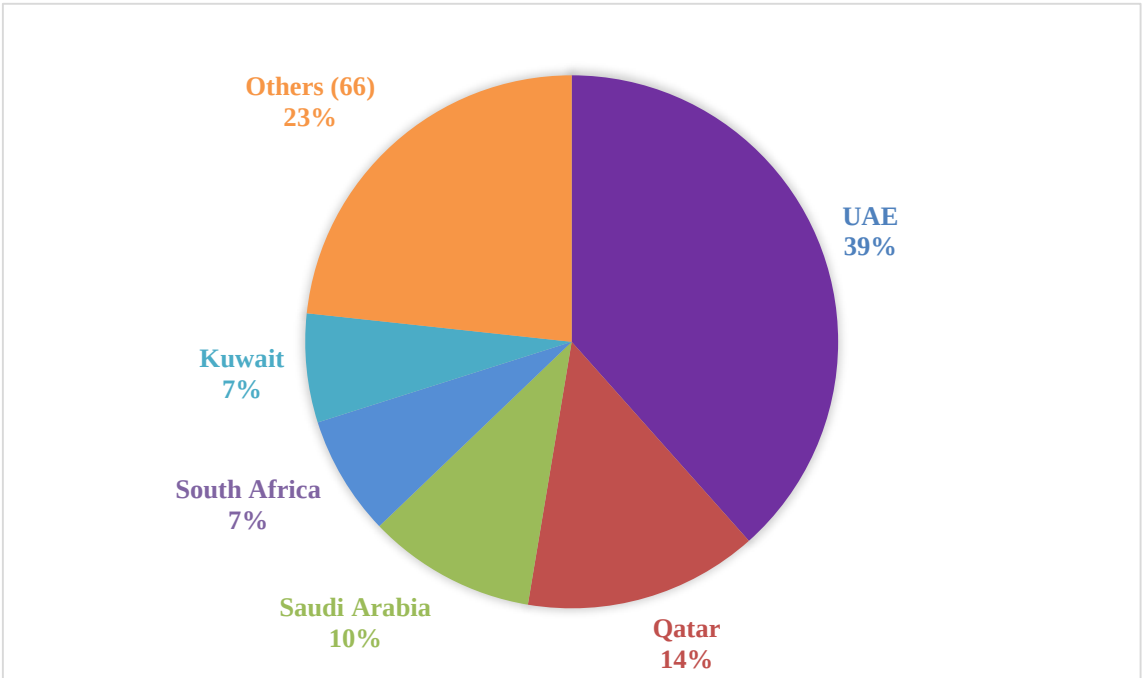

Figure 2. 9 %age Share of Countries in Oil Imports of Pakistan

Source: World Integrated Trade Solution (2019)

2.6 SECTOR WISE CONSUMPTION OF PETROLEUM PRODUCTS

In Pakistan different sectors use oil for energy. The top of the list is transport sector followed by power and energy sector. The transport sector consumed the most percentage of petroleum products in past and the trend is most likely to continue in the future as no significant steps are taken for transfer from oil products to renewable or other sources of energy. The consumption of oil in the government sector and industrial sector declined significantly in FY 2019-20 as compared to FY 2018-19. The transport sector demand increased and is increasing further. In FY 2019-20 transport corresponds to 81% consumption of petroleum products (OGRA Petroleum Industry report 2019-20).The chart below shows the sectorial wise consumption

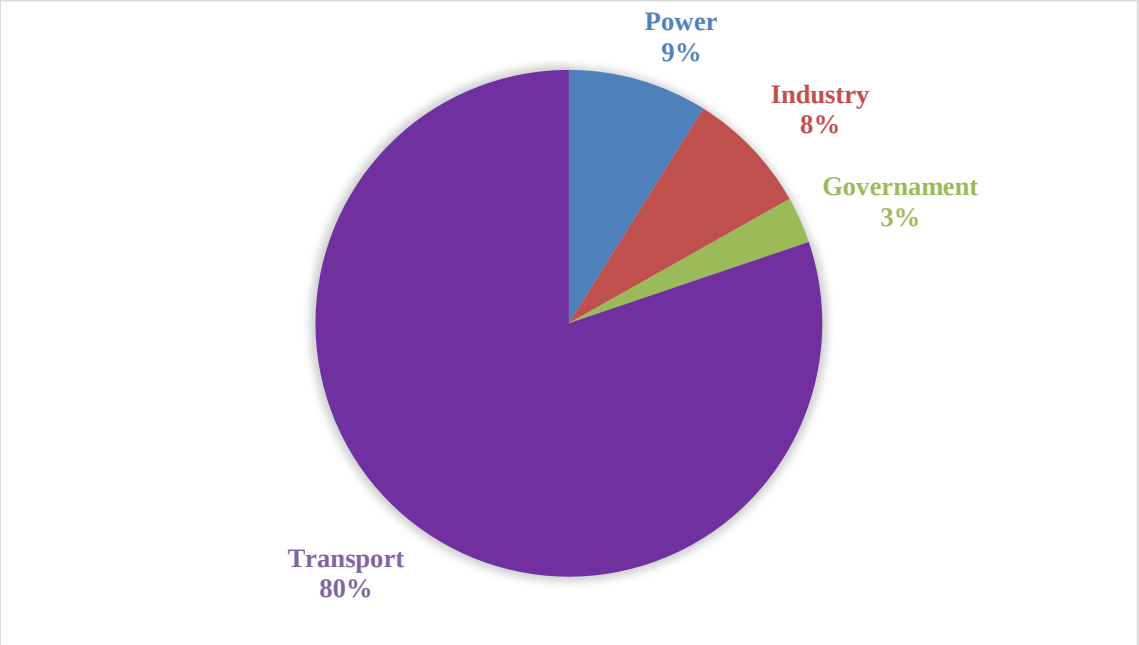

Figure 2. 10 Sector Wise Share in Consumption

2.7 REFINERIES OF PAKISTAN

There ten refineries throughout the country. In Pakistan the refineries are not distributed uniformly. Five of the total refineries are on the coastal line to the south. Province wise distribution is as two are situated in Baluchistan, five in province Sindh and remaining three in province Punjab. The refineries in Sindh are ENAR Petrotech Refinery, BYCO Petroleum Pakistan Limited (BPPL), Pakistan Refinery Limited (PRL), National Refinery Limited (NRL) and Trans Asia Refinery, In Baluchistan Khalifa Coastal Refinery and Bosicor Oil Pakistan are located, In Punjab Dhodak Refinery, Pak Arab Refinery Company Limited (PARCO) and Attock Refinery Limited (ARL) are

located. Seven of the refineries PARCO, BPPL, NRL, ARL, PRL, ENAR and DHODAK are in function. In 2019 BYCO has the largest capacity of 7.19 million tons, followed by PARCO the mid country refinery with 4.5 million tons then NRL, ARL PRL and then ENAR. The PARCO is utilized by almost its full capacity and then ARL is utilized at most. The Table 2.2 shows the maximum capacity and percentage capacity utilized of refineries in years from 2016 to 2019 (OGRA Petroleum Industry report 2019-20).

Table 2. 2 Refineries Capacities and Utilization

Refinery	2016		2017		2018		2019	
	Capacity	%age Utilization	Capacity	%age Utilization	Capacity	%age Utilization	Capacity	%age Utilization
BYCO	7.19	22	7.19	18	7.17	38	7.17	33
PARCO	4.50	100	4.5	100	4.5	100	4.5	89
NR	2.71	85	2.83	85	2.83	86	2.83	81
ATTOCK	1.96	86	2.44	91	2.44	93	2.44	94
ENAR	0.33	97	0.33	88	0.33	97	0.33	97
PR	2.10	81	2.1	76	2.1	81	2.1	76

Note: Capacity Units Million Tons of Oil Equivalent

Source: Petroleum Industry Report

2.7.1 Production by Refineries in FY 2019-20

As PARCO is used at its maximum capacity it has the maximum production of 2.85 million tons followed by BYCO with 2.13 million tons production. Percentage wise PARCO shared 29% then BYCO 22%, ARL 16%, PRL 12%, NRL 16%, ENAR and DHODAK each contributed a 3%. The table below shows the comparison of production and growth in FY 2018-19 and FY 2019-20

Table 2. 3 Refineries Product Wise Production

Refinery	Energy Products	Non-Energy Products	Total (2019-20)	Total (2018-19)	% Growth/ (Decline)
PARCO	2.79	0.07	2.82	3.78	24.50
NRL	1.33	0.23	1.56	2.04	23.50
PRL	1.21	0.00	1.21	1.50	19.70
ARL	1.50	0.06	1.56	2.14	26.8
BPPL	2.10	0.02	2.13	2.33	8.70
ENAR	0.27	0.00	0.27	0.31	12.3
Dhodak	0.26	0.02	0.27	0.29	5.40
Total	9.45	0.41	9.85	12.39	20.43

Note: Units Million Tons of Oil Equivalent

Source: Petroleum Industry Report

The percentage wise share in production for the FY 2019-20 is shown in Figure 2.11

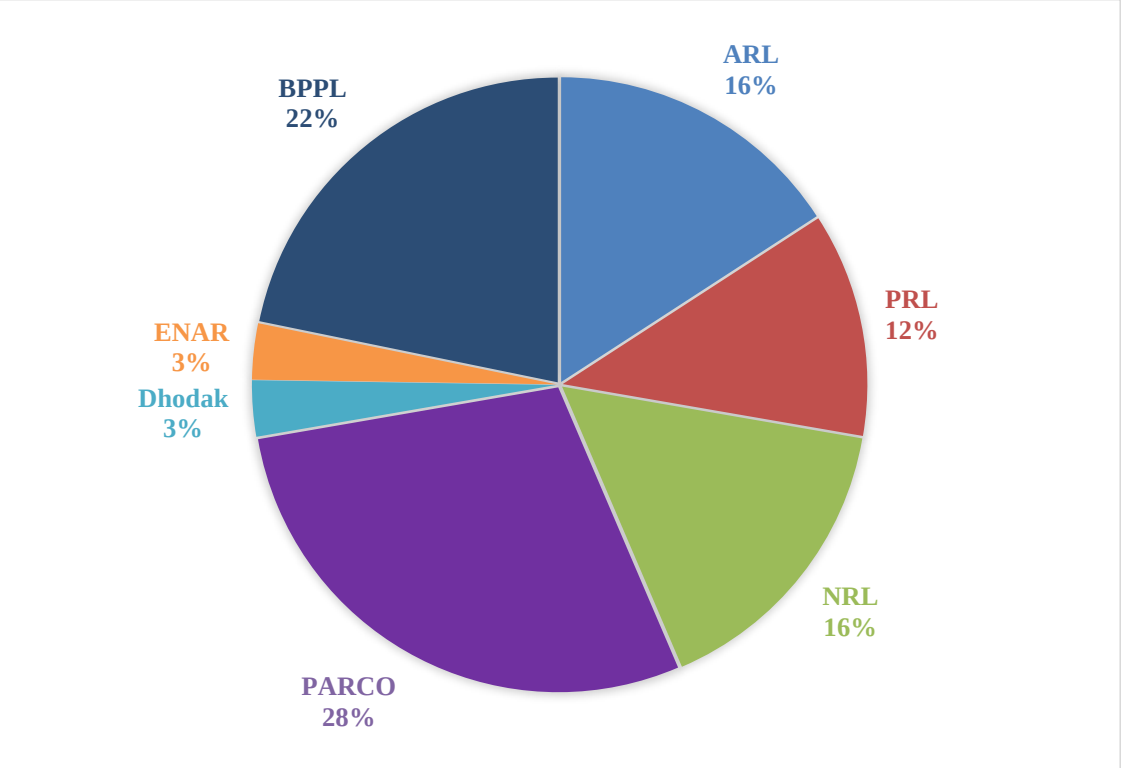

Figure 2. 11 Refineries %age Share in Production

2.8 OIL DEPOTS

In addition to oil refineries oil depots are also very important as the petroleum products need to be stored prior to transportation of it to oil retail outlets. The imported

and locally produced oil is transported to twenty-four depots distributed throughout the country and then to retail outlets to serve consumers. Punjab, as the most populous and industrialized province consume most of petroleum products, have twelve depots of these twenty-four. Sindh have five depots for storages of petroleum products, Baluchistan and KPK each have three depots and Gilgit Baltistan have a single depot. The details of names and locations are summarized in the table below

Table 2. 4 Province Wise Depots Classification

Sr.No	Province	Name of Depot
1	Balochistan	Khuzdar
2		Quetta
3		Hub (Refinery BYCO)
4	Sindh	Keamari
5		Port Qasim
6		Daulatpur
7		Sanghi
8		Shikarpur
9	Punjab	Mahmoodkot
10		Kotla Jam
11		Vehari
12		Sahiwal
13		Sher Shah
14		Kundian
15		Habibabad
16		Gatti/Faisalabad
17		Machike
18		Chak pirana
19		Sihala/Rawalpindi
20		Faqirabad
21	KPK	Tarujabba
22		Serai Nourang
23		Chitral
24	`GB	Juglot

Source: Commission Report

2.9 OIL MARKETING COMPANIES

In Pakistan fifty-nine companies have granted license to serve consumers at the retail end. Out of these fifty-nine twenty-eight are operating currently. Major share around 80% is held by five companies. PSO is the largest stakeholder its share has declined throughout the years. In FY 2019 PSO has the highest share of 41% followed by Attock petroleum with 11% share. The share of PSO in FY 2015 was 57% which is declined to 41% in FY 2019.(OMCs 2019) The year wise percentage share of major OMCs from 2015 to 2019 are shown in Table 2.5

Table 2. 5 OMCs Share in Market FY 2015-2019

OMC	FY15	FY16	FY17	FY18	FY19
PSO	57%	55%	54%	50%	41%
Total Parco Pakistan Ltd	5%	6%	10%	11%	10%
HASCOL Pet	5%	6%	8%	10%	10%
Attock Petroleum	10%	8.5%	8%	10%	11%
Shell	10%	10%	9%	6%	8%
BE Energy	0%	0%	3%	2%	3%
GO	0%	1%	2%	3%	6%
Others	12%	13%	5%	7%	11%

Source: Petroleum Industry Report

2.9.1 White Oil VS Black Oil Share of OMCs

Further the MOGAS, HSD, Jet Fuel, Kerosene and Light Diesel Oil is classified as White oil where Furnace Oil, Lubes and grease are classified as Black oil. The PSO has lost is share in white oil as well as black oil. In FY 2018 PSO has 43% share it dropped to 41% in FY 2019 in white oil, in Black oil the share dropped from 67% in FY 2018 to 52% in FY 2019 (OMCs 2019).The stats are shown in Table 2.6

Table 2. 6 OMCs Share in White Oil

OMCs	FY 18	FY 19
PSO	43%	41%
Total Parco	12%	12%
Shell	10%	10%
Attock	9%	10%
HASCOL	13%	10%
GO	5%	8%
Others	9%	11%

