Comparative Analysis of Inter-Model and Truck-Based Freight Transportation: Case Study of Faisalabad – Karachi Corridor

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(Registration No: NUST: 00000275614)

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In

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Thesis Supervisor: Dr. Sameer-ud-Din (P.E.)

School of Civil and Environmental Engineering

National University of Sciences & Technology (NUST)

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THESIS ACCEPTANCE CERTIFICATE

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No part of this thesis has been submitted anywhere else for any other degree. This thesis is submitted to the Department of Transportation Engineering (TN) in partial fulfillment of the requirements for the degree of Master of Science in field of Transportation Engineering, National University of Sciences & Technology (NUST) Islamabad, Pakistan.

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DEDICATION

I would like to dedicate my thesis to my beloved parents, teachers, siblings and fellow students of the National University of Science Technology.

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I am extremely thankful to Allah Almighty, for giving me strength and patience to complete this research project. A little effort though but inspired by the Verse from The Holy Quran:

"And whoever saves a life is as though he had saved all mankind". **(5: 32)**

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ABSTRACT

Pakistan is facing serious-crisis in railway freight system since 1970 where the inland passenger traffic drastically reduces from 41 % to 10 % while freight traffic operation reduced to 5 %. Pakistan railway has witnessed a golden era before this time where the freight traffic operation was flourishing at 73 % of total freight operations. Railway being an economical and viable option for commodities can play an important role in country's economic growth but the dramatical decline has worsen the condition and there is need to take serious steps to enhance the capacity. In this study, we are proposing a new intermodal route between industrial hub Faisalabad and nearest port Karachi. The investigations found that if proposed model is implemented effectively, 41 % of total freight operation can be shifted from roads to railways resulting in economic spent reduction as well as reduction in hazardous emissions from engines.

Keywords: Railway Engineering, Freight Transportation, Modal Share, Sustainable Transportation, Logistics and Cost Estimates

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LIST OF ABBREVIATIONS

LDHV	-	Low Density High Value
PR	-	Pakistan Railway
C/D	-	Collection / Distribution
VOC	-	Vehicle operating Cost
GDP	-	Gross Domestic Product
GOP	-	Government of Pakistan
NHA	-	National Highway Authority
NTRC	-	National Transport Research Centre
PBS	-	Pakistan Bureau of Statistics
WHO	-	World Health Organization
Fbd	-	Faisalabad
Khi	-	Karachi

CHAPTER 1: INTRODUCTION

Rail transport is considered as cost-effective mode of carrying people and goods over long (i.e. inter-cities) and short (intra-city) distances. Rail traffic has played an important part in the development and economic prosperity of nations throughout the world history. Railways are not only a valuable source of employment but, also help in generating large amounts of revenue to benefit the economy. All the developed countries are shifting most of their logistics to rails in order to make the freight transport more economical and environmental friendly (Blainey, Armstrong, Smith, & Preston, 2015).

It is heart wrenching to see the current state of Pakistan’s freight trains. In current economic challenges, the rail-based freight transportation network could enhance economic activities that is utmost needed by the country. It is staggering to know that over 50 percent of the cargo around the world is hauled by railways. However, it presents a dismal figure of barely 5 percent in Pakistan. (Uddin, Huynh, & Ahmed, 2021).The World Bank deems railways a significant driver of economic development in the world especially developing countries.

Pakistan Railways was the primary mode of transportation in the country till the seventies. The government policies of giving emphasis on the road networks and logistics services expansions has resulted in modal shift. Subsequently, giving less importance on maintenance and upgradation over decades has resulted in declining railway performance and condition (Li, Alam, & Wang, 2018a). It is observed that the inland traffic has reduced from 41 percent to 10 percent for passenger, and 73 percent to 5 percent for freight traffic operations ("Trade Development Authority of Pakistan.

Sectoral Competitiveness and Value Chain Analysis," 2016). Inland traffic stats are shown in Figure 1-1 below.

Transportation sector in pakistan is also responsible for 29% of GHG emissions (Sánchez-Triana, Enriquez, Afzal, Nakawaga, & Khan, 2014). The CO2 and GHG emission from the transport system in Pakistan is estimated to be 37.1 million ton and if not cared properly theses emission can grow as high as 66.6-million-ton CO2 in the future. Trend line shows that no. of vehicles are growing 2% every year (Ilyas, 2007). Logistics providers are also opting for the road based transport due to which no. of trucks on the road are increasing rapidly. GHG emissions have been supplemented by the rising number of motor vehicle in Pakistan (Mir, Purohit, & Mehmood, 2017).

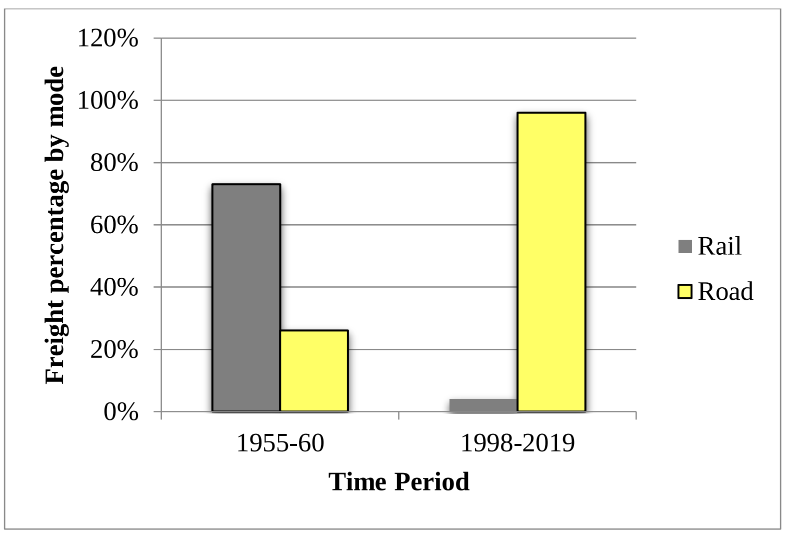


Figure 1-1: Rail and road utilization in Pakistan

Transport sector of Pakistan, accounts for about 17 percent of Gross Capital Formation, 11 percent of its GDP and generates almost 6 percent of employment. Its annual energy consumption is 35% of the total and accounts for approximately 15% of

Development Projects in Public Sector. However, due to overall poor performance of this sector, most of the economic gains that can be reaped from an efficient transport system are lost in Pakistan’s case and the country suffers a loss of 8.5 percent of GDP annually. The size of transport infrastructure affects the economic development of any country. An efficient and good quality transport system contributes to economic growth by lowering production cost. Therefore, it is of paramount importance to investigate the freight-based system of industrial city like Faisalabad and propose a cost effective and potential freight-based rail system for it.

This research is focused on providing a better mode with more efficient freight transportation. Pakistan Railways is perpetually running at loss due to low freight traffic and subsidized passenger tarrif. A journey time in Pakistan takes three times longer than in Europe (Black, Seaton, Ricci, & Enei, 2003). Road freight takes 2 days between ports and the Faisalabad city (approximately 1,100-1200 kilometers) , which is twice what it takes in America and Europe (Idrees, 2019). Textiles contribute 57% of Pakistan's export revenues out of which Faisalabad shares 18%. Provision of efficient freight train will not only provide better logistics mode to industrial city but also the most carbon-efficient motorized means of transport system (Cacchiani, Caprara, & Toth, 2010). keeping in view, the modern day sustainable development and the industrial importance of the Faisalabad city, it will be of great importance to investigate an economical and ecofriendly freight train system for the considered region

Pakistan has ranked 8th in exports of textile related products in Asia. Textile comprises 57% of total exports of Pakistan out of which 15% share is held by Faisalabad (Javed & Qureshi, 2019). Faisalabad is an industrial state comprising of different factories which produce textiles, home furniture, jewelry, food supplies and pharma etc. It has good transport network connecting it to otherbig cities of Pakistan Lahore, Multan, Sargodha and Islamabad/Rawalpindi. According to the published studies (Price water house cooper [PWC]) and 2008 Gross GDP of the top cities in the world, calculated GDP of Faisalabad stands at $35 Billion, the third highest after Karachi and Lahore (RASOOL).

Initially, Faisalabad exports mainly based on agriculture which was shifted to industrial in early eighties. Now, the current exports are comprising of agriculture and industrial both . The vast variety of products from the industriay is comprised of different textile mills, chemical industries, engineering industry, and food processing. Other industries include carpets and rugs, hosiery, nawar and lace, printing and publishing, and pharmaceutical products. Beside main producing industries, a large number of household factories including 60,000 power loom factories have been setup in Faisalabad. According to the reports 65% of the textile exports of Pakistan to international market are produced in Faisalabad. Faisalabad shares a large sum [40%] of the Pakistan total exports. Keeping in view the growth, Faisalabad has undergone net worthy industrialization after the independence to become an industrial center of Pakistan ("Faisalabad peri-urban structure plan final report," 2014).

1.1 Existing Information

In early 2000 a freight train was run between faisalabad and karachi twice a week but due to some reasons it was closed in 2008 (Asim & Nafees, 2014). Now, with the acquiring of new flat wagons and better engines, there is a great potential of running freight train joining this city to the ports. It is unfortunate that Faisalabad is still neglected in the rehabiliation of ML1 route. In this study, we will plan to evaluate this proposal of connecting freight services adjoining this industrial city with Karachi city and port. Look into the project as if it can proclaim value to money or not in terms of micro and macroeconomics perspective. We will propose a change of modal share through, performing quantitative and qualitative analysis.

District Faisalabad has single track railway which connects it to other cities of Pakistan. It can be considered as an important link for freight transportation. Faisalabad alsohas its own dry port located near Nishatabad railway station. The railway lines connecting Faisalabad to other cities are:

1. Faisalabad - Sargodha Single track Line, and
2. Faisalabad - Lahore Single track Line
3. Faisalabad - Khanewal Single track Line,
4. Faisalabad - Rawalpindi Single track Line.

Different types of locomotives are operated in Pakistan. According to age there are three types as shown in Table 1-1 below.

Table 1-1: Types of Locomotives

S/no.	Loco type	Service year
1	Tier 0	1973-2001
2	Tier1	2002-2004
3	Tier2	2004-present

PR used a standard type DE diesel electric engine for almost all their trains, both passenger and freight. Same Diesel electric engines are used for shunting. For our study our representative vehicles will be tier 2 locomotives with 3000hp and 4000hp having carrying capacity of 2000 tons and 3000tn respectively. As for flat wagons for container transportation there are two types commonly used by Pakistan railways. The first is a four-axel 26 tonns wagon which can carry three(3) 20’ containers or combinations of 20’, 30’ and 40’containers. The length of wagon is 19.6 meters with load capacity of 70 tons. The former is four axel 20 tons wagon which can carry two 20’ containers or combinations of 20’, 30’ and 40’containers. The length of wagon is 13 meters with load capacity of 54 tons.

The classification of truck types and their percentages of presance on the road network are expreseed in the Table 1-2 below

Table 1-2 Truck types on road

S/No.	**Truck type**	**Percentage**
1	2-axle truck	53
2	3-axle truck	16
3	4-axle truck	14
4	5-axle truck	5
5	6-axle truck	12

1.2 Problem Statement

Movement of freight through road is responsible for lot of congestion, air pollution and other types of problems. Wear and tear due to heavy vehicles is responsible for high maintenance cost. Logistics should make up to just 10% of total product cost which is higher in case of the trucks. Keeping theses things in mind, there is a need of another mode for logistics system which is efficient, economical and sustainable.

1.3 Study Objectives

Based on our problem statement. Our study object is to:

- Lowering the total cost of freight transport.
- Support and promote logistics based multi-modal transportation.
- Make freight movement environmental friendly.
- Evaluation of the project in terms of tangible and intangible costs.
- Lowering the truck percentage on road network.

1.4 Scope of Study

The freight movement between Faisalabad and Karachi is currently carried out through road network. The road network between these two cities is comprised of following links.

1. M-4 motorway from Faisalabad to Multan,
2. M-5 motorway from Multan to Sukhur,
3. N-5 from Sukkur to Nawabshah,
4. N-55 from Nawabshah to Hyderabad and
5. Karachi-Hyderabad Motorway.

The existing route of Faisalabad to Karachi road network is shown in Figure 1-2 below

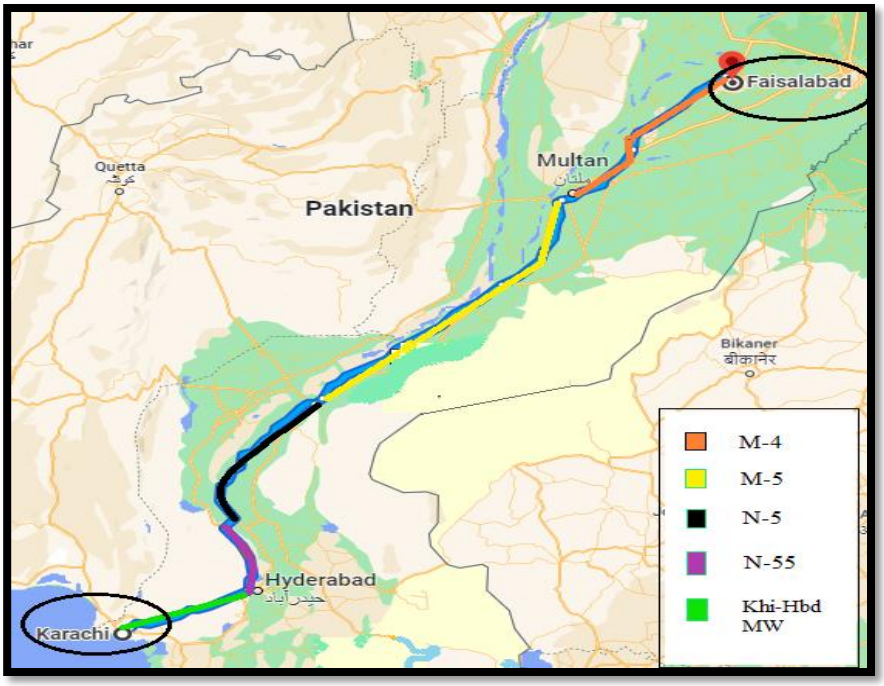


Figure 1-2: Existing route of Faisalabad to Karachi road network

In this research we have proposed intermodal freight movement between karachi and faisalabad which is more cost efficient and helps in reducing carbon footprints. The new route is,

1. Truck transfer between industry and dryports,
2. Rail transfer on single line railway from Faisalabad to Khanewal,
3. Rail transfer on double line railway from Khanewal to Karachi dryport,
4. Truck transfer from Karachi dryport to destination points.

The railway map of proposed rail transfer is shown in Figure 1-3 below

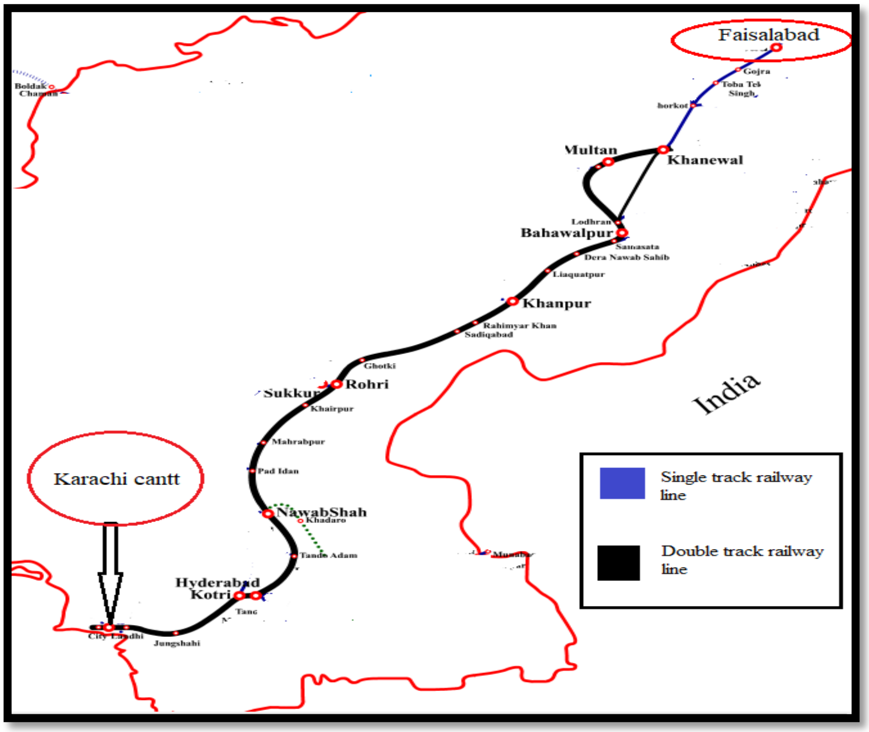


Figure 1-3: Railway line between Faisalabad and Karachi

1.4.1 Research Study Area

Figure 1-4 and Figure 1-5 shows the land use distribution of Faisalabad city and adjoining areas. There is a lot of industry in the study area which is going to benefit from the projrct.

