TRAFFIC CAPACITY ANALYSIS AND TRUCK FREIGHT TRAFFIC MANAGEMENT ON CPEC ROUTES

By

Tabraiz Tehami

(NUST-MCE-205057)

A dissertation submitted in partial fulfilment of the requirements for the degree of Master of Sciences in Transportation Engineering

Supervised by

DR. MUHAMMAD JAWED IQBAL

MILITARY COLLEGE OF ENGINEERING

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY, RISALPUR

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This is certified that following thesis

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Has been accepted for the completion of degree requirements for

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Dr. Muhammad Jawed Iqbal
Military College of Engineering
National University of Sciences and Technology

Declaration

It is certified that the research work titled "***traffic capacity analysis and truck freight traffic management of CPEC routes***" is my genuine work. This work has not been presented anywhere else for evaluation. The contents that have been obtained from other sources have been appropriately acknowledged and referred.

Tabraiz Tehami

(NUST-MCE-205057)

This work is dedicated to

My Family, Teachers and Friends

who give me the

courage and moral support

to accomplish this

significant event of my life.

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All praises are for Allah, the Most Beneficent and the Most Merciful.

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CONTENTS

List of Tables

List of figures

ABSTRACT

Freight transport plays an imperative role in enhancing the economy of the country. Projects under CPEC, which includes energy projects, motorways/ highways, railway links, oil and gas pipelines, special economic zones (SEZ), dry ports and communication links, are expected to bring inclusive economic prosperity in the region especially to Pakistan. The highways in Pakistan are being used extensively for freight movement, which is leading to early deterioration/ failure of pavements and other road infrastructure. According to the survey of ministry of finance, 96% of the national freight traffic is carried on road networks (Ministry of Finance, Pakistan, 2008). With the development of CPEC, the freight demand across the country will increase which will intensify the traffic demand on National highways. In this backdrop, an effort has been made in analysing the current freight load carrying capacity in terms of road transportation on highways and motorways of Pakistan, in order to optimally and efficiently manage the truck freight traffic. Operational analysis of truck freight traffic under different conditions on CPEC routes was carried out to suggest a comprehensive framework to keep the operations of CPEC running under massive load for CPEC scenario. To evaluate the current capacity and improvements/ enhancements required under the effect of CPEC, trade shift from China and other neighbouring countries was the prime focus of this research.

CHAPTER 1

1. INTRODUCTION

1.1.PREAMBLE

Pakistan is a developing country of South East Asia region having the sixth largest population in the world and is strategically located at the intersection of south Asia, west Asia and central Asia; a way from resourceful countries to resource deficient countries. It has a population of over 206 million and total road network of approximately 271,000 km that serve about 29 million vehicles of all types (Economic Survey of Pakistan, 2019-2020). Pakistan provides shortest trade route from Gwadar to Kashgar with eventual possibility of linking it with Central Asian States. To exploit this opportunity China and Pakistan have mutually agreed to establish China Pakistan Economic Corridor commonly known as "CPEC". CPEC is an inclusive development program with an estimated cost of $46 Billion that involves the joining of Gwadar to China through highways, railways, oil and gas pipelines and an optical fibre link, along with different energy projects. It will significantly reduce the distance that the Chinese oil imports have to travel from 12000 kms to 3000 kms, which increases its significance particularly to China. Separate short-term (e.g. construction of Gwadar Airport) and long-term (e.g. construction of a rail link Xinjiang to Gwadar) goals which may take 10 to 15 years for completion have been envisioned under CPEC. Since, there is a very solid positive relationship between a country's quality of its road network and economic development, therefore projects under CPEC are expected to bring overall economic prosperity in the region and specifically help Pakistan in development of its human and physical capital. The geostrategic importance of CPEC demands that it should be structured and operationalized as a truly networked economic corridor and its various faces merit a closer examination in order to maximize its benefits for Pakistan. From transportation infrastructure perspective, the development of multi-modal communication lines, linking Gwadar to Kashgar are expected to result in enormous growth in commercial travel demand. The highway links are not only expected to experience traffic demand from China but also in the long run from other regions such as Afghanistan and Central Asian States. Therefore, detailed review of the existing network in terms of its ability to meet national needs and support regional trade as part of a major corridor is necessary. Any highway segments once part of CPEC shall not only result into induced travel (increased total vehicle kilometre travelled) but shall also result into generated traffic (trips from other routes, times and modes) that need due consideration.

Because of CPEC, Chinese imports and exports to the Middle East, Africa, and Europe would require less time and smaller distance. Besides physical links joining Pakistan and China, the project also foresees establishing numerous economic zones along the corridor. The economic corridor will bring more opportunities for cooperation, more projects in energy and transportation infrastructure sections, more jobs opportunities to both the countries. Details of CPEC including three proposed routes are shown in Figure 1.1.

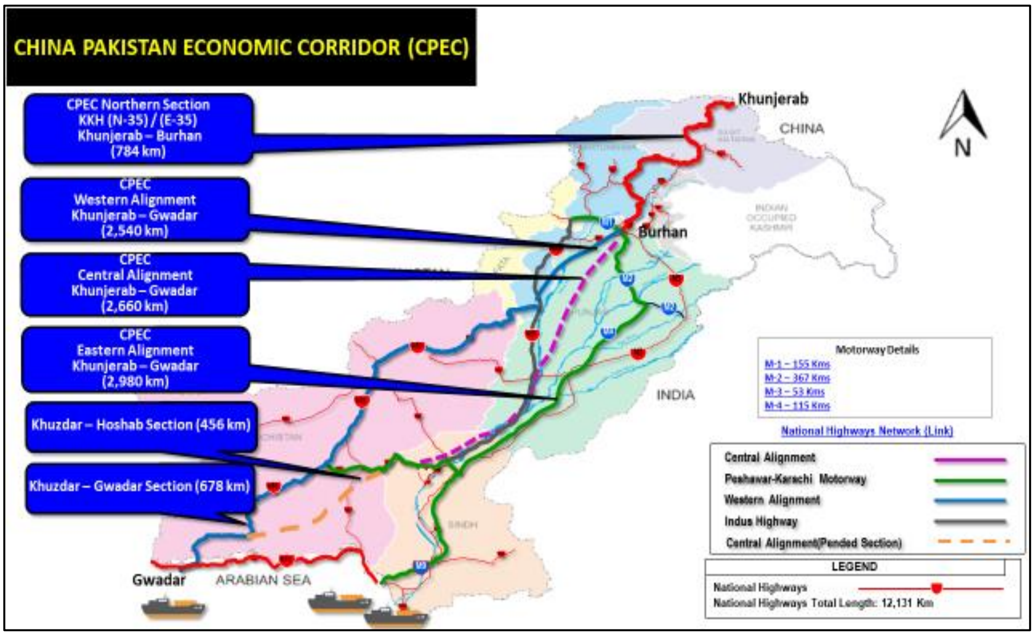


Figure 1.1 : CPEC route alignments

1.2.CPEC ROUTES ALIGNMENT

There are three routes proposed for CPEC by government of Pakistan (GoP) i.e. Western, Central and Eastern, traversing Pakistan from Khunjerab in north to Gwadar in south with different alignments.

1.2.1. Western route alignment

Western route alignment of CPEC starts from Khunjerab in north, passes through Burhan, D.I Khan, Zhob, Quetta, Kalat, Surab, Hoshab ends at Gwadar. It is almost 2,539 kilometers in length as shown in Figure 1.2.

1.2.2. Central route alignment

Central route alignment of CPEC starts from Khunjerab in north, passes through Burhan, DI Khan, DG Khan, Ratodero, Khuzdar, Besima, Hoshab and ends at Gwadar. It is almost 2,660 kilometers in length as shown in Figure 1.3

1.2.3. Eastern route alignment

Eastern route alignment of CPEC mainly consists of motorways. It starts from Khunjerab in north, passes through Burhan, Islamabad, Pindi Bhattian, Faisalabad, Multan, Sukkur, Hyderabad, Karachi and ends at Gwadar. It is almost 2,980 kilometres in length as shown in Figure 1.4.

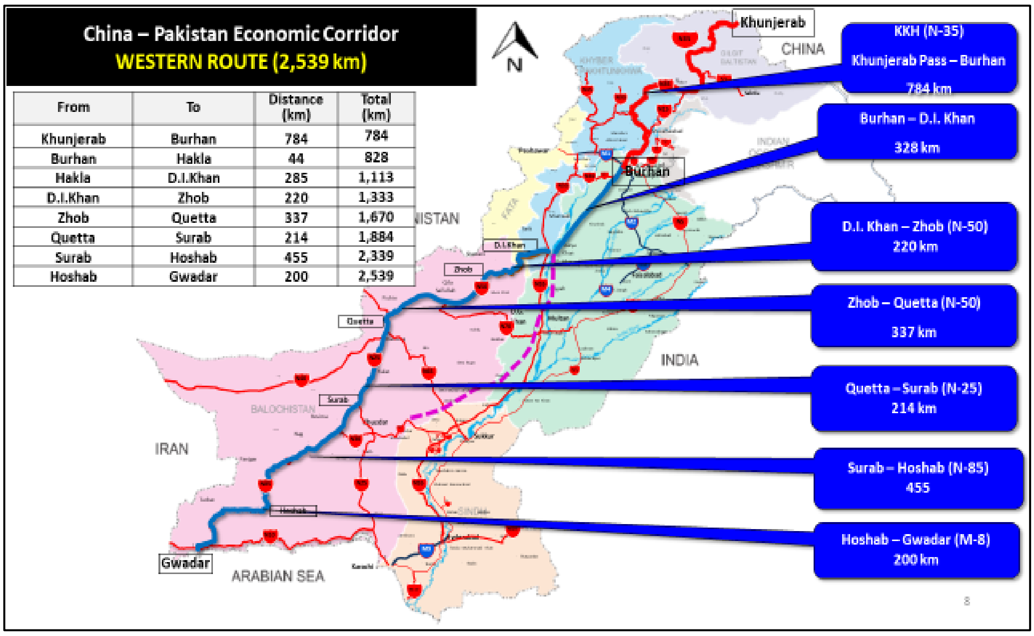


Figure 1.2: CPEC western route alignment

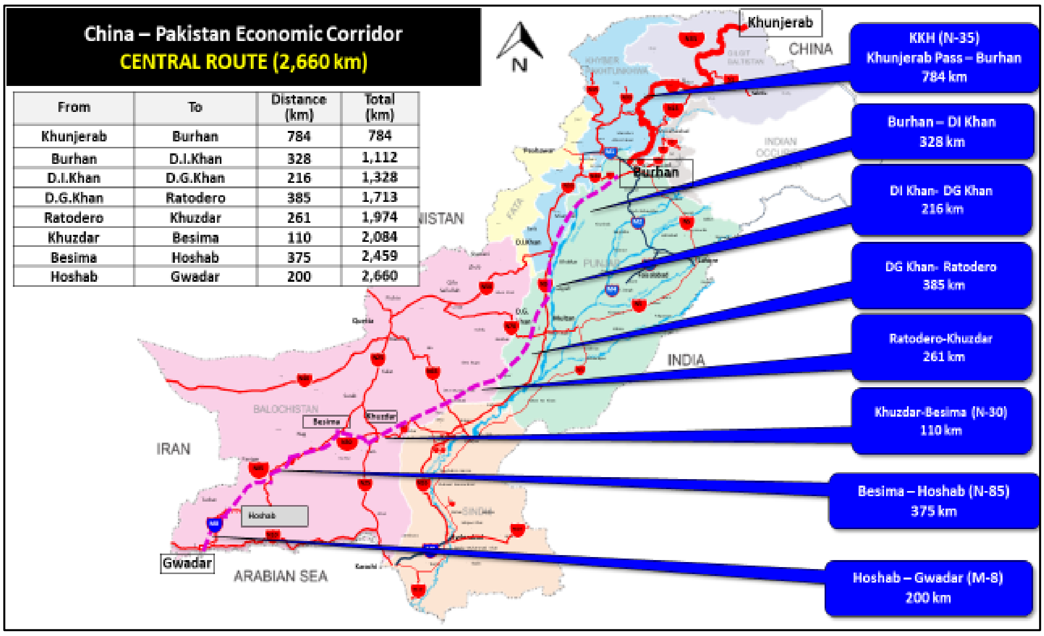


Figure 1.3: CPEC central route alignment

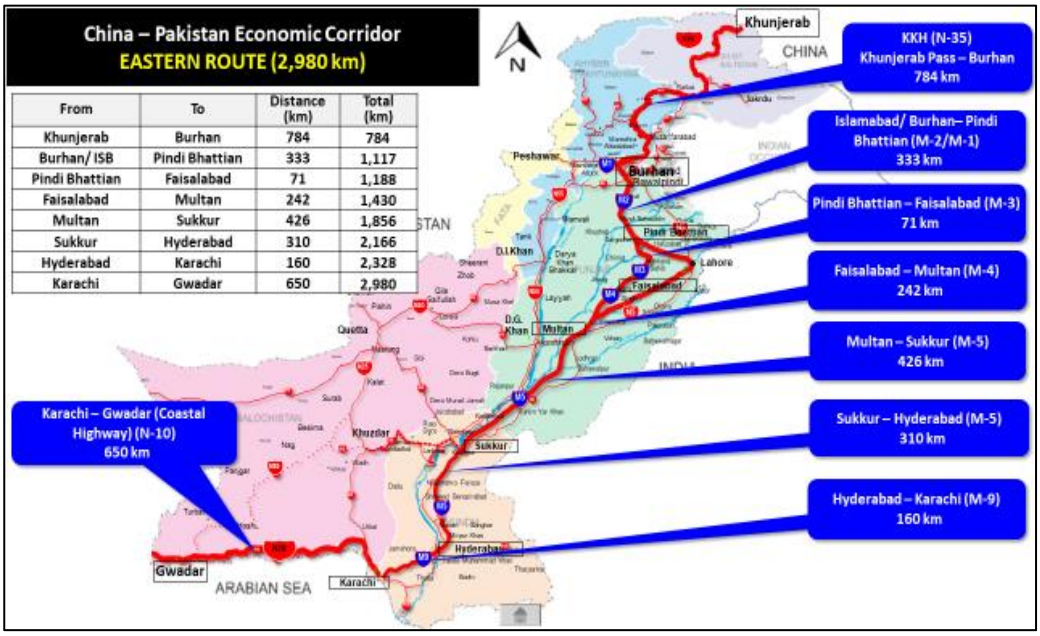


Figure 1.4: CPEC eastern route alignment

CPEC has many different routes to follow through Pakistan including the main routes of Eastern, Central and Western route. Bottleneck section of Burhan Khunjerab will play an important role being in difficult terrain. To efficiently use the CPEC alignments it is important to carry out an analysis of complete CPEC Alignments. Plans of government of Pakistan is to upgrade different sections of road infrastructure. The Eastern alignment being the most developed and part of early phase of CPEC is mostly freeways and motorways traversing through

Khunjerab, Raikot, Thakot, Mansehra, Havelian, Burhan, Islamabad, Salem, Pindi Bhattian, Fasialabad, Gojra, Multan ,Sukkur, Hyderabad Karachi and Gwadar. The Hyderabad and Sukkur motorway is the only link under construction, which will be completed by end of next year. Gwadar to Karachi section of the alignment is the longest section of 635 kms, is undivided highway, and can be considered as the weakest link of eastern alignment. Western route is a part of medium term plan of CPEC with more interest from Pakistan as it passes through a less developed area and can act as a catalyst for development of that region. This section begins at Khunjerab and mainly traverses through Burhan, Dera Ismail Khan, Zhob, Quetta, Surab, Hoshab and Gwadar. The third and most anticipated section of CPEC in the Central alignment and is a part of Long term plan of CPEC. It begins at Khunjerab and traverses through Burhan , Dera Ismail Khan, Dera Ghazi Khan , Rajanpur, Ratodero, Khuzdar, Besima, Hoshab and Gwadar. All these routes passes through different sections and also have some common sections which will play a vital role in truck freight traffic movement.

With this background, this research study shall focus on multi-dimensional capacity analysis of existing and enhanced CPEC alignments with different alternatives (number of lanes and Freight traffic controllers) with a view to develop a systematic and logical methodology for evaluating the most critical section of each alignment in CPEC scenario. Moreover, this research study shall also focus on prediction/ forecast of freight traffic expected on CPEC alignments in CPEC scenario and the amount/ quantity of trade that can be handled by all alignments efficiently.

1.3.PROBLEM STATEMENT

Most of the country's freight movement is being managed through road infrastructure, which in turns deteriorate the existing Infrastructure. CPEC being a powerhouse of trade will increase the freight demand in Pakistan. Under the existing condition, it is considered as a suicide for road and transportation sector of Pakistan. The Transportation sector must pre-plan the management of incoming truck freight traffic load. Any trade/ freight load expected from China has to pass CPEC alignments. It is vital to carry out detailed analysis on the existing infrastructure of CPEC and to identify which sections of CPEC alignments were the capacity defining sections of CPEC under load of CPEC. Effort has been made in analysing the capacity of road network especially CPEC routes, in order to optimally operate and manage truck freight traffic on CPEC routes under the effect of CPEC and trade shift from China. Management and Enhancement plan of CPEC was a basic requirement for transportation sector for efficient management and keeping the operational integrity.

1.4. RESEARCH OBJECTIVES

Following are the identified objectives for this research work:

i. To Analyse the critical capacities of CPEC alignments for 2021 and 2025 determine the number of additional trucks that can be accommodated on each route and to enhance the existing structure to improve capacity

ii. Development of the statistical models, finding the relationship between freight load and economic indicators and applications of the same to estimate the China's trade and corresponding freight load to be handled CPEC alignments in CPEC scenario.

iii. Development of Freight management and enhancement plan under CPEC scenario.

1.5.SCOPE OF STUDY

The scope of this research study is limited to CPEC alignments while carrying out capacity analysis and LOS determination. However, when prediction/ forecast of freight traffic expected in CPEC scenario is done, its horizon is expanded to national level. Moreover, capacity and LOS analysis is carried out for both present and for the analysis year 2025. Prediction/ forecast of freight traffic in CPEC scenario is carried out only for the analysis year 2025. Thus, scope of this research study also includes future planning, management and enhancement.