Source: PACRA

Table 2. 7 OMCs Share in Black Oil

OMCs	FY18	FY19
PSO	67%	52%
Attock	9%	13%
HASCOL	9%	12%
Total Parco	6%	8%
Others	10%	16%

Source: PACRA

2.9.2 Product Wise Share of OMCs

MOGAS being a common man fuel is consumed in the largest quantity, and PSO being the largest stake holder has highest share in sales. In FY 2019-20 PSO served retail customers with 2.89 million tons MOGAS and with 3.04 million tons of HSD. The second in the list is Total Pakistan which has served customers with 0.99 million tons of MOGAS and 0.68 million tons of HSD (OMCs 2019). The stats of PSO, TPPL and all other OMCs are shown in Table 2.8

Table 2. 8 Sale of OMCs FY 2019-20

Product	PSO	TPPL	APL	SPL	GO	HASCOL	BPPL	BEE	Others	Total
MOGAS	2.89	0.99	0.67	0.83	0.69	0.54	0.26	0.19	0.4	7.45
HOBC	0.02	0.01	0	0.01	0	0	0	0	0	0.06
HSD	3.04	0.68	0.64	0.46	0.57	0.57	0.35	0.18	0.24	6.63
FO	1.09	0.09	0.42	0	0	0	0.42	0.04	0.23	2.37
JP-1	0.52	0	0.01	0.02	0	0	0	0	0	0.55
Kerosene	0.06	0.01	0.02	0	0	0	0	0	0	0.09
LDO	0.01	0	0.01	0	0	0	0	0	0	0.02
100LL	0	0	0	0	0	0	0	0	0	0
Total	7.62	1.78	1.76	1.33	1.26	1.09	1.03	0.41	0.88	17.17

Note: Unit Million Tons of Oil Equivalent

Source: OCAC

2.10 OIL MOVEMENT

In Pakistan the five of the major refineries are located at southern part of country near Karachi and most of the oil imports are also received at Karachi sea ports (OGRA Petroleum Industry report 2019-20). But the consumption is highest in the central region i.e. Punjab province and a large quantity is consumed at Northern KPK and adjacent areas. This situation causes oil to be moved at large distance, for this Pakistan uses road oil tankers, pipelines and Pakistan railways. Road dominated the share wise followed by pipelines and a small quantity is moved through railway (OGRA Petroleum Industry report 2019-20). Figure 2.12 shows mode wise oil movement from FY 2015-16 to FY 2019-20

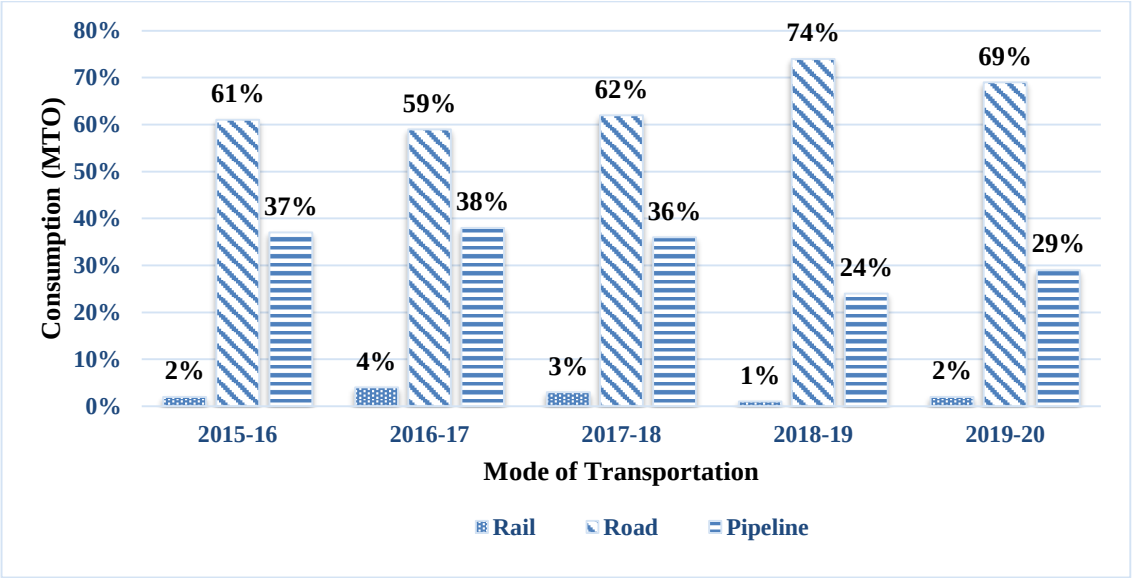

Figure 2. 12 Mode Wise Oil Movement (FY 2015-19)

This section is further discussed in sub sections focusing on each mode separately

2.10.1 Oil Pipelines

Pakistan major oil pipelines are KMK, WOP and MFM. KMK is used to transport crude oil, it is 870 km long starts from Keamari and ends at Mahmoodkot. WOP is 786 km long starts from port Qasim and end at Mahmoodkot, it can transport both HSD and MOGAS. MFM transports HSD from Mahmoodkot to Machike it is 362 km long and its up gradation for dual products transportation is in the pipeline. The details are summarized in the Table 2.9

Table 2. 9 Oil Pipelines in Pakistan

Pipeline/Year of Commission	Operated by	Length(km)	Route	Oil Type
Karachi-Mahmoodkot (KMK)/1981	PARCO	870	Keamari,Bubak, Shikarpur,Fazilpur, Mahmoodkot	Crude Oil
Mahmoodkot-Faisalabad-Machike (MFM)/1997	PARCO	362	Mahmoodkot, Faisalabad, Machhike	HSD
White Oil Pipeline (WOP)/2005	PAPCO	786	Port Qasim, Shikarpur, Mahmoodkot	HSD, MOGAS
Korangi-Port Qasim link/2006	PARCO	22	Port Qasim, Keamari	Multi-Purpose

Source: PACRA

2.10.2 Pakistan Railways

The Pakistan railways transports the Oil for PSO and they have signed a contract. The Pakistan railways provides the services to PSO from four stations they carry the oil and transport it to seven locations. The PR load the oil from Keamari (KMR) or Bin Qasim (BQM) or Mahmoodkot or Attock refinery limited (ARL) and the oil is carried to seven stations Muzaffargarh, Nishatabad (near Faisalabad), Piran Ghaib (near Multan) Lalpir (near Muzaffargarh), Akhundabad (near Gujranwala), Chakpirana (near Gujrat), Sihala (near Islamabad) and Tarujabba (near Nowshera). The above origins and destinations are shown in Table 2.10

Table 2. 10 PR Loading and Unloading Stations for Oil

Stations	
From	**To**
KMR/RG	Muzaffargarh
	Nishatabad
	Piran Ghaib
	Lalpir
MYP/BQM	Muzaffargarh
	Nishatabad
	Piran Ghaib
	Lalpir
	Akhundabad
Mahmoodkot	Chakpirana
	Sihala
	Tarujabba
ARL/Rawalpindi	Lalpir

Source: PR

2.10.3 Road Sector

The road sector carries the bulk from refineries, ports to the storages and from storages to the retail outlets. As of PSO the containers load the oil from Shikarpur, Dhodak, Faisalabad, Mahmoodkot, Keamari, Daulatpur, Sihala, Sangi, Shershah, Parco, Bosicor, Machikey, Morgah, Gatti, Kohat, Habibabad, Kotlajam, Sahiwal, Faqeerabad and Vehari and then transported to multiple further sub storages.

2.11 INLAND FREIGHT EQUILIZATION MARGIN (IFEM)

In Pakistan the petrol prices are kept flat throughout the country through a mechanism of Inland freight equalization margin. Through IFEM mechanism the OMCs are paid for the cost of transportation to 22 depots spread over the whole country. This IFEM is included in Ex-depot sale price per liter and is notified every month by OGRA through its website. The margins of HSD and MOGAS are revised from 3.16/liter in July 2017 to 3.91/liter in July 2018 and 1.3/liter in July 2017 to PKR 1.55 /liter in July 2018 for HSD and MOGAS respectively (OMCs Sector 2020). From year 2017 to 2018 IFEM

increased and then decreased to 2019, the detailed Ex-Depot Sale Price are shown in Table 2.11 and Table 2.12

Table 2. 11 HSD Detailed Ex-Depot Sale Price

Variable	July 2017	July 2018	Jun 2019	Nov 2019
Cost of Supply	45.67	75.96	87.53	81.31
IFEM	1.30	1.55	1.13	1.03
OMC Margin	2.41	2.64	2.64	2.81
Dealer Margin	2.67	2.93	2.93	2.93
Sales Tax	20.05	28.23	14.59	18.47
PL	7.80	8.00	18.00	20.76
Taxes	27.85	36.23	32.59	39.23
Sales Tax Rate (%)	33.50	31.00	13.00	17.00

Note: Unit Price PKR/Liter

Source: PACRA

Table 2. 12 MOGAS Detailed Ex-Depot Sale Price

Variable	July 2017	July 2018	Jun 2019	Nov 2019
Cost of Supply	40.65	65.02	76.56	69.78
IFEM	3.16	3.91	3.29	3.72
OMC Margin	2.41	2.64	2.64	2.81
Dealer Margin	3.16	3.47	3.47	3.47
Sales Tax	12.13	14.46	12.96	16.45
PL	9.79	10.00	13.73	17.18
Taxes	21.92	24.46	26.72	33.63
Sales Tax Rate (%)	20.50	17.00	13.00	17.00

Note: Unit Price PKR/Liter

Source: PACRA

2.12 SUMMARY

In this chapter Pakistan oil industry was briefly discussed. Pakistan energy mix highly depends upon oil, its dependence in different regimes shows that Pakistan energy mix dependence on oil declined significantly as the consumption of Natural gas increased. However, with high declining rate of natural gas resources the oil share in the energy mix is increasing again. MOGAS and HSD the two major energy products of oil are locally produced as well as imported, MOGAS is imported in a large quantity. Pakistan Oil refineries production in FY 2019-20 and product wise production was discussed. Oil movement through the country is discussed in the sub section which shows that road sector dominates the oil transportation and railway share shows small decline or increment with less than five percent share. Oil depots and province wise distribution shows Punjab has the highest number of depots followed by Sindh, then Khyber Pakhtunkhwa, Balochistan, Azad Jammu Kashmir and Gilgit Baltistan. Pakistan keeps the rates of HSD and MOGAS flat throughout the country through a formula mechanism of Inland Freight Equalization Margin (IFEM), oil depots are nominated and cost of transportation to these depots is paid back to Oil Marketing Companies. Current Pipeline structure their annual transportation capacities in tons and product wise transportation capacities are discussed.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 INTRODUCTION

In this study aim was to study and evaluate Pakistan's current petroleum supply chain and identify the problems. After identifying loopholes and inefficiencies, the goal was to examine current pipeline and railway infrastructure, capacity, and utilization. The underused capacity of pipelines and railways was estimated, and a gradual load shift from the road to these two modes was proposed to maximize capacity utilization. Various models are proposed, beginning with a rise in railway share, followed by full utilization of existing pipelines, and finally completion and full utilization of a pipeline project under construction. Each model was then evaluated for its benefits, including the amount of money it would save, the number of vehicles it will cut, and the amount of money it will save on maintenance costs. Model-III was investigated further for future demand, and problems that Pakistan might encounter were revealed.

3.2 RESEARCH STRATEGY

The research strategy of this study is to identify the loopholes and find possible solutions with minimum effort and investments. Pipelines utilization at full capacity and proposition to use the Pakistan railways vacant capacity is the part of strategy. Step wise possible modifications and their benefits are to be determined. Strategy is to optimize Pakistan's current petroleum supply chain by seeking best practices adapted globally. The strategy is to optimize the current infrastructure and do not propose methodologies which require construction of new infrastructures as it is difficult for Pakistan's current economy to bear the construction cost.

3.3 RESEARCH DESIGN

The sub division of this section consists of preliminary study phase, phase of data collection, Analysis phase of data, model development phase and conclusions and recommendation phase. The sub phases are discussed below one by one

The term 'Research design' refers to methodology of doing scientific investigation by developing a plan or strategy of collecting and analyzing the data (Poilt and Hungler, 1985). The research plan has been subdivided into five main phases' i.e. preliminary

study, data collection, data analysis, case study and conclusions/recommendation respectively.

I. **Preliminary Study Phase**, a thorough study of literature generally was carried out to find out the problems of Pakistan petroleum supply chain, The problems for the most part were identified by comparing Pakistan PSC with other developed countries, parameters such as share of each mode for POL transportation, the cost to transport per metric ton, the time taken to transport, the length through which the POL is transported were compared.

II. **Data Collection Phase**, Data from various sources was accumulated. Stakeholders and the major consumers of HSD and MOGAS were identified. Percentage share produced by refineries, consumed by different sectors, locally produced vs, imported were determined. Moreover, the country area was divided into three sections and the percentage share available for transportation on each section essentially was determined.

III. **Data Analysis Phase**, Amount Produced by refineries, consumed by various industries, locally produced vs, imported goods in particular were identified. The country area was divided into three sections in general, and the percentage share available for transportation on each section was calculated. Modes of transportation available on each section, their capacities and utilization were determined.

IV. **Model Development and Analysis Phase**, Different possible models for the POL transportation based on the current existing infrastructure or with up gradation were developed. Moreover, Model with new facility construction was also developed. The economic, environmental and social benefits of each model was determined.

V. **Conclusions and Recommendation Phase**, the results were used for conclusions and recommendations. Recommendations were given to improve the current scenario as well as to cater future problems. The research methodology flow chart is illustrated in Figure 3.1.