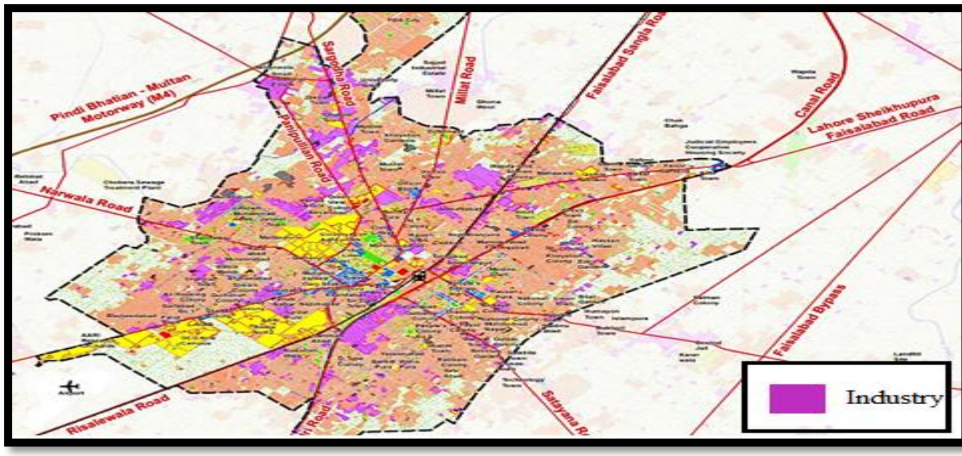


Figure 1-4: Land use map of Faisalabad urban area

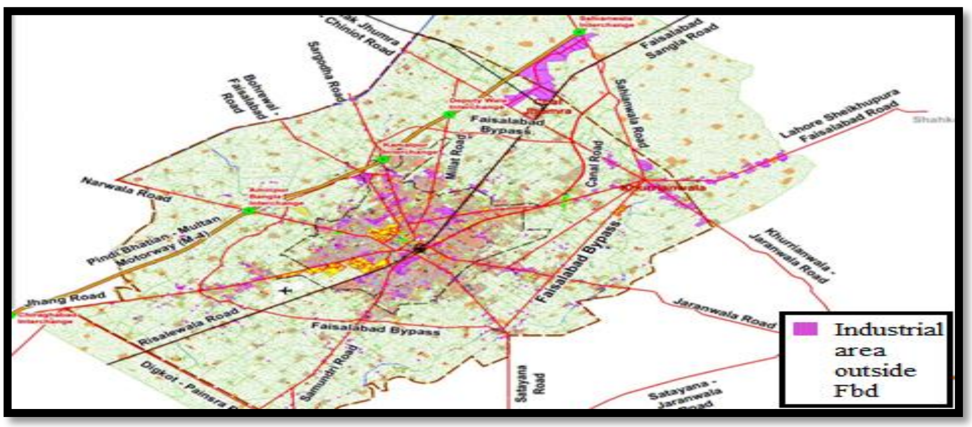


Figure 1-5: Land use map Faisalabad adjoining areas

CHAPTER 2: LITERATURE REVIEW

The different policy-based initiatives to improve the freight-based system will be discussed in this section. It is followed by a detailed comparison of the road- and railway-freight industry.

Choudhary et al has discussed the relationship between federal direct investment and transport infrastructures. He argued that Logistics process is relatively complex in developing countries like Brazil, Argentina, and Pakistan. In developing economies, the logistics costs have exceeded up to 30% of delivered product costs. Whilst, the same has estimated as low as 9% in countries of advanced economies. Pakistan has a logistic performance index of 2.5, which is even less than Brazil. It constitutes that the logistics cost in Pakistan is even higher than 30% of the delivered product cost. The transport and telecom sector has a contribution of 10% in GDP, providing employment to 5.39% locals. This sector has a share of 17% in the Gross Capital Formation and 11.5% in investment. The transportation sector consumes 35% of energy annually and receives 20 to 25% of the annual federal sector development Program. Currently, the Inland Transport System lies mainly on two pillars of roads, and railways. A continuous decline has been observed in the role of Pakistan Railways in freight haulage from the very outset. In the 1950s, the railway's share in freight haulage was over 86% which has decreased currently to a value of 4%, affecting badly on revenue of railway ministry and to treasury at large.(Choudhary, Khan, Arshad, & Abbas, 2007).

(Bryan, Weisbrod, & Martland, 2007) has described rail freight as a solution to assist in mitigating congestion, and actually relieve it in some localities, by diverting freight from the roadways. In some cases, it might be an answer to truck lines hemmed in by labor shortages, lesser resource utilization due to congestion, and skyrocketing fuel prices. Railways have totally separated right-of-way, which can diminish the interaction between trucks and automobiles to some point. In this way security of shared roadways can somehow find a remedy in rail, and a few roads that are becoming truck-dominated routes could also be helped to avoid or postpone that density.

Rail freight is vital to economic development due to its wide range of advantages in serving different forms and flows of freight. Countries with well-functioning freight railways are more competitive and reap wider benefits of balanced transport systems during which the proper freight moves on the proper mode. Well planned and managed, railways can, deliver both higher capacity and lower costs of operation than road freight transport at lower external costs to the community. Railway departments in form of public private partnerships in developing countries are taking various steps towards achieving efficient and effective services in comparison to road based freight transport services. Additionally, it is the key to securing the wider external community benefits e.g. less accidents, Air and noise pollution and Social costs. (Amos, 2009).

We can get benefits from freight transport through re-viewing policy-based initiatives wherein giving emphasis on rail-based freight transportation on priority. The European and developed countries are still rely on developing countries in order to access raw materials, intermediate goods and other resources necessary for their consignment of final product in the market affordably. Aritua has mentioned in study that the mis-management, lack of interest, and intentions has suffered a railway modal share on decline trend over the passage of time. This has influenced industrialist and capitalist to prefer in marginalizing balance between logistics cost and customer satisfaction, leaving far behind a choice of choosing transportation mode. Thus, here comes the role of policy makers and think tanks to play their part to carry-out mitigation steps towards sustainable improvements. The China Pakistan Economic Corridor (CPEC) has three phases investment plans for upgrading railway. It should be fully utilized as an excellent opportunity for both freight and passengers. Additionally, there are various heavy industries associated, involved, and linked with railways (e.g., Pakistan Steel Mill, and etc.). A re-visit on policy would result in paradigm shift in facilitating trade and boosts economic growth (Aritua, 2019)..

Freight trains are mainly used for raw materials but now low-density high value cargo is highly in demand. It consists of semi-finished or finished products but most of it is transported by roads. Zunder and Islam did the qualitative research method to analyzed potential of moving cargo by train. They recommned in adopting revolutionary measures to existing systems (e.g. providing refrigerated containers etc.). Moreover, terminal access and functionality has greater importance than overall cargo handling (Zunder & Islam, 2017).

Behiri and Belmokhtar proposed an environment-friendly freight transportation for urban area using existing passenger rail network. they did a detailed comparison of the road and railway freight industry. They used the porter model to analyze the freight industry. The road freight industry i.e. trucks have a very high modal share so they suggested better planning and infrastructure of the trucking industry. The road share in freight transport has been predominant despite its significant weaknesses such as worsening congestion, low safety and negative environmental impact. A big portion of the carbon dioxide emissions are caused by transportation Sector. They have proposed a framework to model and simulate systems. It comprised of developing models through optimization for solving an important problem addressing global issue (e.g. eco-friendly logistics movement)(Behiri, Belmokhtar-Berraf, & Chu, 2018).

(Hampaeyan Miandoab, Ghezavati, & Mohammaditabar, 2020) has proposed a train scheduling model that aimed for lesser carbon emissions. Model was applied to a single line two-way train network in Iran. Best timetable was gained by implementing a model to GAMS software. It was found that in order to reduce carbon emissions, a major remedy is to reduce delays at stations by calculating demands and adjusting accordingly. Moreover, travel time should be reduced and unnecessary train stops should be eliminated. By providing proper layout of trains at stations and adding sidetracks can reduce dispatching time for passenger and freight trains, thus reducing carbon emissions.

Underdevelopment of railways in terms of track width, voltage, management and traffic control system loses its competitiveness towards other modes of transportation. Permanent link between rolling stock and infrastructure makes its functioning totally dependent on infrastructure. Weak infrastructure by reducing the speed and safety makes it less competitive as compared to other modes. (Pietrzak, 2016) has argued on the idea of self-propelled trains. This idea was also implemented on German railways but ceased after some time due to operational difficulties. Researchers analyzed this system on freight railway transport in West Pomerania Province. They gave the idea of self-propelling light freight railways with control cabins on both sides. Self-propelling trains were also discussed by (Pietrzak, 2016) where they termed them as “trucks on trains”.

(Strale, 2016) study has investigated the usage of high-speed rail for freight in Europe. There is a greater risk in launching high-speed freight rail because of liklihood of greater loss cost in case of de-railment. This service was firstly introduced in la poste France, and that service was terminated in 2014 due to lack of goods due to its high cost in train operations and delivery charges. The only plan for using High Speed Railway (HSR) for freight is the Euro-carex project which connects major European freight airports with high-speed rail. Researchers have concluded that HSR services should only be used for parcel and express mail transport between major airports and cities as it fits with the capacities of HSR: rapid transport, limited volumes, high-level and high-cost services.

In developing cuntries, Indian railway is the largest railway network system running under single management. The international trade has shed light on the advantages of dedicated freight corridors for railways. The researchers provided an empty and loaded train scheduling model for planning of Indian dedicated freight corridors. The rolling stock is extremely expensive and should be used at its fullest efficiency. The researchers formulated the siftware named as CELSP. It is an Integer Program with main objective focusing on maximizing profit and service quality. Integrated loaded flows and empty flows were planned for optimal balance between service quality and operating costs (Upadhyay & Bolia, 2014).

(Dinwoodie, 2006) carried out the economic feasibility analysis of different port-based railway freight routes. Comparison of cost for road and rail freights movement was done. The objective of this research was to reduce lorry miles and give the policy makers a better understanding of train haulage under different circumstances. They concluded that it is must for rail traffic to increase capacity in order to enhance output and cut unit costs. Researchers analyzed different routes connecting Plymouth UK to other Big Cities. Large bulk road movements showed a market potential of freight train with upgraded railhead facilities. They suggested that to reap benefits from intermodal freight transportation, stations should be provided with enhanced loading, storage and processing facilities. By doing so, there is a fair chance of increasing the rail output to three times.

(Woodburn, 2003) Carried out questionnaire based qualitative research to determine the potential of modal shift from road to rail for industrial freight haulage. They interviewed different companies for thieir willingness to shift to the railway. It was found that rail can only gain a substantial increase in mode share only if it meets the much more stringent requirements from industry. These advancements should be more conviencing than it was the dominant mode in the past. The companies which primarily used road haulage said it to be more flexible. Among interviewees 37% were ready to use rail in next 5 years if met with their requirements i.e. cost reduction, Access improvement, tracking facility etc... They concluded that changes of this magnitude would still represent a very considerable increase in the uptake of rail freight services though and the impacts on ton kilometers would be greater.

(Janic, 2007) Developed a model to compare the combined internal and external costs of the intermodal freight transportation system. Roads, internal costs were terminal operator costs, operational costs and transit time costs for. While external costs included other tangible and intangible costs (e.g. congestion, air pollution. noise pollution and traffic accidents). The model was applied to a simplified European transportation network. It was found that these costs decrease with an increase in total distance for for roads and intermodel. It becomes more rapid for an intermodal systems. On the other hand, with an increase in tonnage with respect to the mileage, the costs for road networks remain the same. However, there is an inverse realtionship wherein found the cost decrases for the intermodal systems.

Morlok et al has mentioned that the multimodal system was actually intended for high density cargo (e.g. raw matereial) but its market share is very small. (Morlok, Sammon, Spasovic, & Nozick, 1995) hasindicated the reason for this low share is due to issues realted to productivity and quality problems, particularly in drayage. They have argued that the implementation of an especially promising approach to reorganize the way the different players combine to provide intermodal service are related to one another which perform various tasks, in order to improve its structure stability. According to them there is good potential of high pace level improvements for enhacing productivity and service quality in drayage, which is vital for the overall intermodal transportation service. This is a critical to intermodal transport system to become an effective alternative to all road trucking especailly for intercity markets.

(Bontekoning, Macharis, & Trip, 2004) has urged a need of an independent research dealing with such complex system of intermodal transportation. They have reviewed 92 papers on intermodal freight transportation to identify the scientific knowledge and its application. In their study, they have argued an intermodal freight transportation research currently in a pre-paradigmatic phase. They have proposed a list of different research domains that are needed to consider as mandatory to serve purpose..

(Kai & Li, 2019) carried ot the operational analysis of rail mounted gantry cranes in transhipment terminals. They presented "container truck-container train" operational mode which ought to be more efficient. With the help of this mode, number of lifting and landing operations of gantry cranes are reduced thus minimizing the waiting time. It improves the operational efficiency of rail mounted gantry cranes which have a great significance on the development of transhipment terminals.

(Dampier & Marinov, 2015) have given a concept of interacity transporting freight connecting outer fringers directly to the city center using a metropolitan railway network. They have selected a locations of Tyne and Wear Metro system, and Newcastle upon Tyne to determine the feasibility of the scheme. They have concluded that transporting the majority of freight by road is not only unsustainable but also damaging to both the environment and local communities. Additionally, they have reviewed other modes of transportation wherein emphais on the modal shift as a mandatory in near future. They have modeled the system using COBALT software that demonstrate the implementation of such a scheme would provide vast savings from accident reduction. It will further assist in minimising the social cost. This approach seems viable subjected to further research to be carried out before implementation.

(Bożejko, Grymin, & Pempera, 2017) have determined fastest route based schedule optimiztion of a train using dijkstra's algorithm. They have studied on rail-network in Poland covering 7 cities. The fastest route for single-cargo-trains on railway track line was determined as 30 minutes with buffer time. It is suggested that their algorithm can be used to solve scheduling problems in complex oprations and management wherein handing freight and passenger altogether.

(Michal, Huynh, Shukla, Munoz, & Barthelemy, 2017) have developed a rail simulation software named as “railnet” that simulates and insert new freight trains particulars without disturbing the time table of passenger trains. The software was tested to determine the capacity of the track network at the Port Kembla Coal Terminal in Australia under different scenarios of infrastructure upgrades. Thus, it would assist in the planning and management.

(Potti, Marinov, & Sweeney, 2019) have developed an event-based simulation model in their study to determine a performance of cross-country railway lines in the UK, and evaluated current level of utilization. The model was simulated using SIMUL8 software wherein timetable as an input was used to define different attributes. They have found that the cross-country line was underutilized as far as capacity concern. They have proposed three scenarios of introducing freight trains in the system to enhance utility, and found as viable.

(Li, Alam, & Wang, 2018b) have presented a detailed trend analysis of Pakistan railways using industrial life cycle theory. The lifecycle of Pakistan railways is divided into three eras. The first stage is from 1947 to 1999 where railway was at its peak and normally called as seventies era.. In 1999’s and subsequent years till 2011, it was the worst era to consider in terms of economically and financially hurdles. The decline in logistics/freight trends was due to various factors among which some are more realted to underinvestment, political interference, and rise of the road-based freight competitor services sponsered by state organizations. This era is considered as second stage of life cyclewhere exception was year 2005 in regard to development. The third life cycle (i.e. 2011 to present), the railways has showed a promising development (e.g. purchase of new locomotives, wagons, and other equipment) that has resulted in an increase of number of passengers and freight services.

Vehicle Operating Costs (VOC) is a vital parameter for transportation planning to appraise and compare the highway improvement alternatives, and to evaluate the performance of the transportation system of any country. (Ahmed, 2020) carried out study to calculate VOC of trucks in Pakistan. According to them, VOC consist of following cost components. Energy consumption, Accessing and using the infrastructure, Maintenance of Trucks / rolling stock (rail flat wagons + locomotive(s)), Labor (staff) and Depreciation.

The literature pertaining to definitions are attached as Annex-A.