1.6.SIGNIFICANCE OF RESEARCH STUDY

CPEC is expected to bring overall economic prosperity in the region and specifically help Pakistan in development of its human and physical capital. Freight transportation is an essential element. Thus, it is in our national interest to timely envisage and forecast the expected traffic in CPEC scenario and to suggest viable options/ solutions to accommodate it efficiently. Following are the anticipated advantages/ benefits of the research effort:

i. Provide the status of CPEC alignment and its capacity with respect to LOS.

ii. Provide an estimate of future capacity of CPEC alignments for the analysis year with different route and enhancement options.

iii. Provide an estimate of anticipated freight traffic that could be handled by CPEC alignments in CPEC scenario.

iv. Formulation of Freight management and enhancement plan under CPEC scenario.

1.7. RESEARCH DESIGN/ METHODOLOGY

For successful attainment of research objectives, a detailed methodology was developed and following research tasks were identified in the study:

i. A comprehensive literature review of the past research efforts regarding CPEC, highway capacity analysis, LOS and freight traffic prediction/ forecasting.

ii. Collection and collation of data from different government organisations and institutions.

iii. Multi-dimensional capacity analysis of CPEC alignments w.r.t level of service (LOS) under existing conditions

iv. Capacity analysis of CPEC alignments in analysis year 2025 and identification of critical sections.

v. Determination of additional number of trucks that can be accommodated by each alignment in pre and post CPEC scenario.

vi. Development of the statistical models, exploring the relationship between freight load and economic indicators.

vii. Estimation of the China's trade and corresponding freight load to be handled by CPEC alignments in CPEC scenario, using statistical models.

viii. Formulation of freight management and road infrastructure enhancement framework under CPEC scenario.

ix. In the end summary of the research outcomes, recommendations and directions for the future possible research.

1.8. ORGANISATION OF THE THESIS

The thesis contains eight chapters. *Chapter 1* introduces the research subject and presents background and problem statement for this research followed by the description of objectives and brief methodology of the research study. *Chapter 2* is comprised of a thorough literature review on capacity analysis and statistical estimation of freight traffic in context of Pakistan and other world countries. *Chapter 3* discussed the research methodology and framework in detail. *Chapter 4* deals with the capacity analysis of existing CPEC alignments, capacity analysis and enhancement of various possible route under analysis year 2025. Statistical modelling for estimate of freight traffic in CPEC scenario is discussed in *Chapter 5* while *Chapter 6* deals with the freight management and enhancement plan under CPEC scenario with estimation of percentage of China's trade to be handled by CPEC alignments in CPEC scenario. Lastly, *Chapter 7* summarizes the research, makes conclusion, recommendations, and present possible directions for the future research.

CHAPTER 2

2. LITERATURE REVIEW

2.1.INTRODUCTION AND BACKGROUND

This chapter reflects several past studies and work done related to the field of capacity analysis of a highway and China Pakistan Economic Corridor (CPEC). The discussion also covers different methodologies being followed to estimate and forecast the truck freight traffic in CPEC scenario. Relating the literature together, this chapter further expands the knowledge about the efficient management and enhancement of road infrastructure.

2.2.IMPORTANT CONCEPTS AND TERMINOLOGIES

2.2.1. Capacity and level of service (los) analysis

2.2.1.1.The capacity concept

"The capacity of a facility is the maximum hourly rate at which persons or vehicles can be reasonably expected to traverse a point or uniform segment of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions." For most cases, the rate used is for the peak 15 minutes of the peak hour.

Capacity is defined for a point or uniform section of a facility. This correlates to the "prevailing conditions". A "uniform section" is having consistent normal conditions in terms of mix traffic. Change in conditions results in change of the capacity (Roess et. al, 2011).

2.2.1.2.Level of service (LOS) concept

"Level of Service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures such as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience." Every facility type has LOS defined in terms of a particular Measure of Effectiveness (MOE) (Table 2.1). One more critical concept is that LOS is to be defined in terms of parameters that can be perceived by drivers and passengers and that the definitions should reflect that perception (Roess et. al, 2011).

Type of Flow	Type of Facility	Measure of Effectiveness
Uninterrupted Flow	Freeways	
	Basic sections	Density (pc/mi/ln)
	Weaving areas	Density (pc/mi/ln)
	Ramp junctions	Density (pc/mi/ln)
	Multilane Highways	Density (pc/mi/ln)
	Two-Lane Highways	Average Travel Speed (mi/h)
		Percent Time Spent Following (%)
Interrupted Flow	Signalized Intersections	Control Delay (s/veh)
	Unsignalized Intersections	Control Delay (s/veh)
	Urban Streets	Average Travel Speed (mi/h)
	Transit	Service Frequency (veh/day)
		Service Headway (min)
		Passengers/Seat
	Pedestrians	Space (ft^2/ped)
	Bicycles	Frequency of (Conflicting) Events (events k)

Table 2.1: MOE defining levels of service in HCM 2010 (Roess et. al, 2011)

There are six well-defined levels of service i.e. A-F, which describes operations from best to worst for each type of facility. LOS criteria for basic freeway segments and multilane highways are shown in Table 2.2 (Roess et. al, 2011).

Level of Service	Density Range for Basic Freeway Sections (pc/mi/ln)	Density Range for Multilane Highways (pc/mi/ln)
A	$\geq 0 \leq 11$	$\geq 0 \leq 11$
B	$> 11 \leq 18$	$> 11 \leq 18$
C	$> 18 \leq 26$	$> 18 \leq 26$
D	$> 26 \leq 35$	$> 26 \leq 35$
E	$> 35 \leq 45$	$> 35 \leq$ (40–45) depending on FFS
F	Demand Exceeds Capacity > 45	Demand Exceeds Capacity $>$ (40–45) depending on FFS

Table 2.2: Level of service (LOS) criteria for basic freeway and multilane highways (Roess et. al, 2011)

2.2.2. Two - lane two way highways

Two-lane two-way highways form a significant portion of any nation's road network, one lane for traffic in each direction. On such highways, overtaking takes place in the opposing lane when the sight distance and traffic traversing in opposite direction permit. This is the only type of highway linkage on which traffic in one direction has a distinct operational effect on traffic in the opposite direction. It ranges from heavily traveled intercity routes to sparsely traveled links to isolated areas. Primary Functions of two-lane highways are mobility and accessibility (Roess et. al, 2011)

2.2.3. Multilane highways and freeways

Any highway having two or more number of lanes is classified as multilane highway. The number of lanes and the type of median treatment provided classifies multilane highway segments and the type of median treatment provided. Any highway having two or more number of lanes with un-interrupted flow of traffic is considered as a freeway. The number of lanes classifies freeways. Surface multilane facilities generally consist of four or six-lane alignments. They can be undivided or divided with a physical median separating the two directions of flow. Mostly, capacity analysis models are based on the determination of capacity under ideal roadway, traffic, and control conditions i.e. after having taken into account adjustments for normal conditions like lane width, lateral clearance, type of median, frequency of access points, presence of heavy vehicles and driver population dominated by occasional or unacquainted users of a facility (Roess et. al, 2011)

2.3.SYNTHESIS OF THE PAST RESEARCH

2.3.1. Capacity and level of service (LOS) analysis

Dixon et. al., (2002) evaluated HCM 2000 two-lane rural highway directional and the two-way passing lane analysis processes, based on the data and simulation. Specific consideration was given to the differences in estimates for percent time spent following (PTSF) produced by the two-way and the directional analysis procedures. It was determined that the two-way analysis procedure was found to be more accurate, although both procedures produced estimates that were on the higher side. The passing lane procedure was also considered and the HCM 2000 procedure was found to be conventional in its estimates of PTSF reductions due to a passing lane.

Zeeger et. al., (2008) have established default values to characterise input factors to the approach method used in the analysis of capacity and LOS of roads when they are difficult to measure or predict. It is pragmatic that out of several default parameters, 19 parameters have shown relationship in affecting measure results in the suitable methodology.

Chen et. al., (2009) developed a methodology using fuzzy neural networks to access the LOS observed by road users at signalized junctions. In this study, a neural network containing fuzzy reasoning experiences was used to join the observed attributes in order to determine LOS.

Ko et. al., (2009) conducted a research study to determine from an LOS perception. Defining about what roadway, traffic, and control matters should be concentrated on to better assist the needs of the trucking population. A survey of truck drivers and truck business executives was done to quantitatively measure the relative importance, satisfaction, and improvement preferences of truck LOS determinants and to inspect which features of a truck trip should be analysed to assess truck LOS on each roadway type. Speed variance and pavement quality were found as the service measures for truck LOS on freeways, while PTSF, travel lane and shoulder width and their pavement quality were found for truck LOS on two-lane highways. Truck trip quality on urban arterials was found to depend on factors such as ease of turning manoeuvre, speed variance, traffic density, and pavement quality. Driver's behaviour, pavement condition, level of congestion, and frequency and timing of building activities were other major contributors to truck LOS.

Yu and Washbrun (2009) discussed that currently no operational analysis methodology exists to report two-lane highways with different segment types at the facility level. The scope of analysis provided in the HCM 2000 for the two lane highway is limited to a single segment within the facility. They made an effort to develop a methodology for the operational analysis of a two-lane highway that included irregular isolated signalized intersections. The developed methodology produced a model for the basic structure of a facility level analysis that would be responsive to the combination of a variety of segment types.

Lan and Abia (2010) discussed the HCM idea of using peak hour factor (PHF) design value as 0.92 for congested urban areas and 0.88 for rural areas provided no field measurements are available. They concluded that the default values give broad guidelines but they might be coarse for practical usage. They worked on developing the model actual peak-hour factors are shown as a function of volume-to-capacity ratio and the functional classification of roadways. 1,669 data points were acquired for analysis. The results revealed that among numerous functional forms, the simple power function developed with functional classification of roadways can be used to explain 46% of data variation, which appears to be acceptable, given the implication of data variability. By making a comparison to the HCM default value, the suggested peak-hour factors in general resulted in higher average intersection delays with the optimal signal control. Lastly, the model validation using data collected from two other geographical areas showed that the suggested prediction model is convenient.

Velmurugan et. al., (2010) developed speed–flow formulas for different vehicle types on multi-lane highways in India based on traditional and microscopic simulation models.

Sinha et al., (2011) carried out a theoretical study that investigated highway up-gradation decision making for three different alternatives (do nothing, addition of lanes to existing highway and construction of new expressway) based on standard traffic volume. Using historical traffic volume data from state of Indiana (USA) it was found that, an average benchmark traffic volume for 4-lanes major arterials to be broadened to 6-lanes or improved to expressway have a range between 18,000 to 20,000 vehicles/ day.

Researchers believe that the HCM is a "principal guide in transportation decision making, planning, and design". Research shows the importance of using the HCM for planning; however, they realize the problems in this as well. Advanced research shows the HCM can be used for multiple planning level analyses. *Guttenplan and Davis* worked on the relation of the planning-level analysis and multimodal analysis. This research was made because of the Urban Infill and Redevelopment Act of 1999. This Act encouraged the use of alternative transportation modes instead of the automobile (Ensley, 2010)

Sinha and Labi (2013) studied that highway Capacity is affected by many elements such as traffic volume, level of service and social, political, economic, and environmental factors.

Saha et. al., (2015) carried out work on assessment of speed–flow characteristics on two-lane highways with diverse traffic and found that HCM (Highway Capacity Manual 2010) categorises two-lane rural highway that passes through developed areas as 'Class III' and suggests using Percent Free-Flow Speed (PFFS) as performance measure to define Level Of Service (LOS).

Adeel (2016) conducted the capacity analysis of Burhan Khunjerab alignement of CPEC and suggested that Capacity of Burhan Khunjerab alignment will be the bottle neck capacity and will be the governing capacity of CPEC. Additional number of truck freight traffic was also predicted under different alternatives on Burhan Khunjerab section. The percentage of truck on Burhan Khunjerab section of CPEC from China was calculated under CPEC scenario.

Highways are most valued resource of the governments; even fringe savings due to better practices contribute towards considerable revenues. In background of CPEC vast highways system is planned or initiated in country, for smooth operations of the network, an effective PMS is required. It was observed that, 5% and 8% or higher drop in IRI, on average, in south and northbound traffic respectively, which will increase with CPEC (Irfan et al., 2019).

Usama (2020) conducted the analysis of CPEC load on railways of Pakistan under the development of ML-1 and other improvements in railways under vision 2025 of CPEC. It was concluded that under ideal conditions of CPEC railways can take almost 30% of load share which will in turn lower the load on road infrastructure making it more stable and efficient in long term.

2.3.2. Prediction/ forecast of freight traffic in CPEC scenario

Ying et al., (2008) used prediction method for regional logistics and concluded that the transport system has direct and indirect relation with all the main segments of the country. The size of transportation infrastructure disturbs the economic development of any country in short or long term.

Limao (2008) analyzed the relationship between the level of road freight transport, stated both in number of trips and in km driven, and the economic activity in a region. For this purpose, a cross-sectional data sample of regions within the EU-15 was considered. The sample was analyzed for indication of relationship between the transport indicators and particular measures of the economic activity, i.e. GDP per capita, and indicators linked to the structure of the economy. Relationship analysis appeared to show the presence of relation between most of the transport indicators used and GDP, at substantial levels. However, the significance of these correlations did not continue to be important when the variable relevance is ruled out.

Choudary et.al., (2007) studied Pakistan's freight transportation infrastructure, used Porter's framework and forecasted forthcoming freight demand by means of time series models. The research paper examined the shipping transport industry of Pakistan. The research showed that shipping transport industry of Pakistan is very uneven. The relative trading power of consumers (logistics service consumers) is high, while the relative trading power of traders (logistics service providers) is low. The danger of substitute services is low or the road freight industry because the road transport is mostly used in Pakistan. Due to low bstructions to entry in the industry, the danger of new competitors is relatively high and this xpresses the uneven nature of the industry. Industry wide prospects include construction of National Logistics/ Trade Corridor" that intends to decrease the time to stretch Peshawar from Karachi in 36 hours. This corridor would offer a safe route to the Central Asian States, which bids an exceptional opening to the trucking companies in Pakistan to compete internationally. Growth of Gwadar a regional trade center, for Pakistan. Hence, the trucking stream must be updated in order to facilitate growing trade activities and overcome losses ascending out of sector inadequacies.

Shao et. al., (2009) analyzed the correlation of freight transport and economic growth and GDP on different economic development stages and revealed that the derivative of freight volume with respect to GDP on each stage is decreasing. The core cause of such a phenomenon was described.

Aibin et. al., (2009) concluded an empirical analysis by working on a quantitative research on freight volume. To explore the impact of logistics on economic progress and the association between logistics industry and economic growth, the research paper made quantitative research on the joint correlation of logistics industry and economic growth in Xuzhou grounded on the GDP and freight volume data for past years. The results indicated that the relationship between Xuzhou economic growth and the logistics industry is an inverted U-quadratic curve in early years. Its economy improved quicker than the development of the logistics industry, which staggered the economic growth effectively in later years. Industry has less pull effect on the economic growth and even with a gradually falling trend. The study additionally proposed that to keep the supply and demand equilibrium of logistics in Xuzhou, warrant the favorable interaction between economic growth and logistics industry,

Hali et. al., (2010) deliberated on the different perspective of One Belt and One Road (OBOR) and its impact on China Pakistan Economic Corridor (CPEC). OBOR has two major components: one, overland known as the Silk Road Economic Belt (SREB) and the other the maritime component, is termed as the Maritime Silk Road (MSR). The research paper focused on various aspects of the OBOR and then emphasized different turns and twists the CPEC might take in the future. OBOR's striving project comes at the origin of changing global control dynamics, a major Chinese policy change and the predicted Asian Century. As progress is ongoing on OBOR projects, the US and its allies for whom the recognition of China's dream is a apparent nightmare because of their past rivalries have expressed uncertainty and disbelief. The CPEC will greatly receive the benefits as well as the dividends from the overall Chinese dream. The profits will go past $46 billion in energy and infrastructure projects once they are finished. Chinese planners and their well-wishers have perceived the OBOR as a *Game Changer* for the whole region and afar.

Reza (2013) examined the relationship between logistics and economic growth in Indonesia using time series figures on traffic volume and economic growth for the past 22 years ranging from 1988 to 2010. The information of cargo bulk that trips through sea, air and rail was used as the logistics index, while GDP was used for the economic index. The time series data was tested using stationarity and co-integration tests. Granger causality tests were used, and then a proposed logistic model was obtained. It showed that logistics play an vital role in backing up and sustaining economic growth, is such a way where the economic growth is the major demand-pull effect concerning logistics. Although the model was established in the context of Indonesia, the general statistical analysis can be used to work in other developing economies. Based on the model, the research showed the importance of sustaining economic development with respect to always improve the logistics infrastructure.

Irshad (2016) worked on the SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of Pakistan China free trade agreement (FTA) and determined the pros and cons. To extend the relationship between China and Pakistan, an FTA was signed in 2006, which became effective later in 2007. The research studied the effect of this FTA on trends of imports and exports of both nations in terms of goods. Analysis revealed that the trade trends have improved generally but against that, the trade deficit of Pakistan has also augmented. The Revealed Comparative Advantage (RCA) and SWOT analysis determined that there is a difference in imports and exports by both countries in world markets and between each other, except the top ranked products. Conversely, Pakistan's GDP does not have much effect on its exports to China and neighbouring countries. Consequently, in current conditions

Pakistan benefits more from the bilateral trade because its exports to China are positively associated with China's GDP, which is growing way faster than Pakistan's GDP.

Aqeel (2016) discussed the conception of logistics' shipping cost and transit time and China's need of a short, safe and low-cost trading course to European and Middle Eastern countries and also viability of CPEC. The study investigated the influence of CPEC on trade in terms of the shipping costs, transit time, and compared the existing routes with proposed route. Dry port Kashgar (western China) were taken as starting point and three ports of each European and Middle Eastern countries were taken as last end. In the first step, the variables (transit time and shipping cost) of 40-foot container were considered when transported using current route. In the second step, the same variables were considered using proposed route (CPEC). In the third step, both variables were related for current and proposed route. This study reflected an average value of current road transportation cost. The results presented that shipping costs will drop considerably if proposed route i.e. CPEC is used. The shipping costs between Kashgar and destination ports can be drop by 36% for European ports, 50% for Jeddah and Kuwait and 68% for Oman. In addition, the transit time will decrease by 10-11 days for European ports, eleven to thirteen days for Jeddah, fifteen to eighteen days for Kuwait and ten days for Oman. Thus, CPEC is a feasible option.