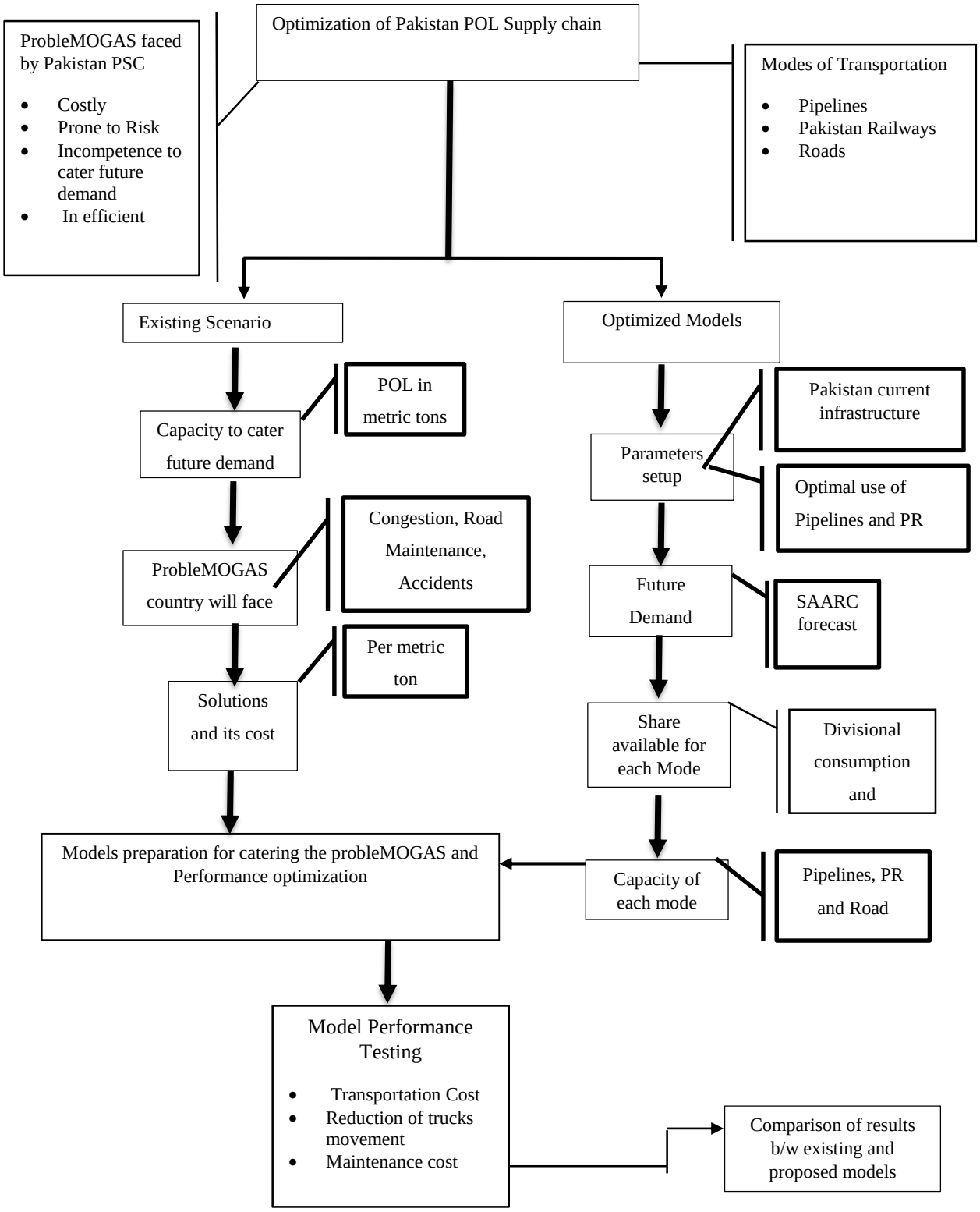

Figure 3. 1 Research Methodology

3.4 RESEARCH SCOPE

The research scope is limited to petroleum supply chain. Coal, Gas, Furnace oil, LNG, MOGAS, HSD and many more are all the energy products but this study scope is limited to MOGAS and HSD supply chain. MOGAS and HSD comprises the major part of oil share in energy mix, so the transportation of these products is considered only, FO is de regulated and other energy products supply chain differ from these two.

3.5 RESEARCH LIMITATION

The scope of the study is confined to suggesting and proposing models that can be implemented for the least amount of money and with the least degree of impact to existing infrastructure. There are no proposals in this paper for new pipelines, railways, or roads to facilitate POL movement. Pakistan is facing serious economic problems and constructing new pipelines or railway infrastructure for this purpose is out of discussion for government sector. No new development is proposed as a result of these considerations. For new construction, public-private partnerships can be helpful, but they also have a number of challenges to overcome. It is not intended to reduce passenger quota trains, nor is it suggested that POL transportation be prioritized over other rail freight. The goal of this study is to make advantage of underutilized railway capacity.

3.6 RESEARCH DIFFICULTIES

The lack of current research on this topic in our location was one of the problems we faced while conducting this study. There has been research on this topic in developed countries, but Pakistan's circumstances are not the same as those investigated, and the difficulties we face are radically different. Furthermore, neither our governmental nor private sectors regularly publish or make their annual reports available. As a result, accurate and dependable data is in short supply. Another challenge was conceiving models that were not only efficient, but also applicable, required less changes, and did not disrupt current processes.

3.7 IDENTIFICATION OF LOOPHOLES

An exhaustive review of literature and country' statistics was done to identify the major problems and loopholes in the supply chain of petroleum. In the care to identify these loopholes international journals, conference proceeding & published research was

consulted. Supply chain of developed and emerging economies was studied to find the similarities and the differences with our supply chain.

3.8 RECOMMENDATIONS

Recommendations for petroleum supply chain optimization and assisting steps in solution to current and forecasted future problems were proposed.

3.9 SUMMARY

This chapter described the framework of the research study on the subject. Literature review was done to identify the problems and their solution through formulating different models with optimizing current pipeline and PR infrastructure utilization. Data has been collected from multiple sources and was analyzed to establish the objectives of this study.

CHAPTER 4
ANALYSIS OF CURRENT PRACTICE AND MODEL DEVELOPMENT

4.1 INTRODUCTION

This chapter, is about the optimized models for Pakistan petroleum supply chain. Section 4.1 discusses the existing scenario of Pakistan supply chain, section wise and product wise distribution through different modes and section 4.2 and onwards focuses on the proposed optimized models. The aim is to develop and propose models for the petroleum supply chain of Pakistan that can give monetary benefits, reduction benefits of accidents, pollution and congestion on roads. The existing model is used as reference model for the other proposed models.

This chapter also compares the proposed models with the existing model. The first model considers the benefits country can enjoy by increasing the share of Pakistan Railway only. The share of pipeline remains the same the increment in railways load reduces the share of road only. The second model proposes that pipelines be used at their full capacity, this will further reduce the load on road and the railway share remains same as proposed in Model-I. The third model considers that new pipeline is built and road share is further reduced for Machike-Tarujabba section.

4.1.1 Pakistan Petroleum Supply Chain

The Pakistan oil supply chain is a vertically integrated complex network, comprised of many activities, infrastructures and authorities. Pipelines, oil tankers and rail special cargo wagons are used for the transportation of crude and refined products. Internationally pipelines are considered as the safest least costly and highly reliable mode of transportation. Crude oil is distributed through the country through pipelines as well as roads. Total length of pipelines in Pakistan is more than twelve thousand kilometers, majority part of pipelines is used for Gas transportation, and precisely 80% pertained to gas sector. Approximately 2,576 km of refined and crude oil pipelines linked the country, 1,087 km is for refined product transportation (Pipeline report 2021). The pipelines start from ports of Karachi and extends north up to Machike near Faisalabad. Total movement of oil through pipelines in FY19 was 18%. Road trucks are costlier and unsafe still unfortunately they transported 70% of total oil products and corresponding railway share was only 2% (PACRA 2020). Figure 4.1 shows the supply line sketch of Pakistan.

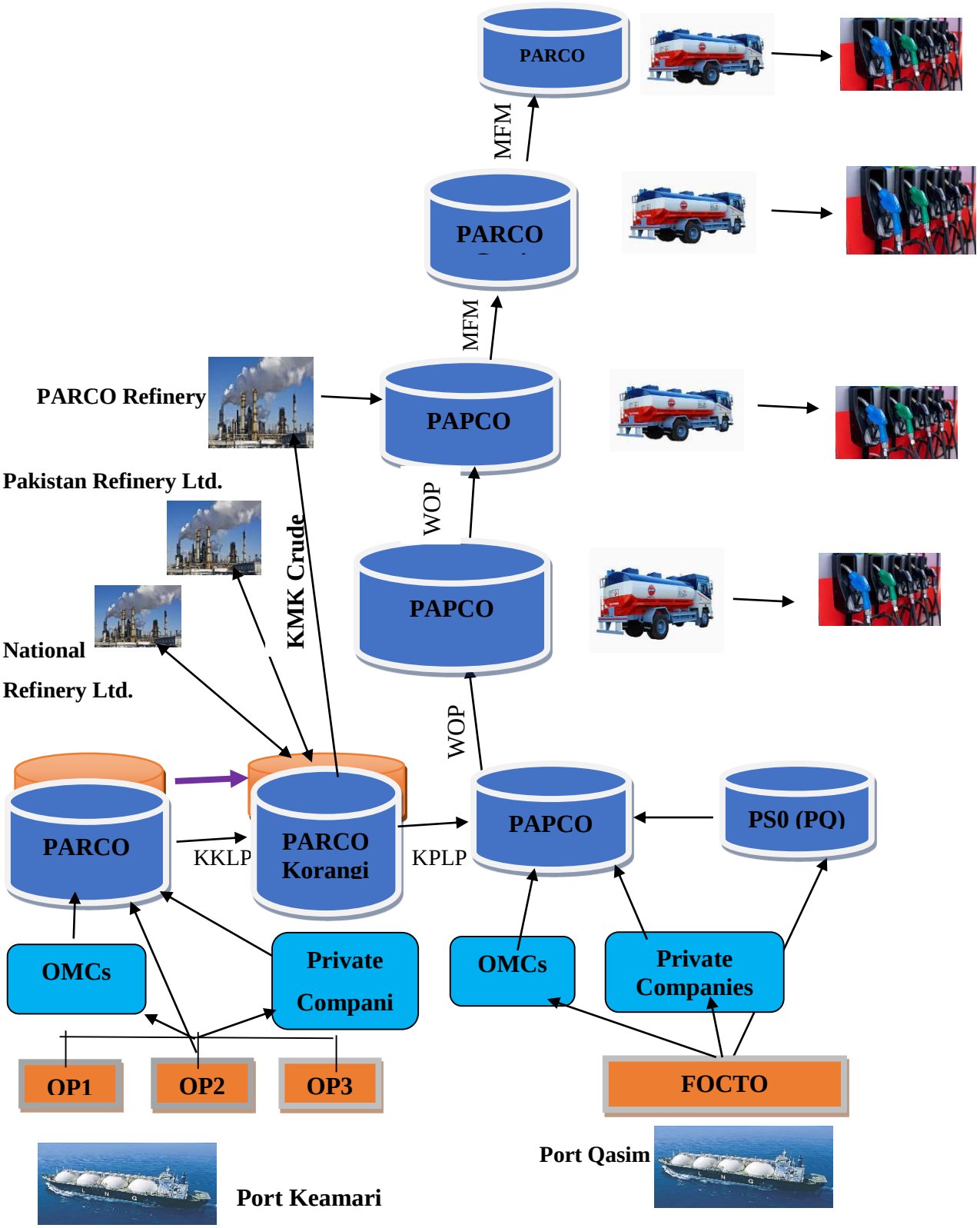

Figure 4. 1: Pakistan's Current Petroleum Supply Chain

4.2 EXISTING SCENARIO

In Pakistan oil distribution is mainly through roads, followed by pipeline and then railways. The pipeline extends to Machike. In the rest country north up, roads and

railway infrastructure distributes the oil. The three pipelines are KMK, WOP and MFM. As discussed earlier the KMK pipeline is used to transport crude oil, WOP transport both HSD and MOGAS, and MFM transports HSD only. The pipelines are not utilized fully at their capacity, WOP capacity utilization remained 28.6% and MFM capacity utilization was 31.3 % (OGRA Petroleum Industry report 2019-20). Road transportation has major share of 69% followed by pipelines with 29% share and Pakistan railways bearing load of 2% share (OGRA Petroleum Industry report 2019-20).

4.2.1 Percentage Share of MOGAS and HSD Available for Transportation

The section wise percentage of product available for transportation varies. Karachi fed area corresponds to about 15.8% of total yearly consumption, this consumption percentage share is assumed same for both MOGAS and HSD (OGRA 2018). Northern refineries contribute 15.3% of total yearly MOGAS consumption and 25.52% of HSD consumption. The contribution of refineries is shown in the Table 4.1

Table 4. 1 %age Share of Refineries in Country Total Consumption

Products (%age Share)	**Northern Refineries**		**Southern Refineries**			**Sum**		
	PARCO	**ARL**	**BPPL**	**NRL**	**PRL**	**Northern**	**Southern**	**Total**
MOGAS	8.78	6.52	5.32	2.66	2.92	15.3	10.91	26.21
HSD	18.31	7.2	13.51	9.45	7.65	25.52	30.63	56.15

Pakistan imports larger quantity of MOGAS as compared to HSD, major share of HSD consumption is locally produced. The percentage share available at Mahmoodkot is 50%, we have assumed it same for both MOGAS and HSD(Frontier Oil Company 2019). Subtracting the Karachi fed area, northern refineries share, for Machike onwards areas based on population share of MOGAS and HSD was calculated and ARL production share was added to it. Share of each section is shown in the Table 4.2

Table 4. 2 HSD,MOGAS Section Wise Movement

Movement (%age Share of Total Consumption)		
Section	**Product**	
	MOGAS	**HSD**
KAR to MMK	68.90%	58.67%
MMK to MCK	58.87%	68.00%
MCK to TJB	40.52%	43%

4.2.2 Section wise Existing Share of Each Mode

Product share varies from section to section. Karachi to Mahmoodkot share of both MOGAS and HSD remains same, for Mahmoodkot to Machike this share varies as MFM is used for HSD transportation only, Machike onwards no pipeline exists so the share varies significantly. Section wise mode share of MOGAS shows that on Mahmoodkot to Machike and Machike to Tarujabba sections the road share is the largest, as pipelines can't transport MOGAS on these sections and PR share is very low.

Table 4. 3 MOGAS Section Wise Movement (% Share)

MOGAS Movement (Mode Wise)			
Mode of Transportation	**Section**		
	KAR to MMK	**MMK to MCK**	**MCK to TJB**
Road	69%	98%	98%
Pipeline	29%	0%	0%
Railway	2%	2%	2%

Section wise mode of share of HSD shows that as compared to MOGAS a greater share is transported through pipelines and road share is comparatively less.

Table 4. 4 HSD Section Wise Movement (% Share)

HSD Movement (Mode Wise)			
Mode of Transportation	**Section**		
	KAR to MMK	**MMK to MCK**	**MCK to TJB**
Road	69%	69%	98%
Pipeline	29%	29%	0%
Railway	2%	2%	2%

4.2.3 Quantity to be Transported by Each Mode 2022-23

The predicted MOGAS consumption in country for year 2022-23 is 16.70 million tons and that of HSD consumption is 13.82 million tons (SAARC 2018). If the same existing scenario continues the quantity to be transported by each mode in 2022-23 section wise will be as

Table 4. 5 Section Wise MOGAS Movement (Quantity)

MOGAS			
Mode of Transportation	**Section**		
	KAR to MMK	**MMK to MCK**	**MCK to TJB**
Road	7.94	6.79	6.63
Pipeline	3.34	2.85	0.00
Railway	0.23	0.20	0.14

Note: Unit in Million Tons

Table 4. 6 Section Wise HSD Movement (Quantity)

HSD			
Mode of Transportation	**Section**		
	KAR to MMK	**MMK to MCK**	**MCK to TJB**
Road	5.59	6.48	5.82
Pipeline	2.35	2.73	0.00
Railway	0.16	0.19	0.12

Note: Unit in Million Tons

4.2.4 Transportation Cost of Different Modes (Per Metric Ton)

Before discussing different scenarios and possible models the cartage rates for HSD and MOGAS per metric ton for different modes should be discussed. With up gradation of WOP the MOGAS is now transferred to Mahmoodkot and onwards it is carried to north up country. MOGAS tariff for Karachi-Mahmoodkot is taken from the oil pipelines report of PACRA, which was given in dollars but converted here to rupees for uniformity, per metric ton rates of Road are determined from the OGRA's document "Determination of upfront tariff for white oil pipeline (WOP) MOGAS project" as given as the pipelines cost is 33% of road cost (OGRA 2018, OGRA 2019). The railway per metric cost was calculated from the "OGRAS's news brief" as given as the pipelines tariff is 85% of railway cost(OGRA News 2021). HSD is transported to Mahmoodkot from where it is dispatched to other locations. HSD rates are considered for Mahmoodkot-Tarujabba, railway rate was taken from railway website and for the other modes was calculated using formulae discussed above.