CHAPTER 3: METHODOLOGY

The following framework is adopted for this study as shown in the **Error! eference source not found.**

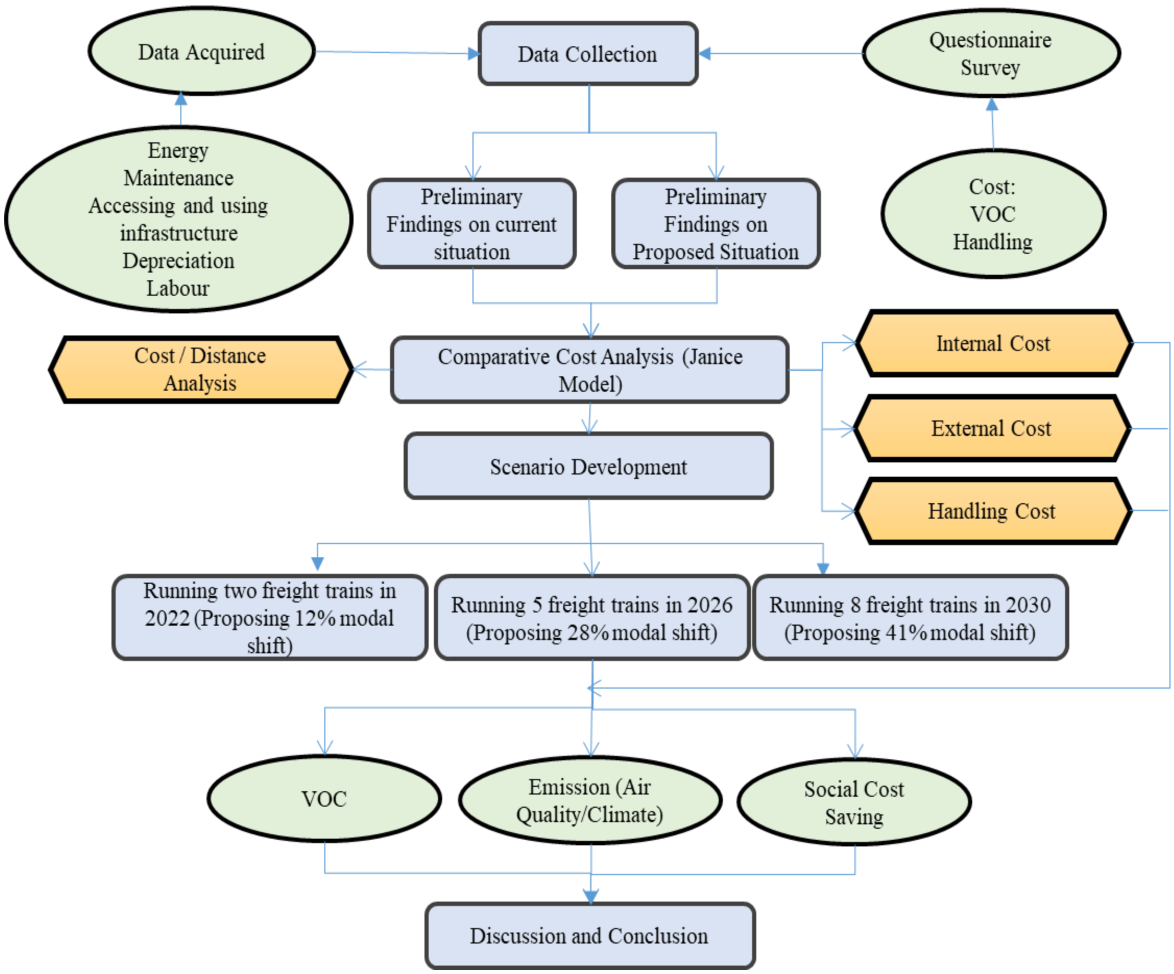
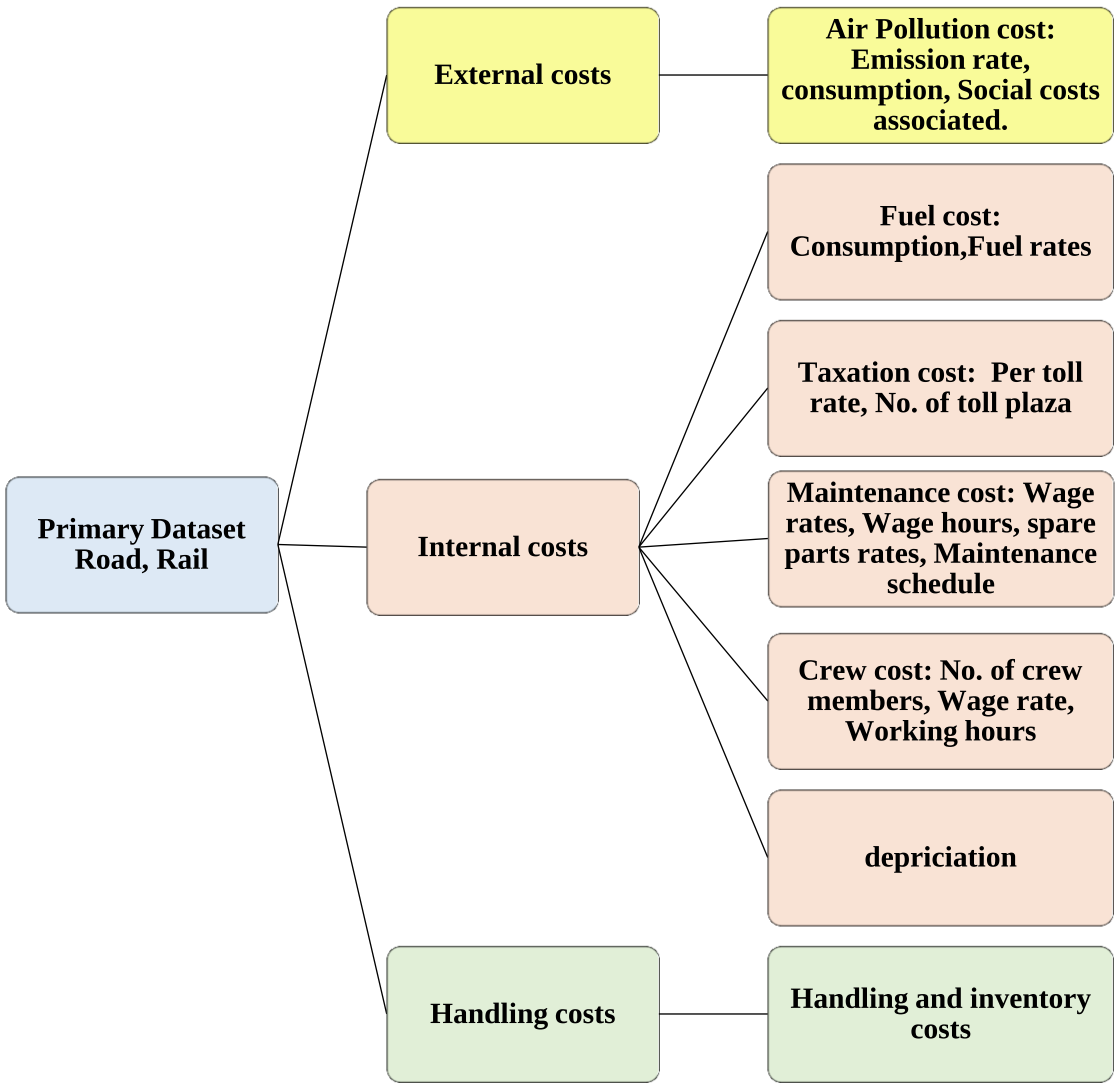


Figure 3-1: Research Framework

3.1 Data Collection

The dataset for this study is comprised of primary and secondary informations. The primary dataset consist of cost informations regarding external, internal, and handling. The details are shown in Figure 3-2 below. It was obatined through conducting cost survey on fuel cost, taxation cost, maintenance cost, crew/labour, and handling cost through questionnare. However, the information on emission, and depresiation was extracted using a web based tool. The secondary datset illustrates about demand, distance, representative vehicles, time table, characteristics of representative vehicle and



growth rate as shown in Figure 3-3 below.

Figure 3-2: Components of primary dataset

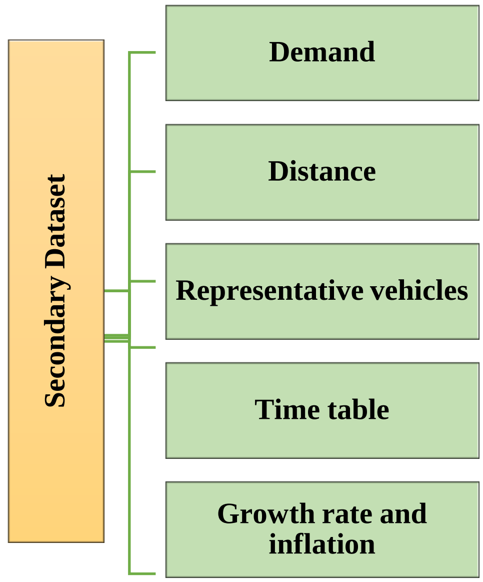


Figure 3-3: Components of secondary dataset

3.2 Primary Dataset

3.2.1 Cost Estimation

In our study, we have considered three (3) different types of costs. These are: internal cost, handling cost, and external cost.

The data on the internal cost was obtained from public and private agencies realted to trasnportation of logistics and goods. The priavate agenies includes: contacting engine oil brands, spare parts dealers, maintenance workshops, tyre dealers, and websites. However, the government agencies that we have approached for data collection are: Railway Authorities (e.g. at stations, official websites, cargo handling agencies, Pakistan railway stores, maintenance department and etc.).

The second is the handling cost which includes: loading, unloading, and truck stand surcharge. These are obtained from questioning from truck operators as well as truck station in-charges. However, terminal container handling includes an additional cost termed as intermodal network costs. This data was taken from Faisalabad dry port trust authorities which as they update tariff rates online every month.

Third, external cost includes the vehicle emissions. There are two way of calculating pollutents cost as there is no direct way of calculations. These are either using micro-simulation model or mechamatical (bottom up) approach. We have selected a bottom-up approach to estimate monetary value of pollutents in an environment. .. The summary is detailed discussed in Table 3-1: Tabular Synopsis.

3.2.1.1 Factors for determining social costs

The following factors are used

- EPA Emission Factors for different vehicles.
- Types of representative vehicles.
- Type of fuel used.
- Emissions from a specific fuel type.
- Fuel consumption.
- Ammount of GHG in the environment from representative vehicles.
- Illness due to GHG.
- Amount spent on illness.

3.2.1.2 Emission Calculations

The standard emissions are taken from EPA manual for different engine types. (EPA, 2008)

Monetary value of damages from air pollution is analyzed and then the factors are applied to get the value of portion of damages caused due to the trucks. Then from the emission data per gram cost of the pollutants is calculated. The EPA emissions factors for trucks and locomotives were used (EPA, 2008). The collected data is than validated by existing literature to ensure the accuracy.

Table 3-1: Tabular Synopsis

Cost category	**Transport mode**	**Variant**	**Calculation method for total costs**	**Validation**	**Remarks**
Fuel	Road	Diesel	Average Consumption of trucks taken from field survey. Per km cost was calculated.	Data was validated from NTRC study.	Fuel prices were taken for October 2021
	Rail	High speed diesel	Fuel consumption data was taken from Pakistan railways. And calculated PKm cost.	Validated from PR engineering wing.	Fixed amount of fuel was taken for per shunting
Tire	Road	Locally manufactured tires	Cost of tire taken from field survey. PKm cost calculated from average age of tire.	Validated from trucking companies	Tire cost as of October 2021
	Rail	N/A	N/A	N/A	Included in maintenance cost.
Toll	Road	Toll plaza tax	Toll list from NHA website	Validated from existing literature	Average of 2 axle and other trucks
	Rail	Per container tax	Per container tax from field survey	Validated from dry port tariff sheet	Cost as of October 2021

Cost category	Transport mode	Variant	Calculation method for total costs	Validation	Remarks
Crew	Road	Driver, Helper	Field survey	Existing literature	N/A
	Rail	Driver, Helper, Guard	Field survey	Pakistan railway	N/A
Maintenance (parts)	Road	Regular maintenance	Field survey	Existing literature	N/A
	Rail	Scheduled maintenance	Pakistan Railway store	PR concerned authorities	N/A
Maintenance (labor)	Road	Workshop labor	Field survey	Existing literature	N/A
	Rail	Railway mechanics	Pakistan Railway maintenance dept.	Field survey	N/A
Air pollution	Road	Social costs associated with GHG	Existing literature	Field survey	Emission factors taken for medium trucks
	Rail	Social costs associated with	Existing literature	Field survey	Emission factors taken for tier 2

Cost category	**Transport mode**	**Variant**	**Calculation method for total costs**	**Validation**	**Remarks**
		GHG			locomotives
Handling	Road	Load unload and adda surcharge	Field survey	Existing literature	N/A
	Rail	Transshipment and inventory charges	Dry port tariff rates	Field survey	N/A

3.3 Secondary Dataset

3.3.1 Existing/Current Data

In secondary data set, the road traffic demand is estimated by carryingout origin and destination (O/D) Surveyat entry and exit points of Faisalabad. to provide the 'With Scheme Flows' section. We have used the equation 3. 1 to estimate annual average daily traffic (AADT) from peak hour volume (PHV) (Nor, Puan, Mashros, & Ibrahim, 2006).

$$PHV = 0.0801\ (AADT) \qquad \text{(Eq. 3-1)}$$

The legnth of journey routes either for truck or tain was achieved through two sources. The first source is a local knowledge where as the second is the google maps. We have build zones as explain the introduction in order to model a cobined effect of various industrial locations to get an overall picture. It is the average value used for calculating distance and modes (e.g. various trucks sized and etc.) from industrial areas to dry port station. Time table and other parameters of railway were taken from Pakistan railway handbook. The characteristics of a typical train and truck were taken from representative departments.

3.4 Data Sorting

The data obtained from questionnare was expressed in spreadsheets for further analysis purpose. It was further scroutnized and to achive required sample size of 100 with error ratio of 10%. The sample size of the dataset is based on the following equation.

$$n = \frac{N}{1+Ne^2} \qquad \text{(Eq. 3-2)}$$

where:

n = No. of samples
N = Total Demand
e = Error margin / margin of error

3.5 Scenario Development/Proposed Scheme

Our proposed scheme is based on the inter-model network for the movement of logistics. The steps involved in it are collection and distribution, and line-haul. The main goal is to shift as much percentage of freight to rails as possible. In this study it is proposed to achive 41% modal shift in ten years. It is impossible to shift that much load to railway in single step because many new trains have to be scheduled and added to the current system. To achive the goal, this modal shift is devided in three steps. In first step we have proposed to add 2 freight trains next year to the current system and then adding 6 new trains (three in 2026 and three in 2030) in two steps with the interval of 4 years. In this way 41% of modal shift is achieved in ten years. Analysis is also carried out in three steps to shed the light on the results achieved by inducting different no. of freight trains. This study is carried out for running new trains in the existing schedule therefore no full scheduling is carried out and new routes are adjusted in ongoing railway schedule. Time table for the running trains was taken from Pakistan railway. To calculate the number of vehicles that would be removed from the roads under the new system, the the number of inducted trains was taken and multiplied by 75 (train haul capacity). This was then subtracted from the flows calculated by OD surveys.

3.5.1 Growth Rate / Forecasting

To carry out the analysis for the future scenarios, growth rate of vehicles and inflation rate for the costs are key parameters. Growth rate was taken from existing literature, inflation was taken and verified from different websites.

We have applied a growth factor of 2% as recommneded by the literature. Growth rate is taken from different studies of NTRC (Ahmed, 2020) Using this data different scnerios are prepared for different time intervals.

Inflation rate varies with the time which depends on different factors. Inflation for next five years was taken from (statista, 2021) as shown in the Annex C. Subsequently, the inflation value for the next five years was estimated based on the extrapolation.

3.6 Cost Estimation Model

We have used the following equation to determine the costs for existing and proposed schemes. The cost model are composed of Inter-Model Network and Road Network.

The overall cost function is expressed as shown in following equation. It is the combination of collection and disctribution, and line haul according to the (Janic, 2008).

We have amended this equations beause this model is used to calculate coists on the basis of weight. We are dealing with LDHV goods weight cannot be deciding factor. Representative vehicles will not be running on full capacity. LDHV goods have average weight of 5tn for 20 ft. containers which is almost half the capacity. Therefore, instead of weight we will analyze our costs on the basis of quantity. This purpose is achieved by replacing weight variable with quantity or demand variable. Freight per ton kilometer cost is calculated by dividing VKm cost by the number of tons carried. The model used for analysis is as follow.

$$CF = Cc + Clh + Cd \quad \text{(Eq. 3-3)}$$

$$CF = \sum_{i=1}^{3}\sum_{k=1}^{K} C_{c/i/k} + f[C_o(W, q, d) + C_e(W, q, d)] + \sum_{i=1}^{3}\sum_{k=1}^{K} C_{d/i/k} \quad \text{(Eq. 3-4)}$$

So, after substituting weight with demand the equation becomes as follows.

$$CF = \sum_{i=1}^{3}\sum_{k=1}^{K} C_{c/i/k} + f[C_o(q, d) + C_e(q, d)] + \sum_{i=1}^{3}\sum_{k=1}^{K} C_{d/i/k} \quad \text{(Eq. 3-5)}$$

The sub total of Collection and Distribution Cost equation is:

$$\sum_{i=1}^{3}\sum_{k=1}^{K} C_{c/i/k} \quad \text{(Eq. 3-6)}$$

The sub total of Line-Haul Cost is:

$$C_{lh} = \sum_{i=1}^{4} C_{i/lh} \quad \text{(Eq. 3-7)}$$

Each three component of this above equation are further sub-divided into three sections of internal, external, and handling cost. In inter-model network, the collection and distribution is done by the same mode (trucks) so their equation reamin as the same.

The cost of the road nework, which is comprised of collection, distribution, and line haul, is calculated by using equation as follows..

Total cost function for road network:

$$\sum_{i=1}^{3} \sum_{kl=1}^{KL} C_{i/kl} \qquad \text{(Eq. 3-8)}$$

Each component of collection, distribution and line haul have further three catrgories named as internal, handling, and external which is expressed n equation form as follows. However, the line haul equation is based on the rails. These are detailed discussed in Table 3-3 below.