2.4.CHAPTER SUMMARY AND CONCLUSIONS

The detailed literature review revealed that HCM method is world widely used for capacity and LOS analysis. Very few research studies have been done at international level on capacity analysis of any corridor while almost none at national level. Very few research studies have been considered on social and economic aspects of CPEC but no significant study has been carried out on transportation and logistics aspect. No significant study has been carried out at national or international level on capacity analysis CPEC alignment as a whole in pre and post CPEC scenario. CPEC is a special project and will prove to have great benefits not only for Pakistan and China but for the whole region. Transport sector has significant effect on economic prosperity of any country. Evidences of the relationship between economic indicators and freight load exist in the past literature. Pakistan GDP is positively correlated with the amount of trade between Pakistan and China. CPEC will tremendously reduce the shipping cost and the transit time for the China's trade with European and Middle Eastern countries. Thus, the literature review revealed that this study will be one of the very few studies to carry out a detailed and multi-dimensional capacity analysis of CPEC alignments in CPEC scenario and its result shall assist national and provincial highway agencies to cope up with the freight traffic expected in CPEC scenario efficiently.

CHAPTER 3

3. METHODOLOGY

3.1.INTRODUCTION

The conclusions of literature review provide an outline of different methods of highway capacity and level of service analysis, CPEC and its impacts and methods of freight traffic prediction followed worldwide. This chapter contains the methodology of this thesis, which helps in understanding a way to achieve the research objectives as specified in Chapter 1. The research has been carried out in nine distinct phases as stated below.

3.2.RESEARCH DESIGN

In first phase, after development of research proposal, extensive literature review was carried out to understand the basics of China Pakistan Economic Corridor (CPEC), highway capacity analysis, LOS and freight traffic prediction. Google scholar and other prominent internet sites like TRB, ASCE, Taylor and Francis, science direct or Elsevier etc. were used as a search tools for different scholarly research papers and writings.

In second phase, comprehensive literature/ data/ documents were collected on CPEC and its 3R alignments from planning commission of Pakistan, Finance division, National transportation research centre (NTRC), Frontier Work Organization (FWO), Chinese studies centre and different websites.

In third phase, traffic counts data for the year 2019-2020 was collected for different sections under Eastern, Western and Central Alignment of CPEC from National transportation research centre (NTRC) Islamabad. The traffic counts data consists of traffic counts observed on different sections of national highways and motorways through different provinces of Pakistan. This traffic data was used as an input in capacity analysis of existing infrastructure using HCM method. Various time series data related to Pakistan were also collected from internet and other sources like GDP, road freight (million tons kms), number of registered trucks, number of trucks on road, trade (import/ export) in million tons and million USD, population, and length of roads etc. Moreover, similar data related to China was also collected like GDP, economy and Trade etc.

In fourth phase, 2 alignments (i.e Western and Central Alignment) of CPEC was sub-divided into further sub sections and capacity analysis of existing infrastructure of each section was carried out using HCM method. However, as for the eastern alignment, most sections are motorways where highway methods of HCM method could not be applied so freeway method of HCM was used for capacity analysis. MS excel was used and excel workbooks were formulated basing upon HCM method and tables to carry out capacity analysis of existing alignments which itself was a laborious task. Moreover, year 2025 was selected as the "year of analysis" in this research study; assuming that CPEC would be completed and fully operational and will start effecting the economy of Pakistan. Although, Government of Pakistan (GoP) had announced 2018 as the date of completion of first phase of CPEC i.e. early harvest phase, but due to severe pandemics and other unforeseen effecting the whole world GoP is still thriving for effective completion.

In fifth phase, LOS of 3 alignments of CPEC was determined for analysis year i.e. 2025 by applying growth factor to existing traffic counts. It was tried to establish as what would be the LOS of this alignment if the same infrastructure continue to exist without any expansion in geometrics i.e. lane addition.

In sixth phase, an attempt was made to determine capacity of same alignment in post CPEC scenario i.e. number of trucks, which could be accommodated on various sections of same alignment if LOS is kept "C" till the analysis year 2025. Excel workbooks based upon HCM 2010 were used for above purpose. Also various options of highway expansion i.e. four lanes, six lanes existing and new alignments were also incorporated to have a wholesome approach towards capacity analysis.

In seventh phase, prediction/ forecast of freight traffic in terms of number of trucks expected in CPEC scenario was carried out using statistical analysis tool i.e. SPSS (Statistical Package for the Social Sciences). The three points kept in consideration was Gwadar, Karachi and Havelian dry port (as major traffic assignment nodes) for which various strategies/ methods and regression models were used to calculate the number of expected trucks on different alignments from Havelian dry port to Gwadar in CPEC scenario.

In eight phase, statistical methods were used to calculate the trade from China and corresponding truck freight traffic that will be accommodated on three alignments of CPEC through Pakistan. Various strategies and statistical methods used to calculate the trade is USD and tonnes. Conclusion and recommendation were made at the end. Analytical framework for the research design is shown in Figure 3.1

In *ninth phase*, framework for management, maintenance and enhancement plan was formulated using the ESAL concept, for the design life of highway infrastructure. Using the framework decrease in design life was also suggested.

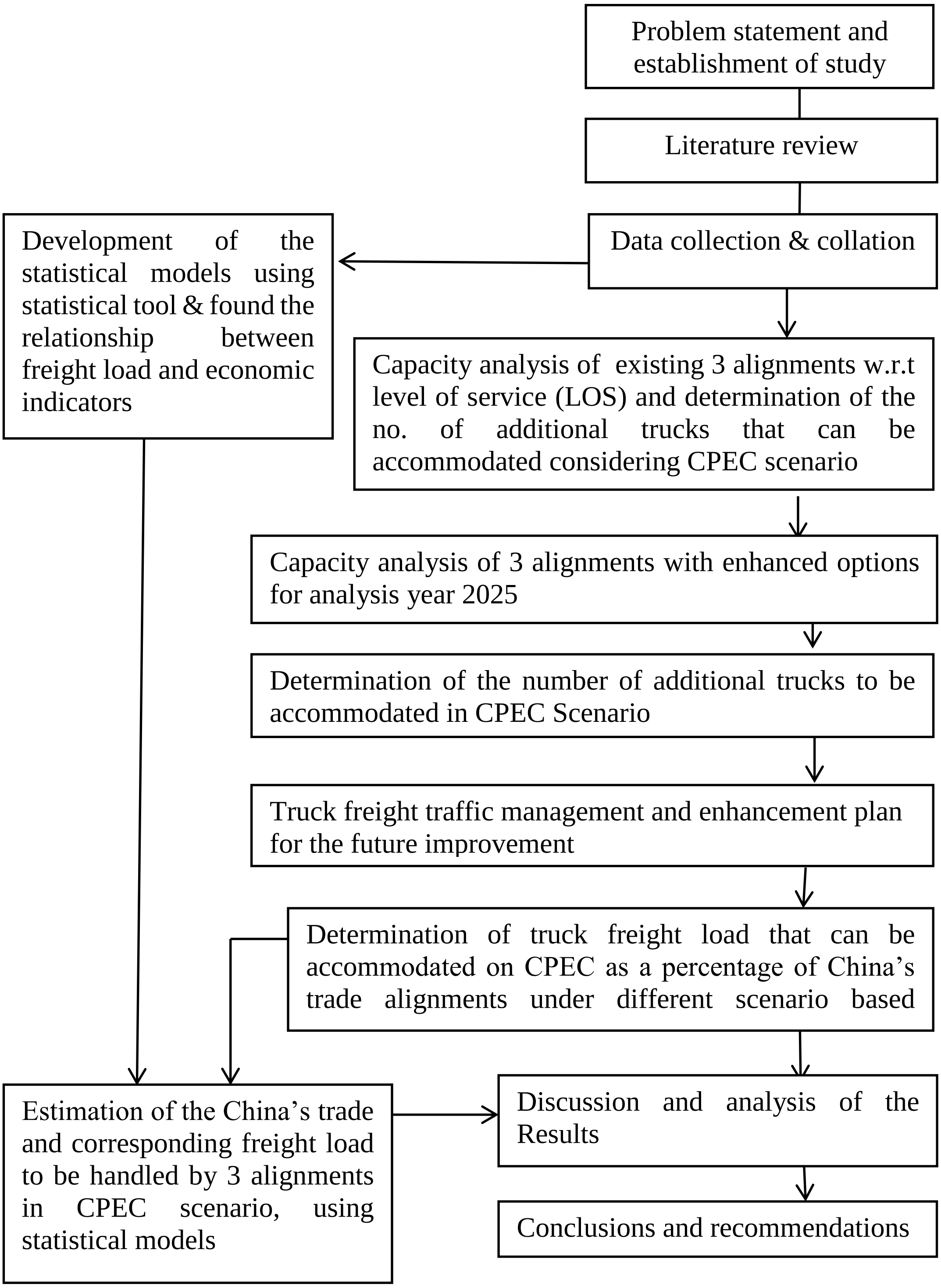


Figure 3.1: Analytical framework for the research design

CHAPTER 4

4. ANALYSIS OF CAPACITY AND LEVEL OF SERVICE FOR CPEC ALIGNMENTS

4.1. INTRODUCTION

Capacity analysis of different routes of CPEC was carried out according to the method defined in highway capacity manual (HCM 2010). The three major routes included in the analysis were Eastern alignment, Western alignment and Central alignment (long-term plan) whereas the analysis of Burhan Khunjerab alignment being common alignment of all the routes of CPEC was carried out separately. Analysis was done with respect to LOS using HCM method keeping density, average travel speed (ATS) and percent time spent following (PTSF) as the measure of effectiveness. In the first stage the analysis of existing alignments of CPEC was carried out using HCM methodology for freeways, multi lane highways and two-lane two-way highways accordingly and LOS for the existing condition were determined. In second stage, keeping the non-truck traffic constant and increasing the number of trucks on the alignments, analysis was done and additional number of trucks on all these alignments were calculated under the condition of LOS "C" and LOS 'D' for the year 2021. Same procedure was repeated for year 2025 under the consideration that there is no change in the existing infrastructure. Second option has been calculated improving the infrastructure that is already under LOS C. After the calculation of critical capacities under LOS 'C', matrix was formulated to establish the critical capacities of each of the routes using respective critical capacities of their sections.

4.2. CAPACITY ANALYSIS OF EXISTING CPEC ALIGNMENTS

For the purpose of capacity analysis based on LOS, all the routes of CPEC were divided into sections depending upon geometrics and geographical salient and keeping under consideration the socioeconomic factors. The three major routes of CPEC were defined as Eastern alignment, Western Alignment and Central Alignment, fourth and common route of CPEC was from Khunjerab to Burhan. The subsections of Eastern alignment were divided as follows

- **Eastern alignment**

Section 1:Khunjerab-Raikot	335 km	2 Lane undivided Highway
Section 2:Raikot - Thakot	270 km	2 Lane undivided Highway
Section 3:Thakot - Mansehra	80 km	2 Lane undivided Expressway
Section 4:Mansehra- Havelian	40 km	4 Lane divided Expressway
Section 5:Havelian - Burhan	60 km	6 Lane divided Expressway
Section 6:Burhan – Islamabad	73 km	6 Lane divided Motorway
Section 7:Islamabad - Pindi Bhattian	258km	6 Lane divided Motor
Section 8:Pindi Bhattian- Faisalabad	71km	4 Lane divided Motorway
Section 9:Faisalabad - Multan	242km	4 Lane divided Motorway
Section 10:Multan- Sukkur	426km	6 Lane divided Motorway
Section 11:Sukkur – Hyderabad	310km	4 Lane divided Highway
Section 12:Hyderabad - Karachi	162km	6 Lane divided Motorway
Section 13Makran Coastal Highway (Karachi - Gwadar)	653km	2 Lane undivided Highway

Total length of eastern alignment is approx. 2980 km with sections of different geometric and geographical features. However, the routing option for eastern alignment is available and decreases the distance from 2980 km to 2815 km bypassing Hyderabad Karachi and Makran coastal highway (1125 km) while traversing through Sukkur – Khuzdar – Besima – Hoshab section to reach Gwadar (950 km).

Second route was the central alignment having total length of 2660 KM and is subdivided as follows

- **Central alignment**

Section 1:Khunjerab-Raikot	335 km	2 Lane undivided Highway
Section 2:Raikot – Thakot	270 km	2 Lane undivided Highway
Section 3:Thakot - Mansehra	80 km	2 Lane undivided Expressway
Section 4:Mansehra- Havelian	40 km	4 Lane divided Expressway
Section 5:Havelian - Burhan	60 km	6 Lane divided Expressway
Section 6:Burhan Hakla	43.2 km	6 Lane divided Motorway
Section 7:Hakla - DI Khan	285 km	4 Lane divided Motorway
Section 8:DI Khan - DG Khan	216 km	2 Lane undivided Highway
Section 9:DG Khan - Ratodero	385 km	2 Lane undivided Highway

Section 10:Ratodero - Khuzdar 261 km 2 Lane undivided Motorway

Section 11:Khuzdar - Basima 110 km 2 Lane undivided Highway

Section 12:Basima - Hoshab 375 km 2 Lane undivided Highway

Section 13:Hoshab- Gwadar 200 km 2 Lane undivided Motorway

Third route of CPEC is western alignment having a total length of 2539 km and is subdivided into the following sections.

- **Western alignment**

Section 1:Khunjerab-Raikot 335 km 2 Lane undivided Highway

Section 2:Raikot – Thakot 270 km 2 Lane undivided Highway

Section 3:Thakot - Mansehra 80 km 2 Lane undivided Expressway

Section 4:Mansehra- Havelian 40 km 4 Lane divided Expressway

Section 5:Havelian - Burhan 60 km 6 Lane divided Expressway

Section 6:Burhan Hakla 43.2 km 6 Lane divided Motorway

Section 7:Hakla - DI Khan 285 km 4 Lane divided Motorway

Section 8:DI Khan - Zhob 220km 2 Lane undivided Highway

Section 9:Zhob - Quetta 337km 2 Lane undivided Highway

Section 10:Quetta - Kalat 140km 2 Lane undivided Highway

Section 11:Kalat-Surab 74km 2 Lane undivided Highway

Section 12:Surab - Hoshab 455km 2 Lane undivided Highway

Section 13:Hoshab- Gwadar 200 m 2 Lane undivided Motorway

Summary of all the sections and possible routes along with total length are as Table 4.1

Alignment	Routes	Major Nodes/ sections	Length (Km)
Central Alignment	Route 1	Khunjerab-Burhan-DI Khan- DG Khan-Ratodero-Khuzdar-Besima -Hoshab-Gwadar	2660 (784Km Burhan to Khunjerab)
Eastern Alignment	Route2	Khunjerab-Burhan-Islamabad-Pindi Bhattian- Faisalabad- Multan-Sukkur-Hyderabad-Karachi-Gwadar	2980 (784Km Burhan to Khunjerab)
	Route 3	Khunjerab-Burhan-Islamabad-Pindi Bhattian- Faisalabad- Multan-Sukkur-Ratodero-Khuzdar-Hoshab-Gwadar	2815 (784Km Burhan to Khunjerab)
Western Alignment	Route 4	Khunjerab-Burhan-DI Khan-Quetta -Sorab-Hoshab-Gwadar	2539 (784Km Burhan to Khunjerab)

Table 4.1: Summary and classification of routes of CPEC with total lengths

4.2.1. Capacity analysis methodology for two-lane two way highway

Methodology described in HCM 2010 for analysing the capacity of two-lane two-way rural highways, multilane highways and freeways was adopted. For two-lane two way highways, highway capacity software (HCS) was considered and checked for working on capacity analysis of existing conditions of the alignment but after the revelation of some drawbacks it was finalized to do it with manual way using excel sheets which was a strenuous task in itself. The major drawbacks of HCS being unable to conduct analysis on two-lane two-way highway. Updated version of HCS i.e. HCS 2010 is the only version that had the procedure to do capacity analysis of two-lane two-way highways but its availability with the NUST was an issue. Secondly, there was a limitation for truck proportion of 25 % only on freeways and multilane highways, which restricted the analysis. Consequently, excel worksheets were developed and formulated based upon HCM 2010 method to carry out capacity analysis of two lane two way highways on existing alignment. Methodology for the analysis is as shown in figure 4.1

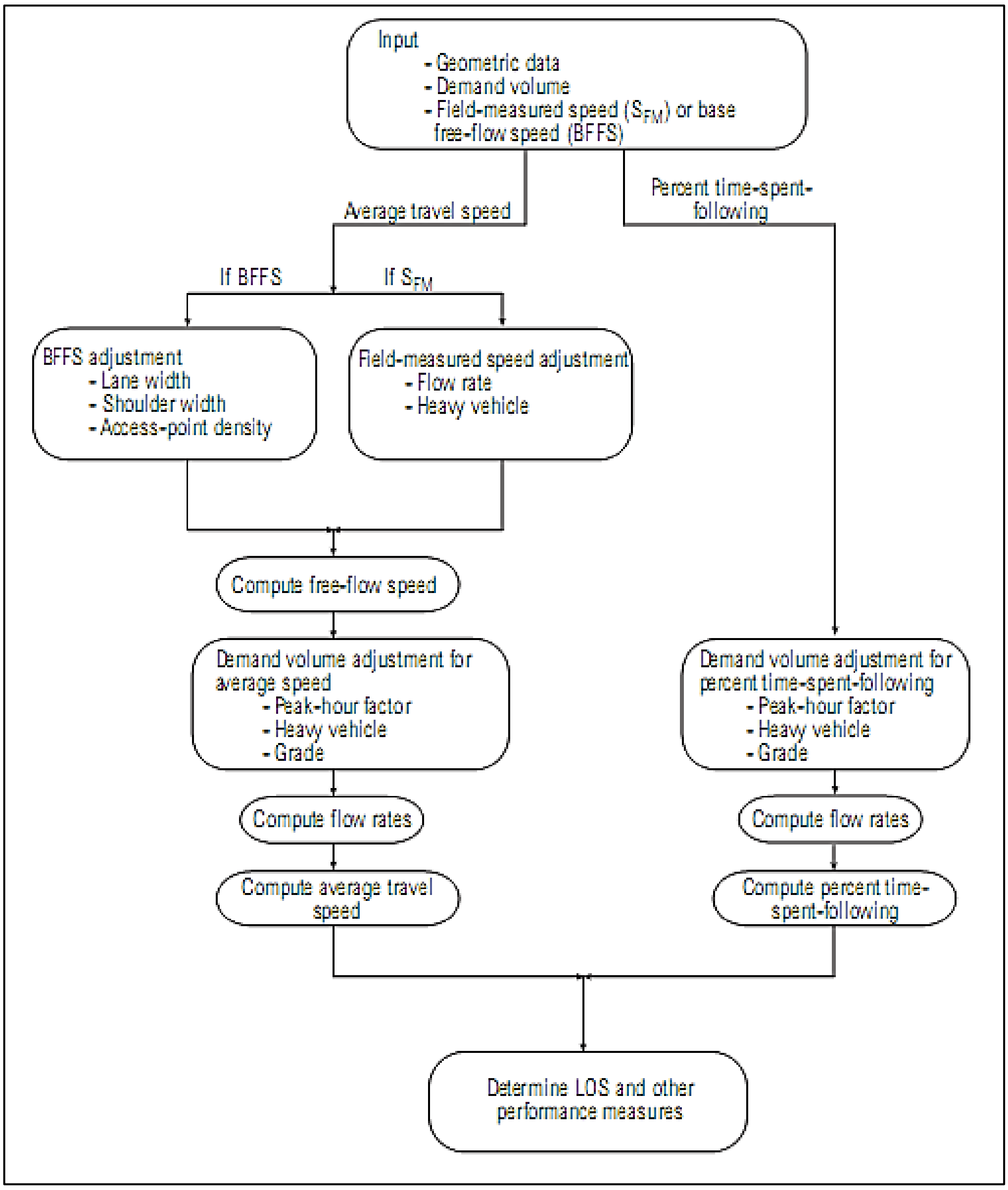


Figure 4.1: Basic methodology for capacity and LOS analysis of two lane highways (Roess et. al., 2011)