Rates per metric ton for different origins and destination are shown sequentially. The rates from Karachi to Mahmoodkot are given in the Table 4.7

Table 4. 7 Tariff for Karachi-Mahmoodkot Section

Tariff (PKR/Metric Ton)			
Product	**Mode of Transportation**		
	Road	**Pipeline**	**Railway**
MOGAS	6,018	2,006	2,360
HSD	5,562	1,854	2,182

Note: Road, Railway Tariff is Calculated and Pipeline Tariff is given by PACRA

From Mahmoodkot through MFM pipelines MOGAS and HSD is transferred to Machike. The rates from Mahmoodkot to Machike are given in the Table 4.8

Table 4. 8 Tariff for Mahmoodkot-Machike Section

Tariff (PKR/Metric Ton)			
Product	**Mode of Transportation**		
	Road	**Pipeline**	**Railway**
MOGAS	6,681	2,227	2,620
HSD	2,552	851	1,001

Note: Road, Pipeline Tariff is Calculated and Railway Tariff is given by OGRA

From Machike there is no existing pipeline, but Frontier Oil Company is constructing a pipeline to Tarujabba. So the rates for this origin destination are given in Table 4.9

Table 4. 9 Tariff for Machike-Tarujabba Section

Tariff (PKR/Metric Ton)			
Product	**Mode of Transportation**		
	Road	**Pipeline**	**Railway**
MOGAS	7,878	2,626	3,089
HSD	2,985	995	1,170

Note: Road, Pipeline and Railway Tariff is Calculated on Considerations

4.2.5 Cost of Transportation

The quantity if transported through the same pattern the section wise total cost, no of trucks required and the total quantity of HSD and MOGAS to be transported through road will be is given in Table 4.10

Table 4. 10 Cost, Quantity & No of Trucks (Existing Scenario)

Section	**Quantity**		
	Total Cost	**Quantity through Roads**	**No of Trucks**
KAR to MMK	90,867	14	11,564
MMK to MCK	83,863	16	13,760
MCK to TJB	70,202	12	10,641

Note: Cost in PKR Million and Quantity in Million Tons

Population density between Mahmoodkot and Machike is the highest so is the consumption and major transportation is through road so we can see the highest number of trucks movement in this section

4.2.6 Problems With Existing Scenario

The existing scenario is causing a number of problems such as it is costly, it is deteriorating roads, it is causing congestion on roads and it is major fatal accidents. Some of the factors will be discussed in the subsections

4.2.6.1 Costly

The existing scenario is very costly as the bulk is transferred through roads and road is the costliest mode of transportation for freight transport. As discussed earlier the road transportation is 3 times costlier than pipelines and about 2.5 times costlier than railway transportation(OGRA 2018, OGRA News 2021). If the same pattern following is continued the Pakistan will loss a huge amount of revenue otherwise saved.

4.2.6.2 Congestion on Roads

Pilot traffic was conducted by SCEE (NUST 2017), Five sections of N-5 were selected and data was collected for seven days. Analysis of the section of highways was done and the study showed that Gujranwala and Pabbi, KPK section were the most critical sections. At that time the Level of service calculated for both the section showed F and E for south bound traffic of Gujranwala and Pabbi respectively. The North bound level of service for Gujranwala and Pabbi sections was C and D respectively (NUST 2017). Study reveals if the growth of traffic continues high as it is, the pattern of passenger and freight remains the same, N-5 at both these sections will be failed.

4.2.6.3 Increment in Maintenance Cost of Roads

In Pakistan most of the trucks are overloaded due to which its speed reduces and so is its bad impact on surface of road. The deterioration caused by these trucks is causing a huge increment in maintenance cost of roads. An increment of 50 trucks to traffic stream causes maintenance cost to increase by 183.1 $/mile/year (Gibby, Kitamura et al. 1990).So a huge amount of increment in maintenance cost is faced Pakistan road agencies.

4.2.6.4 Cause of Deadly Accidents

Commercial vehicles are involved in most of the accidents and the fatalities caused by commercial vehicles as far greater than fatalities caused due to other vehicles accidents. A study shows that commercial vehicle is involved in 56% accidents, and fatal crashes involving a truck was 89% of multi vehicle crash (NTRC 2018).

4.3 MODEL-I

The majority of oil transportation is done by road; the burden on roads can be reduced in a number of ways, one of which is increasing railway share from 2% to 20%. However, transferring this load from road to railway will necessitate checking railway capacity to handle this extra load, which will be examined in a separate section of this discussion. Railways after pipelines is the second most efficient mode of transportation for oil transportation. In developed countries railways is used in combination with pipelines to achieve the goal of safest, cheapest and reliable transportation of POL products. Unfortunately, Pakistan railways is not utilized as it should be. Pakistan railways is struggling because of many reasons one of these reasons is having the lowest share in country's freight transportation. If we talk about share in oil transportation it has only 2% share which is the lowest as compared to other developed countries.

While formulating this model it is assumed that Pakistan railways do nothing but using the current available locomotives and structure. Following consideration are done while formulating this model

Pakistan railways don't change its policy of prioritizing passenger trains over freight trains

- Average hauling capacity of locomotives not enhanced
- Tank wagons numbers remains same no enhancement

4.3.1 Share of Oil Transportation Increased from 2% to 20%

This model proposes to increase Pakistan railways share in oil transportation from 2% to 20%. Pipelines share doesn't change as the increment caused in share of Pakistan railways is the deduction in road share of oil transportation.

Before discussing the benefits Pakistan will get through this model, first a brief introduction of PR will be given and then capacity of Pakistan railways will be discussed

4.3.2 Pakistan Railway

First of all, a brief overview of Pakistan railways and its capacity is done in this section.

4.3.2.1 ML-1, ML-2 and ML-3

Pakistan railways is inherited from British India and most of its railway track is still the one laid by Britishers. Pakistan railways has broad gauge, meter gauge and

narrow gauge railway tracks, meter gauge is abandoned and the narrow gauge is dismantled. ML-1 is the main and most used railway line it stretches 1,872 KMOGAS, starting at country South Karachi and end in country North at Peshawar. ML-1 traverses from Karachi-Rohri-Khanewal-Lahore-Rawalpindi-Peshawar and Taxila-Havelian. The Karachi-Lahore section is dual line and Lahore-Peshawar is single track and its dualization is in progress. ML-2 starts from Rohri traverses from Kotri-Dadu-Jacobabad-DG Khan-Attock city and it is 1,254 KMOGAS. It's up gradation is to be done under CPEC. ML-3 stretches 996 KMOGAS, it traverses Rohri-Sukkur-Sibi-Quetta-Dalbandin-Taftan. The Path traversed by ML-1, ML-2 and ML-3 is shown in the Figure 4.2

(MAHMOOD HASAN 2015)

Figure 4. 2 Pakistan Rail Network (ML-1, ML-2, ML-3)

4.3.2.2 Capacity of ML-1

We will discuss the Oil transportation through ML-1 so will discuss the capacity of ML-1 only. Capacity of ML-1 will be further shown in two segments as ML-1 is dual line from Karachi to Lahore and is single lane from Lahore to Peshawar. The dual line capacity is 50 pair of trains/ day or 100 trains/day whereas the single line capacity is 60

trains/day (Khan 2019). Track use ratio of ML-1 Single Line and Double Line is shown in the Figure 4.3 and Figure 4.4 respectively

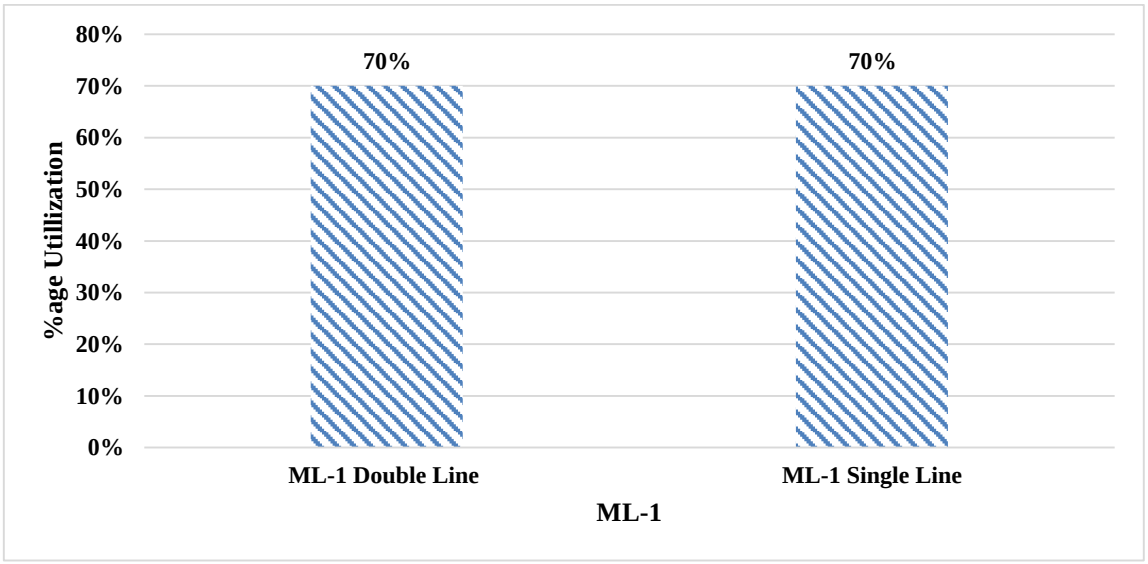

Figure 4. 3 Track Use Ratio ML-1

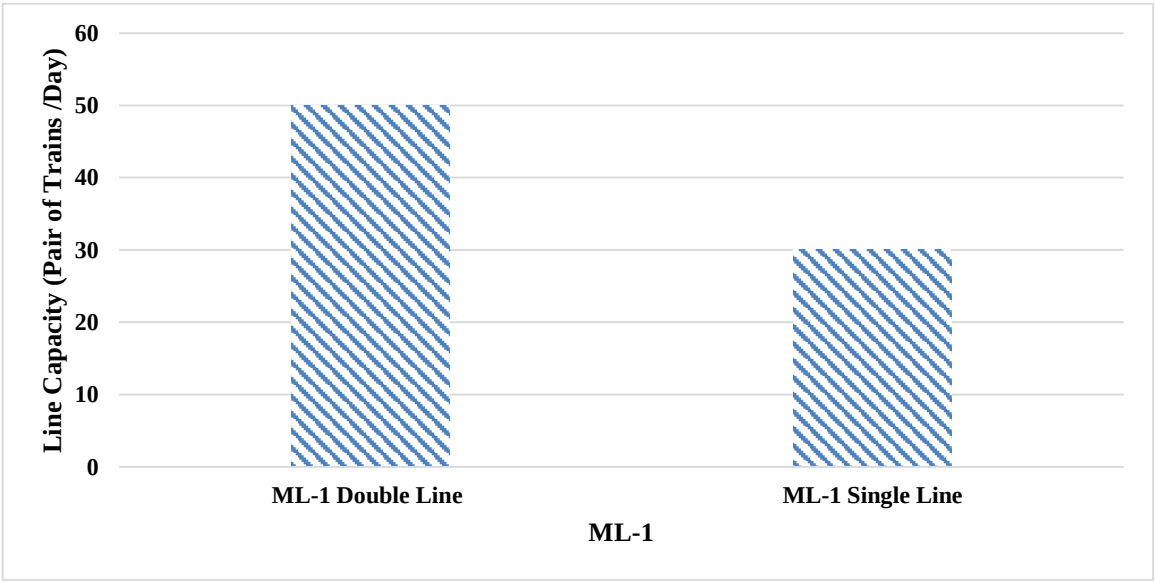

Figure 4. 4 ML-1 Line Capacity (Pair of Trains /Day)

4.3.2.2.1 Vacant Capacity of PR

Pakistan railway line can bear total 198 trains/day. 62% of these trains is passenger trains and 12% trains are freight trains, unused capacity is 26% which is 52 trains/day. If Pakistan railways keep minimum 10% capacity vacant to effectively manage its trains (Khan 2019) .If this percentage is subtracted from 26% still 16% that is 32 freight trains can be accommodated on the line. The details are shown in the Table 4.11

Table 4. 11 Passenger vs. Freight Trains and Vacant Capacity

Category of Train	Trains/Day	
	No.	%age
Total	198	100
Passenger	123	62
Freight	23	12
Vacant	52	26

4.3.2.2.2 Trains, Locomotives Required for POL Transportation

Pakistan railways Business plan is to transport 2.592 million tons per year from Karachi to Lalpir/Muzzafargarh 3 trains in one direction will be required daily. This will require 12 locomotives and will earn a considerable revenue for Pakistan railways (Usama 2016). The details are shown in the Table 4.12

Table 4. 12 PR Section Wise Plan for Oil Movement

Commodity	Loading Station	Unloading station	Train/day - One Direction	Freight	Revenue	Locomotives
Oil	Karachi	Lalpir/Muzzafargarh	3.00	2.59	7,156.00	12.00
		Tarujabba	1.00	0.86	4,400.00	8.00
	Mehmood kot	Chak Pirana/Sihala	1.00	0.86	1,867.00	3.00

Note: Units of freight in Million Tons of Oil Equivalent and Revenue in PKR million

4.3.2.2.3 No of Trains Required for 20% Share of HSD and MOGAS

The no of trains required for transportation of 20% section wise share of MOGAS and HSD are determined using the Table 4.13 and Table 4.14 respectively

Table 4. 13 MOGAS Share (20%) and Trains Required

Section	Product	Daily share (tons/day)	No. of Trains (Per Day in Each Direction)
KAR to MMK	MOGAS	6,301.36	3.00
MMK to MCK		9,780.82	3.00
MCK to TJB		6,751.85	2.00

Table 4. 14 HSD Share (20%) and Trains Required

Section	Product	Daily share (tons/day)	No. of Trains (Per Day in Each Direction)
KAR to MMK	HSD	4,438.35	2.00
MMK to MCK		5,150.68	3.00
MCK to TJB		3,232.87	2.00
Total No of Trains (HSD+MOGAS)		15.00	

Total number of trains required for moving 20% section wise share is 30 and the vacant capacity without the minimum limit is 32, so easily further 18% load can be accommodated by PR.