Table 3-2: Equations for Inter-modal and Road network

Discription	**Inter Model**		**Road Network**
	Collection & Distribution	*Line Haul*	
Internal Cost Transport cost = Frequency × Cost per frequency = Demand / (Load factor × Vehicle capacity) × Cost per frequency	$C_{1/k} = \left(\frac{Q_k}{Ʌ_k M_k}\right) C_{ok}(d_k)$ (Eq. 3-9)	$C_{\frac{1}{lh}} = fC_o(q,d) = (Q/q_t)c_o(q,d)$ (Eq. 3-10)	$C_{1/kl} = \left(\frac{Q_{kl}}{Ʌ_{kl} M_{kl}}\right) C_{zkl}(d_{kl})$ (Eq. 3-11)
Handling Cost Handling cost = Demand × Cost per unit of demand	$C_{2/k} = Q_k t_{h/k} C_{h/k}$ (Eq. 3-12)	$C_{2/t} = Q(c_{h1} + c_{h2})$ (Eq. 3-13)	$C_{2/kl} = Q_{kl} C_{h/kl}$ (Eq. 3-14)
External Cost External cost = Frequency × External cost per frequency = Demand/(Load factor × Vehicle capacity) × External cost per frequency	$C_{3/k} = \left(\frac{Q_k}{Ʌ_k M_k}\right) C_{ek}(d_k)$ (Eq. 3-15)	$C_{3/lh} + C_{4/lh} = Q(c_{e1} + c_{e2}) + fC_e(q,d)\ Q(c_{e1} + c_{e2}) + (Q/q)c_e(q,d)$ (Eq. 3-16)	$C_{3/kl} = \left(\frac{Q_{kl}}{Ʌ_{kl} M_{kl}}\right) C_{ekl}(d_{kl})$ (Eq. 3-17)

The internal and external cost component co (q,d), and ce (q,d) for trains are distributed into various and single categories as shown in Table 3-3 below

Table 3-3: Internal cost components for inter-modal & road network transfer

Cost component	**Inter Model Equation**	**Road Network**
	Internal {co (q,d)}	
Energy consumption	$C_{o3} = c_b eqd$ (Eq. 3-18)	$C_{z3} = c_b ed$ (Eq. 3-19)
Accessing and using the infrastructure	$C_{o2} = c_a qd$ (Eq. 3-20)	$C_{z2} = c_t d$ (Eq. 3-21)
Maintenance of Trucks / rolling stock (rail flat wagons + locomotive(s))	$C_{o1} = \sum_{j=1}^{2} n_{m/j}\, c_{m/j} d$ (Eq. 3-22)	$C_{z1} = c_m d + c_l d + c_w d$ (Eq. 3-23)
Labor (staff)	$C_{o4} = \sum_{i=1}^{N} n_{s/i}\, c_{s/i} t_{ai}$ (Eq. 3-24)	$C_{z4} = \sum_{i=1}^{N} n_{s/i}\, c_{s/i} t_{ai}$ (Eq. 3-25)
Depreciation		$C_{z5} = c_d d$ (Eq. 3-26)
	External {ce (q,d)}	
Air pollution	$C_{e1} = (c_{e1} + c_{e2}) + qc_{ap} ead$ (Eq. 3-27)	$C_{e1} = c_{ap} d$ (Eq. 3-28)

Where;

c_b = cost per unit of fuel

e = unit fuel consumption of a train

q = payload on the train

d = distance of given rail line connecting two intermodal terminals (km)

c_a = unit cost of accessing the railway infrastructure

c_t = unit cost of accessing the road infrastructure

$n_{m/j}$ = is the number of rolling stock of type (j)

$c_{m/j}$ = unit maintenance cost of rolling stock of type (j)

c_m = Cost of maintenance for trucks per Km

c_l = Cost of maintenance parts for trucks per Km

c_w = Cost of maintenance labor for trucks per Km

$n_{s/i}$ = number of crew type (i) on a vehicle.

$c_{\frac{s}{i}}$ = labor cost of the staff of type (i) on a vehicle.

t_{ai} = engagement time of crew to serve and operate a vehicle.

c_{ap} = unit cost of damage by air pollution.

a = Quantity of GHG emissions per unit of the energy consumed by a train.

CHAPTER 4: RESULTS AND DISCUSSIONS

We have presented results based on our methodological way wherein comparing current situation with scenario (future) development which is rail-based inter-modal system. The data pertaining to current statistics are illustrated as follows.

4.1 Current Situation

In this section we have focused on vehicle operating cost (VOC), handling, and external costs. The VOC is named in this study as an internal cost. Therefore, we will proceed further using internal cost which is followed by the handling and external costs for current situation.

4.1.1 Estimation of VOC – Internal Cost for Truck Based Freight

The components of VOC are discussed in detail below.

The fuel prices used in trucks are based on estimation by OGRA Pakistan (OGRA, 2021). Since various lubricants are avaialble in the market which is an input for calcuating internal cost. These details of it are expressed in the Table 4-1 below.

Table 4-1: Trucks fuel cost per km

S/No.	Fuel type	PKR/litre	Consumption l/km	Cost/km
1.	Diesel	116.4	0.25	29.1
2.	Lubricant	650	0.00466	3.029

We have calculated fuel cost for different distances using equation

(Eq. 3-19) as mentioned in Chapter 3. It would assit in calcualting fuel cost compstion over verious distances as shown in Annex B Table B. 2.

After the fuel cost, the out of pocket cost is the toll charges. The data regarding the toll sections and charges was collected from NHA source. Moreover, the toll charges of using motorways is usually higher than of national highways. And, the trucks use both the commodities. Therefore, we have carried out caluculations for both motorways and highways and the used an average value of it as shown in Table 4-2 below.

Table 4-2: Average toll taxes in PKR

S/No.	**Description**	**No. of toll plaza**	**Single toll plaza charges avg.**	**Pindi to Karachi toll**	**Distance (km)**	**Cost per km toll c_t (pkr)**
1.	Motorway	N/A	N/A	8000	1150	7
2.	Highway	28	140	3920	1150	3
Average						5

cost for different distances using equation (Eq. 3-21). It would assit in calcualting fuel cost compstion over verious distances as shown in Annexture B.

The next in line to the intenral cost is the maintence cost. The maintenance costs are composed of two components (i.e. maintenance parts consumption, and maintenance labor hours). We have calculated maintenance cost by doing revealed prefernce appraoch (RPA) and for that we have contacted automotive industry outlets/workshops have a regular plan for periodic service or repair, including the labor number of hours and cost. High-end workshops operated by Honda, Suzuki, Toyota, and local workshops were visited to obtain information on labor hours, rates, car maintenance schedules, Overhead, and other key information. Table 4.6 details the data collected from various sources as well as the values of various factors that will be used in VOC models.

Table 4-3: Labour cost for maintenance

S/No.	Maintenance	Cost for 1000 km	Maintenance cost (Rs./km)
1.	Labour	4,000	4
2.	Parts	5,000	5

As the vehicle moves, the tires are constantly depleted. Tire wear and tear is a significant component of vehicle operating costs, particularly for heavier vehicles. The Tire costs were acquired through distributors and online web sources, as well as from a poll of vehicle operators for various vehicle classes.

Table 4-4: Cost of tires

Cost of Tire (PKR)	Average age of Tire (Km)	Tire cost/km	No. Of tires	Total cost for tires/km (PKR)
40,000	80,000	0.5	6	3

Total maintenance cost per km for trucks = maintenance parts+ maintenance labour + tires

= 5+4+3 =12 PKR

Cost for Various distances was calculated using equation (Eq. 3-23) which is shown in Annexture B.

The commercial vehicles mostly consist of two crew member that are driver and one helper. Questionaire survey was conducted from the commercial vehicle owners and operators about the crew wages. Table 4.9 shows the average driver and helper wage for each category of vehicle.

Table 4-5: Average wage of drivers and helpers

S/No.	**Crew type**	**Monthly pay (pkr)**	**Working hours**	**Working hours per day**	**hourly pay (pkr)**	**Kms driven per hour**	**Cost / km (pkr)**	t_{ai}	$C_{z4} = \sum_{i=1}^{N} n_{s/i}\, c_{s/i} t_{a}$
1.	Driver	45,000	224	8	201	60	3		N/A
2.	Helper	30,000	224	8	134	60	2		N/A
Total					335	120	5.58	20	6,696

Cost for different distances was calculated using equation (Eq. 3-25) which is shown in Annex B.

Depreciation in vehicle value is defined as a loss in vehicle worth caused by use over time or technical obsolescence that is not recovered by vehicle maintenance or repairs. Data on vehicle sale prices for various vehicles was gathered from internet portals such as Pakwheels. The mileage was used to compute the depreciation of the car over time and the cost of depreciation per 1000 kilometers was computed. Depreciation cost is Rs. 5/km.

Cost for different distances using equation (Eq. 3-26) . Depriciaton cost over verious distances as shown in Annexture B.

4.1.2 Summary of Truck Internal Costs (cz (q, d)) for Fbd-Khi Corridor

Table 4-6: Trucks internal cost summary

S/No.	Attribute	Eq.	Cost in PKR
1.	Energy consumption	$C_{z3} = c_b e d$	38,555
2.	Accessing and using the infrastructure	$C_{z2} = c_t d$	6,240
3.	Maintenance of trucks	$C_{z1} = c_m d + c_l d + c_w d$	14,400
4.	Labour (staff)	$C_{z4} = \sum_{i=1}^{N} n_{s/i} c_{s/i} t_{ai}$	6,696
5.	Depreciation	$C_{z5} = c_d d$	6,000
Total		c_z (q, d)	71,891

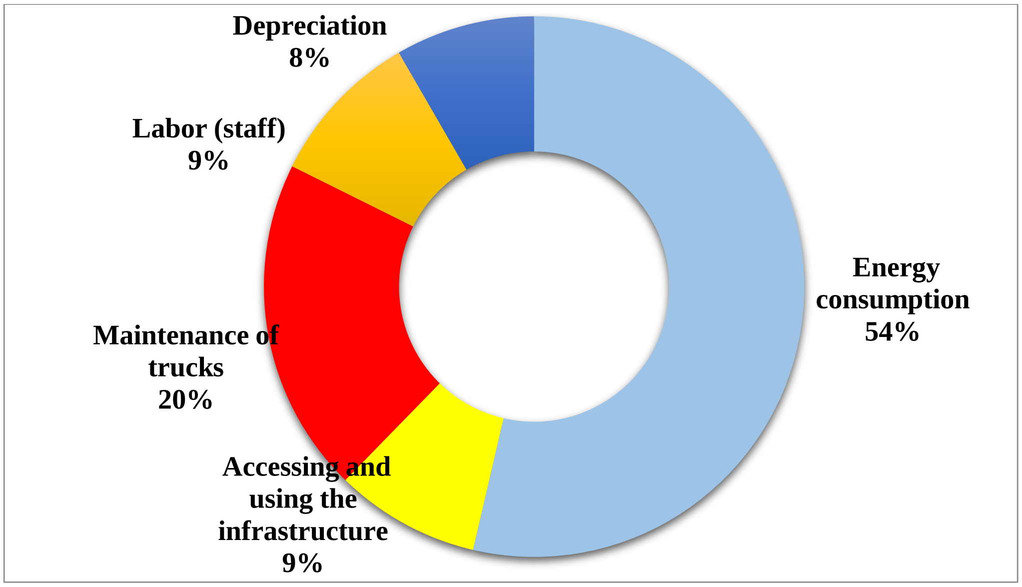


Figure 4-1: Attributes of truck internal cost

4.1.3 Handling Cost for Trucks ($C_{h/kl}$)

Trucks operate from door to door so there is not much handling cost involved with the trucks. The main handling cost include, loading, unloading and truck stand surcharge. Data regarding the cost of the loaders and station surcharge was collected from truck operators as well as truck station IN charges. There is another thing to be noted that handling cost remains almost the same for all distances.

Table 4-7: Handling cost of trucks

S/No.	Cost category	Cost
1.	Loading	2,000
2.	Unloading	1,000
3	Station surcharge	500
4	Total ($C_{h/kl}$)	3,500

4.1.4 Trucks External (air pollution) Costs ce (q, d)

Calculation of air pollution cost is very complicated, as there is no direct way to calculate it, So, we have adopted bottom-up approach is used. Monetary value of damages from air pollution is analyzed and then the factors are applied to get the value of portion of damages caused due to the trucks. Then from the emission data per gram cost of the pollutants is calculated. Factors involved are discussed in detain in Annex A

Pakistan is a big country so it is almost impossible to take the air pollution disease related data from every hospital in the country. Due to this reason air pollution cost of Karachi city was calculated and used as benchmark. Money spent on different diseases in Hospitals at Sindh district was taken from (Sánchez-Triana, Enriquez, Afzal, Nakagawa, & Khan, 2014) and inflation was applied to get current data. Cost of deseases is shown in Annexture B.

This is amount spent due to air pollution from all the sources. For our study we will access the amount of pollution spread due to transportation, specifically trucks. Below in Fig-4.3 is the amount of pollution spread due to different sources while Fig 4.4 further elaborates the shares of different modes of transportation in pollution (EPA, 2021).

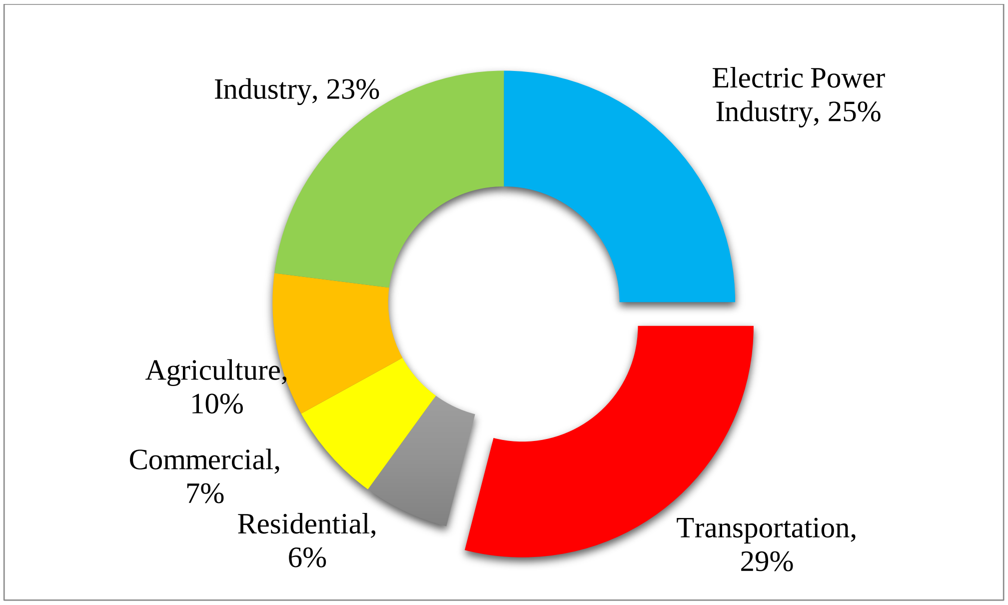


Figure 4-2: Sources of Air pollution

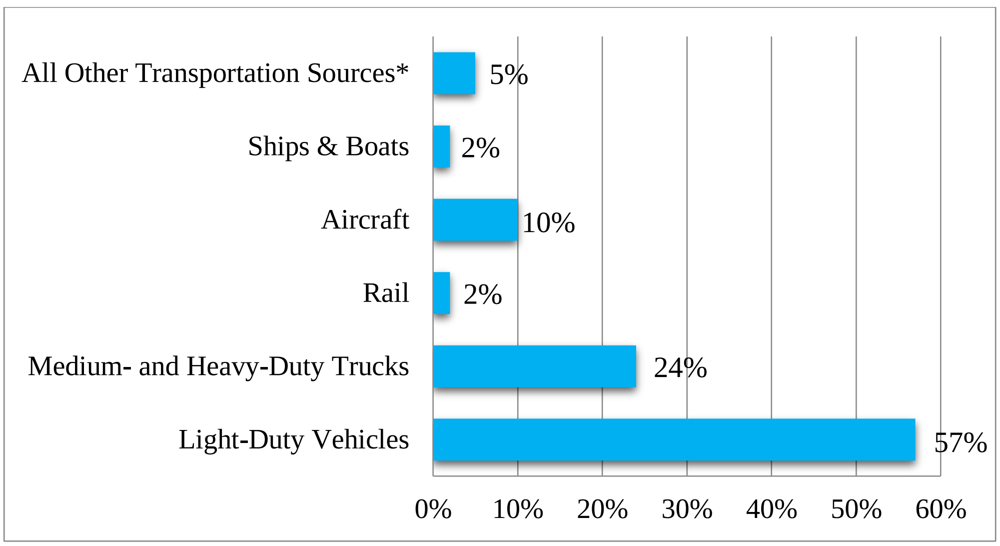


Figure 4-3: Percentage of air pollution from different traffic sources

Amount spent on diseases due to air pollution from truck traffic

$$= 108.39*0.29*0.24$$

$$=7.54 \text{ bn PKR}$$

Weightage factors from the truck engine was taken from EPA website (www.epa.gov). Respective tables are shown in Annexture. To calculate the external cost per km, total emissions are divided by these factors to calculate the vehicle kilometers travelled. In the same way we have calculated the amount cost for single pollutant. Calculation steps are shown in table 4.19 while the distance wise costs are given in Annex C in the table 4.20.