4.2.2. Basic methodology for analysis of two-lane two-way highway

The steps involved in the capacity analysis of two-lane two- way highway are as follows

- Collection of traffic data
- Applying Growth factor
- Classification of existing highways
- Measure of effectiveness (MOE)
- Free flow speed
- Demand Flow rate

- Estimation of ATS (Average travel speed)
- Determining PTSF (Percent time spent following)
- Establishing LOS for ATS and PTSF
- Determination of combined LOS

For the above-mentioned steps, methods included in HCM 2010 were followed. Collection of data was done from different departments of Govt. of Pakistan. Traffic data was obtained from recently done O-D survey of Pakistan for year 2019-20 by National transportation research centre (NTRC). The data obtained was then compiled according to the sections under consideration and then used in the excel sheets to obtain AADT (veh/day). The traffic data included traffic counts of cycles, animal drawn, motor cycles, rickshaws, cars, jeeps, wagons, pickups, coasters, minibuses, buses, rigid 2 axles trucks, rigid 3 axles trucks, articulated 4 axles trucks, articulated 5 axles trucks, articulated 6 axles trucks, tractors trolley and recreational vehicles (RVs). For ease of calculations and applying HCM method, traffic counts were divided into four main classes i.e. trucks, buses, RVs and motor cars. Equivalent factors were assumed and multiplied with number of under-mentioned vehicles to convert following vehicles into number of motor cars. These equivalent factors values were assumed by taking opinions of various traffic engineering experts:

- Cycles: 0
- Animal Drawn: 0
- Motor Cycles: 0.50
- Rickshaw: 0.50
- Jeeps/Wagon/Pickups: 1

Rigid 2 axles trucks, rigid 3 axles trucks, articulated 4 axles trucks, articulated 5 axles trucks, articulated 6 axles trucks, tractors trolley were added to give value of total number trucks. Since no recreational vehicle (RV) was found travelling on CPEC alignments therefore total number of RV was taken as “0” (zero). New value of AADT was calculated by adding total numbers of all four main classes of vehicles mentioned above naming it total AADT. Proportions/ percentages of all four main classes of vehicles i.e. cars, buses, trucks (P_T) and RVs (P_R) with respect to new total AADT were also determined. The trucks, buses and RVs factor for different terrains (level, rolling and mountainous) were consulted from HCM 2010 and equivalent factors were used accordingly for calculating heavy vehicle factor.

Growth factor for the analysis was taken as 3% per year after consulting literature for Pakistan and international analysis for similar terrain. Since the road user of this highway consist both of commuters (familiar) and recreational users (unfamiliar) drivers, therefore driver population factor (f_p) was assumed as 0.95. Peak hour factor generally varies between a value of 0.70 for rural to 0.98 in urban areas. Therefore, PHF for highway was taken as 0.70.

Measure of effectiveness (MOE) for different highways were conducted as per the classes of highways. For Class-I highway ATS and PTSF both were the measure of effectiveness where as for Class-II only PTSF was selected. Two type of analysis was conducted based on the class of highways, which are as follows

- Single-directional analysis of general extended sections (≥ 2.0 mi) in level or rolling terrain for both ATS & PTSF Determination
- Single-direction analysis of specific grades (Specific Upgrades and Specific Downgrade for PTSF Determination)

HCM 2010 recommends that free-flow speeds (FFS) should be measured in field where practical, but where measurement is not practical it also offers a methodology for their appropriate estimation. In our case, method of estimating FFS was adopted (Roess et al., 2011)

$$\boldsymbol{FFS = BFFS - f_{LS} - f_A} \quad \textbf{(4.1)}$$

where,

FFS = Free-Flow Speed for the facility (mph)

BFFS = Base Free-Flow Speed for the facility, (mph)

f_{LS} = Adjustment for lane and shoulder width, (mph)

f_A = Adjustment for access point density, (mph)

Base free flow speed is generally limited to a range of 45-65 mph, with Class I highways usually in the 55-65 mph range and Class II highways usually in the 45-50 mph range (Roess et al., 2011). In case of CPEC alignments, access point density of 10 was assumed after considering the nature of terrain and ground condition. FFS of various sections differs from each other due to different geometric conditions of roadway.

In the next step, demand flow rate was estimated as per the HCM 2010 methodology for two-lane-two way highways. Following equation was used

$$v = \frac{V}{PHF * f_{HV} * f_G} \quad \textbf{..(4.2)}$$

where,

v = Demand flow rate, pc/h

V = Hourly demand volume under prevailing conditions, veh/h

PHF = Peak hour factor (as defined by HCM 2010)

f_{HV} = Adjustment for heavy vehicle presence (as defined by HCM 2010)

f_G = Adjustment for grades (as defined by HCM 2010)

After the calculation of demand flow rate ATS was calculated using Equation 4.3 (Roess et al. 2011)

$$ATS_d = FFS - 0.00776\,(v_d + v_o) - f_{npA} \quad \textbf{...............................(4.3)}$$

Where,

ATS_d = Average travel speed in the direction of analysis, (mph)

FFS_d = Free flow speed in the direction of analysis, (mph)

v_d = Demand flow rate in the direction of analysis, (pc/h)

v_o = Demand flow rate in the opposing direction, (pc/h)

f_{npA} = Adjustment to ATS for the existence of "No Passing zones"

For the purpose of calculation of PTSF Equation 4.4 used.

$$PTSF_d = BPTSF_d + f_{npP}\left(\frac{v_d}{v_d + v_o}\right)$$

$$BPTSF_d = 100\left[1 - \exp\left(a v_d^b\right)\right] \quad \textbf{...(4.4)}$$

Where,

$PTSF_d$ = Percent time spend following, single direction (%)

$BPTSF_d$ = Base percent time spend following, single direction (%)

v_d = Demand flow rate in the direction of analysis, (pc/h)

v_o = Demand flow rate in the opposing direction, (pc/h)

f_{npP} = Adjustment to PTSF for the effect of "No Passing zones" (% NPZ) in the study segment, (%)

a, b = Calibration Constants on Opposing Flow Rate Single-direction analysis

LOS was determined for different sections of two-lane two-way alignments using LOS criteria for two-lane highways (Roess et. al., 2011) as shown in Figure 4.2

Table 14.4: Level-of-Service Criteria for Two-Lane Rural Highways

Level of Service	Class I Facilities: Average Travel Speed (mi/h)	Class I Facilities: Percent Time Spent Following (%)	Class II Facilities: Percent Time Spent Following (%)
A	>55	≤35	≤40
B	>50–55	>35–50	>40–55
C	>45–50	>50–65	>55–70
D	>40–45	>65–80	>70–85
E	≤40	>80	>85

Note: Level of service F occurs whenever the demand flow rate exceeds the segment capacity.
(Used with permission of Transportation Research Board, National Research Council, *Highway Capacity Manual*, 4th Edition, Washington DC, 2000, Exhibits 20-2 and 20-4, pgs. 20-3 and 20-4.)

Figure 4.2: Level of service criteria for two-lane rural highways (Roess et. al., 2011)

4.2.3. Capacity analysis methodology for multi-lane highways and freeways

Capacity analysis techniques for freeways and multilane highways are dependent on standardized speed-flow diagrams for segments with different free-flow speeds operating under normal conditions. The steps involved in the capacity analysis of multi-lane highways and freeways are as follows

- Collection of traffic data
- Applying Growth factor

} Same as Two-Lane two-way highway

- Classification of existing highways according to Geometric Features
- Measure of effectiveness (MOE)
- Free flow speed

- Demand Flow rate
- Estimating Density of selected section
- Establishing LOS for Density

Freeways are mostly classified under the condition of uninterrupted flows on the basis of no. of lanes. For a six lane motorway, 3 lanes on both sides are considered. Most commonly used freeways can have four, six eight lanes, however, in our case we will be considering four and six lane motorways with having 2 lanes and 3 lanes in in each direction respectively. For Multi lane highways, No. of lanes in each direction. A Multi-lane highway could be minimum 4 lanes having 2 lanes in each direction. Operational analysis of freeways or Multi-lane highways have many common features in determining the Capacity analysis. Measure of effectiveness defining level of service analysis in HCM 2010 are as shown in figure 4.3

Type of Flow	Type of Facility	Measure of Effectiveness
Uninterrupted Flow	Freeways	
	Basic sections	Density (pc/mi/ln)
	Weaving areas	Density (pc/mi/ln)
	Ramp junctions	Density (pc/mi/ln)
	Multilane Highways	Density (pc/mi/ln)
	Two-Lane Highways	Average Travel Speed (mi/h)
		Percent Time Spent Following (%)
Interrupted Flow	Signalized Intersections	Control Delay (s/veh)
	Unsignalized Intersections	Control Delay (s/veh)
	Urban Streets	Average Travel Speed (mi/h)
	Transit	Service Frequency (veh/day)
		Service Headway (min)
		Passengers/Seat
	Pedestrians	Space (ft^2/ped)
	Bicycles	Frequency of (Conflicting) Events (events *k*)

Figure 4.3 : MOEs of different facilities under flow conditions (Roess et al. 2011)

For Multi-lane highways and basic freeways section, Density was used as the basic measure of effectiveness. For the analysis purposes, free flow speed has been calculated to be used in speed – flow relationship curves to find the LOS of by using density and demand flow. For free flow speed of multi-lane highway and Freeways following equations are used as given below

- **Freeway**

$$FFS = BFFS - f_{LW} - f_{LC} - 3.22TRD^{0.84} \text{..............................} \textbf{(4.5)}$$

where:

FFS = free-flow speed of the freeway, mi/h

BFFS = base free-flow speed of the freeway

f_{LW} = adjustment for lane width, mi/h

f_{LC} = adjustment for lateral clearance, mdh

TRD= Total ramp density

- **Multi-Lane Highway**

$$FFS = BFFS - f_{LW} - f_{LC} - f_M - f_A \text{..} \textbf{(4.6)}$$

where:

FFS = free-flow speed of the multilane highway, mi/h

BFFS = base free-flow speed

F_{LW} = adjustment for lane width, mi/h

F_{LC} = adjustment for lateral clearance, mi/h

f_M = adjustment for type of median

f_A = adjustment for access points, mi/h

Adjustment for Lane width and Lateral clearance is same for both facilities with 12 ft being the base condition of analysis. Adjustment is done for less then 12 feet Lateral clearance on the freeway or Highway. Lane width, median adjustment and access points for multilane highways and number of lanes and interchange density for free ways were considered as per the geometrical feature of the roads and the adjustment factor was calculated from tables provided by HCM 2010. After the calculation of free flow speeds, heavy vehicle factor was calculated using truck buses and RVs proportion. The following formula was used for calculating the f_{HV}

$$f_{HV} = \frac{1}{1+P_T(E_T-1)+P_R(E_R-1)} \text{..} \textbf{(4.7)}$$

where:

P_T = proportion of trucks and buses in the traffic

P_R = proportion of RVs in the traffic stream

E_T = passenger car equivalent for trucks and

E_R = passenger car equivalent for RVs

For calculation of PCE for trucks buses and RVs the table for general terrain sections of freeways and Multi-lane highways were used as given in HCM 2010. To determine the level of service on the selected section of multi-lane or freeway, demand flow rate was calculated using the following Equation 4.8

$$\upsilon_p = \frac{V}{PHF * N * f_{HV} * f_P} \quad \text{...(4.8)}$$

where:

V	=	Peak hour volume veh/h
PHF	=	peak hour factor
N	=	Number of lanes
fHv	=	Adjustment factor for heavy vehicles.
f_P	=	Driver population factor

LOS was determined using the base speed flow curves using density and flow rate as shown in figure 4.4 and 4.5

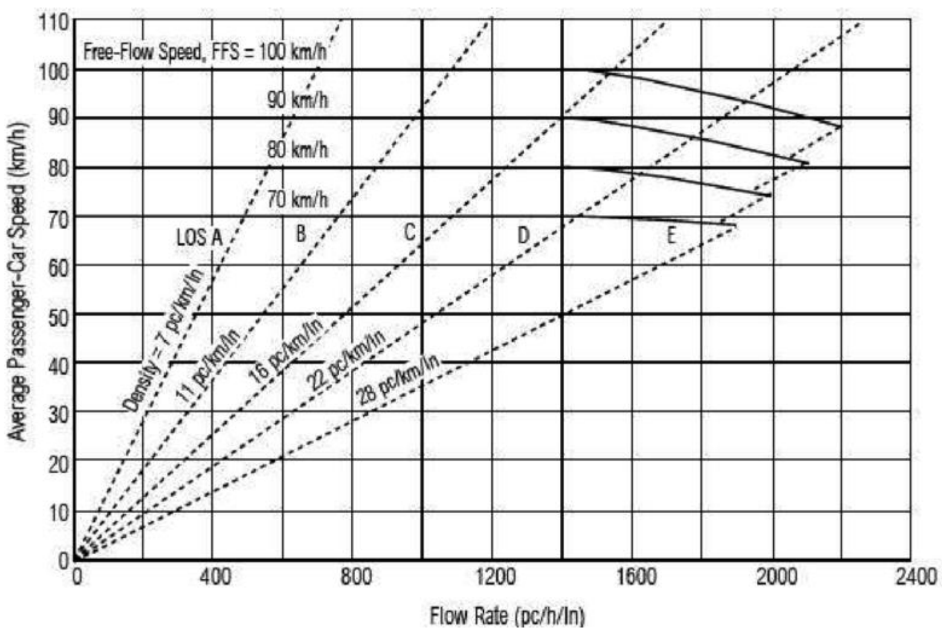


Figure 4.4: Speed flow curves to determine LOS on multi-lane highways (Roess et al. 2011)

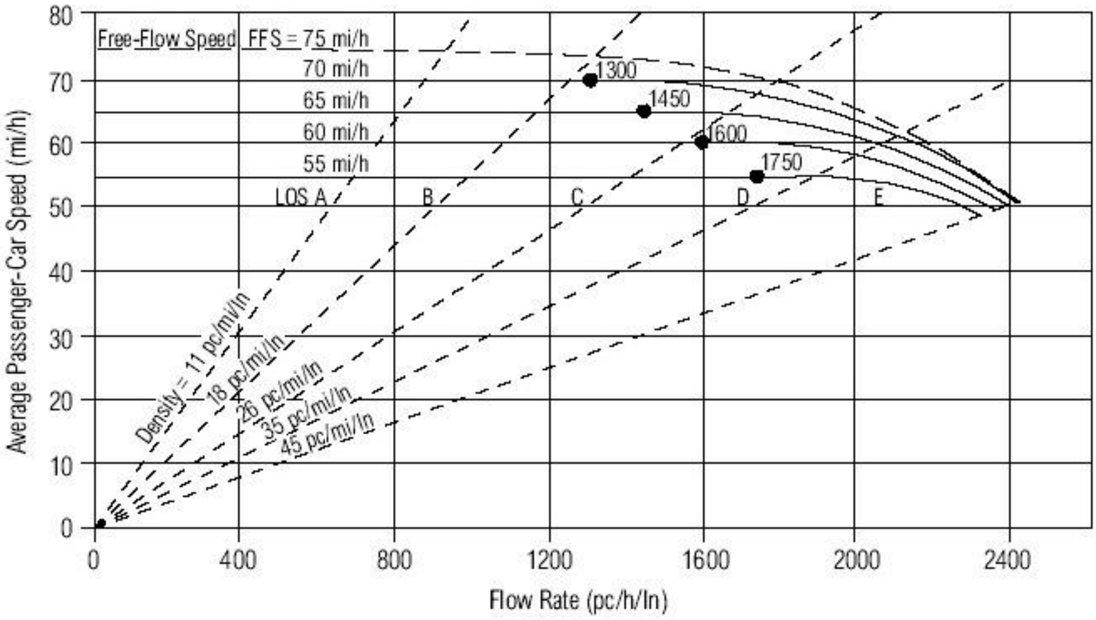


Figure 4.5: Speed flow curves to determine LOS on freeway sections.

(Roess et al. 2011)

Flow chart for methodology of capacity analysis of multi-lane highways and freeway sections are as figure 4.6 and 4.7

4.2.1. Number of trucks to be accommodated by existing cpec alignments in CPEC scenario

After selection of methods for capacity analysis of different facilities under a specific LOS, excel sheets were used to perform the analysis under LOS"C". For the ease of analysis, as use of excel for doing the analysis was a laborious job, the AADT was converted into truck and non-truck traffic proportion. As AADT was in existing condition, Growth factor of 3% was applied and traffic was calculated for analysis year 2025. AADT in 2021 was then divided into truck and non-truck traffic accordingly. At this point, truck traffic was separated and increased until the roadway facility drops from LOS "C" and the number of additional trucks on each of CPEC alignments were calculated in existing condition (sample excel sheet is attached as Annex-A). The same procedure was repeated for analysis year 2025 and number of additional trucks were calculated under existing conditions.