4.3.3 Section Wise Share of Different Modes (Model-I)

This model proposes to increase the share of railway from 2% to 20%. As railway is mode of transportation on all the three sections, its impact is seen on all the three sections.

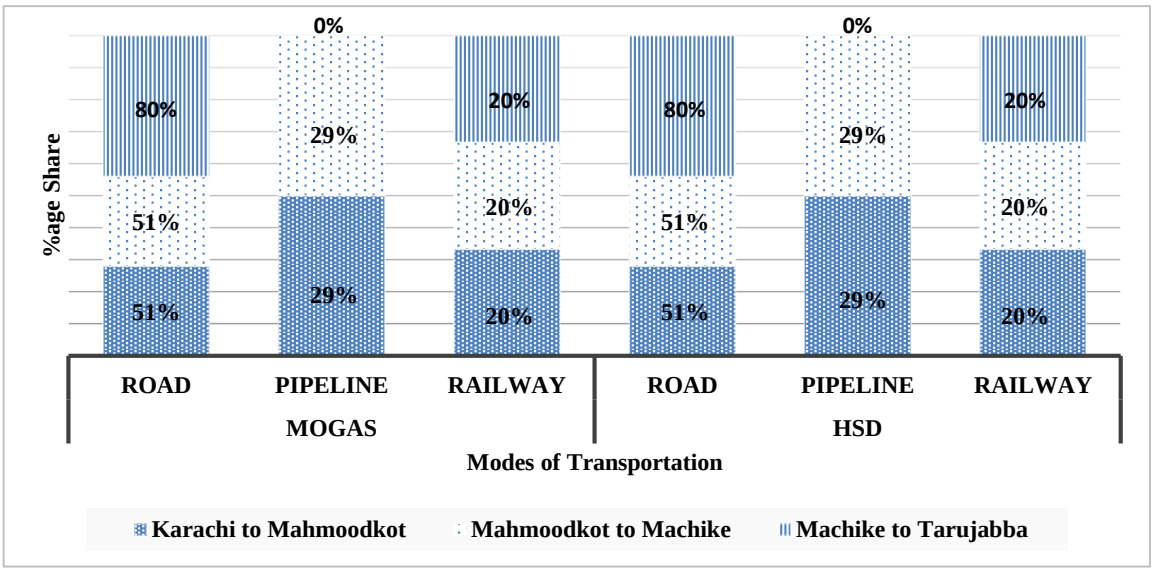

Figure 4. 5 Section Wise %age Share (Model-1)

4.3.3 Benefits of Model-I

This model will benefit Pakistan to reduce the cost of movement, trucks movement, maintenance cost and pollution. These benefits are discussed below one by one

4.3.3.1 Monetary Savings

As already discussed railway cartage cost is 2.5 times less than that of road cost. So Pakistan will save a huge amount of revenue if the 18% load from road is transferred to railways. This model will shift 9.27 million tons from road to railways and will save PKR 30 billion revenue for Pakistan. Calculations are shown in the Table 4.15

Table 4. 15 Increment in Quantity of PR and Revenue Saved

Section	Additional Burden on Railway	Savings
KAR to MMK	3.53	12,512
MMK to MCK	3.46	9,802
MCK to TJB	2.28	7,776
Total	9.27	30,090

Note: Unit Quantity in MTO and Savings in PKR Million

4.3.3.2 Reduction in Trucks Movement

Oil tankers on road carries an average of 32K liters which is equivalent to 35 tons and considering 1184 tons is carried by single train, then 34 oil tankers will be reduced on roads through the movement of a single oil freight train. However, for calculation we will use figure quoted by PACRA that movement of 4.68 million tons through WOP has reduced 4000 trucks movement from Karachi to Mahmoodkot and vice versa. For the above consideration a total of 7937 trucks movement will be reduced on all sections. The Table 4.16 shows the section wise trucks movement reduction

Table 4. 16 Reduction in Trucks Movement (Model-I)

Section	Reduced No. of Trucks
KAR to MMK	3,018
MMK to MCK	2,963
MCK to TJB	1,956
Total	7,937

4.3.3.3 Reduction in Maintenance Cost

According to Transportation research record an increment of 50 trucks will increase maintenance cost by 183.1$ per year per mile. For the above consideration the saving in maintenance cost of roads by the country will be PKR 5.17 million for the reduction of 7937 trucks movement. The section wise saving in maintenance cost is shown in the table 4.17

Table 4. 17 Savings in Maintenance Cost (Model-I)

Section	Saving in Maintenance Cost
KAR to MMK	1.96
MMK to MCK	1.93
MCK to TJB	1.27
Total	5.17

Note: Unit PKR Million/mile

4.4 MODEL-II

This model proposes the utilization of pipelines at their full capacity. WOP and MFM the two major pipelines are not used at full capacity, according to oil industry report during FY 2019-20 the capacity utilization of WOP and MFM was 286.6% and 31.3% respectively(OGRA Petroleum Industry report 2019-20).WOP pipeline is recently upgraded for the movement of MOGAS as it was used for HSD only in recent past. The MFM pipeline up gradation is under process and it is hoped that it will be completed by end of 2022. WOP capacity is 12 million tons/year and that of MFM is 7.5 million tons/year (OGRA Petroleum Industry report 2019-20).

Following provisions were considered while formulating this model

- Railway share remains 20% for all sections.
- MFM is upgraded for dual product transportation as well.
- HSD is given priority to be transported through pipelines, if demand exceeds capacity then surplus MOGAS and HSD quantity moved through roads and railways.

4.4.1 Section Wise Share of Different Modes (Model-II)

This model proposes the utilization of pipelines at full capacity. Currently Karachi-Mahmoodkot Section and Mahmoodkot-Machike Section are traversed by pipelines so impacts will be seen on these two sections.

4.4.1.1 Karachi to Mahmoodkot

This section will observe changes as WOP traverses from this section. 68.90% of total MOGAS consumption and 58.67% of total HSD consumption is to be moved through this section. This total into 19.57 million tons, so this reveals that the total demand can’t be transported through pipelines if they are used at their full capacity. Iterations were done to calculate the possible share of MOGAS and HSD through WOP.

HSD was given priority so at max the 70% HSD and 55% MOGAS available for transportation in this section can be transported through WOP.

4.4.1.2 Mahmoodkot to Machike

MFM pipeline capacity is 7.5 million tons. For this section 58.78% MOGAS and 68% HSD of total consumption is available for transportation, if the quantity of both HSD and MOGAS is summed 19.2 million tons is to be transported through this section. The required quantity for transportation clearly exceeds the MFM capacity. So iterations are done to calculate percentage wise share of HSD and MOGAS so that it can be transported through the MFM pipeline.

4.4.1.3 Machike to Tarujabba

This model doesn't incorporate construction of new oil pipeline and currently no oil pipeline exists between this region so the share of each mode in this section will not change. Percentage share of each mode on different sections is shown in Figure 4.6

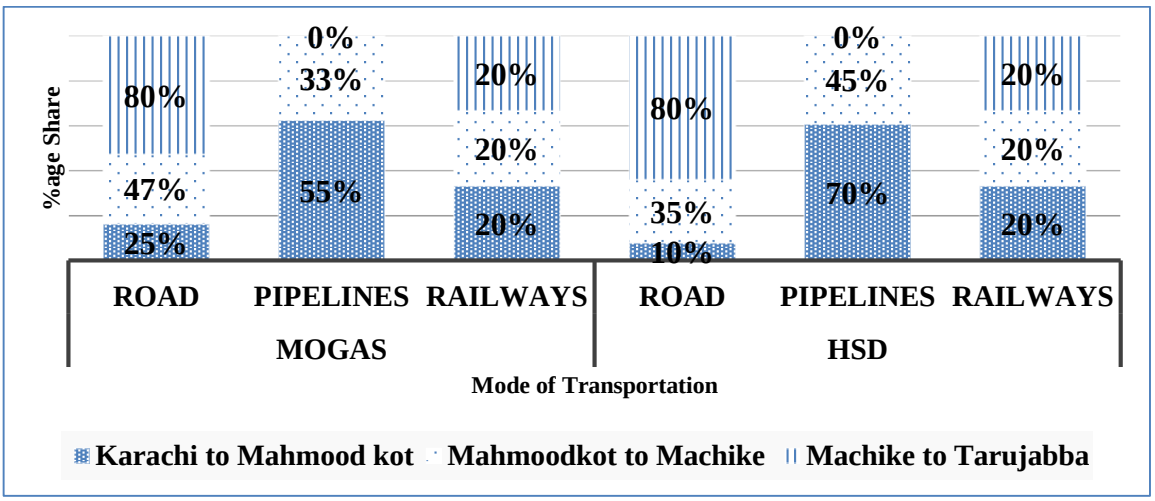

Figure 4. 6 Section Wise %age Share (Model-II)

4.4.2 Benefits of Model-II

4.4.2.1 Monetary Savings

This model will reduce movement of 9.36 million tons through roads, as pipelines are three times cheaper than road transportation country will save further PKR 63.6 billion with respect to existing scenario.

Table 4. 18 Increment in Quantity of Pipeline and Revenue Saved

Section	Additional Burden on Railway	Savings
KAR to MMK	4.62	36.8
MMK to MCK	4.74	26.7
MCK to TJB	0.00	0.00
Total	9.36	63.6

Note: Unit Quantity in MTO and Savings in PKR Million

4.4.2.2 Reduction in Trucks Movement

Movement of 9.36 million tons through pipeline will reduce trucks movement on two sections Karachi-Mahmoodkot section and Mahmoodkot-Machike section, trucks reduced will be 3,950 and 4,054 respectively. Machike-Tarujabba trucks movement will not be reduced as this model have no impact on this section.

Table 4. 19 Reduction in Trucks Movement (Model-II)

Section	Reduced No. of Trucks
KAR to MMK	3,950
MMK to MCK	4,054
MCK to TJB	0
Total	8,004

4.4.2.3 Reduction in Maintenance Cost

The reduction of 8,000 trucks will save a total revenue of PKR 5.21 million per mile otherwise which would be lost. Greater number of trucks reduced on Mahmoodkot-Machike section so greater revenue saved and on Machike-Tarujabba section as no trucks movement were reduced so no saving in terms of maintenance.

Table 4. 20 Savings in Maintenance Cost (Model-II)

Section	Saving in Maintenance Cost
KAR to MMK	2.57
MMK to MCK	2.64
MCK to TJB	0.00
Total	5.21

Note: Unit PKR Million/mile

4.5 MODEL-III

Pipelines are the safest and efficient mode of transportation and if Pakistan extends its pipeline network majority of the current problems can be solved. Machike Thallian Tarujabba pipeline is under construction. The pipeline is intended to transport both MOGAS and HSD. Through its completion a network of pipelines from Karachi to Tarujabba will be established. The following consideration were taken while formulating this model

- Machike-Thallian-Tarujabba pipeline is complete and its capacity is fully utilized
- Railway share remains same as 20 %
- Other Pipelines are also utilized at their full capacity

4.5.1 Machike Thallian Tarujabba WOP Pipeline

Before discussing and analyzing this scenario some brief discussion about Machike-Thallian-Tarujabba project is necessary, as existing pipelines are discussed previously.

The length of this pipeline is 427km. This is a BOT project of FOC through which it is aimed that a multi-product pipeline from Karachi to Khyber is completed. This project is aimed to reduce transportation cost, reduce congestion on roads, and reduce deadly accidents due to oil tankers, degradation rate of environment and a reliable transportation of petroleum products. This pipeline is aimed to transport crude oil, HSD and MOGAS. This pipeline will have capacity to transport 7 MT/Year. This line will start from Machike and will traverse Chak Pirana, Thallian, Rawat and Tarujabba will be its end terminal. The segments of pipeline are

1. Machike-Chak Pirana length approximately 135km
2. Chak pirana-Rawat approximately 117km
3. Rawat-Tarujabba approximately 175km

The alignment of this pipeline is shown in Figure 4.7

Figure 4. 7 Machike-Thallian-Tarujabba Pipeline

Source: Frontier Oil Company (FOC)

As shown in the figure this pipeline traverses THALIAN where a new storage is aimed to be built, and from there a subsidiary can also be built to connect it with Attock refinery limited (ARL).

4.5.2 Section Wise Share of Different Modes (Model-III)

This model will affect the Machike-Tarujabba section, the other two section will not observe any changes in their mode wise percentage share.

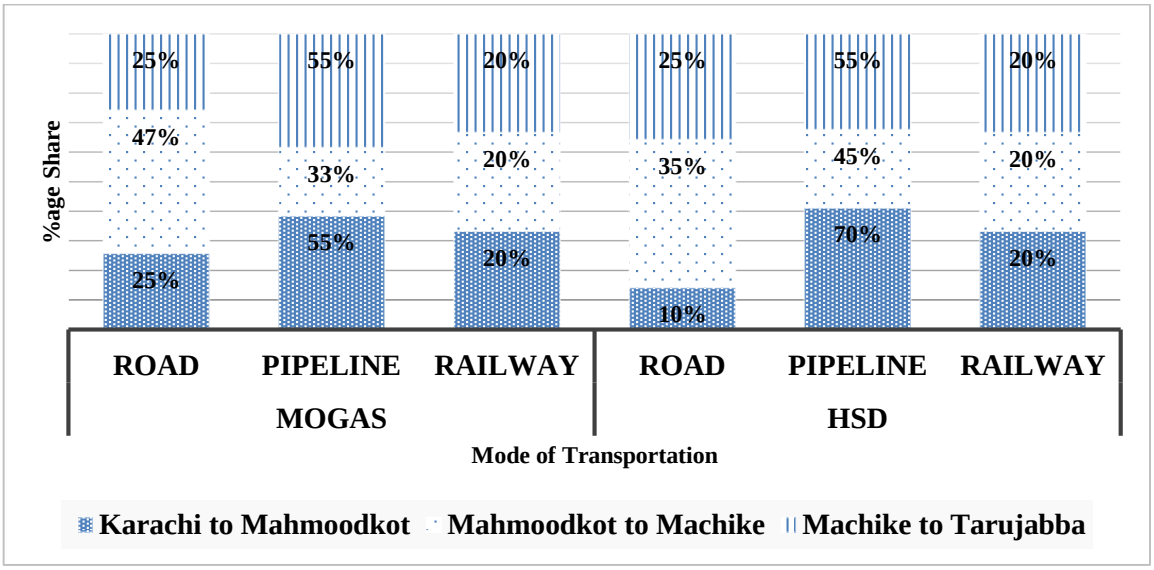

Figure 4. 8 Section Wise Share %age Share (Model-III)

4.5.2.1 Machike to Tarujabba

The pipeline initial capacity is claimed will be 7 million tons/year. If used with full capacity 55 % share of both MOGAS and HSD for FY2022-23, will be transferred from road to pipelines. The share of this section in the previous model and this model are shown as

4.5.3 Benefits of Model-III

Benefits of Model-III are discussed in the following sub sections

4.5.3.1 Monetary Savings

This model will reduce movement of 6.99 million tons through roads, as pipelines are three times cheaper than road transportation country will save further PKR 33.8 billion in addition to PKR 63 billion saving from Model-II, with respect to existing scenario.