Table 4-8: Cost expenditures of different pollutants

S/ No.	Pollutant	Emissions in Tons	Weightage	Amount spent in billions	Emissions g/mile	G/km	c_{ap} (Rs/km)	Rs/g
1.	NO_x	66296	76%	5.76	9.19	5.70	0.50	0.087
2.	PM_{10}	1680	2%	0.15	0.23	0.14	0.01	0.087
3.	$PM_{2.5}$	1550	2%	0.13	0.22	0.13	0.01	0.087
4.	CO	17268	20%	1.50	2.40	1.48	0.13	0.087
Total		86786	100%	7.54	N/A	N/A	0.65	0.348

4.2 Inter-Modal Transfer Cost Calculation

4.2.1 Estimation Of Train Internal Costs co (q, d)

Train VOC cost components are discussed below.

There are three types of fuel costs involved. Firstly, the cost of high-speed diesel during the line haul, secondly the cost of loop oil consumed during the line haul and the third is cost of HSD consumed during the shunting process. The consumption for line haul and shunting processwas taken from PR engineering department and used in the study. Table 4.22 and Table 4-10 below shows the fuel costs associated while distance wise cost distribution in presented in Annexture table Table B. 8.

Table 4-9: Fuel consumption cost for locomotive

S/No.	Type of fuel	Consumption in litres	Total distance	Price/litre	Journey cost FBD to KHI	Cost/km
1.	**fuel**	4	1200	122	585600	488
2.	**lubricant**	0.16	1200	300	57600	48
3.	**shunting**	N/A	N/A	122	7612.8	12.688

Table 4-10: Coefficients for train fuel Cost

S/No.	Cost Co-efficient	Fuel	lubricant	Shunting
1.	c_b	122	300	122
2.	**e**	0.053333	0.0021333	0.000693
3.	q	75	75	75

Rail infrastructure (tracks, etc.) is publicly owned in Pakistan Government and each railway operator pays a fee to use the infrastructure. The fee is divided into one fixed fee part for the train and one flexible element that changes depending on train weight/length. We will take the average tax per container of the train. Table 4.25 Describes the taxes involved in movement of the train.

Table 4-11: Train toll taxes

S/No.	Distance	Single container tax ($c_a d$)	No. of containers (q)	$c_a q d$
1.	1-600	3,000	75	2,25,000
2.	600-1200	5,000	75	3,75,000

Maintenance cost of rail depends on different factors i.e. length of run, time of run etc. maintenance cost related data was acquired from PR maintenance department. There is a proper schedule for inspection and maintenance of locomotives and rail cars per scheduled maintenance price was taken and converted into P/Km cost. Labor cost is also derived in the same way. No. of labor required for the maintenance was known. Their per hour remittance is known. P/Km costs are calculated by deducing the values from the schedule. It is noted that locomotive travels 400 km in one cycle and average locomotive is used for 120 cycles each year. There are 20 persons involved and one person spends 200 hour/month.

PR maintenance (parts) schedule and costs are given in table 4.26 while table 4.27 shows the labor maintenance cost below.

Table 4-12: Maintenance cost and schedule

S/No.	Commodity	Maintenance schedule	Maintenance parts cost (PKR)	Kms travelled	Cost/km (PKR)
1.	Locomotive	Avg. maintenance 1 per cycle	2,000	400	5
		maintenance 2 after one year	50,000	48,000	1.04
		maintenance 3 after three years	2,50,000	1,44,000	1.74
		Over all maintenance parts cost for locomotives			7.74
2.	Flat wagons	maintenance After one year	10,000	60,000	0.17

Table 4-13: Labor maintenance cost

S/No.	Maintenance type	Avg. Pay (pkr)	Hourly wage (pkr)	Maintenance time (hr)	Maintenance after kms.	Hourly labour cost (pkr)	labour cost/km (pkr)
1.	Maintenance of locomotive	32,000	160	1hr	400	3,200	8
2.	Maintenance of rail cars	32,000	160	1hr	20,000	3,200	0.16

Maintenance cost for loco and rails in Rs is given by $C_{o3} = \sum_{j=1}^{2} n_{m/j}\, c_{m/j} d$

Where;

n_m (Locomotives) = 1,

c_m (Flat Wagons) = 0.33

c_m (Locomotives) = 15.78,

n_m (Flat Wagons) = 36

The freight train mostly consists of five crew member that are two drivers and three guards. Wage data was taken from commercial vehicle owners and. Table 4.29 shows the average driver and guard wage for freight movement.

Table 4-14: Average wages of crew from Fbd to Khi

S/No.	**Crew**	**No. Of staff** $\boldsymbol{n_{s/i}}$	**Salary** (PKR)	**Working hours in month**	**hourly remittance** $\boldsymbol{c_{s/i}}$ (PKR)	**Fbd. To Khi. Time** $\boldsymbol{t_{ai}}$ (hours)	**remittance /trip** (PKR)
1.	Drivers	2	42,000	200	210	24	10,080
2.	Guards	3	25,000	200	125	24	9000

4.2.2 Summary of Train's Internal Costs

Table 4-15: Trains internal cost summary

S/No.	**Cost component**	**Equation**	**Cost in PKR**
1.	Energy consumption	$C_{o3} = c_b eqd$	6,50,520
2.	Accessing and using the infrastructure	$C_{o2} = c_a qd$	3,75,000
3.	Maintenance of rolling stock (rail flat wagons + locomotive(s))	$C_{o1} = \sum_{j=1}^{2} n_{m/j}\, c_{m/j} d$	33,168
4.	Labour (staff)	$\boldsymbol{C_{o4} = \sum_{i=1}^{N} n_{s/i}\, c_{s/i} t_{ai}}$	19,080
	Total	c_z (q, d)	10,85,676

4.2.3 Handling Cost for Train $(c_{h1} + c_{h2})$

The main handling cost in intermodal network includes the costs incurred on intermodal terminals. There are different types of costs involved in on terminal container handling. The data regarding these costs was taken from Faisalabad dry port trust authorities ("Faisalabad Dry Port Trust Terrif Rates," 2021). Details of terminal handling costs are provided in table 4.32 These costs are incurred on both, departure and arrival terminals. Handling costs(c_{h1}, c_{h2}) are almost same on both terminals.

Table 4-16: Terminals handling cost

S/No.	Cost component	Monetary value (PKR)
1.	Inventory	300
2.	Crane	1,250
3.	Shifting	1,000
4.	Labour	3,000
5.	Seal	275
6.	Automation	100
c_{h1}		5,925
$(c_{h1} + c_{h2})$		11,850

4.2.4 Train's External (Air Pollution) Costs co (q, d)

The fraction of the emission is taken from EPA website for our representative vehicle i.e. tier 2 diesel electric locomotives (Norris, Ntziachristos, Samaras, & Zierock) and multiplied by per gram price. There are two types of external costs involved in train operations. One is on terminal air pollution which is caused due to shunting and other is produced during the line haul. Table 4.33 and Table 4.34 shows the air pollution costs involved in shunting and line haul process respectively.

Table 4-17: Train line haul air pollution cost

S/No.	**Pollutant**	**Emissions kg/ton**	**(a) g/l**	**Consumption (e) l/km**	**Emissions g/km**	**Cap Rs/g**	**Rs/km**
1.	NOx	63	52.5	4	210	0.087	18.26
2.	PM10	1.8	1.5	4	6	0.087	0.52
3.	PM2.5	1.1	0.92	4	3.7	0.087	0.32
4.	CO	18	15	4	60	0.087	5.22
Total							24.31

Table 4-18: Shunting process air pollution cost

S/No.	**Pollutant**	**Emissions Kg/ton**	**G/l**	**Consumption (l)**	**Rs/g**	**Rs/ shunting**	**Rs/ container**
1.	NOx	54.4	45.3	30	0.087	118.23	
2.	PM10	2.1	1.75	30	0.087	4.56	
3.	PM2.5	2	1.67	30	0.087	4.35	
4.	CO	10.8	9	30	0.087	23.47	
Total						150.62	2.0

Shunting is not distance dependent process. It is just demand dependent. This is why it is not included in cost function co (q,d). it is directly added into the external cost in the final calculation.

4.2.5 Collection Distribution (C/D)

For the collection distribution step, P/km costs are same as the all-road scenario. Just toll tax costs are deducted from the internal costs of the truck. All calculated P/km costs are multiplied with collection distribution distance (15 km) to get the overall costs of collection distribution step. Table 4.35 represents internal costs of transportation involved in C/D step.

Table 4-19: Internal C/D transportation cost

S/No.	**Attribute**	**Eq.**	**Cost in PKR**
1.	Energy consumption	$C_{z3} = c_b e d$	482
2.	Maintenance of trucks	$C_{z1} = c_m d + c_l d + c_w d$	180
3.	Labour (staff)	$C_{z4} = \sum_{i=1}^{N} n_{s/i}\, c_{s/i} t_{ai}$	83.7
4.	Depreciation	$C_{z5} = c_d d$	75
	Total	c_z (q, d)	820

Handling cost in C/D step is also same as the road line haul step, because trucks are responsible for the factory to terminal transfer. The handling cost of different attributes and Air pollution costs are shown in Table 4-20 and Table 4-21 respectively.

Table 4-20: C/D handling cost

S/No.	Cost category	Cost
1.	Loading	2,000
2.	Unloading	1,000
3.	Station surcharge	500
4.	Total ($C_{h/kl}$)	3,500

Table 4-21: C/D external air pollution cost

S/No.	Pollutant	G/km	(Rs/km)	Rs/g	Air pollution cost
1.	NOx	5.7	0.5	0.087	15
2.	PM10	0.14	0.01	0.087	0.3
3.	PM2.5	0.13	0.01	0.087	0.3
4.	CO	1.48	0.13	0.087	3.9
Total			0.65	0.348	19.5

4.3 Total costs

After calculation off all the variables, values are put in the model equation to get the result. Analysis is carried out for Q=1227 (per day) and d=1200. Step wise calculation of All road and intermodal scenario is carried out below.

4.3.1 All Road (Collection, Distribution, line hauls)

Transport (internal) cost:

$$C_{1/kl} = (Q_{kl}/Ʌ_{kl}M_{kl})C_{zkl}(d_{kl})$$

$$C_{1/kl} = \text{PKR 65.3 Millions}$$

Handling cost:

$$C_{2/kl} = Q_{kl}C_{h/kl}$$

$$C_{2/kl} = \text{PKR 4.2 Millions}$$

External costs:

$$C_{3/kl} = (Q_{kl}/Ʌ_{kl}M_{kl})C_{ekl}(d_{kl})$$

$$= \text{PKR 0.708 Millions}$$

Total cost function for road network:

$$\sum_{i=1}^{3}\sum_{kl=1}^{KL} C_{i/kl}$$

= PKR 70.32 Millions

4.3.2 Intermodal Network

(Collection, distribution)

Transport (internal) cost:

$$C_{1/k} = 2(Q_k/ʎ_k M_k)C_{ok}(d_k)$$

= PKR 2.33 Millions

Handling cost:

$$C_{2/k} = Q_k t_{h/k} C_{h/k}$$

= PKR 4.2 Millions

External costs:

$$C_{3/k} = 2(Q_k/ʎ_k M_k)C_{ek}(d_k)$$

= PKR 0.022787.14 Millions

Sub Total:

$$\sum_{i=1}^{3}\sum_{k=1}^{K} C_{c/i/k}$$

= PKR 6.6 Millions

Lines haul:

Transport (internal) cost:

$$C_{1/lh} = fC_o(q,d) = \frac{Q}{(q_t)c_o(q,d)}$$

$= \text{PKR } 22.04 \text{ Millions}$

Handling cost:

$$C_{2/t} = Q(c_{h1} + c_{h2})$$

$= \text{PKR } 14.5 \text{ Millions}$

External costs:

$$C_{3/lh} + C_{4/lh} = Q(c_{e1} + c_{e2}) + fC_e(q,d) = Q(c_{e1} + c_{e2}) + \left(\frac{Q}{q}\right) c_e(q,d)$$

$= \text{PKR } 0.5 \text{ Millions}$

Sub Total:

$$\mathrm{C_{lh}} = \sum_{\mathrm{i=1}}^{4} \mathrm{C_{i/lh}}$$

$= \text{PKR } 37.1 \text{ Millions}$

4.3.3 Total Cost Function for Intermodal Network

$$\mathrm{CF} = \mathrm{C_c} + \mathrm{C_{lh}} + \mathrm{C_d}$$

$$= \sum_{\mathrm{i=1}}^{3} \sum_{\mathrm{k=1}}^{\mathrm{K}} \mathrm{C_{c/i/k}} + \mathrm{f}[\mathrm{C_o}(\mathrm{q,d}) + \mathrm{C_e}(\mathrm{q,d})] + \sum_{\mathrm{i=1}}^{3} \sum_{\mathrm{k=1}}^{\mathrm{K}} \mathrm{C_{d/i/k}}$$

$= \text{PKR } 43.7 \text{ Millions}$

Using the models dveloped in the previous chapter, we will carry out the cost comparison analysis of the three modes related to LDHV freight. From Figure 4-4, it can be confidently concluded that intermodal transportation is comparitively less expensive mode of providing intercity freight transportation in the context of the Fbd-Khi corridor, even when we consider social costs.

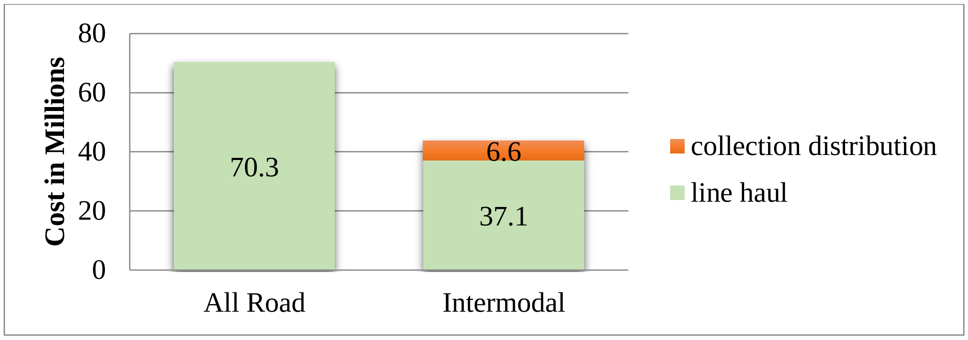


Figure 4-4: Total cost comparison of Fbd-Khi corridor

Figure 4-5 gives the insight on internal costs of different modes for a freight trip between Faisalabad and Karachi. The total internal cost for a single container would be PKR 53,237 by highway, PKR 17,963 by Rail, and PKR 19,863 by intermodal (truck-Rail) transfer. This difference in internal costs accounts for the main difference in total costs of the logistics. The reason behind this is that for 75 containers only one freight train is needed which is hauled by one or two locomotives. On the other hand, different truck is needed for every container to be transferred.

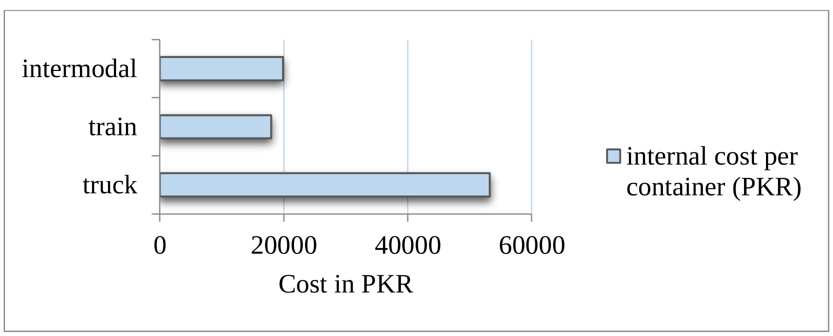


Figure 4-5: Internal cost per container

From Figure 4-6, we can see that handling cost for intermodal freight transport is very high as compared to trucks. Handling cost for single container in intermodal freight transfer is PKR 15350 which is almost five times the handling cost for trucks (PKR

3500). During the intermodal freight transfer container is to be handled on two intermodal terminals and in collection distribution step. On the contrary road transport transfers the freight for door-to-door distance that is why very low handling charges are involved. In intermodal freight transfer, handling charges contribute to almost 40% of total costs.

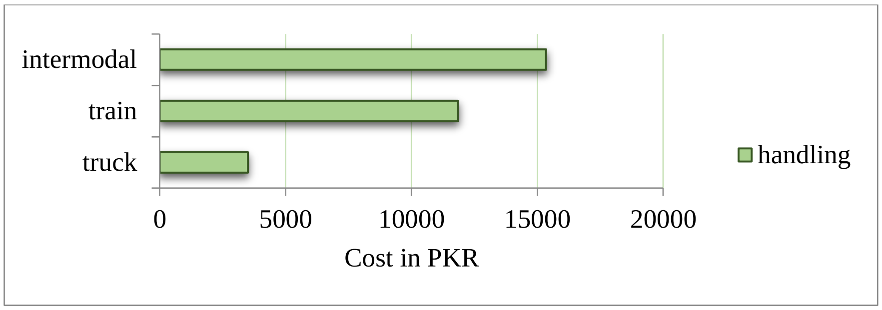


Figure 4-6: Handling cost per container

Figure 4-7, gives the insight on external or social costs of transferring a container from Faisalabad to Karachi through different modes. Social costs are not very high as compared to internal or handling costs. Social costs for Intermodal freight transfer is almost 20% less as compared to roads, making this modal shift necessary for sustainability.