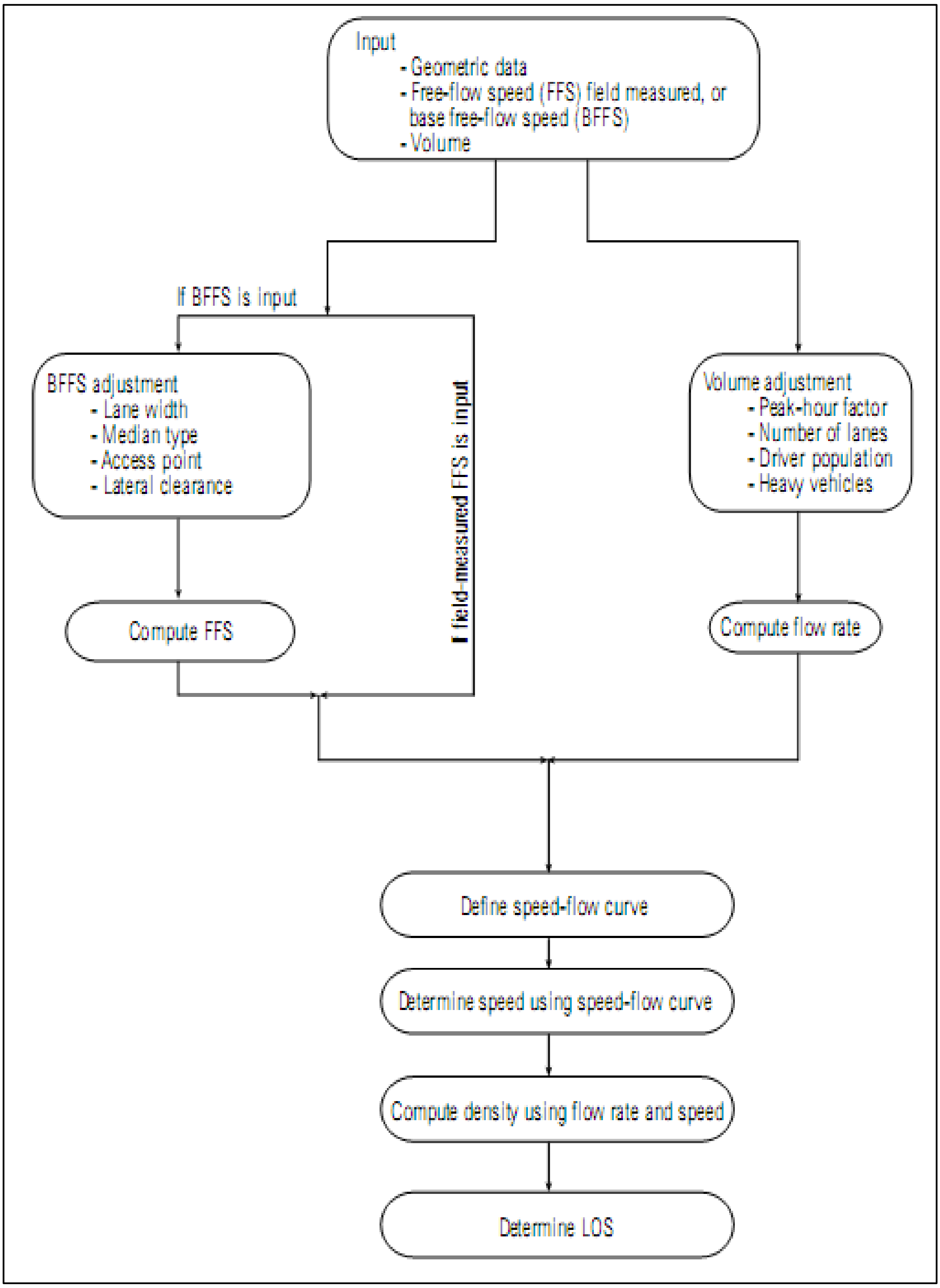


Figure 4.6: Flow chart of Multi-lane highways methodology for capacity analysis (Roess et al. 2011)

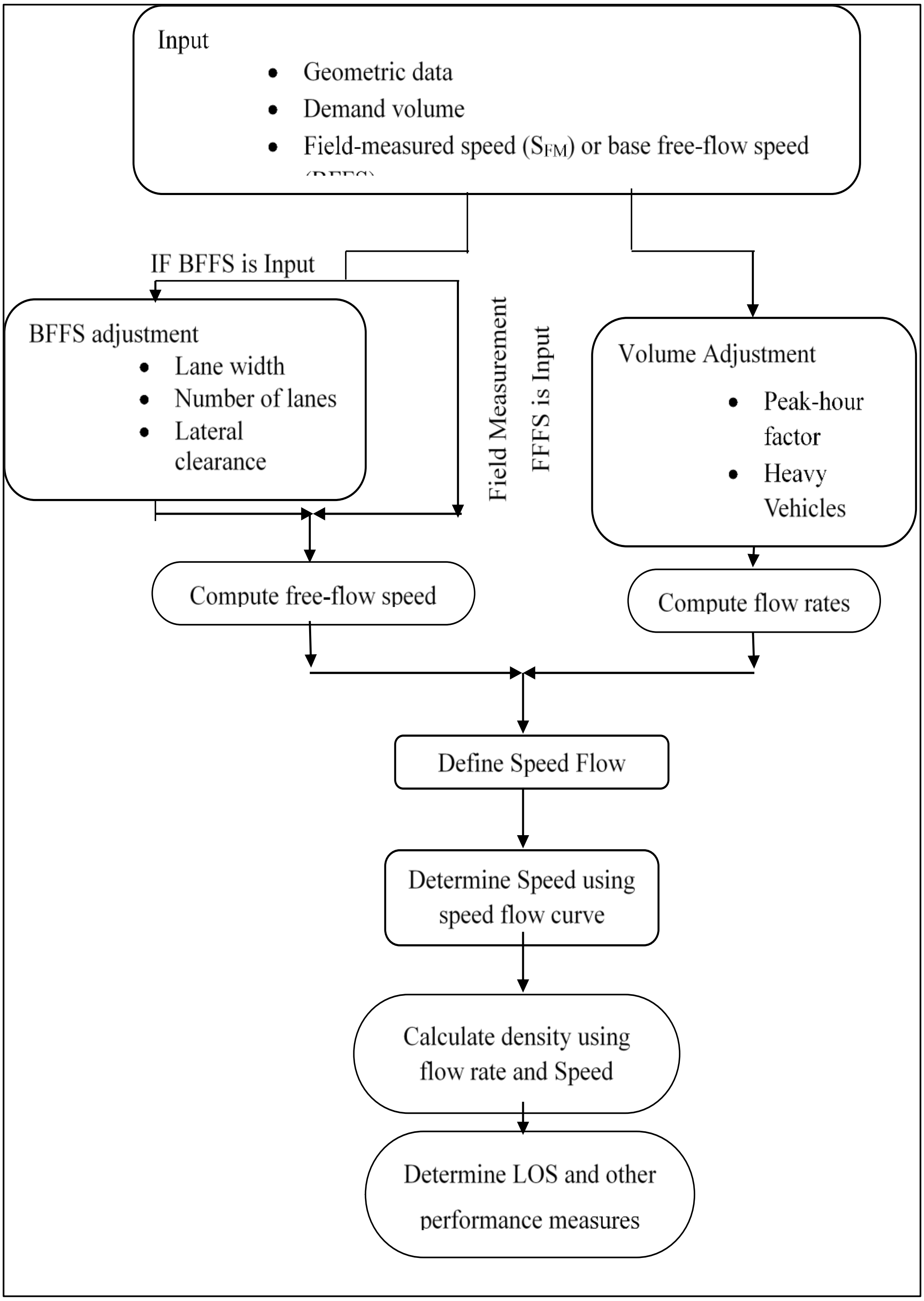


Figure 4.7: Flow chart of Freeway section methodology for capacity analysis (Roess et al. 2011)

4.3.RESULTS OF CAPACITY ANALYSIS OF CPEC ROUTES

All the routes of CPEC were analysed using the formulated excel sheets as the percentage of trucks in HCM was limited to 25% only for multi lane highway sections and freeway sections. In this case manual analysis was done using excel sheets and additional number of trucks on each alignment/ route was calculated. During the analysis, it was also observed that Burhan Khunjerab alignment was the major bottleneck under existing conditions, so the analysis of Khunjerab - Burhan alignment was done as a separate section. The results of capacity analysis on different routes of CPEC are as shown in Table 4.2 to 4.13.

- **Central alignment route 1**

	Existing		**Cr capacity**		**Additional trucks 2021 (LOS C)**			
Sections	**AADT 2021**	**LOS**	**LOS C**	**LOS D**	**Trucks at par**	**% Truck at LOS C**	**Total No. of trucks at C**	**Additional trucks**
Burhan - Hakla	21837	A	44801	58814	7228	0.67	30196	22698
Hakla DI Khan	18494	B	34197	41514	6404	0.65	22091	15687
DI Khan - DG Khan	9396	D	-	14759	1334	-	-	-
DG Khan - Ratodero	4785	C	6310	11065	1976	0.56	3546	1570
Ratodero Khuzdar	17229	D	-	17765	2555	-	-	-
Khuzdar Hoshab	7374	C	8758	14913	329	0.20	1717	1338
Hoshab-Gwadar	8028	C	8817	14810	690	0.17	1481	791

Table 4.2: Critical capacity for existing central alignment of CPEC 2021(Route 1)

	Existing		Cr capacity		Additional trucks (LOS C)			
Sections	**AADT 2025**	**LOS**	**LOS C**	**LOS D**	**Trucks at par**	**% Truck at LOS C**	**Total No. of trucks at C**	**Additional trucks**
Burhan - Hakla	24577	A	47335	61672	8450	0.65	30910	22460
Hakla DI Khan	20815	B	36227	40977	7207	0.62	22606	15399
DI Khan - DG Khan	10576	D	-	15345	1334	-	-	-
DG Khan - Ratodero	5386	C	6326	11517	2225	0.52	3258	1033
Ratodero Khuzdar	19391	E	-	-	2408	-	-	-
Khuzdar Hoshab	8300	C	9091	15035	329	0.13	1164	854
Hoshab - Gwadar	9036	C	9293	15210	690	0.11	1022	382

Table 4.3: Critical capacity for existing central alignment of CPEC in 2025 (Route 1)

	Existing		Cr capacity		Additional trucks (LOS C)			
Sections	**AADT 2025**	**LOS**	**LOS C**	**LOS D**	**Trucks at par**	**% Truck at LOS C**	**Total No. of trucks at C**	**Additional trucks**
Burhan - Hakla	24577	A	47335	61672	8135	0.65	30910	22460
Hakla DI Khan	20815	B	36227	40977	7207	0.62	22606	15399
DI Khan - DG Khan	10576	A	35265	43934	1501	0.74	26202	24701
DG Khan - Ratodero	5386	A	29673	38449	2225	0.89	26498	24273
Ratodero Khuzdar	19391	A	37794	44837	2875	0.56	21278	18403
Khuzdar Hoshab	8300	A	32458	43841	370	0.76	24538	24168
Hoshab Gwadar	8836	A	31301	36192	829	0.74	23288	22459

Table 4.4: Critical capacity for enhanced central alignment of CPEC 2025 (Route 1)

- **<u>Eastern alignment route 2</u>**

	Existing		Cr capacity			Additional trucks LOS C		
Sections	**AADT 2021**	**LOS**	**LOS C**	**LOS D**	**Trucks at par**	**% truck at LOS C**	**Total no. of trucks at C**	**Additional trucks**
Burhan - Islamabad	21837	A	44801	58814	7228	0.67	30017	**22789**
Islamabad - Kallar Kahaar	1743	A	42496	56039	216	0.96	40924	**40708**
Kallar Kahaar - Salam	3195	A	26753	32141	386	0.90	23944	**23558**
Salam-Pindi Bhattian	2895	A	70094	92479	433	0.97	67641	**67208**
Pindi Bhattian-Faisalabad	3064	A	42413	58836	92	0.93	39444	**39352**
Faisalabad - Gojra	572	A	41833	59183	57	0.99	41331	**41274**
Gojra- Multan	24651	B	49032	64392	8715	0.68	33097	**24382**
Multan- RYK	23018	A	45832	63064	14315	0.81	37124	**22809**
RYK- Sukkur	21001	A	44907	60526	9749	0.75	33635	**23886**
Sukkur - Hyderabad	21313	B	49214	61751	9974	0.77	37895	**27921**
Hyderabad - Karachi	30607	A	71499	94988	9720	0.71	50621	**40901**
Makran Coastal Highway (Karachi - Gwadar)	10305	D	-	11908	**-**	**-**	-	**-**

Table 4.5: Critical capacities at existing eastern route via Hyd-Khi-MCHW 2021(Route 2)

	Analysis year		Cr capacity			Additional trucks at LOS C		
Sections	**AADT 2025**	**LOS**	**LOS C**	**LOS D**	**Trucks at par**	**% truck at LOS C**	**Total no. of trucks at C**	**Additional trucks**
Burhan - Islamabad	24577	A	47335	61672	8520	0.65	30910	22390
Islamabad - Kallar Kahaar	1962	A	42372	55826	268	0.96	40635	40367
Kallar Kahaar - Salam	3596	A	26700	31997	435	0.88	23549	23114
Salam-Pindi Bhattian	3259	A	69970	92208	487	0.96	67171	66684
Pindi Bhattian-Faisalabad	3448	A	41617	54286	92	0.92	38288	38196
Faisalabad - Gojra	644	A	42663	56593	64	0.95	40530	40466
Gojra- Multan	27744	B	48721	63008	9809	0.68	33130	23321
Multan- RYK	25907	A	47440	60360	16111	0.79	37667	21556
RYK- Sukkur	23636	A	47099	63081	10972	0.73	34429	23457
Sukkur - Hyderabad	23989	B	47993	64343	11225	0.73	35227	26961
Hyderabad - Karachi	34448	A	69207	90416	10940	0.66	45677	40358
Makran Coastal Highway (Karachi - Gwadar)	13210	D	-	18069	4320	-	-	-

Table 4.6: Critical capacities at existing eastern route Via Hyd-Khi-MCHW in 2025 (Route 2)

	Existing		Cr capacity			Additional trucks LOS C		
Sections	**AADT**	**LOS**	**LOS C**	**LOS D**	**Trucks at par**	**% truck at LOS C**	**Total no. of trucks at C**	**Additional trucks**
Burhan - Islamabad	24577	A	53553	76240	8135	0.57	30525	22390
Islamabad - Kallar Kahaar	1962	A	41737.9	55247	244	0.97	40611	40367
Kallar Kahaar - Salam	3596	A	27067.8	31289	435	0.87	23549	23114
Salam-Pindi Bhattian	3259	A	70706	78891	487	0.95	67171	66684
Pindi Bhattian-Faisalabad	3448	A	41617	54286	104	0.92	38288	38196
Faisalabad - Gojra	644	A	41147.2	55684	64	0.99	40530	40466
Gojra- Multan	27744	B	54400	57456	9809	0.61	33130	23321
Multan- RYK	25907	A	49562	55764	16111	0.76	37667	21556
RYK- Sukkur	23636	A	48355.3	58497	10972	0.71	34429	23457
Sukkur - Hyderabad	23989	A	70922.5	81816	11225	0.80	56738	45513
Hyderabad - Karachi	34448	A	80153	90416	10940	0.64	51298	40358
Makran Coastal Highway (Karachi - Gwadar)	13210	B	46893	63592	4862	0.77	35967	31105

Table 4.7: Critical capacities at enhanced eastern route Via Hyd-Khi-MCHW 2025 (Route 2)

- **<u>Eastern alignment route 3</u>**

	Existing		Cr capacity			Additional trucks at LOS C		
Sections	**AADT 2021**	**LOS**	**LOS C**	**LOS D**	**Trucks at par**	**% truck at LOS C**	**Total no. of trucks at C**	**Additional trucks**
Burhan - Islamabad	21837	A	44801	58814	7228	0.67	30017	22789
Islamabad - Kallar Kahaar	1743	A	42496	56039	216	0.96	40924	40708
Kallar Kahaar - Salam	3195	A	26903	30957	386	0.89	23944	23558
Salam-Pindi Bhattian	2895	A	70094	92479	433	0.97	67641	67208
Pindi Bhattian-Faisalabad	3064	A	42413	58836	92	0.93	39444	39352
Faisalabad - Gojra	572	A	41833	59183	57	0.99	41331	41274
Gojra- Multan	24651	B	49032	64392	8715	0.68	33097	24382
Multan- RYK	23018	A	45832	54360	14315	0.81	37124	22809
RYK- Sukkur	21001	A	44907	60526	9749	0.75	33635	23886
Sukkur - Ratodero - Khuzdar	17229	D	-	17746	2555	-	-	-
Khuzdar Hoshab via Besima	6951	C	8708	12784	329	0.19	1663	1338
Hoshab- Gwadar	7568	A	8817	14810	690	0.17	1481	791

Table 4.8: Critical capacities at existing Eastern route via Ratodero Khuzdar Hoshab Gwadar 2021(Route 3)

	Existing		Cr capacity			Additional trucks at LOS C		
Sections	**AADT 2025**	**LOS**	**LOS C**	**LOS D**	**Trucks at par**	**% truck at LOS C**	**Total no. of trucks at C**	**Additional trucks**
Burhan - Islamabad	24577	A	47335	61672	8520	0.65	30910	22390
Islamabad - Kallar Kahaar	1962	A	42372	55826	268	0.96	40635	40367
Kallar Kahaar - Salam	3596	A	26700	31997	435	0.88	23549	23114
Salam-Pindi Bhattian	3259	A	69670	92208	487	0.96	67171	66684
Pindi Bhattian-Faisalabad	3448	A	41617	54286	92	0.92	38288	38196
Faisalabad - Gojra	644	A	42663	56593	64	0.95	40530	40466
Gojra-Multan	27744	B	48721	63008	9809	0.68	33130	23321
Multan-RYK	25907	A	47440	60360	16111	0.79	37667	21556
RYK-Sukkur	23636	A	47099	63081	10972	0.73	34429	23457
Sukkur - Ratodero - Khuzdar	20090	D	-	17746	2408	-	-	-
Khuzdar Hoshab via Besima	7374	A	9091	15035	310	0.13	1164	854
Hoshab-Gwadar	8836	A	9293	15210	650	0.11	1032	382

Table 4.9: Critical capacities at existing eastern route via Ratodero Khuzdar Hoshab Gwadar in 2025 (Route 3)