Table 4. 21 Increment Quantity Section Wise of Pipeline and Revenue Saved

Section	Additional Burden on Railway	Savings
KAR to MMK	0.00	0.00
MMK to MCK	0.00	0.00
MCK to TJB	6.99	33.8
Total	6.99	33.8

Note: Unit in PKR million

4.5.3.2 Reduction in Trucks Movement

Movement of 6.99 million tons through pipeline will reduce trucks movement on two sections. On Machike-Tarujabba 5,975 trucks movement will be reduced.

Table 4. 22 Section Wise Reduction in Trucks Movement

Section	Reduced No. of Trucks
KAR to MMK	0
MMK to MCK	0
MCK to TJB	5,975
Total	5,975

4.5.3.3 Reduction in Maintenance Cost

The reduction of 59,75 trucks will save a total revenue of PKR 3.89 million per mile in addition to PKR 5.21 million from Model-II, otherwise which would be lost. A large number of trucks reduced on Machike-Tarujabba section so revenue will be saved on this section.

Table 4. 23 Section Wise Savings in Maintenance Cost

Section	Saving in Maintenance cost
KAR to MMK	0.00
MMK to MCK	0.00
MCK to TJB	3.89
Total	3.89

Note: Unit PKR Million/mile

4.6 MODEL-III ANALYSIS FOR FUTURE

Model-III looks very beneficial for FY 2022-23, as on all sections trucks movement will be reduced and will save maximum revenue in terMOGAS of transportation charges and maintenance charges. Analyzing how this model will function for 2030 demand. By 2030 country MOGAS demand will be 30.41 million tons and HSD demand will be 16.82 million tons (SAARC 2019).

4.6.1 Determining Possible Section Wise Shares for Each Mode

For 2030 using the predicted demand calculation shows that the percentage share used in Model-III for FY 2022-23 can't be transported through the pipelines. New share will be calculated by reducing MOGAS share through pipelines to equalize it to capacity.

Table 4. 24 Railway Capacity Vs Surplus Analysis (MOGAS)

Variable	Section			
	Product	KAR to MMK	MMK to MCK	MCK to TJB
%age Share to be moved	MOGAS	68.9	58.78	40.52
Railway Share		4.19	3.57	2.46
Remaining		16.76	14.29	9.85

Note: Unit in Million Tons

Table 4. 25 Railway Capacity Vs Surplus Analysis (HSD)

Variable	Section			
	Product	KAR to MMK	MMK to MCK	MCK to TJB
%age Share to be moved	HSD	9.86	11.43	7.23
Railway Share		1.97	2.28	1.44
Remaining		7.88	9.14	5.78

Note: Unit in Million Tons

Table 4. 26 Pipeline Capacity Vs Surplus Analysis

Pipeline	Capacity	Quantity Available for Movement	Surplus of Capacity
WOP	12	24.648	12.648
MFM	7.5	23.44	15.94
MTT	7	15.64	8.64

Note: Unit in Million Tons

4.6.1.1 Karachi to Mahmoodkot

Keeping the HSD share same as now the new share of road will be 75.65% which is 15.85 million tons.

4.6.1.2 Mahmoodkot to Machike

Keeping the HSD share same as now the new share of road will be 86.85% which is 15.52 million tons.

4.6.1.3 Machike to Tarujabba

Keeping the HSD share same as now the new share of road will be 68.51% which is 8.43 million tons.

Table 4. 27 Quantity to be Moved Through Road (2030)

Section	Extra burden on road	
	%age Share	Quantity (MTO)
KAR to MMK	75.65	15.85
MMK to MCK	86.85	15.52
MCK to TJB	68.51	8.43

4.6.2 Problems of Model-III in Future 2030

A study was carried to determine how long Pakistani roads had left in service. Over 10,000 kilometers of road were evaluated, and it was discovered that 11% of roads are on the verge of failing, 22% have a service life of 0 to one year, and only 16% have a service life of more than five years. The international roughness index (IRI) of roads was 5.65 in 2014-15, according to NHA figures (Ashraf 2012).This IRI value shows that the roads are in poor condition if a normal travel speed of 60 km/hr is used. This number would rise by 6.5 percent, as a result of increasing traffic from the CPEC, aggravating

the situation even more (Irfan, Mehmood et al. 2018). The above studies show if Model-III is continued, in 2030 due to a significant increase in demand will made the situation very problematic. Some of the problems are discussed in following sub sections.

4.6.2.1 Large Trucks Movement

Movement of 15.85 million tons through road will require 13,550, 13,266 and 7,206 truck movements on Karachi to Mahmoodkot, Mahmoodkot to Machike and Machike to Tarujabba sections respectively. This increment will cause increment in accidents and will cause unbearable congestion on roads.

Table 4. 28 Section Wise Increase in Trucks Movement

Section	Trucks Movement Increased
KAR to MMK	13,549
MMK to MCK	13,266
MCK to TJB	7,206
Total	34,021

4.6.2.2 Increase in maintenance cost

The increase of 3,4021 trucks movement will cause maintenance cost to increase by PKR 22.16 million per mile. As obvious larger truck movement will be required on Karachi to Mahmoodkot section so this section will observe the largest increment of PKR 8.83 million in maintenance cost.

Table 4. 29 Section Wise Increase in Maintenance Cost

Section	Increment in Maintenance Cost
KAR to MMK	8.83
MMK to MCK	8.64
MCK to TJB	4.69
Total	22.16

Note: Unit in PKR Million /mile

4.7 SUMMARY

This chapter focused on developing possible models for Pakistan's oil supply chain that can help cut transportation costs, alleviate traffic congestion, and protect the environment. Three different models were proposed, and their advantages were discussed. Model-I offers just a railway share increase; however, the capacity of the railway to withstand the increased load was checked, and it was found that the railway can easily accept the additional share without any upgrades or policy changes. Model-III

was further examined for 2030 demand, as well as a few of the potential issues Pakistan would encounter. Model-I, Model-II, and Model-III will save PKR 30 billion, PKR 63 billion, and PKR 97 billion, respectively, if optimized models are implemented. The movement of trucks can be minimized if certain measures are taken.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

The study's main purpose was to examine Pakistan's current petroleum supply chain in depth, identify flaws, and recommend long-term remedies to improve its transportation efficiency. Efficient practices were explored by looking at the models used by advanced countries. The best possible solutions were found by maximizing the use of pipelines and railway infrastructure. Current and future oil demand, as well as pipeline and PR transportation capacity, were examined, and the best models were suggested. Model-I advocated a 20 percent increase in railway share, Model-II proposed fully utilizing the capacity of Pakistan's major pipelines (WOP and MFM), and Model-III proposed full utilization of the pipeline (under construction) MTT.

5.2 REVIEW OF RESEARCH OBJECTIVES

The objectives of this study are:

- To analyze current POL transportation supply chain management of Pakistan.
- Formulation of framework for POL transportation, considering cost effectiveness, safety and best practices adopted by progressing economies.

Collection of facts and recognizing the shortcomings and problems of Pakistan petroleum supply chain fulfilled the requirement of first objective. The research found out the modes of transportation for oil, their corresponding shares, their utilization and the vacant capacity of pipelines and railways that can be utilized for POL transportation. The second objective to formulate possible effective models for Pakistan oil supply chain was met by developing various different models, by increasing share of railway and pipeline and utilizing their full potential. Additionally, based on the findings recommendation were offered to further optimize the supply chain.

5.3 FINDINGS OF THE STUDY

The following points were concluded while conducting this study in relation to the objectives are discussed below in the sub sections.

5.3.1 Pakistan Petroleum Supply Chain (PSC)– An Inefficient Model

- Freight transportation model followed by developing and developed countries is to reduce road share in freight transportation with time. In Pakistan the share increased with time (Khan 2019).
- Pipelines is the preferred mode used by major developed countries. US pipeline share is 71% in oil transportation where Pakistan **pipeline share is only 29%** (Pipelines 2015, OGRA Petroleum Industry report 2019-20).
- Pipelines are fully utilized for oil transportation in developed countries, unfortunately Pakistan even doesn't utilize its pipeline capacity by 50% (OGRA Petroleum Industry report 2019-20).
- Neighborhood country India pipelines share is 52% and Rail share is 16%. While in Pakistan railway share is only 2% (India 2015).
- Developed countries imports oil from countries on different ports, in Pakistan the imports are majorly received at Karachi ports which then require large distance hauling (OGRA Petroleum Industry report 2019-20).
- Refineries are distributed in developed countries evenly or at multiple locations. In Pakistan the refineries are not evenly located.
- These points clearly highlight the inefficiency of Pakistan Petroleum Supply chain.

5.3.2 Problems of Existing PSC

a. Road sector is the costliest mode of Freight transportation, Pakistan transports majority of Oil through road so the cost per metric ton is the highest.
b. The oil tankers transportation is degrading road service by increasing the maintenance cost.
c. The oil tankers cause congestion on roads and are the one of the major contributor to fatal accidents.
d. The current supply chain bear losses in the form of oil stolen as well. Almost $ 200 million worth furnace oil annually is stolen while transporting it through oil tankers.
e. Oil tankers are not traced are supervised during its transportation journey except Shell Company (Commission report 2020).

5.4 CONCLUSIONS

Based on a review of existing petroleum supply chain management in Pakistan and best practices adopted by developing/developed countries, this study proposes 3x Models, with the following conclusions:

5.4.1 Model-I: Railway Share Increased from 2% to 20%

a. Model-I can save a total of **PKR 30 billion** revenue annually if implemented.
b. Model-I can reduce a total of **7,937 trucks** movement annually on all the three sections.
c. Model-I can save **PKR 5.17** per year per mile million annually in terms of maintenance cost.

5.4.2 Model-II: Existing Pipelines Utilized at Full Capacity

a. Model-II can save a total of **PKR 6.3 billion** annually with respect to existing scenario million revenue if implemented.
b. Model-II can reduce a total of **8,004 trucks** movement annually in addition to reduction through Model-I on all the three sections.
c. Model-II can save **PKR 5.21 million** per year per mile million annually in addition to saving through Model-I in terms of maintenance cost.

5.4.3 Model-III: MTT Pipeline Built and Used at Full Capacity

a. Model-III can save a total of **PKR 33.83 billion** annually revenue in addition to saving through Model-II if implemented.
b. Model-III can reduce a total of **5,975 trucks** movement annually in addition to reduction through Model-II on all the three sections.
c. Model-III can save **PKR 3.89 million** per year per mile million annually in addition to saving through Model-II in terms of maintenance cost.

5.4.4 Model-III for Demand of FY 2030:

a. Model-III if not upgraded further will move **12.66, 15.96 and 8.66 million tons** annually back to road on Karachi-Mahmoodkot, Mahmoodkot-Machike and Machike-Tarujabba section respectively.
b. Model-III capacity if not upgraded further will need **10,820, 13,266 and 7,206 trucks** movement annually Karachi-Mahmoodkot, Mahmoodkot-Machike and Machike-Tarujabba section respectively.

5.5 RECOMMENDATIONS

Following necessary measures are recommended for short term and long term benefits

5.5.1 Formulation of SOPs

Standard operating procedures for transportation of POL neither exists properly nor are they implemented completely. If proper SOPs are formulated and they are implemented this will benefit all stakeholders.

5.5.2 New Pipeline

FOC subsidiary of FWO has already requested for grant of permission to construct new pipeline from Mahmoodkot to Tarujabba. The permission was granted for Machike-Tarujabba section; this will indeed benefit the supply chain but to cater future demand Mahmoodkot-Machike section should also be enhanced capacity wise with addition of new pipeline.

5.5.3 Capacity Enhancement of Machike-Tarujabba Pipeline

With the construction of Machike-Tarujabba pipeline major problems of this section will be solved. But with the increase in demand, in 2030 new problems will surge. To cater the future problems capacity of this pipeline section be enhanced, as FOC claimed capacity can be enhanced.

5.5.4 Increase in Railway Share

From 2016-19 the railway share is decreased from 4% to 2% instead of increasing (OGRA Petroleum Industry report 2019-20).To assist the POL industry in solving current and future forecasted problems PR share should be increased.

5.5.5 Increase in Storage Capacity

Pakistan storage capacity of oil at different locations should be increased so that the daily movement over large distances can be decreased.

5.5.6 Multiple Import Handling Points

Pakistan major imports are handled at Karachi ports, more handling points for oil should be developed to decrease burden on Karachi-Mahmoodkot section.

5.5.7 Capacity Enhancement /New Refineries Construction

Consumption on north is more than the production capacity of refineries, if capacities of these refineries are enhanced or new refineries are built long distance movement from Mahmoodkot north up can be reduced.

5.6 KNOWLEDGE CONTRIBUTION

This study was a pioneer effort to analyze current supply chain, identify its loop holes and propose suitable models which can solve these problems to a maximum extent. Indeed, all stakeholders will be benefited if the proposed steps are undertaken. This study revealed the need of further research in this area through evaluation.

REFERENCES

Ashraf, E. T. (2012). "Maintenance of Roads in Pakistan."

commision, E. P. (2020). "Ch 19 Energy."

Commission report, C. G. o. P. (2020). "REPORT OF THE INQUIRY COMMISSION ON SHORTAGE OF PETROLEUM PRODUCTS IN PAKISTAN ".

Frontier Oil Company, F. (2019). "Application for construction of new Pipeline."

Gibby, R., R. Kitamura and H. Zhao (1990). "Evaluation of truck impacts on pavement maintenance cost." Transportation Research Record **1262**: 48-56.

India, P. (2015). "Petroleum Planning and analysis cell India."

Irfan, M., Y. Mehmood, A. Ahmed and H. Wang (2018). "Highway Asset Management Framework for Longevity of Infrastructure–A Case Study for China-Pakistan Economic Corridor." American Journal of Civil Engineering **6**(6): 185-194.

Islamabad, P. I. o. D. E. (2021). "Gas and Petroleum Market Structure and Pricing."

Khan, E. U. (2019). "REVITILIZATION OF PAKISTAN RAILWAYS FREIGHT TRANSPORTATION UNDER CPEC (CHINA PAKISTAN ECONOMIC CORRIDOR) SCENARIO."

MAHMOOD HASAN, C. O. S. N. C. o. S. T. (2015). "Revival of Pakistan Railways."