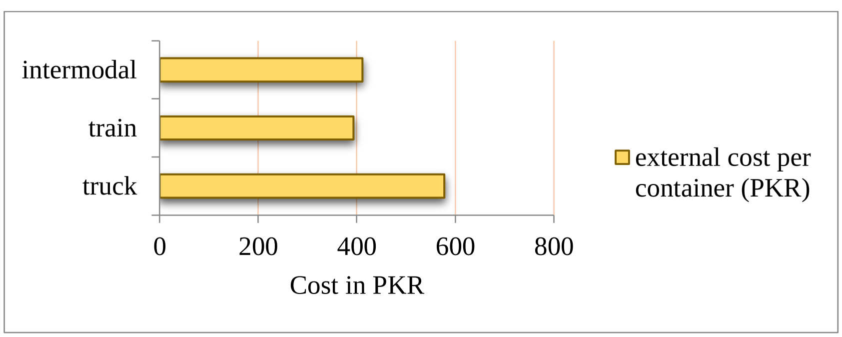


Figure 4-7: External cost per container

4.4 Hierarchy of Distances

The cost comparison of intermodal and road freight transport is sometimes shown by a simplified diagram showing a breakeven point when the cost of rail falls less than that of road. The diagram's core rationale is based on two assumptions: rail haul prices are lower than road haul costs, and intermodal incurs significant extra costs in transferring consignments to, from, and through terminals. The results of the examined route confirm this basic pattern. In terms of transport costs, rail has an average benefit of roughly 2.26 PKR/tkm. The cost of transshipments along the route, the necessity to haul to and from terminals, and the fact that the route distance by rail is invariably longer undermine rail's dominance in transferring consignments.

In the examined corridor, the trip by multimodal transport is 5 to 10% longer than the road system. In reality, this additional distance is likely to be significantly greater in circumstances where terminals are not conveniently located or intermodal services are not available on the more direct route. The high density of road network in Pakistan offers it an advantage over rail.

Distance plays an important role in selection of the modes. Figure 4.11 depicts the overall cost of transporting a 20' container across various distances. The graph depicts that at just over 500km, an apparent crossover point occurs which shows that for the the given demand, below 500km it is more feasible to use trucks as a mode of freight transport while with the increase in distance intermodal becomes the better solution. The cost difference between road and intermodal will vary depending on, the length of the pre- and post-hauls, the extra distance that hauling to and from terminals adds to overall distance for intermodal, the existence of truck-train transshipment and the actual cost of main rail haul. Fig 4.12 represents the relationship of distance with per ton km charges of the freight movement.

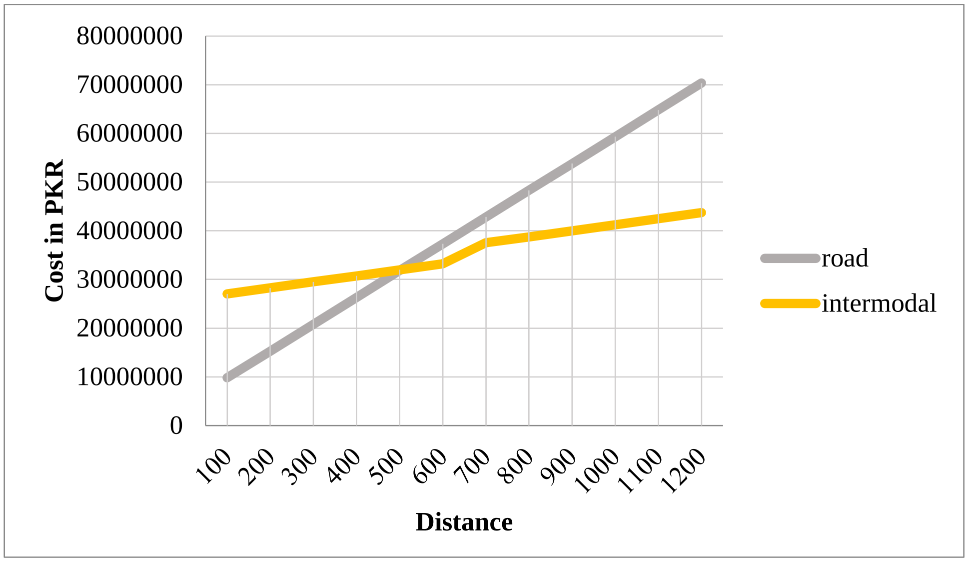


Figure 4-8: Cost vs Distance for 20' container

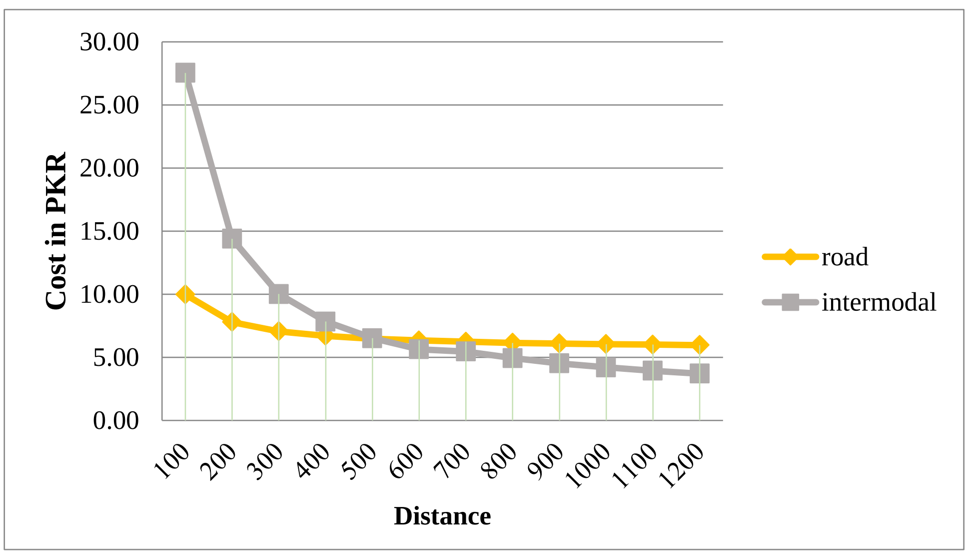


Figure 4-9: Distance-wise cost variation per ton km

The Figure 4-10 represents the internal costs of two modes of transportation for a given corridor. Whilst the points referring to their internal costs fall in the general area of the two lines, they do illustrate the important point that, for a given corridor distance, the cost comparison can vary dramatically depending on circumstances. Simple conclusions about relative intermodal and road costs at different distances are not possible. A closer look on the internal costs of representative modes shows that due to direct increase in no. of units in road transportation the internal cost increases linearly, whilst there is slight increase in internal costs of the train. The crossover occurs just at 160km. in intermodal transportation generally the handling and transshipment cost are very high but due to the haulage of multiple containers by single unit internal costs are very low. That accounts for the big difference in costs of two modes. Thus, rail's advantage emerges as distance increases but there is still a large share that road retains.

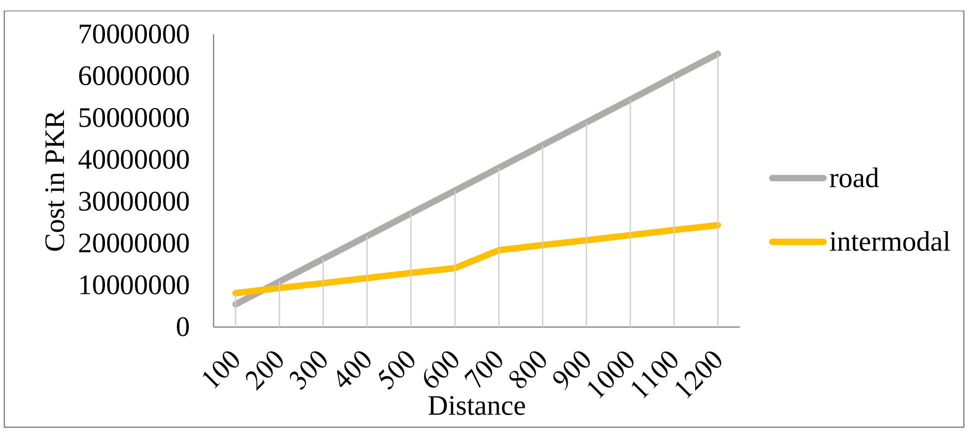


Figure 4-10: Internal cost vs distance

4.5 Costs Benefit Analysis

To study the benefits which can be fetched through implementation of intermodal freight transportation, different scenarios were designed for the future and analyzed with the help of model. Transportation cost of single unit through truck and intermodal in 2021 is taken as base cost and inflation is applied for future costs. These costs are enlisted in table 4.38 in Annexture A While fig 4.14 represents cost difference of moving single unit through both modes in coming years. With the help of calculations demand is shifted to intermodal network in following steps and analyzed.

- First step; Running two freight trains in 2022 (Proposing 12% modal shift)
- Second step; Running 5 freight trains in 2026 (Proposing 28% modal shift)
- Third step; Running 8 freight trains in 2030 (Proposing 41% modal shift)

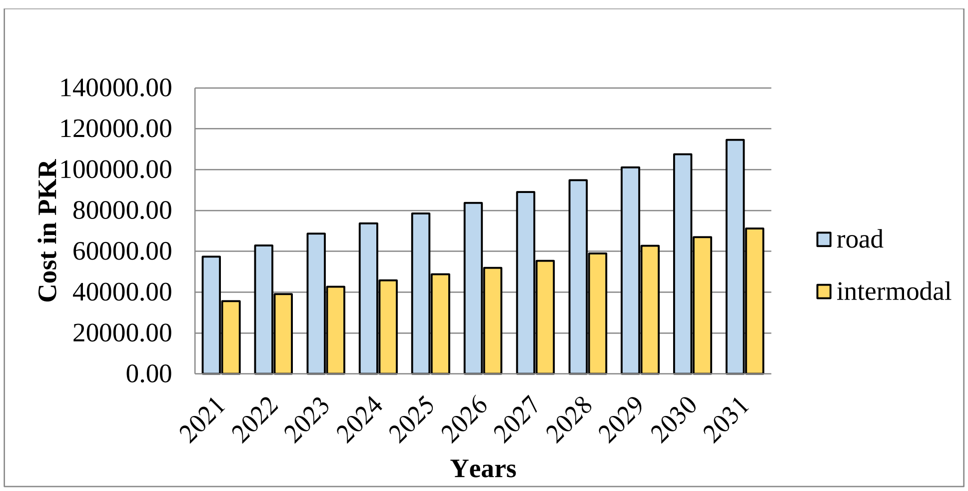


Figure 4-11: Cost of moving single container in coming years

4.6 About Economy

4.6.1 First Approach; Running 2 Freight Trains in 2022 (Proposing 12% Modal Shift)

In the first step of analysis just 12% of demand is shifted to intermodal network by running two freight trains. It is evident by the calculations that By doing so, 1.3 billion rupees can be saved annually. Table 4.39 shows the cost difference between running fully on the trucks and inducting 2 freight trains for Faisalabad Karachi corridor which can also be seen in fig 4.15

Total demand in year 2022 = 1252 units

Truck share (88%) = 1102 units

Rail share (12%) = 150 units

Cost of single unit by truck in 2022 = 62874 PKR

Cost of single unit by rail in 2022 = 39080 PKR

Table 4-22: Cost saving with proposed 12% modal shift

S/No.	Description	Present case (pkr in billions)	Proposed 12% modal shift (pkr in billions)
1.	Road	28.7	25.3
2.	Intermodal		2.1
3.	Total	28.7	27.4
Annual saving			1.3

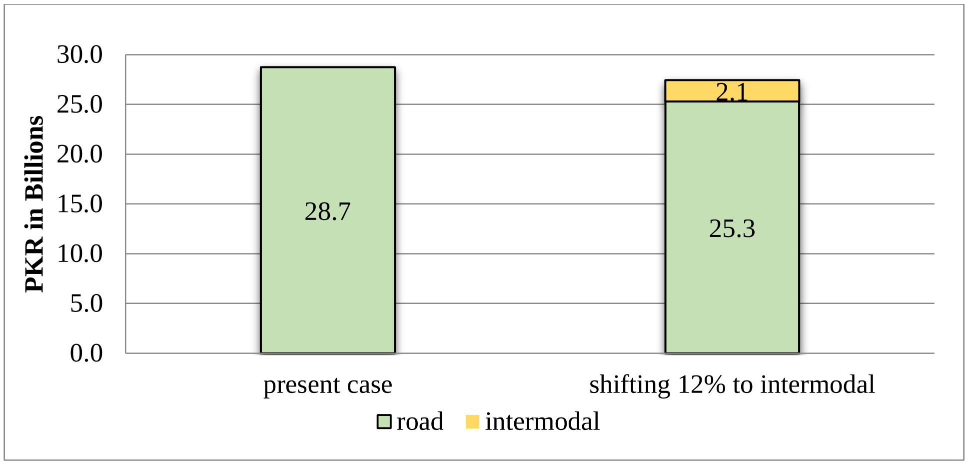


Figure 4-12: Total cost saving with proposed 12% modal shift

4.6.2 Second Approach; Running 5 Freight Trains in 2026 (Proposing 28% Modal Shift)

Our main goal is to shift as many loads to intermodal network as possible. It cannot be done overnight or in days so in second step we ought to shift 28% demand on trains in 2026, which can be accomplished by running 5 freight trains between Faisalabad and Karachi. With the growth of 2% every year, our total demand in year 2026 will be 1355 units daily amongst which 375 units will be shifted to rail. By the analysis it is found that annually 4.3 billion PKR can be saved by shifting 28% demand to the railway. Table 4.40 shows the cost difference between present modal choice and proposed scenario for Faisalabad Karachi corridor which is also illustrated in fig 4.16 for better understanding.

Table 4-23: Cost saving with proposed 28% modal shift

S/No.	Description	Present case (pkr in billions)	Proposing 28% to intermodal (pkr in billions)
1.	Road	41.4	29.9
2.	Intermodal		7.1
3.	Total	41.4	37.0
	Annual savings		4.3

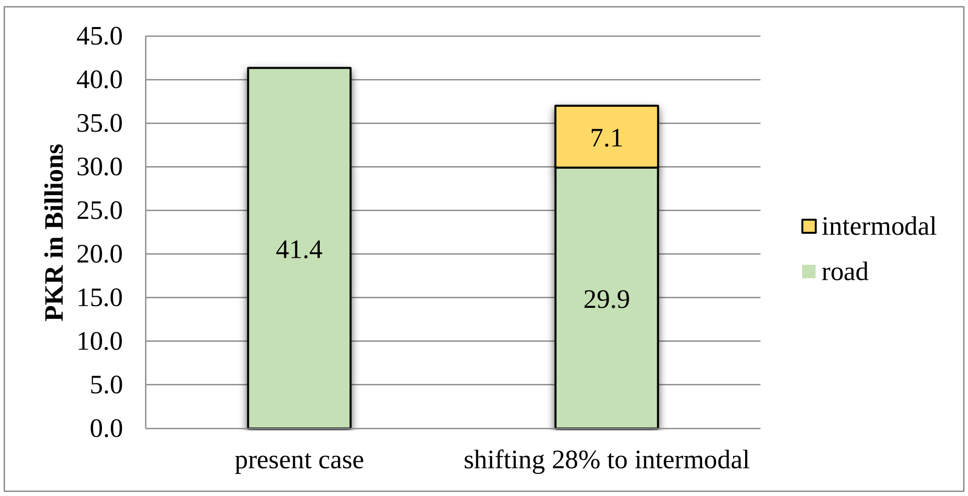


Figure 4-13: Cost saving with proposed 28% modal shift

4.6.3 Third Approach; Running 8 Freight Trains in 2030 (Proposing 41% Modal Shift)

The final step to achieve our goal is 41% shift of demand on the railways in nine years, which is accomplished by inducting 8 freight trains daily between Faisalabad and Karachi. From table 4.41 in year 2030 our daily demand will be 1466 units per day. To achieve desired modal shift 600 containers will be shifted to rail. By analysis it is found that annually a whopping amount of 8.9 billion PKR can be saved in this way. Table 4.41 shows the cost difference between present modal choice and proposed scenario in 2030 for Faisalabad Karachi corridor.