	Existing		Cr Capacity			Additional trucks at LOS C		
Sections	**AADT 2025**	**LOS**	**LOS C**	**LOS D**	**Trucks at par**	**% truck at LOS C**	**Total No. of trucks at C**	**Additional trucks**
Burhan - Islamabad	24577	A	53553	76240	8135	0.57	30525	22390
Islamabad - Kallar Kahaar	1962	A	41737.9	55247	244	0.97	40611	40367
Kallar Kahaar - Salam	3596	A	27067.8	31289	435	0.87	23549	23114
Salam-Pindi Bhattian	3259	A	70706	78891	487	0.95	67171	66684
Pindi Bhattian-Faisalabad	3448	A	41617	54286	104	0.92	38288	38196
Faisalabad - Gojra	644	A	41147.2	55684	64	0.99	40530	40466
Gojra-Multan	27744	B	54400	57456	9809	0.61	33130	23321
Multan-RYK	25907	A	49562	55764	16111	0.76	37667	21556
RYK-Sukkur	23636	A	48355.3	58497	10972	0.71	34429	23457
Sukkur - Ratodero - Khuzdar	19391	A	37794	44837	2875	0.56	21278	18403
Khuzdar Hoshab via Besima	7374	A	32971	40503	370	0.76	25058	24168
Hoshab Gwadar	8836	A	31301	36192	829	0.74	23288	22455

Table 4.10: Critical capacities at enhanced eastern route via Ratodero Khuzdar Hoshab Gwadar 2025 (Route 3)

- **Western alignment route 4**

	Existing	Cr Capacity				Additional trucks at LOS C		
Sections	**AADT in 2021**	**LOS**	**LOS C**	**LOS D**	**Trucks at par**	**% truck at LOS C**	**Total no. of trucks at C**	**Additional trucks**
Burhan-Hakla	21837	A	44801	58814	7228	0.67	30196	22698
Hakla DI Khan	18494	B	34197	41514	6404	0.65	22091	15687
DI Khan-Zhob	2390	B	6127	10688	251	0.65	3989	3738
Zhob - Quetta	4048	B	7043	11218	657	0.52	3648	2991
Quetta - Kalat	12439	D	-	15817	1823	-	-	-
Kalat-Surab	8610	C	8610	14042	1343	0.16	1343	-
Surab - Hoshab	1728	B	5732	11303	100	0.72	4104	4004
Hoshab-Gwadar	7568	A	8817	14810	690	0.17	1481	791

Table 4.11: Critical capacities at existing western route 2021 (Route 4)

	Existing	Critical capacity				Additional trucks at LOS C		
Sections	**AADT in 2025**	**LOS**	**LOS C**	**LOS D**	**Trucks at par**	**% truck at LOS C**	**Total no. of trucks at C**	**Additional trucks**
Burhan - Hakla	24577	A	47335	61672	8450	0.65	30910	22460
Hakla DI Khan	20815	B	36227	40977	7207	0.62	22606	15399
DI Khan-Zhob	2690	B	6117	11155	237	0.61	3707	3470
Zhob - Quetta	4557	B	7214	11826	619	0.47	3398	2779
Quetta - Kalat	14000	D	-	15946	1718	-	-	-
Kalat-Surab	9690	C	-	13389	1263	-	-	-
Surab - Hoshab	8300	B	6031	10832	112	0.68	4101	3989
Hoshab-Gwadar	8836	A	9293	15210	650	0.11	1032	382

Table 4.12: Critical capacities at existing western route 2025 (Route 4)

	Existing		Cr Capacity			Additional trucks at LOS C		
Sections	**AADT in 2025**	**LOS**	**LOS C**	**LOS D**	**Trucks at par**	**% truck at LOS C**	**Total no. of trucks at C**	**Additional trucks**
Burhan - Hakla	24577	A	47335	61672	8135	0.65	30910	22460
Hakla DI Khan	20815	B	36227	40977	7207	0.62	22606	15399
DI Khan-Zhob	2690	A	29591	37767	283	0.91	26928	26645
Zhob - Quetta	4557	A	28617	36076	739	0.87	24897	24158
Quetta - Kalat	14000	A	33973	43222	2051	0.65	22082	20031
Kalat-Surab	9690	A	31174	40828	1508	0.73	22757	21249
Surab - Hoshab	8300	A	32971	40503	370	0.76	25058	24688
Hoshab Gwadar	8836	A	31301	36192	829	0.74	23288	22459

Table 4.13: Critical capacities at enhanced Western route 2025 (Route 4)

For the common route of CPEC from Burhan to Khunjerab, Capacity analysis was carried out based on existing infrastructure i.e. Highway and freeway sections. After the complete analysis of all the routes of CPEC including the common routes, it was established that common alignment of CPEC i.e from Burhan to Gwadar will play a vital role in the freight traffic management of CPEC. It needs to be analysed along with all the possible major routes of CPEC, which will be done at a later stage in this research. However, the summary of critical capacities of all the critical sections under existing infrastructure of CPEC with year 2021 and 2025. After finding critical sections, the sections are improved to make the susceptible to more traffic by increasing lanes where possible. New option after the enhancement in critical sections of all routes was analysed and new critical sections were determined in year 2025 are as shown in table 4.14

Route	Critical capacity under existing infrastructure 2021 (LOS C)	Critical capacity under existing infrastructure 2025 (LOS C)	Critical capacity under enhanced infrastructure in 2025 (LOS C)
Central alignment route 1	0	0	Hakla- DI Khan 15,399 trucks/day
Eastern alignment route 2	0	0	Multan - Rahim Yar Khan 21,556 trucks/day
Eastern alignment route 3	0	0	Ratodero – Khuzdar 18,403 trucks/day
Western alignment route 4	0	0	Hakla – DI Khan 15,399 trucks/day

Table 4.14: Additional number of trucks/ day on CPEC alignments under LOS C

CHAPTER 5

5. STATISTICAL MODELLING & ESTIMATION OF TRUCK FREIGHT TRAFFIC IN CPEC SCENARIO

5.1.INTRODUCTION

Transportation system has the primary and secondary linkages with most of the sectors of the country's economy and trade. The size of transportation infrastructure influences the trade, economic growth and development of any country. An effective and worthy transport system contributes to economic growth by dropping production budget. CPEC is expected to bring a lot of freight load/ trade to Pakistan from other countries, especially China that is going to substantially increase the traffic or freight load on existing road infrastructure. The total volume of Pakistan's trade presently is 65-70 Billion USD, whereas China has a total trade volume of over 4.1 Trillion USD (4100 Billion USD) which will increase further [tradingeconomics.com]. This part of the research study is mainly based on two hypotheses. First hypothesis is that "if 5 % worth of the China's total trade (in USD or Tons) goes through CPEC, present infrastructure of Pakistan will get choked" (Asghar, 2016) or "If even 5% worth of the China's total trade volume (in USD or Tons) goes through CPEC, our current spare capacity cannot handle it" (Shiekh, 2016). The obvious reason for this hypothesis is that the current trade of Pakistan is very less as compared to that of China and existing road infrastructures are not ready to deal with such a huge amount of trade/ freight traffic, which are expected from China or other countries, when CPEC is going to be completed and fully operationalized. Thus, it is very essential to analyse China's trade volume by trade amount (US Dollars) from the point of view, which may enable us to reasonably estimate and translate some of its share into freight traffic for CPEC and also compare it with the existing capacity of roadway infrastructures of Pakistan so that it could be dealt with efficiently.

This part of the research study aims to analyze and quantify above hypotheses. To carry out this analysis, statistical modeling was adopted and various economic indicators/ variables related to Pakistan trade/ economy were selected. Moreover, various strategies were adopted to establish any significant relationships among different combinations of variables for prediction of freight traffic and finally these developed relationships were used in prediction/ forecasting of freight traffic on

CPEC Alignments in CPEC scenario.

5.2. ANALYTICAL FRAMEWORK FOR PREDICTION OF FREIGHT TRAFFIC

Analytical framework for prediction of freight traffic on CPEC alignments is shown in Figure 5.1

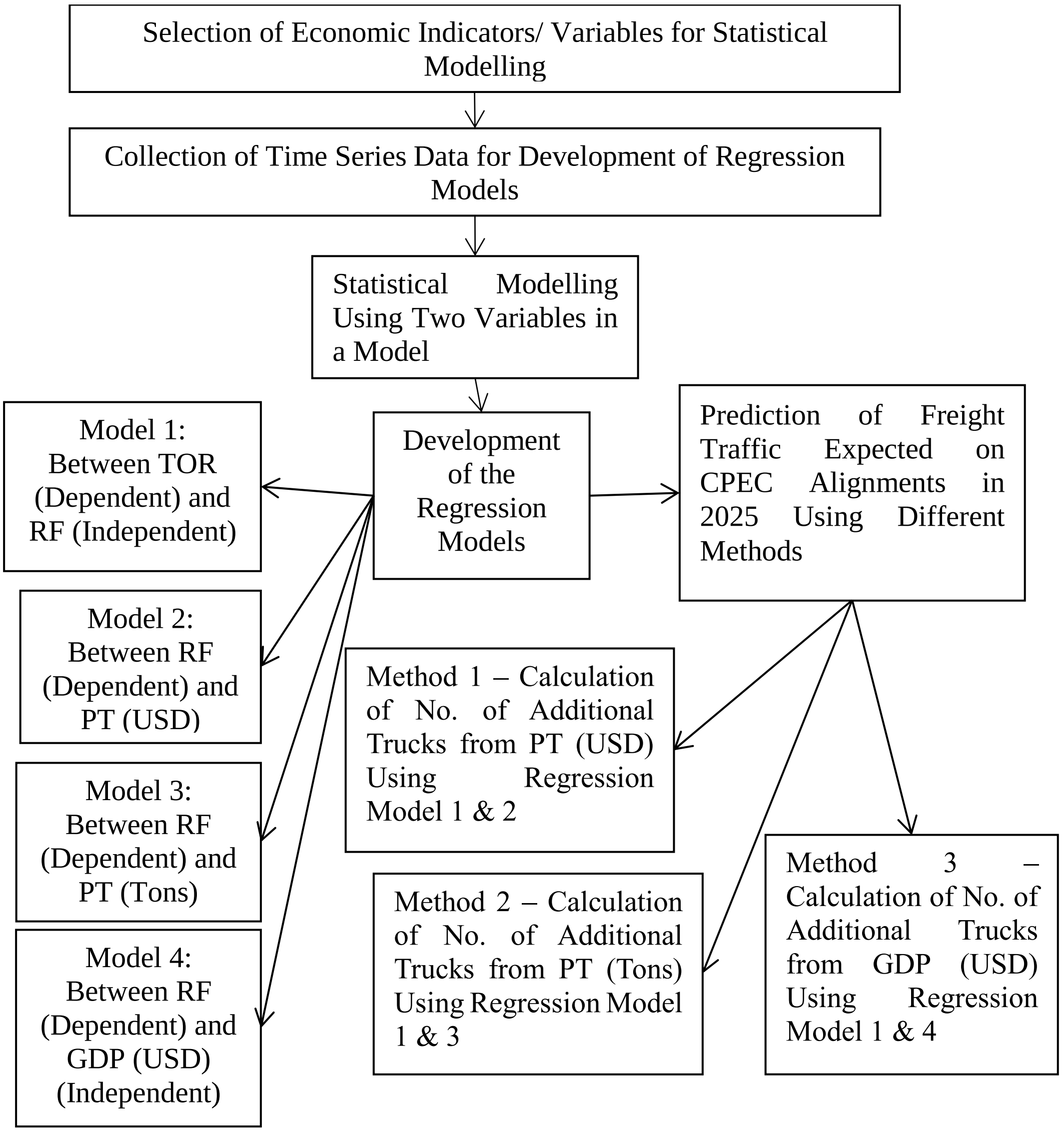


Figure 5.1: Analytical framework for prediction of freight traffic

RF = Pakistan road freight *(Million Ton kms),* **TOR** = Number of trucks on road *(numbers),* **PT (USD)** = Pakistan trade in USD *(Million USD),* **PT (Tons)** = Pakistan trade in tons *(million tons),* **GDP (USD)** = Pakistan GDP in USD *(billion USD.*

5.3. ESTIMATION OF FREIGHT TRAFFIC IN CPEC SCENARIO

Various economic indicators/ variables related to Pakistan economy and social growth were used in statistical modelling. Details are given in Table 5.1

S/No.	Model variables	Type of variable	Sources
1.	GDP (Billion USD)	Continuous variable	(*Economic Survey of Pakistan*, 2018-2019) & ("The World Bank Organisation," 2019)
2.	Road freight (Million Ton kms)	Continuous variable	(*Economic Survey of Pakistan*, 2018-2019)
3.	Population (Million)	Discrete variable	(*Economic Survey of Pakistan*, 2018-2019)
4.	Number of registered motor vehicles	Discrete variable	(*Economic Survey of Pakistan*, 2018-2019)
5.	Number of registered trucks	Discrete variable	(*Economic Survey of Pakistan*, 2018-2019)
6.	Number of motor vehicles on road	Discrete variable	(*Economic Survey of Pakistan*, 2018-2019) & (National Transport Research Center (NTRC)
7.	Number of trucks on road	Discrete variable	(*Economic Survey of Pakistan*, 2018-2019) & (National Transport Research Center (NTRC)
8.	Length of roads (Kms)	Continuous variable	(*Economic Survey of Pakistan*, 2018-2019) & (National Transport Research Center (NTRC)
9.	Pakistan trade (Million USD)	Continuous variable	("Pakistan Bureau of Statistics (Govt. of Pakistan)," 2019), ("The World Bank Organisation," 2019) & ("Trading Economics," 2018)
10.	Pakistan trade (Million Tons)	Continuous variable	(*Economic Survey of Pakistan*, 2018-2019) & ("The World Bank Organisation," 2019)

Table 5.1: Economic indicators/ model variables

5.3.1. Statistical modeling using two variables in a model

In this strategy, four regression models each comprising of two different combinations of variables were successfully developed and number of trucks on road in Pakistan were determined from these models in three different ways. These models and their methods have been explained in next sections in detail and are summarized below in Table 5.2.

S/No.	Regression models	Dependent / Outcome variables	Independent / Predictor variables
1.	Model 1	No. of trucks on road (TOR) (numbers)	Road freight (RF) (million tons kms)
2.	Model 2	Road freight (RF) (million tons kms)	Pakistan trade in USD [PT(USD)]
3.	Model 3	Road freight (RF) (million tons kms)	Pakistan trade in tons [PT(Tons)]
4.	Model 4	Road freight (RF) (million tons kms)	GDP in USD [GDP(USD)]

Table 5.2 : Statistical modelling using two variables in a model

5.3.2. Prediction of freight traffic expected on CPEC alignments

Relationship between freight development and economic growth is very well established– there is a lead or lag process between the both. There are mainly two different opinions on the correlation between the economic growth and the modern logistics theoretically. One is the theory of logistic-push which states that modern logistic and contribute to regional economic development and second is the economic pull, thinking that the rapid economic development also pulls the further development of, modern logistics (Liu & Li, 2007). To find out whether any relationship exists between freight traffic, trade and economic growth of Pakistan, time series data of various variables (as already discussed in Table 5.1) was collected and empirical analysis was carried out using statistical tool. SPSS was selected as statistical tool and the method adopted for construction of regression model was “simple linear regression”. Time series data for the last 26 years was collected from internet to be used in regression modeling i.e. from 1992 to 2018. Out of which 21 years data was used for development of regression model while randomly selected 5 years data (almost 26% of total data) was used for model validation. The year, which was selected for analysis was 2025; assuming, that CPEC would be completed and fully operationalized.

5.3.3. Descriptive statistics of variables used in regression modeling

Descriptive statistics of variables used in regression modeling is given in Table 5.3.

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
RoadFreightRF	22	150352	41536	191888	2710016	123182.55	8697.440	40794.609	1664200129	-.047	.491	-.828	.953
PAKGDP	22	266	49	315	3120	141.82	18.308	85.874	7374.320	.621	.491	-1.008	.953
TrucksonRoadTOR	22	204200	75800	280000	3670600	166845.45	12792.562	60002.434	3600292121	.400	.491	-.948	.953
PTTONS	22	80	20	101	1111	50.52	4.678	21.943	481.490	.386	.491	-.419	.953
PTUSD	22	68640	15367	84007	904272	41103.27	4960.164	23265.231	541270951.1	.343	.491	-1.542	.953
Valid N (listwise)	22												

Table 5.3: Descriptive statistics of variables used in regression modelling (SPSS)

5.3.4. Development of regression models and their statistics

This strategy was used for CPEC freight traffic estimation/ forecasting due to its more realistic and significant relation. In this strategy, four regression models each comprising of two different combinations of variables were successfully developed and number of trucks on road were determined from these models by using three different methods. These regression models are described in detail along with their statistics as follows

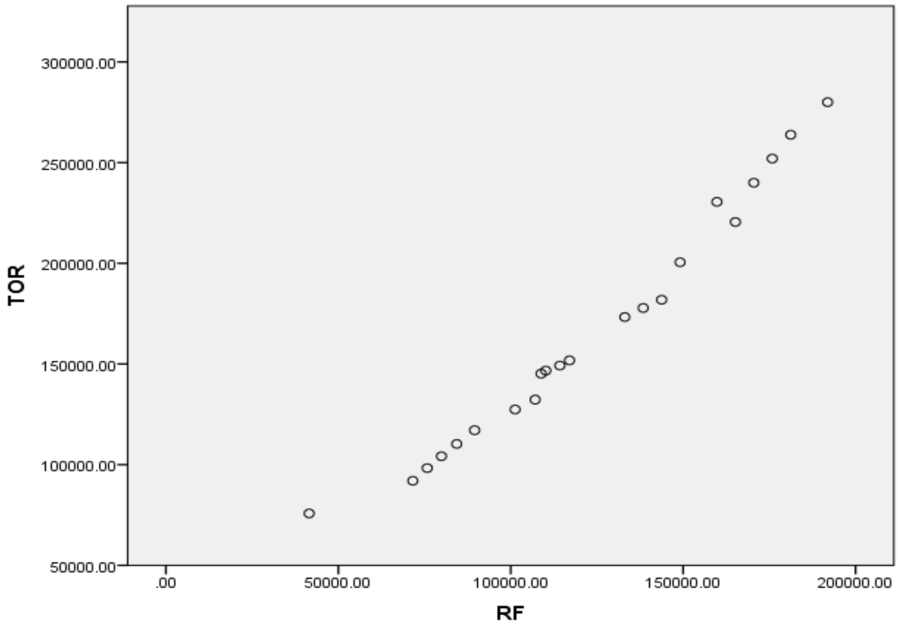
5.3.4.1. Regression model 1 – relationship of number of trucks on road in Pakistan (TOR) with Pakistan road freight (RF)

a. Variables used in development of model:

Number of trucks on road (TOR) = dependent discrete variable

Pakistan road freight (RF) = independent continuous variable

b. Statistics of regression model



Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.987[a]	.973	.972	10059.21803	.973	727.186	1	20	.000

a. Predictors: (Constant), RF

b. Dependent Variable: TOR

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.358E+10	1	7.358E+10	727.186	.000[b]
	Residual	2023757349	20	101187867.4		
	Total	7.561E+10	21			

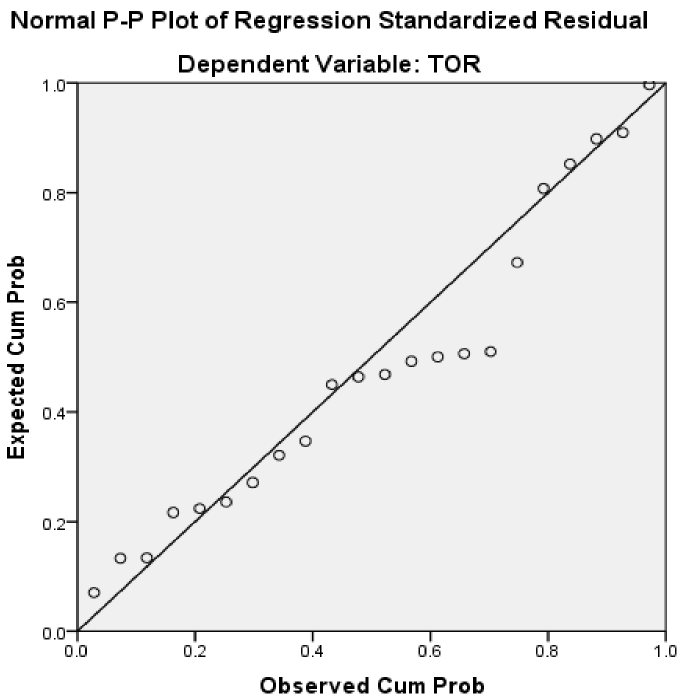
a. Dependent Variable: TOR

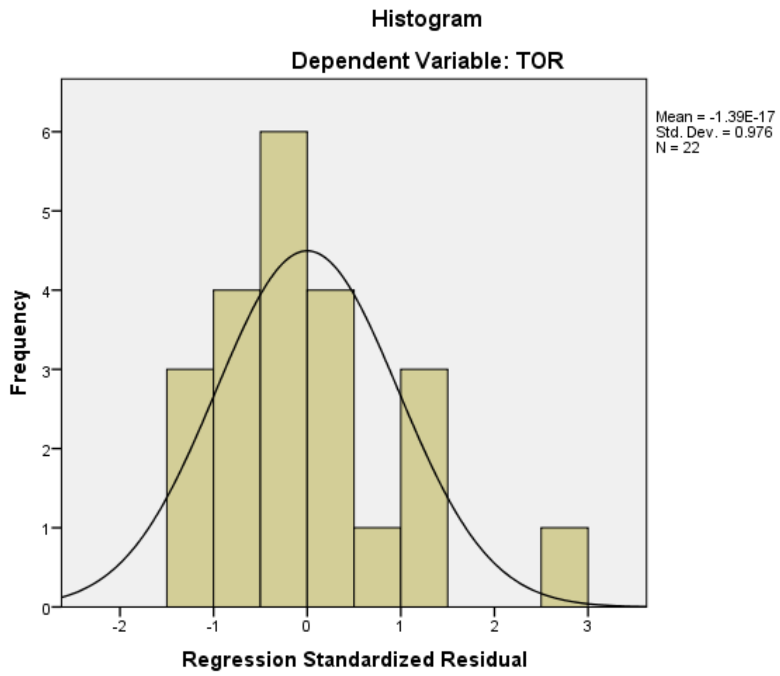
b. Predictors: (Constant), RF

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	-11895.329	6966.604		-1.707	.103					
	RF	1.451	.054	.987	26.966	.000	.987	.987	.987	1.000	1.000

a. Dependent Variable: TOR





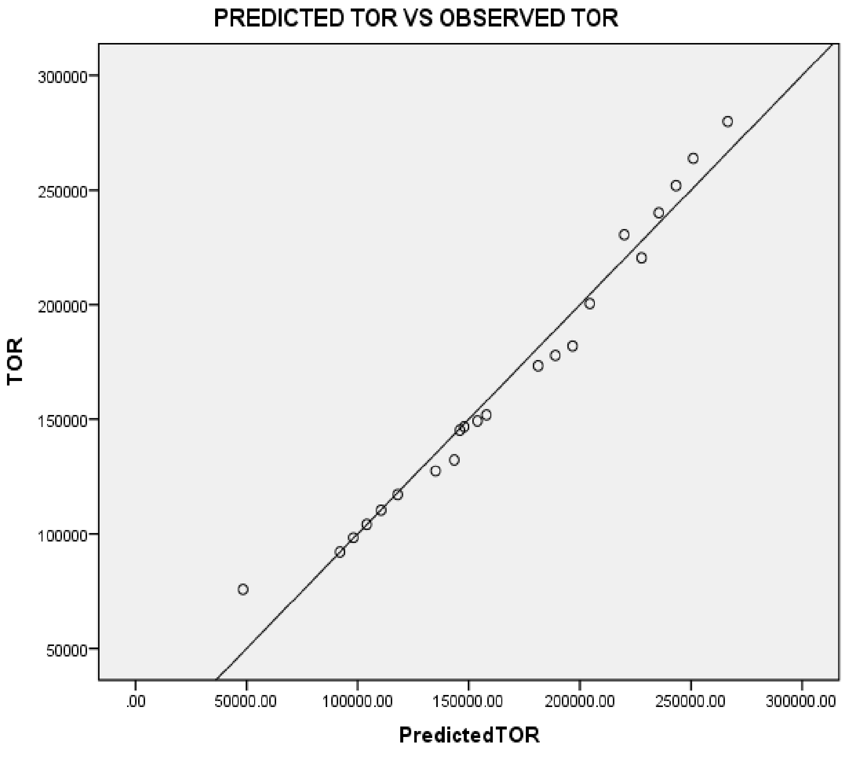


Figure 5.2: Statistics of regression models – 1

c. Equation of regression model:

Unstandardized coefficients of constant and independent variable RF were -11895.329 and 1.451 respectively, indicated in Figure 5.2. Thus, the regression model equation can be expressed as:

$$TOR = -11895.329 + 1.451 * RF \text{ ....} \textbf{(5.1)}$$

Or, Number of trucks on road in Pakistan = -11895.329 + 1.451 * (Pakistan road freight)

This shows that with an increase of 1 million ton kms in Pakistan road freight, the estimated increase in the number of trucks on road in Pakistan would be 1.451.

d. Analysis of regression model:

The scatter plot between number of trucks on road (TOR) and Pakistan road freight (RF) indicated a positive linear correlation as shown in Figure 5.2. Therefore, linear regression analysis was conducted to examine the relationship between predictor RF and outcome TOR. The regression model produced R = 0.987, indicating a strong positive relationship between TOR and RF and R^2 = 0.973, indicating 97.3 % of the variation in outcome is explained by variation in predictor. The t-stats i.e. t = 26.966 > 2.3060 with Sig. (P value) = 0.000 < 0.05 (95% Confidence level), indicated a significant linear relationship between TOR and RF at 0.05 level of significance. The F stats i.e. F = 727.186, Sig. (P value) = 0.000 < 0.05 further confirmed the independent variable to be significant. Therefore, each of the number of trucks on road (TOR) data is positively and significantly correlated with Pakistan road freight (RF), demonstrating increase in Pakistan road freight will eventually increase the number of trucks on road in Pakistan.

e. Validation of regression model:

The final step in the model-building process is to validate the selected regression model to check whether the model's predictive performance deteriorates substantially when applied to data that were not used in model estimation. As mentioned earlier, 26% of the total data i.e. 5 years data was used for model validation. Mean Squared Prediction Error (MSPE) was calculated for validation data and compared with Mean Squared Error (MSE) of original model based on regression data as shown in Table 5.4. Since MSPE is fairly close to MSE for the developed model and the difference between them is 27.11% < 35%, therefore it satisfy the validation and the model has potentially reasonable prediction.

Years	Road freight (RF) (Observed Y_i) (Mn ton kms)	Pakistan trade in USD (Observed X_i) (Mn USD)	Road freight (Predicted $\hat{Y}_i$) using developed model	$(Y_i - \hat{Y}_i)^2$	Number of cases in the validation data set (n)	Mean squared Prediction Error (MSPE) = $\sum (Y_i - \hat{Y}_i)^2 / n$	Mean squared error (MSE) (from ANOVA table)	Percentage difference of MSPE from MSE (%)
Predicted RF = 55622.277 + 1.644 * PT(USD)								
1993	53719	16754	83165.85	867117151	5	236677205	211966242	11.66
1999	95246	17211	83917.16	128342593				
2005	116327	34989	113144.19	10130260				
2011	154456	65224	162850.53	70468184				
2017	186540	73332	176180.09	107327838				
		$\sum (Yi - \hat{Y}i)^2 =$ 1183386028.19						

Table 5.4: Validation of regression model – 1

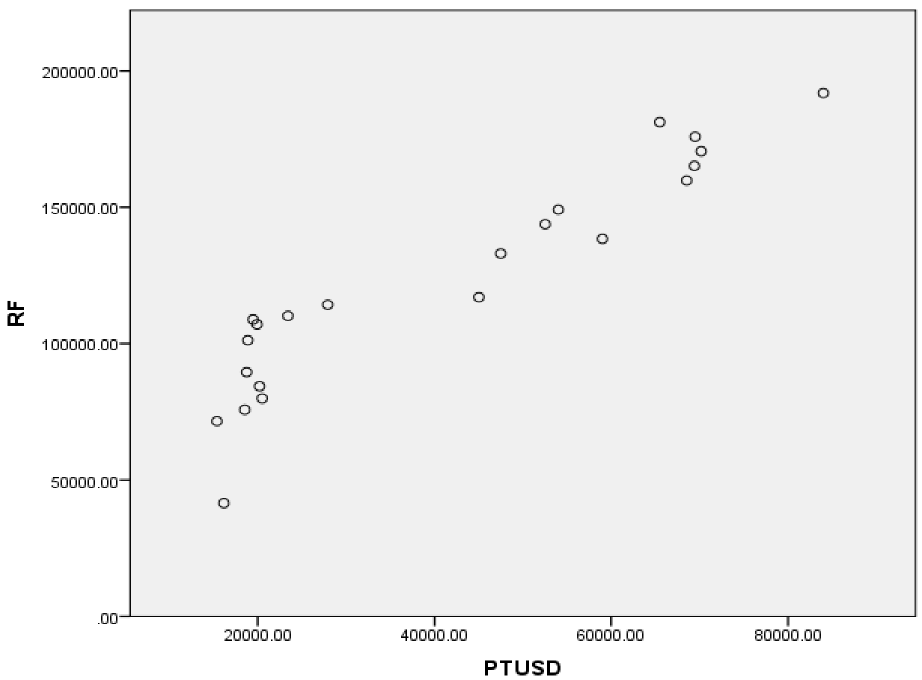
5.3.4.2. Regression model 2 – relationship of Pakistan road freight (RF) with Pakistan trade in US Dollar

a. Variables used in development of model:

Pakistan road freight (RF) = Dependent continuous variable

Pakistan trade in US Dollar PT (USD) = Independent continuous variable

b. Statistics of regression model



Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.937[a]	.879	.873	14559.06049	.879	144.876	1	20	.000

a. Predictors: (Constant), PTUSD

b. Dependent Variable: RF

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.071E+10	1	3.071E+10	144.876	.000[b]
	Residual	4239324850	20	211966242.5		
	Total	3.495E+10	21			

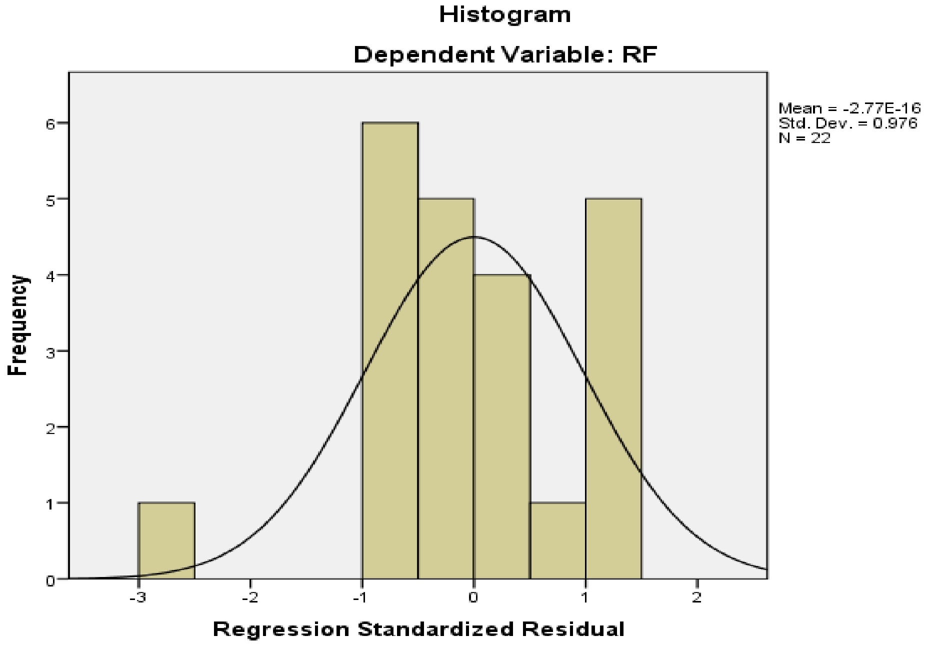
a. Dependent Variable: RF

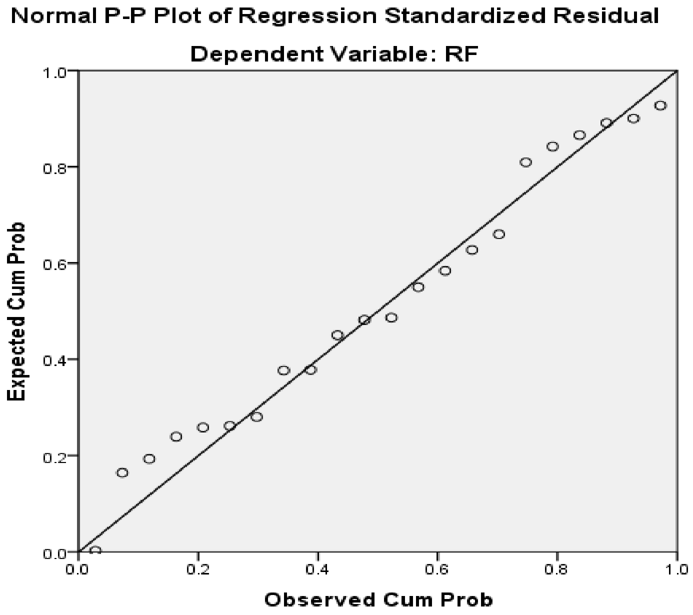
b. Predictors: (Constant), PTUSD

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	55622.277	6414.068		8.672	.000					
	PTUSD	1.644	.137	.937	12.036	.000	.937	.937	.937	1.000	1.000

a. Dependent Variable: RF





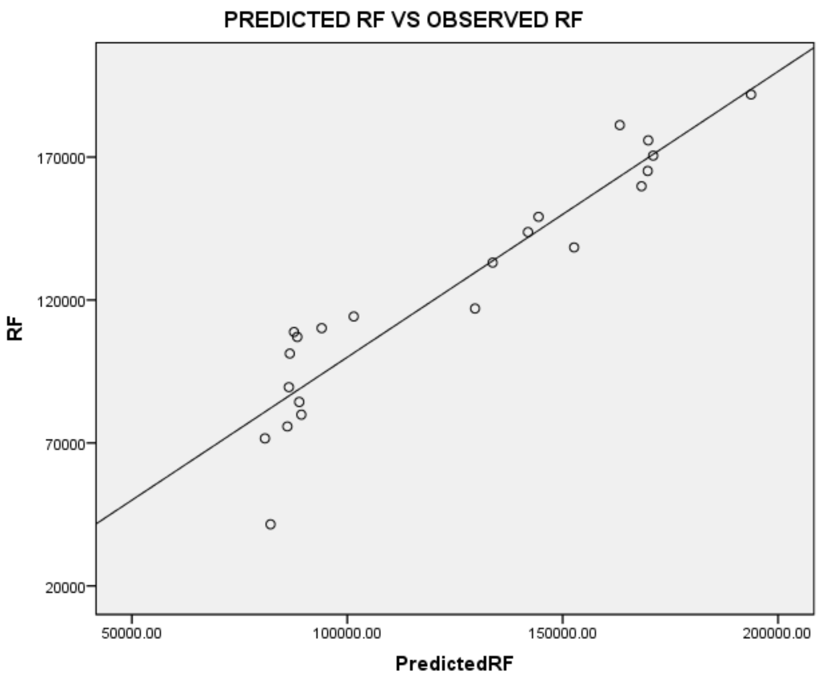


Figure 5.3: Statistics of regression Model – 2

c. <u>Equation of regression model</u>:

Unstandardized Coefficients of constant and independent variable PT (USD) were 55622.277 and 1.644 respectively. Thus, the linear regression model equation can be expressed as:

RF = 55622.277 + 1.644 * PT (USD)………………………… **(5.2)**

Or,

Pakistan road freight = 55622.277 + 1.644 * (Pakistan Trade in USD)

This shows that with an increase of 1 Million USD in Pakistan trade, the estimated increase in Pakistan road freight would be 1.644 Million Ton kms.

d. Analysis of regression model

The scatter plot between Pakistan road freight (RF) and Pakistan trade in USD [PT (USD)] indicated a positive linear correlation as shown in Figure 5.3. Therefore, linear regression analysis was conducted to examine the relationship between Predictor PT (USD) and outcome RF. The regression model produced R = 0.937, indicating a strong positive relationship between RF and PT (USD) and R^2 = 0.879, indicating 87.9 % of the variation in outcome is explained by variation in predictor. The t-stats i.e. $t = 12.036 > 2.3060$ with Sig. (P value) = $0.000 < 0.05$ (95% confidence level), indicated a significant linear relationship between RF and PT (USD) at 0.05 level of significance. The F stats i.e. F = 144.876, Sig. (P value) = $0.000 < 0.05$ further confirmed the independent variable to be significant. Therefore, each of the road freight (RF) data is positively and significantly correlated with Pakistan yrade in USD [PT (USD)], demonstrating more the Pakistan trade in USD more will be its road freight.

e. Validation of regression model:

The final step in the model-building process is to validate the selected regression model to check whether the model's predictive performance deteriorates substantially when applied to data that were not used in model estimation. As mentioned earlier, 26% of the total data i.e. 5 years data was used for model validation. Mean Squared Prediction Error (MSPE) was calculated for validation data and compared with Mean Squared Error (MSE) of original model based on regression data as shown in Table 5.5. Since MSPE is fairly close to MSE for the developed model and the difference between them is 11.66% < 35%, therefore it satisfy the validation and the model has potentially very good prediction.