Ministry of Planning development & Special Initiatives , G. o. P. (2021). "Pakistan Energy Demand Forecast (2021-30)."

NTRC, G. O. P., MINISTRY OF COMMUNICATIONS (2018). "National Road Safety Strategy 2018-30."

NUST, S. (2017). "Pilot Traffic Study on N-5."

OGRA (2019). "Determination of MOGAS tarriff."

OGRA, G. o. P. (2018). "Determination of MOGAS WOP tariff."

OGRA News, G. o. P. (2021). "OGRA NEWS BRIEF."

OGRA Petroleum Industry report, G. o. P. (2019-20). "Petroleum Industry Report 2019-20."

OMCs, P. (2019). "OIL MARKETING COMPANIES."

OMCs Sector, P. (2020). "OMCs sector study."

PACRA (2020). "Pakistan pipelines sector study."

Pakistan, C. C. o. (2016). "Road Freight transport sector & Emerging competitive Dynamics."

PIDE (2021). "Gas and Petroleum sector and priceing."

Pipeline report, P. (2021). "Pipeline Network Sector Study

".

Pipelines, A. o. O. (2015). "Oil transportaion through Pipelines."

SAARC (2018). "SAARC Energy Outlook 2030."

SAARC, C. (2019). "SAARC Energy Outlook 2030."

Usama, E. (2016). "REVITILIZATION OF PAKISTAN RAILWAYS FREIGHT TRANSPORTATION UNDER CPEC (CHINA PAKISTAN ECONOMIC CORRIDOR) SCENARIO."

ANNEXURES

ANNEXURE – A

EXISTING SCENARIO COST CALCULATION (SECTION 1)

Existing Scenario		
Section: Karachi to Mahmoodkot		
MOGAS		
Demand(MOGAS) (68.9% to be transported north up)	11.51	MTO
Share of Road	69.00	%
Quantity through roads	7.94	MTO
Share of pipelines	29.00	%
Quantity through pipelines	3.33	MTO
Share of Railways	2.00	%
Quantity through railways	0.23	MTO
Cost per MT of roads	6,018.00	Rupees
Cost per MT of pipelines	2,006.00	Rupees
Cost per MT of Railways	2,360.00	Rupees
T.cost through Roads	47,796.15	PKR Million
T. cost through pipelines	6,696.07	PKR Million
T. cost through railways	543.29	PKR Million
Total	55,035.52	PKR Million
HSD		
Demand(HSD) (58.67% to be transported north up)	8.10	MTO
Share of Road	69.00	%
Quantity through roads	5.59	MTO
Share of pipelines	29.00	%
Quantity through pipelines	2.35	MTO
Share of Railways	2.00	%
Quantity through railways	0.16	MTO
Cost per MT of roads	5,562.14	Rupees
Cost per MT of pipelines	1,854.04	Rupees
Cost per MT of Railways	2,182.00	Rupees
T.cost through Roads	31,118.24	PKR Million
T. cost through pipelines	4,359.56	PKR Million
T. cost through railways	353.84	PKR Million
Total	35,831.65	PKR Million

ANNEXURE – B

EXISTING SCENARIO COST CALCULATION (SECTION 2)

Existing Scenario		
Section: Mahmoodkot to Machike		
MOGAS		
Demand(MOGAS) (58.78% to be transported north up)	9.81	MTO
Share of Road	98.00	%
Quantity through roads	9.62	MTO
Share of pipelines	0.00	%
Quantity through pipelines	0.00	MTO
Share of Railways	2.00	%
Quantity through railways	0.19	million tons
Cost per MT of roads	6,681.00	Rupees
Cost per MT of pipelines	2,227.00	Rupees
Cost per MT of Railways	2,620.00	Rupees
T.cost through Roads	64,293.87	PKR Million
T. cost through pipelines	0.00	PKR Million
T. cost through railways	514.55	PKR Million
Total	64,808.43	PKR Million
HSD		
Demand(HSD) (68% to be transported north up Mahmoodkot)	9.39	MTO
Share of Road	69.00	%
Quantity through roads	6.48	MTO
Share of pipelines	29.00	%
Quantity through pipelines	2.72	MTO
Share of Railways	2.00	%
Quantity through railways	0.18	MTO
Cost per MT of roads	2,552.00	Rupees
Cost per MT of pipelines	850.70	Rupees
Cost per MT of Railways	1,000.82	Rupees
T.cost through Roads	16,548.04	PKR Million
T. cost through pipelines	2,318.41	PKR Million
T. cost through railways	188.10	PKR Million
Total	19,054.56	PKR Million

ANNEXURE – C

EXISTING SCENARIO COST CALCULATION (SECTION 3)

Existing Scenario		
Section: Machike to Tarujabba		
MOGAS		
Demand(MOGAS) (40.52% to be transported north up)	6.76	MTO
Share of Road	98.00	%
Quantity through roads	6.63	MTO
Share of pipelines	0.00	%
Quantity through pipelines	0.00	MTO
Share of Railways	2.00	%
Quantity through railways	0.13	MTO
Cost per MT of roads	7,878.15	Rupees
Cost per MT of pipelines	2,626.05	Rupees
Cost per MT of Railways	3,089.00	Rupees
T.cost through Roads	52,262.74	PKR Million
T. cost through pipelines	0.00	PKR Million
T. cost through railways	418.20	PKR Million
Total	52,680.95	PKR Million
HSD		
Demand(HSD) (43% to be transported north up Machike)	5.94	MTO
Share of Road	98.00	%
Quantity through roads	5.82	MTO
Share of pipelines	0.00	%
Quantity through pipelines	0.00	MTO
Share of Railways	2.00	%
Quantity through railways	0.11	MTO
Cost per MT of roads	2,984.73	Rupees
Cost per MT of pipelines	994.91	Rupees
Cost per MT of Railways	1,170.48	Rupees
T.cost through Roads	17,382.31	PKR Million
T. cost through pipelines	0.00	PKR Million
T. cost through railways	139.11	PKR Million
Total	17,521.42	PKR Million

ANNEXURE – D

MODEL-I COST CALCULATION (SECTION 1)

Model-I: Railway share is increased to 20%		
Section: Karachi to Mahmoodkot		
MOGAS		
Demand(MOGAS) (68.9% to be transported north up)	11.50	MTO
Share of Road	51.00	%
Quantity through roads	5.87	MTO
Share of pipelines	29.00	%
Quantity through pipelines	3.33	MTO
Share of Railways	20.00	%
Quantity through railways	2.30	million tons
Cost per MT of roads	6,018.00	Rupees
Cost per MT of pipelines	2,006.00	Rupees
Cost per MT of Railways	2,360.00	Rupees
T.cost through Roads	35,327.59	PKR Million
T. cost through pipelines	6,696.07	PKR Million
T. cost through railways	5,432.92	PKR Million
Total	47,456.59	PKR Million
HSD		
Demand(HSD) (58.67% to be transported north up)	8.10	MTO
Share of Road	51.00	%
Quantity through roads	4.13	MTO
Share of pipelines	29.00	%
Quantity through pipelines	2.35	MTO
Share of Railways	20.00	%
Quantity through railways	1.62	MTO
Cost per MT of roads	5,562.14	Rupees
Cost per MT of pipelines	1,854.04	Rupees
Cost per MT of Railways	2,182.00	Rupees
T.cost through Roads	23,000.44	PKR Million
T. cost through pipelines	4,359.56	PKR Million
T. cost through railways	3,538.41	PKR Million
Total	30,898.42	PKR Million

ANNEXURE – E

MODEL-I COST CALCULATION (SECTION 2)

Model-I: Railway share is increased to 20%		
Section: Mahmoodkot to Machike		
MOGAS		
Demand(MOGAS) (58.78% to be transported north up)	9.81	MTO
Share of Road	80.00	%
Quantity through roads	7.85	MTO
Share of pipelines	0.00	%
Quantity through pipelines	0.00	MTO
Share of Railways	20.00	%
Quantity through railways	1.96	MTO
Cost per MT of roads	6,681.00	Rupees
Cost per MT of pipelines	2,227.00	Rupees
Cost per MT of Railways	2,620.00	Rupees
T.cost through Roads	52,484.79	PKR Million
T. cost through pipelines	0.00	PKR Million
T. cost through railways	5,145.56	PKR Million
Total	57,630.36	PKR Million
HSD		
Demand(HSD) (68% to be transported north up Mahmoodkot)	9.39	MTO
Share of Road	51.00	%
Quantity through roads	4.79	MTO
Share of pipelines	29.00	%
Quantity through pipelines	2.72	MTO
Share of Railways	20.00	%
Quantity through railways	1.87	million tons
Cost per MT of roads	2,552.00	Rupees
Cost per MT of pipelines	850.70	Rupees
Cost per MT of Railways	1,000.82	Rupees
T.cost through Roads	12,231.16	PKR Million
T. cost through pipelines	2,318.41	PKR Million
T. cost through railways	1,881.06	PKR Million
Total	16,430.64	PKR Million

ANNEXURE – F

MODEL-I COST CALCULATION (SECTION 3)

Model-I: Railway share is increased to 20%		
Section: Machike to Tarujabba		
MOGAS		
Demand(MOGAS) (40.52% to be transported north up)	6.76	MTO
Share of Road	80.00	%
Quantity through roads	5.41	MTO
Share of pipelines	0.00	%
Quantity through pipelines	0.00	MTO
Share of Railways	20.00	%
Quantity through railways	1.35	MTO
Cost per MT of roads	7,878.15	Rupees
Cost per MT of pipelines	2,626.05	Rupees
Cost per MT of Railways	3,089.00	Rupees
T.cost through Roads	426,63.467	PKR Million
T. cost through pipelines	0.00	PKR Million
T. cost through railways	4,182.05	PKR Million
Total	46,845.52	PKR Million
HSD		
Demand(HSD) (43% to be transported north up Machike)	5.94	MTO
Share of Road	80.00	%
Quantity through roads	4.75	MTO
Share of pipelines	0.00	%
Quantity through pipelines	0.00	MTO
Share of Railways	20.00	%
Quantity through railways	1.18	million tons
Cost per MT of roads	2,984.73	Rupees
Cost per MT of pipelines	994.91	Rupees
Cost per MT of Railways	1,170.48	Rupees
T.cost through Roads	14,189.64	PKR Million
T. cost through pipelines	0.00	PKR Million
T. cost through railways	139,1.14	PKR Million
Total	1558,0.78	PKR Million

ANNEXURE – G

MODEL-II COST CALCULATION (SECTION 1)

Model-II: Pipeline used at full capacity		
Section: Karachi to Mahmoodkot		
MOGAS		
Demand(MOGAS) (68.9% to be transported north up)	11.51	MTO
Share of Road	25.00	%
Quantity through roads	2.87	MTO
Share of pipelines	55.00	%
Quantity through pipelines	6.33	MTO
Share of Railways	20.00	%
Quantity through railways	2.30	MTO
Cost per MT of roads	6,018.00	Rupees
Cost per MT of pipelines	2,006.00	Rupees
Cost per MT of Railways	2,360.00	Rupees
T.cost through Roads	17,317.44	PKR Million
T. cost through pipelines	12,699.46	PKR Million
T. cost through railways	5,432.92	PKR Million
Total	35,449.83	PKR Million
HSD		
Demand(HSD) (58.67% to be transported north up)	8.10	MTO
Share of Road	10.00	%
Quantity through roads	0.81	MTO
Share of pipelines	70.00	%
Quantity through pipelines	5.67	MTO
Share of Railways	20.00	%
Quantity through railways	1.62	MTO
Cost per MT of roads	5,562.14	Rupees
Cost per MT of pipelines	1,854.04	Rupees
Cost per MT of Railways	2,182.00	Rupees
T.cost through Roads	4,509.89	PKR Million
T. cost through pipelines	10,523.08	PKR Million
T. cost through railways	3,538.41	PKR Million
Total	18,571.39	PKR Million

ANNEXURE – H

MODEL-II COST CALCULATION (SECTION 2)

Model-II: Pipeline used at full capacity		
Section: Mahmoodkot to Machike		
MOGAS		
Demand(MOGAS) (58.78% to be transported north up)	9.81	MTO
Share of Road	47.00	%
Quantity through roads	4.61	MTO
Share of pipelines	33	%
Quantity through pipelines	3.24	MTO
Share of Railways	20	%
Quantity through railways	1.96	MTO
Cost per MT of roads	6,681.00	Rupees
Cost per MT of pipelines	2,227.00	Rupees
Cost per MT of Railways	2,620.00	Rupees
T.cost through Roads	30,834.82	PKR Million
T. cost through pipelines	7,216.66	PKR Million
T. cost through railways	5,145.56	PKR Million
Total	43,197.05	PKR Million
HSD		
Demand(HSD) (68% to be transported north up Mahmoodkot)	9.39	MTO
Share of Road	35.00	%
Quantity through roads	3.28	MTO
Share of pipelines	45.00	%
Quantity through pipelines	4.22	MTO
Share of Railways	20.00	%
Quantity through railways	1.87	MTO
Cost per MT of roads	2,552.00	Rupees
Cost per MT of pipelines	850.70	Rupees
Cost per MT of Railways	1,000.82	Rupees
T.cost through Roads	8,393.93	PKR Million
T. cost through pipelines	3597.54	PKR Million
T. cost through railways	1,881.06	PKR Million
Total	13,872.54	PKR Million

ANNEXURE – I

MODEL-II COST CALCULATION (SECTION 3)

Model-II: Pipeline used at full capacity		
Section: Machike to Tarujabba		
MOGAS		
Demand(MOGAS) (40.52% to be transported north up)	6.76	MTO
Share of Road	80.00	%
Quantity through roads	5.41	MTO
Share of pipelines	0.00	%
Quantity through pipelines	0.00	MTO
Share of Railways	20.00	%
Quantity through railways	1.35	MTO
Cost per MT of roads	7,878.15	Rupees
Cost per MT of pipelines	2,626.05	Rupees
Cost per MT of Railways	3,089.00	Rupees
T.cost through Roads	42,663.47	PKR Million
T. cost through pipelines	0.00	PKR Million
T. cost through railways	4,182.05	PKR Million
Total	46,845.52	PKR Million
HSD		
Demand(HSD) (43% to be transported north up Machike)	5.94	MTO
Share of Road	80.00	%
Quantity through roads	4.75	MTO
Share of pipelines	0.00	%
Quantity through pipelines	0.00	MTO
Share of Railways	20.00	%
Quantity through railways	1.18	MTO
Cost per MT of roads	2,984.73	Rupees
Cost per MT of pipelines	994.91	Rupees
Cost per MT of Railways	1,170.48	Rupees
T.cost through Roads	14,189.65	PKR Million
T. cost through pipelines	0.00	PKR Million
T. cost through railways	1,391.14	PKR Million
Total	15,580.79	PKR Million

ANNEXURE – J

MODEL-III COST CALCULATION (SECTION 1)