Table 4-24: Cost saving with proposed 41% modal shift

S/No.	**Description**	**Present case (pkr in billions)**	**Shifting 41% to intermodal (pkr in billions)**
1.	Road	57.6	34.0
2.	Intermodal		14.6
3.	Total	57.6	48.7
4.	annual savings		8.9

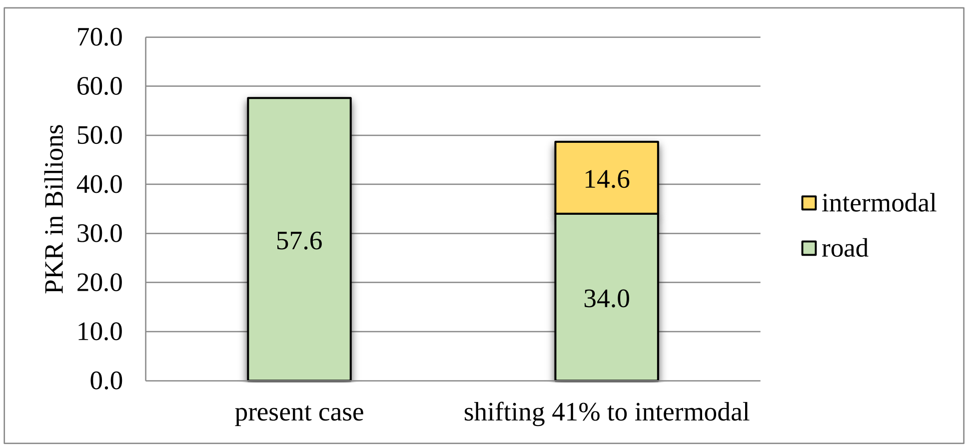


Figure 4-14: Cost saving with proposed 41% modal shift

4.7 About Environment

Along with cost saving it is also our motive to reduce the Air pollution and social costs associated with it. For this purpose, our proposed scenarios are also checked for air pollution. Table 4.42 contains the value of per km and per trip emissions of all road and intermodal freight transportation. The difference of emissions between two modal choices is shown in fig 4.17

Table 4-25: Emissions from all transport modes per km per trip

S/No.	Pollutant	G/km	Truck emissions for single trip (g)	Train emissions for single trip (g)	C/d step emissions for single trip (g)	Intermodal emissions for single trip. (g)
1.	NOx	5.70	6838.104	3220	170.9526	3390.9526
2.	PM10	0.14	173.352	92	4.3338	96.3338
3.	PM2.5	0.13	159.96	56.2	3.999	60.221222
4.	CO	1.48	1781.88	920	44.547	964.547
	Total	7.45	8953.296	4380.2	223.832	4512.1

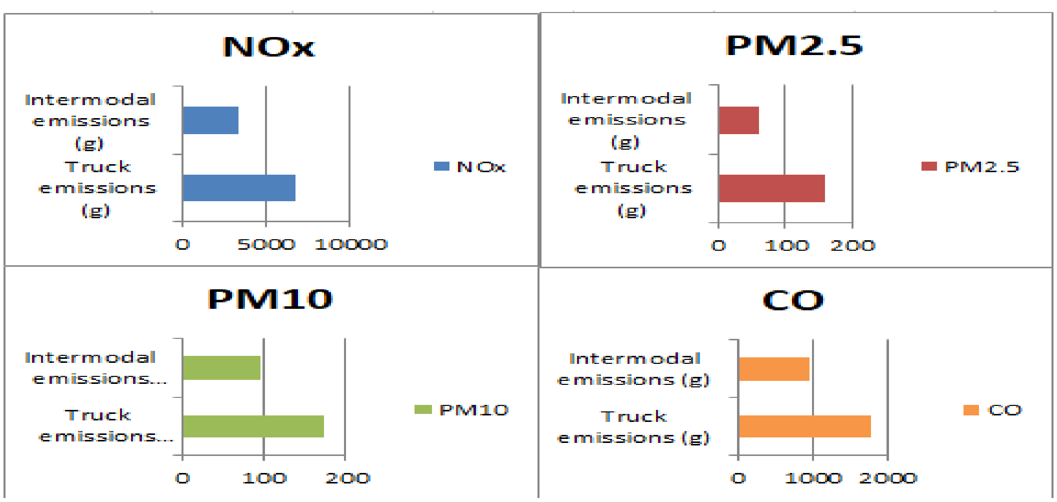


Figure 4-15: Emission comparison of different transport modes

4.7.1 Reduction in Pollution

From the fig 4.17 to fig 4.19, it can be easily understand that the emission cost of both the COx and NOx from the trucks used as main transporting modes is high as compare to the intermodal freight transportation making the intermodal mode of transportation more ecofriendly and sustainable in the long run.

Table 4-26: Emission reduction in 2022 (proposed 12% modal shift)

S/No.	Pollutant	Total all road emissions (tons)	Total emissions with shifting 12% to intermodal (tons)	Reduction in emissions (tons)
1.	NOx	3124.9	2938.1	186.75
2.	PM10	79.2	75.1	4.14
3.	PM2.5	73.1	67.7	5.39
4.	CO	814.3	769.9	44.35

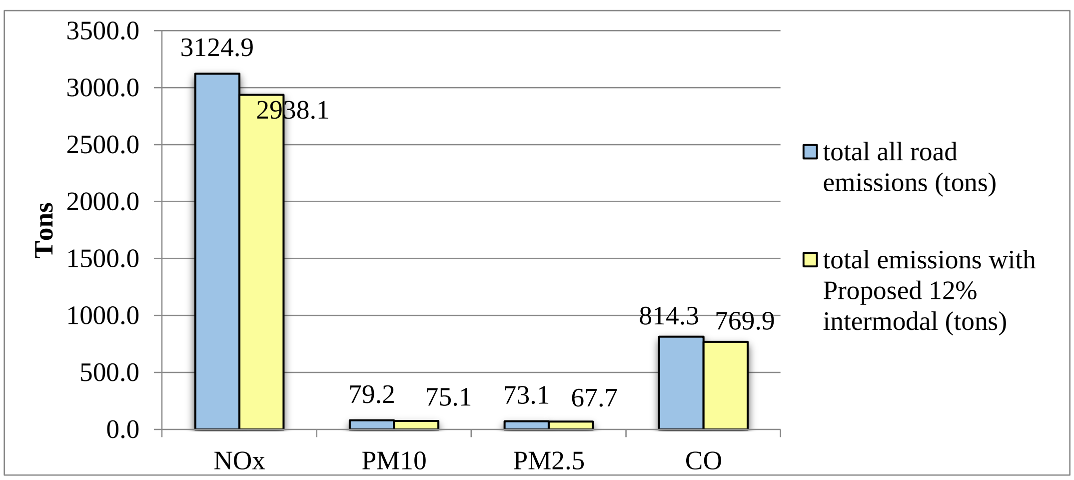


Figure 4-16: Emission reduction in 2022 (proposed 12% modal shift)

Table 4-27: Emission reduction in 2026 (proposed 28% modal shift)

S/No.	Pollutant	Total all road emissions (tons)	Total emissions with Proposed 28% modal shift	Reduction in emissions (tons)
1.	NOx	3382	2915	467
2.	PM10	86	75	10
3.	PM2.5	79	66	13
4.	CO	881	770	111

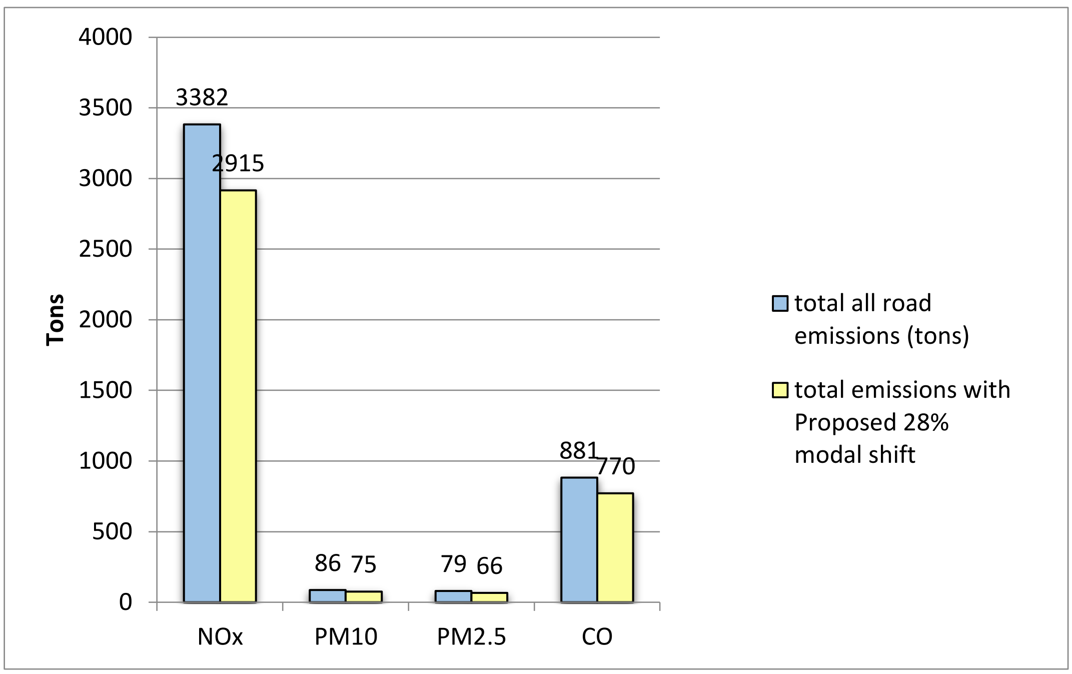


Figure 4-17: Emission reduction in 2026 (proposed 28% modal shift)

Table 4-28: Emission reduction in 2030 (proposed 41% modal shift)

S/No.	Pollutant	Total all road emissions (tons)	Total emissions with Proposed 41% modal shift	Reduction in emissions (tons)
1.	NOx	3659	2912	747
2.	PM10	93	76	17
3.	PM2.5	86	64	22
4.	CO	953	776	177

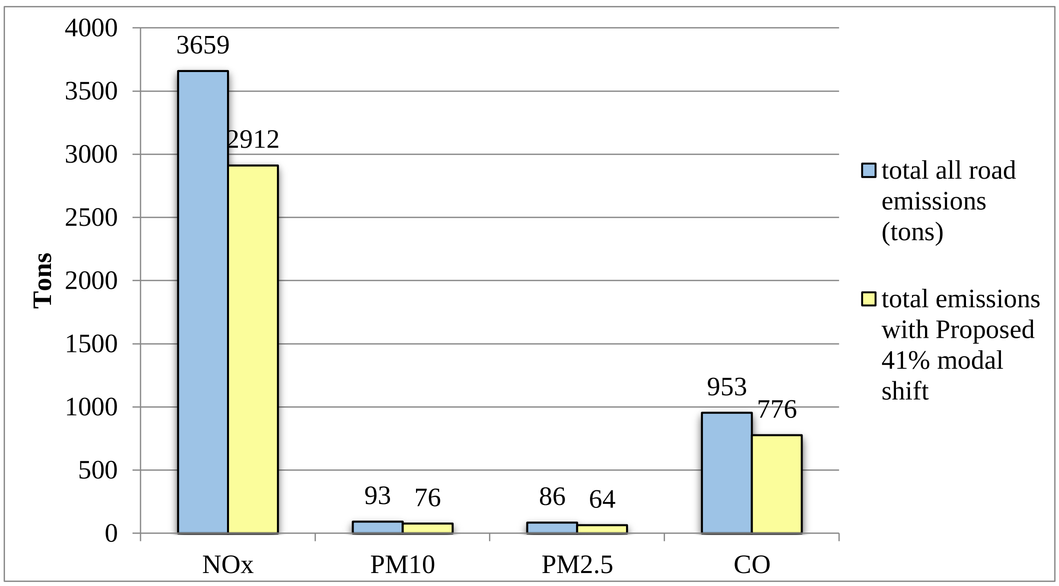


Figure 4-18: Emission reduction in 2030 (proposed 41% modal shift)

4.7.2 Reduction in Social Costs

Along with Less emission from the intermodal transport, the social cost of the intermodal transport in 2022, 2026 and 2030 is also less as compared to trucks as represented in the Figure 4-19 below. Therefore, keeping in mind for the future transportation scenarios and the sustainable development goals, the intermodal transport may be preferred over the conventional truck mode of transportation.

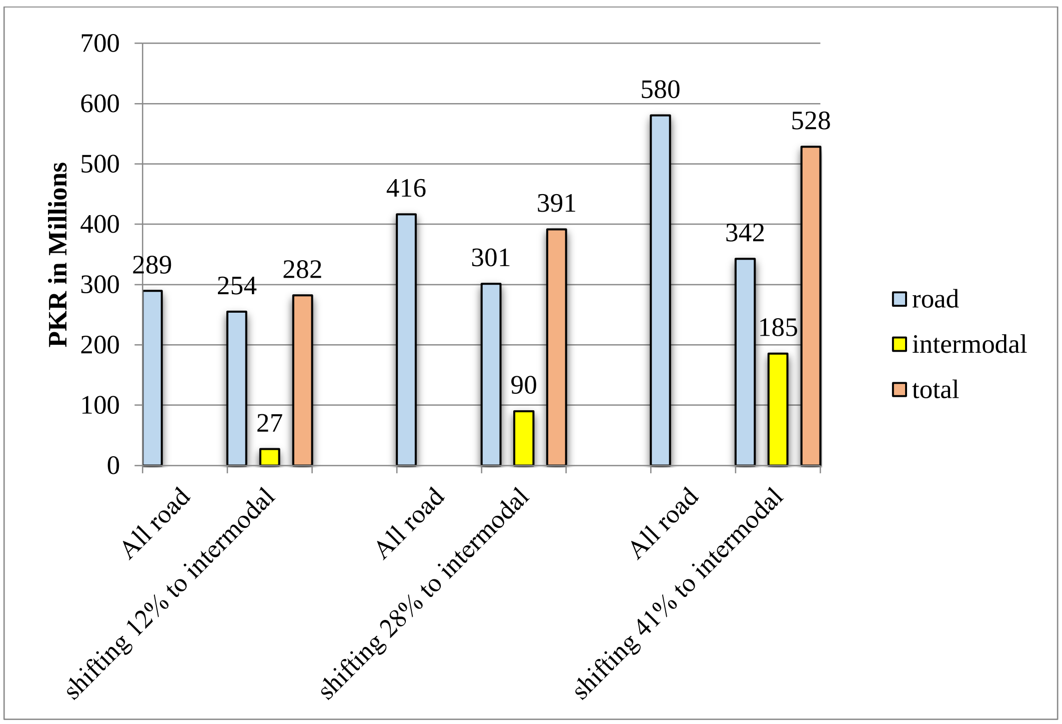


Figure 4-19: Social cost comparison of existing and proposed scenario in 2022, 2026 and 2030

4.8 About Operations

As it is evident from the results that Railway is better than road transport in terms of economy and causes less pollution. But it should be checked that if our new proposed routes are in the capacity constraint. For this purpose capacity analysis of Pakistan railway is carried out in proceeding sections.

4.8.1 Calculation of Capacity of a Railway Track

Common Factors:

Table 4-29: Characteristics of freight Train

S/No.	**Characteristics of freight Train**	
1.	Tare of a container	(20' =2.3ton) , (40'=4 ton)
2.	Average load efficiency of loaded container wagon	= 0.59
3.	Average tonnage of loaded container	5.0 ton
4.	Gross weight of loaded container	7.3 ton
5.	Gross tonnage of Containers + Wagon	26.4 ton
6.	Average length of a wagon	40ft
7.	locomotive	3,000HP diesel
8.	Maximum speed	80 km/hr
9.	Hauling capacity	1,800 ton
10.	Net transported tonnage	1,800 ton/train
11.	Ratio of track use	0.7
12.	Speed of train	70% of Maximum

13.	Blocking time	0 for Automatic
		3 min for Token less
		5 min for Token block system
14.	Distance between two stations	12 Km
15.	Signal sight distance	1.2 km
16.	length of train	0.6 km

4.8.2 Scott's Formula

$$N = f * T/(t + c) \qquad \text{(Eq. 4-1)}$$

Where;

N= Capacity of railway line / day.

f= Track use ratio

t = 60 * l/v (running time) (min.)

T= 24 hours

Signal sighting distance + 2 block sections + train length (km) (Automatic block system)

c= Time required for blocking

V= Speed of train (km/hr)

L= Distance among two stations

Source (JTRC)

4.8.3 Capacity of Single Line-track in Primary Lines (Faisalabad to Khanewal)

4.8.3.1 Present state (Single track section, Automatic block, mainly 4-weeler freight wagons)

Table 4-30 Present state trains/day (Both directions)

S/No.	Properties	Value taken
1.	adjoining stations distance	12km
2.	Successive Operation Ratio in same direction	20% of train speed 55 km/hr * 0.7 = 38.5km/hr
3.	Signal sighting distance + a train length + 2 block sections	7.9 km
4.	Block system (automatic)	Train exchange; c = 0.5
		Successive operation; c = 0
N		58 trains/day (Both directions)

4.8.3.2 With improvement (Block (automatic), high performance freight wagons)

Table 4-31: After improvement trains/day (Both directions)

S/No.	Properties	Value taken
1.	adjoining stations distance	12km
2.	Successive Operation Ratio in same direction	10% Train speed: 80 * 0.7 = 56 km/hr
3.	Signal sighting distance + a train length + 2 block sections	7.9 km
4.	Block system (automatic)	Train exchange; c = 0.5
		Successive operation; c = 0
N		77 trains/day (Both directions)

4.8.4 Line Capacity of Double-track in Karachi - Lahore

4.8.4.1 Present Case (Block system (automatic), high performance freight wagons)

Table 4-32: Present case trains/day double track

S/No.	Properties	Value taken
1.	Signal sighting distance + a train length + 2 block sections	7.9 km
2.	Speed of a Train	80 km/hr * 0.7 = 56 km/hr
3.	Block system (automatic)	c = 0
N		122 trains/day-direction

4.8.4.2 With electrified improvement (Block system (automatic), mainly high performance (electrified) freight wagons)

Table 4-33: After improvement trains/day double track

S/No.	Properties	Value taken
1.	Signal sighting distance + a train length + 2 block sections	7.8 km
2.	Block system (automatic)	C=0
3.	Speed of a Train	100 km/hr * 0.7 = 70 km/hr
N		152 trains/day-direction

4.8.5 Availability of Slots

Pakistan railway is currently running 38 and 16 trains on daily basis on its double track and single track which has capacity of 122 trains per day and 58 trains per day respectively. So, there are many slots available for proposed trains to run.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

Proposed scheme would be beneficial in reducing the freight transportation cost and saving billions of rupees anually. In the intermodal situation, full and internal costs decline more rapidly with increasing distance than in the road transport network. As a result, the costs of both networks equalised at a break-even distance - shorter for internal costs and longer for full costs. Reduction in GHG emissions is the need of time. Proposed scheme analysis shows that thousands of tons of various GHG gasses can be reduced in the atmosphere by implying this modal shift. Additionally, the modal shift will contribute in reducing traffic congestion on the existing road network, Thus decreasing travel time and enhancing road safety. The proper utilization of rail network would not only benefit the rail industry (promoting sustainable freight transportation) but add value of money to the government treasury. Implementation of such schemes would also serve as beneficial in restructuring and reviewing the rail based freight industry. It is a time of need to have an integrated sustainable transport policy, and for that it needs an input from professionals and researchers from industry and academia.