Model-III:Tarujabba pipeline built & Other Pipes used at full capacity		
Section: Karachi to Mahmoodkot		
MOGAS		
Demand(MOGAS) (68.9% to be transported north up)	11.51	MTO
Share of Road	25.00	%
Quantity through roads	2.87	MTO
Share of pipelines	55.00	%
Quantity through pipelines	6.33	MTO
Share of Railways	20.00	%
Quantity through railways	2.30	MTO
Cost per MT of roads	6,018.00	Rupees
Cost per MT of pipelines	2,006.00	Rupees
Cost per MT of Railways	2,360.00	Rupees
T.cost through Roads	17,317.44	PKR Million
T. cost through pipelines	12,699.46	PKR Million
T. cost through railways	5,432.92	PKR Million
Total	35,449.83	PKR Million
HSD		
Demand(HSD) (58.67% to be transported north up)	8.10	MTO
Share of Road	10.00	%
Quantity through roads	0.81	MTO
Share of pipelines	70.00	%
Quantity through pipelines	5.67	MTO
Share of Railways	20.00	%
Quantity through railways	1.62	MTO
Cost per MT of roads	5,562.14	Rupees
Cost per MT of pipelines	1,854.04	Rupees
Cost per MT of Railways	2,182.00	Rupees
T.cost through Roads	4,509.89	PKR Million
T. cost through pipelines	10,523.08	PKR Million
T. cost through railways	3,538.41	PKR Million
Total	18,571.39	PKR Million

ANNEXURE – K

MODEL-III COST CALCULATION (SECTION 2)

Model-III:Tarujabba pipeline built & Other Pipes used at full capacity		
Section: Mahmoodkot to Machike		
MOGAS		
Demand(MOGAS) (58.78% to be transported north up)	9.81	MTO
Share of Road	47.00	%
Quantity through roads	4.61	MTO
Share of pipelines	33.00	%
Quantity through pipelines	3.24	MTO
Share of Railways	20.00	%
Quantity through railways	1.96	MTO
Cost per MT of roads	62,681.00	Rupees
Cost per MT of pipelines	2,227.00	Rupees
Cost per MT of Railways	2,620.00	Rupees
T.cost through Roads	30,834.82	PKR Million
T. cost through pipelines	7,216.66	PKR Million
T. cost through railways	5,145.56	PKR Million
Total	43,197.05	PKR Million
HSD		
Demand(HSD) (68% to be transported north up Mahmoodkot)	9.39	MTO
Share of Road	35.00	%
Quantity through roads	3.28	MTO
Share of pipelines	45.00	%
Quantity through pipelines	4.22	MTO
Share of Railways	20.00	%
Quantity through railways	1.87	MTO
Cost per MT of roads	2,552.00	Rupees
Cost per MT of pipelines	850.70	Rupees
Cost per MT of Railways	1,000.82	Rupees
T.cost through Roads	8,393.93	PKR Million
T. cost through pipelines	3,597.54	PKR Million
T. cost through railways	1,881.06	PKR Million
Total	13,872.54	PKR Million

ANNEXURE – L

MODEL-III COST CALCULATION (SECTION 3)

Model-III:Tarujabba pipeline built & Other Pipes used at full capacity		
Section: Machike to Tarujabba		
MOGAS		
Demand(MOGAS) (40.52% to be transported north up)	6.76	MTO
Share of Road	25.00	%
Quantity through roads	1.69	MTO
Share of pipelines	55.00	%
Quantity through pipelines	3.72	MTO
Share of Railways	20.00	%
Quantity through railways	1.35	MTO
Cost per MT of roads	7,878.15	Rupees
Cost per MT of pipelines	2,626.05	Rupees
Cost per MT of Railways	3,089.00	Rupees
T.cost through Roads	13,332.33	PKR Million
T. cost through pipelines	9,777.04	PKR Million
T. cost through railways	4,182.05	PKR Million
Total	27,291.43	PKR Million
HSD		
Demand(HSD) (43% to be transported north up Machike)	5.94	MTO
Share of Road	25.00	%
Quantity through roads	1.48	MTO
Share of pipelines	55.00	%
Quantity through pipelines	3.26	MTO
Share of Railways	20.00	%
Quantity through railways	1.18	MTO
Cost per MT of roads	2,984.73	Rupees
Cost per MT of pipelines	994.91	Rupees
Cost per MT of Railways	1,170.48	Rupees
T.cost through Roads	4,434.26	PKR Million
T. cost through pipelines	3,251.79	PKR Million
T. cost through railways	1,391.14	PKR Million
Total	9,077.20	PKR Million

ANNEXURE – M

MODEL-I ANALYSIS (KAR TO MMK)

Model-I: Analysis			
Section: Karachi to Mahmoodkot			
MOGAS			
Demand in 2022-23		16.7	MTO
Demand (68.89% to be transported north up)		11.47	MTO
Share of Road	Existing Scenario	69	%
	Model-I	51	
Share of pipelines	Existing Scenario	29	%
	Model-I	29	
Share of Railways	Existing Scenario	2	%
	Model-I	20	
HSD			
Demand in 2022-23		13.82	MTO
Demand (58.67% to be transported north up)		8.1	MTO
Share of Road	Existing Scenario	69	%
	Model-I	51	
Share of pipelines	Existing Scenario	29	%
	Model-I	29	
Share of Railways	Existing Scenario	2	%
	Model-I	20	
Savings w.r.t Existing Scenario		12,512	PKR Million
Quantity movement reduction on roads	MOGAS	2.07	MTO
	HSD	1.46	MTO
	Total	3.53	MTO
Reduction in Trucks		3,018	Trucks
Saving in Maintenance Cost (Per Year Per Mile)		11,051.89	Dollar
		1.96	PKR Million

ANNEXURE – N

MODEL-I ANALYSIS (MMK TO MCK)

Model-I: Analysis			
Section: Mahmoodkot to Machike			
MOGAS			
Demand in 2022-23		16.7	MTO
Demand (58.78% to be transported north up)		9.81	MTO
Share of Road	Model-I	80	%
	Model-II	25	
Share of pipelines	Model-I	29	%
	Model-II	55	
Share of Railways	Model-I	20	%
	Model-II	20	
HSD			
Demand in 2022-23		13.82	MTO
Demand (68% to be transported north up)		9.39	MTO
Share of Road	Existing Scenario	69	%
	Model-I	51	
Share of pipelines	Existing Scenario	29	%
	Model-I	29	
Share of Railways	Existing Scenario	2	%
	Model-I	20	
Savings w.r.t Existing Scenario		9,802	PKR Million
Quantity movement reduction on roads	MOGAS	1.76	MTO
	HSD	1.7	MTO
	Total	3.46	MTO
Reduction in Trucks		2,963	Trucks
Saving in Maintenance Cost (Per Year Per Mile)		10,850.92	Dollar
		1.93	PKR Million

ANNEXURE – O

MODEL-I ANALYSIS (MCK TO TJB)

Model-I: Analysis			
Section: Machike to Tarujabba			
MOGAS			
Demand in 2022-23		16.7	MTO
Demand (40.52% to be transported north up)		6.76	MTO
Share of Road	Model-I	80	%
	Model-II	80	
Share of pipelines	Model-I	0	%
	Model-II	0	
Share of Railways	Model-I	2	%
	Model-II	20	
HSD			
Demand in 2022-23		13.82	MTO
Demand (43% to be transported north up)		5.94	MTO
Share of Road	Model-I	98	%
	Model-II	80	
Share of pipelines	Model-I	0	%
	Model-II	0	
Share of Railways	Model-I	2	%
	Model-II	20	
Savings w.r.t Existing Scenario		7,776	PKR Million
Quantity movement reduction on roads	MOGAS	1.21	MTO
	HSD	1.07	MTO
	Total	2.28	MTO
Reduction in Trucks		1,955	Trucks
Saving in Maintenance Cost (Per Year Per Mile)		7,161.67	Dollar
		1.27	PKR Million

ANNEXURE – P

MODEL-II ANALYSIS (KAR TO MMK)

Model-II: Analysis			
Section: Karachi to Mahmoodkot			
MOGAS			
Demand in 2022-23		16.7	MTO
Demand (68.89% to be transported north up)		11.47	MTO
Share of Road	Model-I	51	%
	Model-II	25	
Share of pipelines	Model-I	29	%
	Model-II	55	
Share of Railways	Model-I	20	%
	Model-II	20	
HSD			
Demand in 2022-23		13.82	MTO
Demand (58.67% to be transported north up)		8.1	MTO
Share of Road	Model-I	51	%
	Model-II	10	
Share of pipelines	Model-I	29	%
	Model-II	70	
Share of Railways	Model-I	20	%
	Model-II	20	
Savings	w.r.t Model-I	24,334	PKR Million
	w.r.t Existing Scenario	36,845	PKR Million
Quantity movement reduction on roads	MOGAS	1.29	MTO
	HSD	3.32	MTO
	Total	4.62	MTO
Reduction in Trucks		3,950	Trucks
Saving in Maintenance Cost (Per Year Per Mile)		14,465.43	Dollar
		2.57	PKR Million

ANNEXURE – Q

MODEL-II ANALYSIS (MMK TO MCK)

Model-II: Analysis			
Section: Mahmoodkot to Machike			
MOGAS			
Demand in 2022-23		16.7	MTO
Demand (58.87% to be transported north up)		9.81	MTO
Share of Road	Model-I	80	%
	Model-II	47	
Share of pipelines	Model-I	0	%
	Model-II	33	
Share of Railways	Model-I	20	%
	Model-II	20	
HSD			
Demand in 2022-23		13.82	MTO
Demand (68% to be transported north up)		8.1	MTO
Share of Road	Model-I	51	%
	Model-II	10	
Share of pipelines	Model-I	29	%
	Model-II	70	
Share of Railways	Model-I	20	%
	Model-II	20	
Savings	w.r.t Model-I	16,992	PKR Million
	w.r.t Existing Scenario	26,793	PKR Million
Quantity movement reduction on roads	MOGAS	3.24	MTO
	HSD	1.5	MTO
	Total	4.74	MTO
Reduction in Trucks		3,950	Trucks
Saving in Maintenance Cost (Per Year Per Mile)		14,848.77	Dollar
		2.64	PKR Million

-

ANNEXURE – R

MODEL-II ANALYSIS (MCK TO TJB)

Model-II: Analysis			
Section: Machike to Tarujabba			
MOGAS			
Demand in 2022-23		16.7	MTO
Demand (40.52% to be transported north up)		11.47	MTO
Share of Road	Model-I	80	%
	Model-II	80	
Share of pipelines	Model-I	0	%
	Model-II	0	
Share of Railways	Model-I	20	%
	Model-II	20	
HSD			
Demand in 2022-23		13.82	MTO
Demand (43% to be transported north up)		8.1	MTO
Share of Road	Model-I	80	%
	Model-II	80	
Share of pipelines	Model-I	0	%
	Model-II	0	
Share of Railways	Model-I	20	%
	Model-II	20	
No Change of Model-II on this section so is no savings			

ANNEXURE – S

MODEL-III ANALYSIS (MCK TO TJB)

Model-III: Analysis			
Section: Machike to Tarujabba			
MOGAS			
Demand in 2022-23		16.7	MTO
Demand (40.52% to be transported north up)		6.76	MTO
Share of Road	Model-I	80	%
	Model-II	25	
Share of pipelines	Model-I	0	%
	Model-II	55	
Share of Railways	Model-I	20	%
	Model-II	20	
HSD			
Demand in 2022-23		13.82	MTO
Demand (43% to be transported north up)		5.94	MTO
Share of Road	Model-I	80	%
	Model-II	25	
Share of pipelines	Model-I	0	%
	Model-II	55	
Share of Railways	Model-I	20	%
	Model-II	20	
Savings w.r.t Existing Scenario		7,776	PKR Million
Quantity movement reduction on roads	MOGAS	3.72	MTO
	HSD	3.26	MTO
	Total	6.99	MTO
Reduction in Trucks		5,975	Trucks
Saving in Maintenance Cost (Per Year Per Mile)		21,822.67	Dollar
		3.89	PKR Million

ANNEXURE – T

MODEL-III ANALYSIS FOR 2030 (KAR TO MMK)

Model-III: Analysis for FY 2029-30			
Section: Karachi to Mahmoodkot			
MOGAS			
Demand in 2029-30	30.41	MTO	
Demand (68.89% to be transported north up)	20.95	MTO	
Share of Road	11.66	MTO	
Share of pipelines	5.1	MTO	
Share of Railways	4.19	MTO	
HSD			
Demand in 2029-30	16.82	MTO	
Demand (58.67% to be transported north up)	9.86	MTO	
Share of Road	1.00	MTO	
Share of pipelines	6.90	MTO	
Share of Railways	1.97	MTO	
Quantity movement reduction on roads	MOGAS	11.95	MTO
	HSD	1.00	MTO
	Total	12.66	MTO
Increment in Trucks		108,20.00	Trucks
Increment in Maintenance Cost (Per Year Per Mile)		396,22.84	Dollar
		7.05	PKR Million

ANNEXURE – U

MODEL-III ANALYSIS FOR 2030 (MMK TO MCK)

ANNEXURE – O

Model-III: Analysis for FY 2029-30			
Section: Mahmoodkot to Machike			
MOGAS			
Demand in 2029-30	30.41	MTO	
Demand (58.78% to be transported north up)	17.87	MTO	
Share of Road	11.95	MTO	
Share of pipelines	2.35	MTO	
Share of Railways	3.57	MTO	
HSD			
Demand in 2029-30	16.82	MTO	
Demand (68% to be transported north up)	11.43	MTO	
Share of Road	4.01	MTO	
Share of pipelines	5.14	MTO	
Share of Railways	2.28	MTO	
Quantity movement reduction on roads	MOGAS	11.95	MTO
	HSD	4.01	MTO
	Total	15.96	MTO
Increment in Trucks		13,266	Trucks
Increment in Maintenance Cost (Per Year Per Mile)		48,582.28	Dollar
		8.64	PKR Million

ANNEXURE – V

MODEL-III ANALYSIS FOR 2030 (MCK TO TJB)

Model-III: Analysis for FY 2029-30			
Section: Machike to Tarujabba			
MOGAS			
Demand in 2029-30	30.41	MTO	
Demand (40.52% to be transported north up)	12.32	MTO	
Share of Road	5.98	MTO	
Share of pipelines	3.88	MTO	
Share of Railways	2.46	MTO	
HSD			
Demand in 2029-30	16.82	MTO	
Demand (43% to be transported north up)	7.23	MTO	
Share of Road	2.68	MTO	
Share of pipelines	3.11	MTO	
Share of Railways	1.44	MTO	
Quantity movement reduction on roads	MOGAS	5.98	MTO
	HSD	1.44	MTO
	Total	8.66	MTO
Increment in Trucks		7207	Trucks
Saving in Maintenance Cost (Per Year Per Mile)		26,391.91	Dollar
		4.69	PKR Million