For future, it should be focused on considering vehicles of the different capacity and load factor to collect and distribute load units in a given zone. The different distances for different zones in collection and distribution step should be analysed and model should be applied to urban freight movement.

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ANNEXTURES

Annex A	Definitions & Theory
Annex B	Tables
Annex C	Figures

a. Classification of Trucks Used in this Study

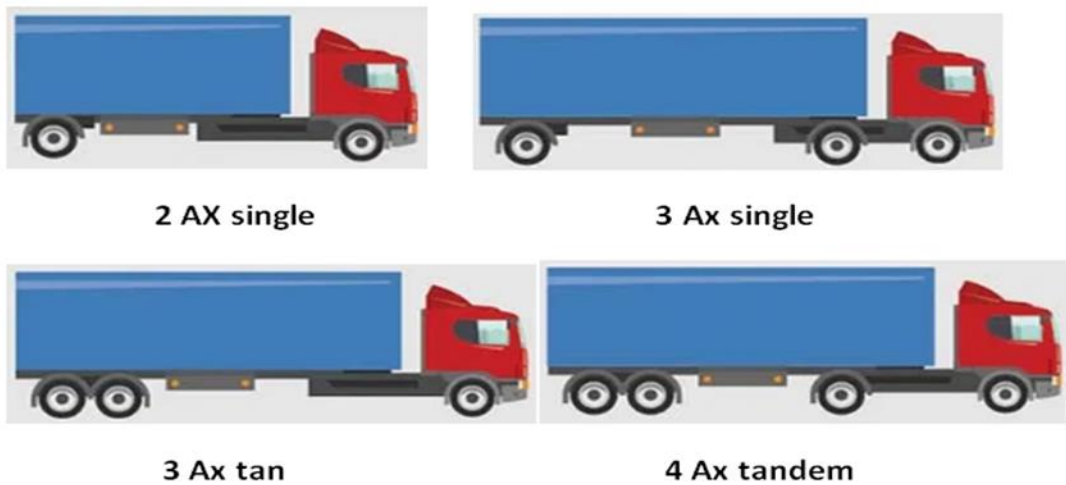

Figure A. 1 Types of truck w.r.t Axle

A.1. Damages due to Air-Pollution

Pollutants in the air can cause a variety of problems. The health impacts of air pollution are the most important and likely the most well studied. Other damages, including as structural and material damage, crop losses, and biodiversity loss, are also important.

Health Effects

Inhaling air pollutants such as particles (PM10, PM2.5) and nitrogen oxides (NOx) increases the risk of respiratory and cardiovascular illness (e.g. bronchitis, asthma, lung cancer). These poor health effects result in medical treatment expenditures, lost productivity at work (due to illness), and, in some circumstances,

Crop Losses

Ozone, a secondary air pollutant (mostly created by NOx and VOC emissions), and other acidic air pollutants (e.g., SO2, NOx) can harm agricultural crops. As a result, increased ozone and other chemical concentrations may result in poorer crop yields (e.g., for wheat).

Material and Building Damages

Pollutants can primarily cause two forms of harm to buildings and other materials: a) polluting of building surfaces via particles and dust; and b) damage to building facades and materials owing to corrosion processes produced by acidic substances (e.g., nitrogen oxides NOx or Sulphur oxide SO2).

Biodiversity Loss

Air Contamination can destroy ecosystems. The most serious consequences are a) acidification of soil, rainfall, and freshwater (caused, for example, by NOx and SO2), and b) eutrophication of ecosystems (e.g., by NOx, NH3). Ecosystem damage can result in a reduction in biodiversity (flora & fauna).

Building and material damage and biodiversity losses cannot be monetized so we will just focus on health damages because in the end all these things effect on the health.

A.2. Emissions from the Trucks

The main factors influencing the external costs of air pollution from road vehicles are:

- Vehicle emission standard
- Speed of driving (correlated to road types: urban/extra-urban/motorway drives)
- Load of vehicle - Road gradient
- Location of drive: urban / extra-urban

A.3. Types of Costs Involved

Loading/unloading - Shipper / consignee

The companies that send and receive the consignment are the first and last steps in the transportation procedure. Their expenses include the expenditures of loading (unloading) and storing the transport units (containers, trailers). A corporation may also incur expenditures by leasing or owning units used for moving products.

Pre haulage / Post haulage

Road transport businesses often provide pre and post haulage to and from terminals (e.g., rail). Road haulage firms face costs associated with vehicle ownership and operation, which in most cases includes the payment of taxes. The overall costs include the time spent loading and unloading as well as the transportation. Tolls may be used to pay for infrastructure, which incurs additional costs.

Transhipment

This is the location where loading units are physically moved from one vehicle to another comparable vehicle of the same mode (e.g., truck to truck). The capital cost of the equipment required for transhipment, its operation, and the storage room required are all costs involved.

Terminal Transfer

A terminal is described as a location that houses the functions and technical assets that allow a loading unit to be transferred between two different types of carrying units. Transfers between modes of transportation - rail and vehicle – are possible.

Marshalling Yard Transfer

The function of a marshalling yard is the transshipment of loading units from one train to another, or, more commonly, the rearrangement of wagons into a single train.

Main haulage: Road

Road haulage firms face costs associated with vehicle ownership and operation, which in most cases includes the payment of taxes. Tolls and road charges may also incur costs for infrastructure payment. This includes all national road tax stickers, motorway tags, and tolls for national highways.

Main haulage: Rail / Train

The costs are for a rail ride from one terminal to another. It includes any fees for using the rail infrastructure. These payments may or may not cover the infrastructure costs.

As well as breaking down a journey into individual activities it is possible to disaggregate the costs into a set of standard elements. These are

Depreciation Costs

This comprises all expenditures associated with providing and maintaining transportation, loading units, and other technical equipment for the various tasks

Personnel Costs

It comprises all costs incurred by operators in providing salaries, social security, and wage bonuses to their staff

Consumption Costs

Includes all expenditures for fuels, oil, tyres, and electric power for all forms of transportation.

Maintenance Costs

This includes all costs for repairing and operating transportation and loading units, Infrastructure upkeep is not included.

Insurance Costs

Which solely includes the price of insuring modes of transportation and loading units

Taxes

Which include taxes paid on the purchase, use, and operation of automobiles However, indirect taxes such as VAT are not allowed.

Tolls and Charges

It comprises all costs and tolls incurred by operators in the various forms of transportation for infrastructure use

Other Costs

This encompasses all costs associated with the organization and delivery of transportation services These are borne by operators and service providers (such as forwarders).

External Costs

Externalities have become a prominent factor in the design and implementation of transportation policy. Transport activity generates costs in terms of additional resources spent or damage to humans that are not internalized; that is, the costs are not borne by the transport service provider - they are external.

Annex B.

TABLES

Table B. 1: Base Model Equations

Collection distribution step:		**Line Haul**	
Transport (internal) cost			
$\boldsymbol{C_{1/k} = (Q_k/\lambda_k M_k)C_{ok}(d_k)}$		$C_{1/lh} = fC_o(W,q,d) = (Q/q_t)c_o(W,q,d)$	
Handling cost:			
$\boldsymbol{C_{2/k} = Q_k t_{hk} C_{hk}}$		$C_{2/t} = Q(c_{h1} + c_{h2})$	
External costs:			
$\boldsymbol{C_{3/k} = (Q_k/\lambda_k M_k)C_{ek}(d_k)}$		$C_{3/lh} + C_{4/lh} = Q(c_{e1} + c_{e2}) + fC_e(W,q,d) = Q(c_{e1} + c_{e2}) + (Q/q)c_e(W,q,d)$	
Sub-total:			
$\boldsymbol{\sum_{i=1}^{3}\sum_{k=1}^{K} C_{c/i/k}}$		$C_{lh} = \sum_{i=1}^{4} C_{i/lh}$	
Total: $\boldsymbol{C_F = C_c + C_{lh} + C_d}$			

Source: (Janic, 2007)

Table B. 2: Distance-Wise Distribution of Trucks internal Cost

S/No.	d	Fuel Consumption $C_{z3} = c_b ed$ (PKR)	Maintenance $C_{z2} = c_t d$	Maintenance $c_m d + c_l d + c_w d$	Labour $c_c d$	Depreciation $c_d d$
1	100	3,212	520	1200	558	500
2	200	6,425	1040	2400	1116	1000
3	300	9,638	1560	3600	1674	1500
4	400	12,851	2080	4800	2232	2000
5	500	16,064	2600	6000	2790	2500
6	600	19,277	3120	7200	3348	3000
7	700	22,490	3640	8400	3906	3500
8	800	25,703	4160	9600	4464	4000
9	900	28,916	4680	10800	5022	4500
10	1000	32,129	5200	12000	5580	5000
11	1100	35,341	5720	13200	6138	5500
12	1200	38,554	6240	14400	6696	6000

Table B. 3: Costs of Different Diseases in Hospital

Hospital visits	**PKR in billion**
ALRI mortality (children <5 years)	4.9
Cardiopulmonary mortality (adults)	24.4
Lung cancer mortality (adults)	0.7
Chronic bronchitis	3.3
Hospital admissions	0.6
Emergency room visits	1.7
Restricted activity days	6.7
Lower respiratory illness in children	5.1
Respiratory symptoms	5.3
Annual cost (PRs Billion)	52.7

This data is from whole Sindh. According to (Sánchez-Triana, Enriquez, Afzal, Nakagawa, et al., 2014) 80% of this cost is spent in Karachi. So, the amount spent on air pollution in Karachi is 42.16 billion. These figures are from 2009 so applying inflation rates.

Table B. 4: Annual Inflation and Cost of Air Pollution

Year	**Inflation rate**	**Amount spent on diseases due to Air pollution**
2009	13.65	42.20
2010	12.94	47.96
2011	11.92	54.17
2012	9.68	60.62
2013	7.69	66.49
2014	7.19	71.60
2015	2.53	76.75
2016	3.77	78.69
2017	4.09	81.66
2018	5.08	85.00
2019	10.58	89.32
2020	9.74	98.77
2021		108.39

Table B. 5: Categorization of Trucks [www.epa.gov]

IIb:	8,501-10,000 lb (e.g., full-size pick-up trucks, very large passenger vans)
III:	10,001-14,000 lb (e.g., panel trucks, small enclosed delivery trucks)
IV:	14,001-16,000 lb (e.g., city delivery trucks, rental trucks)
V:	16,001-19,500 lb (e.g., bucket utility trucks, large walk-in delivery trucks)
VI:	19,501-26,000 lb (e.g., rack trucks, single axle vans)
VII:	26,001-33,000 lb (e.g., tow truck, garbage collection trucks)
VIIIa:	33,001-60,000 lb (e.g., long-haul semi-tractor trailer rigs)
VIIIb:	60,000 lb (e.g., double long-haul semi-tractor trailer rigs)

Table B. 6: Emissions from Different Categories of Trucks

Pollutant	Fuel	IIb	III	IV	V	VI	VII	VIIIa	VIIIb
CO	gas	11.2	15.81	33.86	19.58	18.13	23.13	28.56	-1.00
	diesel	0.84	0.91	1.16	1.19	1.37	1.72	2.40	3.11
NOx	gas	2.73	2.92	4.13	3.74	3.65	4.20	4.89	-1.00
	diesel	3.09	3.30	4.35	4.55	5.99	7.47	9.19	10.99
PM2.5	gas	0.04	0.05	0.06	0.05	0.05	0.05	0.05	-1.00
	diesel	0.09	0.07	0.09	0.08	0.17	0.18	0.22	0.24
PM10	Gas	0.05	0.05	0.07	0.06	0.05	0.06	0.06	-1.00
	Diesel	0.10	0.08	0.10	0.09	0.19	0.19	0.23	0.26

Table B. 7: Air Pollution Cost Variation with Distance

d	$c_{ap}d$
100	65
200	130
300	195
400	260
500	325
600	390
700	455
800	520
900	585
1000	650
1100	715
1200	780

Table B. 8: Fuel Cost Variation with Distance

d	**Energy consumption** $c_b eqd$	**Maintenance of rolling stock (rail flat wagons + locomotive(s))** $C_{o3} = \sum_{j=1}^{2} n_{m/j} c_{m/j} d$	**Labour (staff)** $C_{o4} = \sum_{i=1}^{N} n_{s/i} c_{s/i} t_{ai}$
100	54210	2764	1590
200	108420	5528	3180
300	162630	8292	4770
400	216840	11056	6360
500	271050	13820	7950
600	325260	16584	9540
700	379470	19348	11130
800	433680	22112	12720
900	487890	24876	14310
1000	542100	27640	15900
1100	596310	30404	17490
1200	650520	33168	19080

Table B. 9: Single Container Cost Comparison through Road and Intermodal

Year	Demand with 2% growth every year	Inflation	Cost of single unit through road	Cost of single unit through intermodal
2021	1227	9.70%	57315.08	35624.76702
2022	1252	9.24%	62874.644	39080.36942
2023	1277	7.35%	68684.261	42691.39555
2024	1302	6.5%	73732.554	45829.21313
2025	1328	6.5%	78525.17	48808.11198
2026	1355	6.5%	83629.306	51980.63926
2027	1382	6.5%	89065.211	55359.38081
2028	1409	6.5%	94854.449	58957.74056
2029	1438	6.5%	101019.99	62789.9937
2030	1466	6.5%	107586.29	66871.34329
2031	1496	6.5%	114579.4	71217.98061

Annex C.
FIGURES

Inflation rates

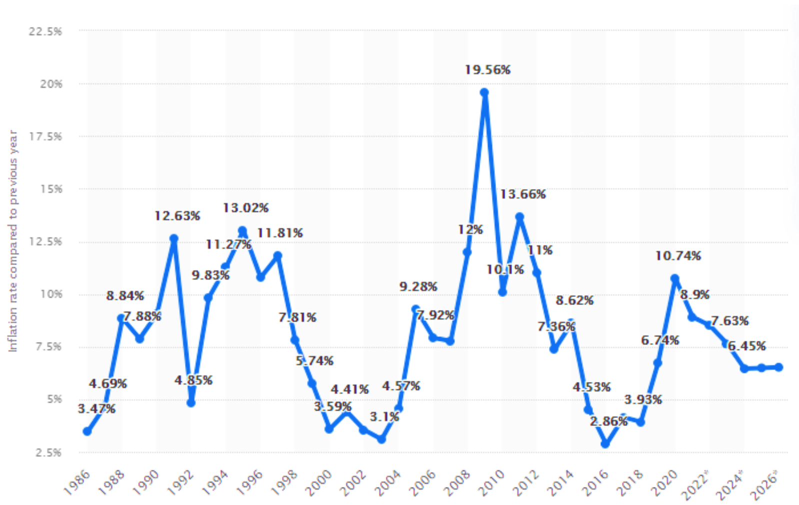

Fig C. 1: Pakistan annual inflation rate

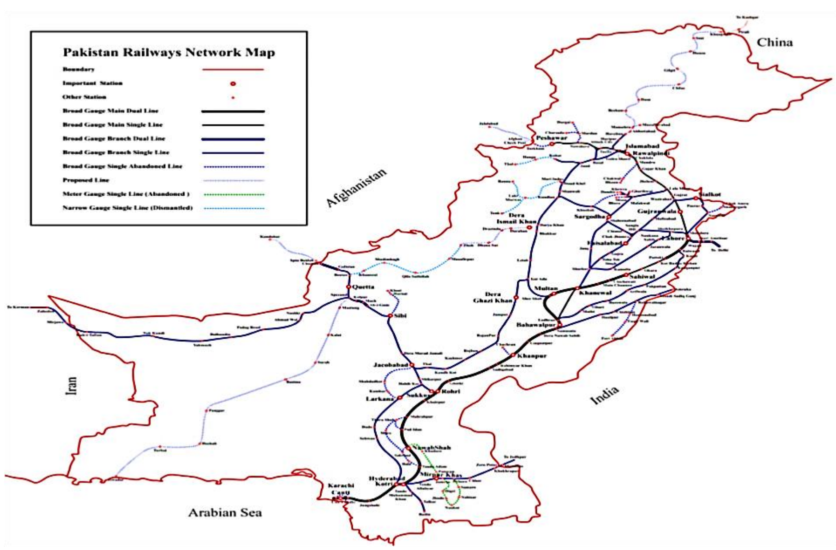

Fig C. 2: Railway system of Pakistan