Years	Number of trucks on road in pakistan (TOR) *(Observed Yi)* (No.)	Road freight (RF) *(Observed Xi)* (Mn Ton Kms)	Road freight *(Predicted Y^i)*	(Yi - Y^i)^2	Number of cases in the validation data set (n)	Mean squared prediction error (MSPE) = ∑ (Yi - Y^i) ^{2} / n	Mean squared error (MSE) (From ANOVA Table)	Percentage difference of MSPE from MSE (%)
Predicted TOR = -11895.329+1.451 (RF)								
1993	84200	53719	66050.94	329388378	5	128623592	101187867	27.11
1999	121000	95246	126306.62	28160183				
2005	151800	116327	156895.15	25960533				
2011	209500	154456	212220.33	7400178				
2017	276200	186540	258774.21	303658122				
		∑ (Yi - Y^i)^2 =694567397						

Table 5.5 : Validation of regression model – 2

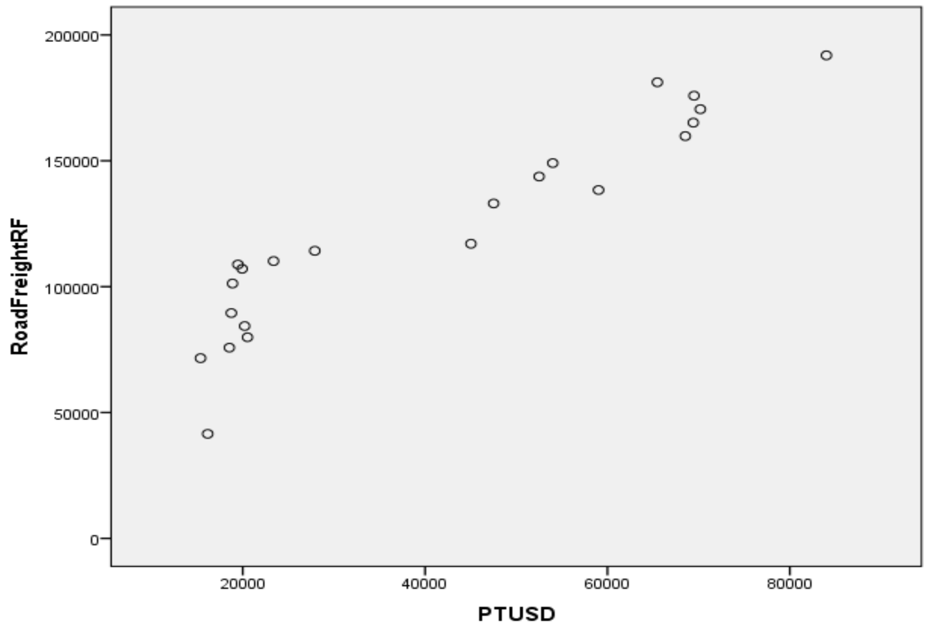
5.3.4.3. Regression model 3 – relationship of Pakistan road freight (RF) with Pakistan trade in tons

a. Variables used in development of model:

Pakistan road freight (RF) = Dependent continuous variable

Pakistan rrade in tons PT (Tons) = Independent continuous variable

b. Statistics of regression model:



Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.961[a]	.923	.919	11623.515	.923	238.672	1	20	.000

a. Predictors: (Constant), PTTONS

b. Dependent Variable: RoadFreightRF

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.225E+10	1	3.225E+10	238.672	.000[b]
	Residual	2702122245	20	135106112.3		
	Total	3.495E+10	21			

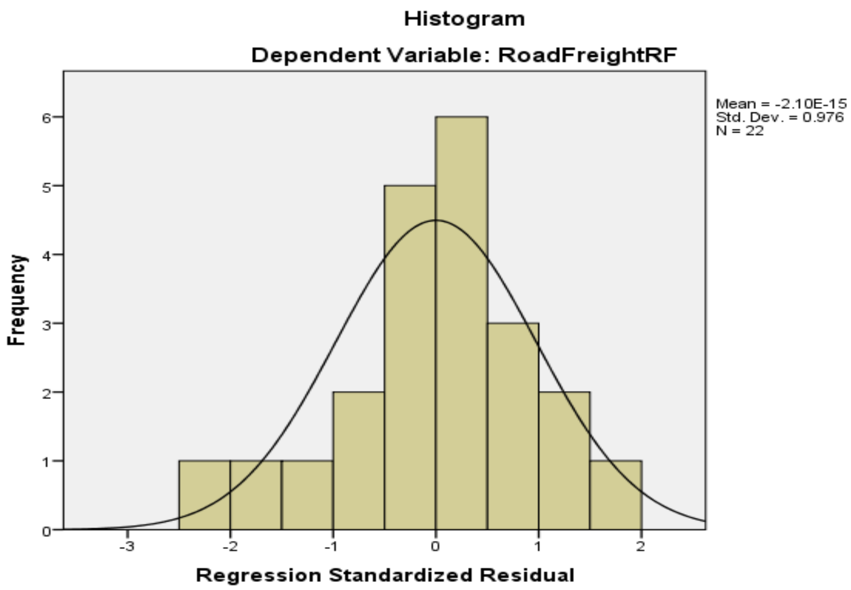
a. Dependent Variable: RoadFreightRF

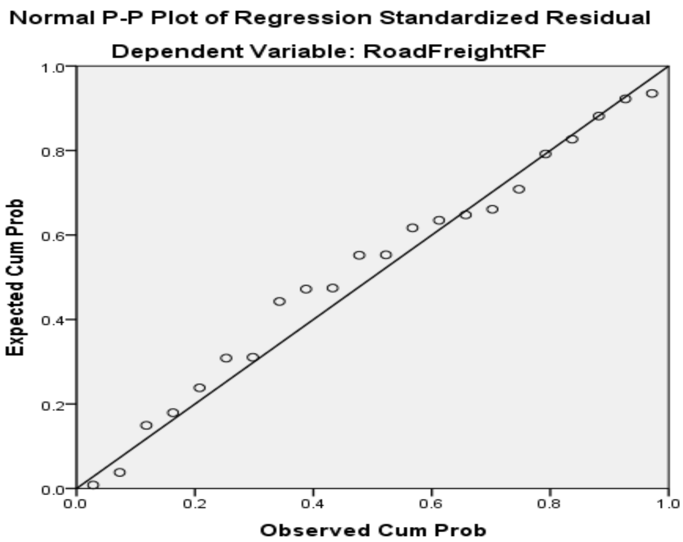
b. Predictors: (Constant), PTTONS

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	32965.906	6343.699		5.197	.000
	PTTONS	1785.809	115.594	.961	15.449	.000

a. Dependent Variable: RoadFreightRF





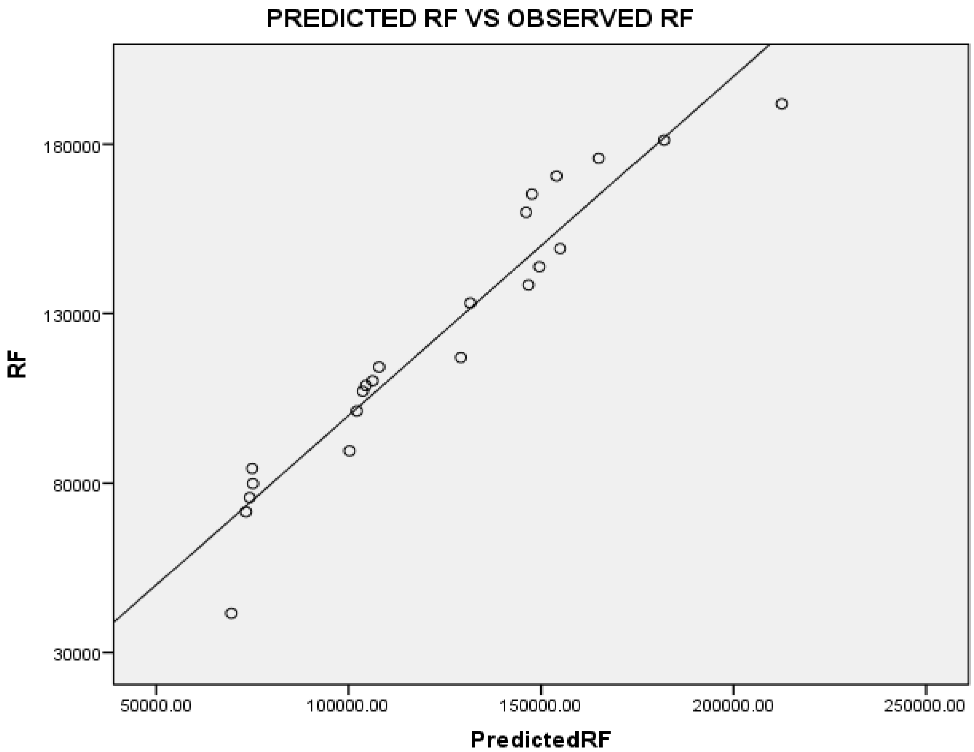


Figure 5.4 : Statistics of regression models – 3

c. Equation of regression model:

Unstandardized Coefficients of constant and independent variable PT (Tons) were 32965.906 and 1785.809 respectively, as indicated in Figure 5.4.

Thus, the regression model equation can be expressed as:

RF = 32965.906 + 1785.809 * PT (Tons)**………………………… (5.3)**

Or,

Pakistan road freight = = 32965.906 1785.809 * (Pakistan trade in tons)

This shows that with an increase of 1 million tons in Pakistan trade, the estimated increase in Pakistan road freight would be 1785.809 Million Ton kms.

d. Analysis of regression model:

The scatter plot between Pakistan road freight (RF) and Pakistan trade in tons [PT (Tons)] indicated a positive linear correlation as shown in Figure 5.4. Therefore, linear regression analysis was conducted to examine the relationship between Predictor PT (tons) and outcome RF. The regression model produced R = 0.961, indicating a strong positive relationship between RF and PT (Tons) and $R^2 = 0.923$, indicating 92.3 % of the variation in outcome is explained by variation in predictor. The t-stats i.e. $t = 15.449 > 2.3060$ with Sig. (P value) = 0.000 < 0.05 (95% Confidence level), indicated a significant linear relationship between RF and PT (Tons) at 0.05 level of significance. The F stats i.e. F = 238.672, Sig. (P value) = 0.000 < 0.05 further confirmed the independent variable to be significant. Therefore, each of the toad freight (RF) data is positively and significantly correlated with Pakistan Trade in Tons [PT (Tons)], demonstrating more the Pakistan trade in Tons more will be its road freight.

e. Validation of regression model:

The final step in the model-building process is to validate the selected regression model to check whether the model's predictive performance deteriorates substantially when applied to data that were not used in model estimation. As mentioned earlier, 25% of the total data i.e. 5 years data was used for model validation. Mean Squared Prediction Error (MSPE) was calculated for validation data and compared with Mean Squared Error (MSE) of original model based on regression data as shown in Table 5.6. Since MSPE is fairly close to MSE for the developed model and the difference between them is 28.88 < 35%, therefore it satisfy the validation and the model has potentially good prediction.

Years	Road freight (RF) (Observed Yi) (Mn Ton Kms)	Pakistan trade in tons (Observed X_i) (Mn Tons)	Road freight *(Predicted Y^i)*	$(Y_i - Y^\wedge_i)^2$	Number of cases in the validation data set (n)	Mean squared prediction error (MSPE) = $\sum (Y_i - Y^\wedge_i)^2 / n$	Mean squared error (MSE) (From ANOVA Table)	Percentage difference of MSPE from MSE (%)
Predicted RF = 42609.204 + 1683.974* PT(Tons)								
1993	53719	22.17	79943	687693329	5	174121305	135106112	28.88
1999	95246	37.99	106577	128383411				
2005	116327	48.05	123528	51847526				
2011	154456	68.08	157252	7820244				
2017	181193	83.42	183082	3568082				
		$\sum (Yi - Y^\wedge i)^2 =$		879312592				

Table 5.6: Validation of regression model – 3

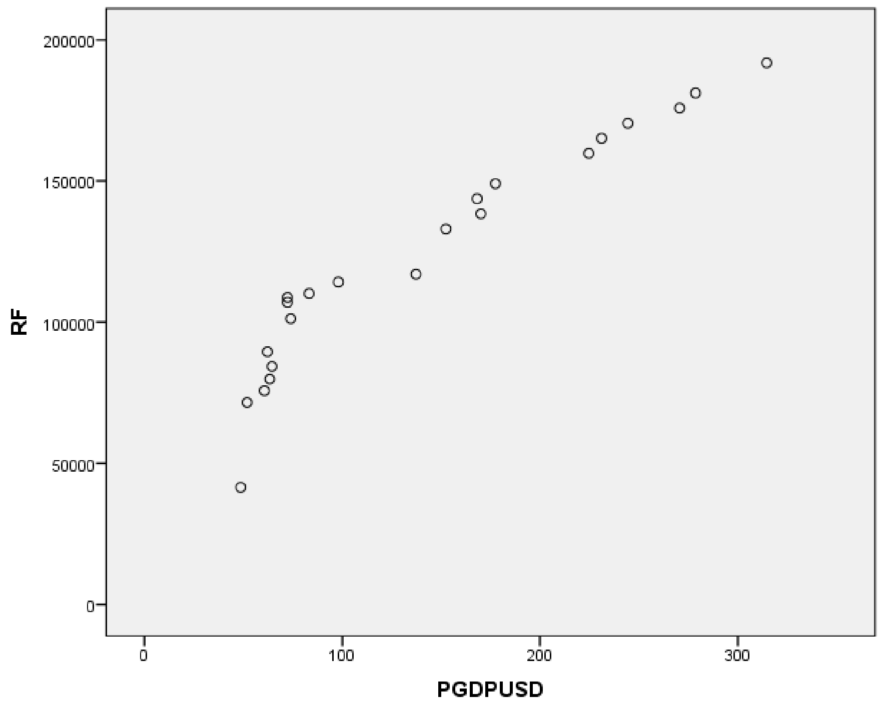
5.3.4.4. Regression model 4 – relationship of Pakistan road freight (RF) with Pakistan gdp in US Dollar GDP (USD)

a. Variables used in development of model:

Pakistan road freight (RF) = Dependent continuous variable

Pakistan GDP in US Dollars GDP (USD) = Independent continuous variable

b. Statistics of regression model:



Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.954[a]	.910	.906	12526.386	.910	202.727	1	20	.000

a. Predictors: (Constant), PGDPUSD

b. Dependent Variable: RF

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.181E+10	1	3.181E+10	202.727	.000[b]
	Residual	3138206900	20	156910345.0		
	Total	3.495E+10	21			

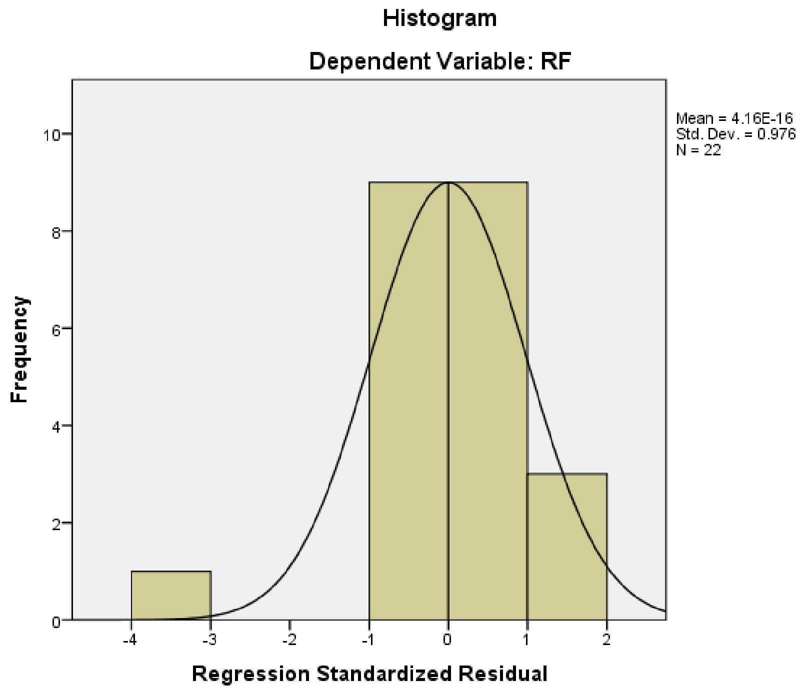
a. Dependent Variable: RF

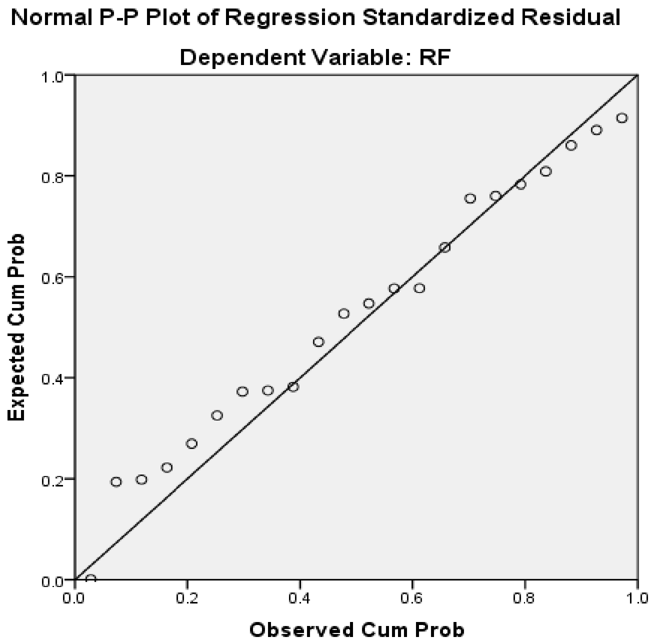
b. Predictors: (Constant), PGDPUSD

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	58904.718	5245.243		11.230	.000
	PGDPUSD	453.222	31.831	.954	14.238	.000

a. Dependent Variable: RF





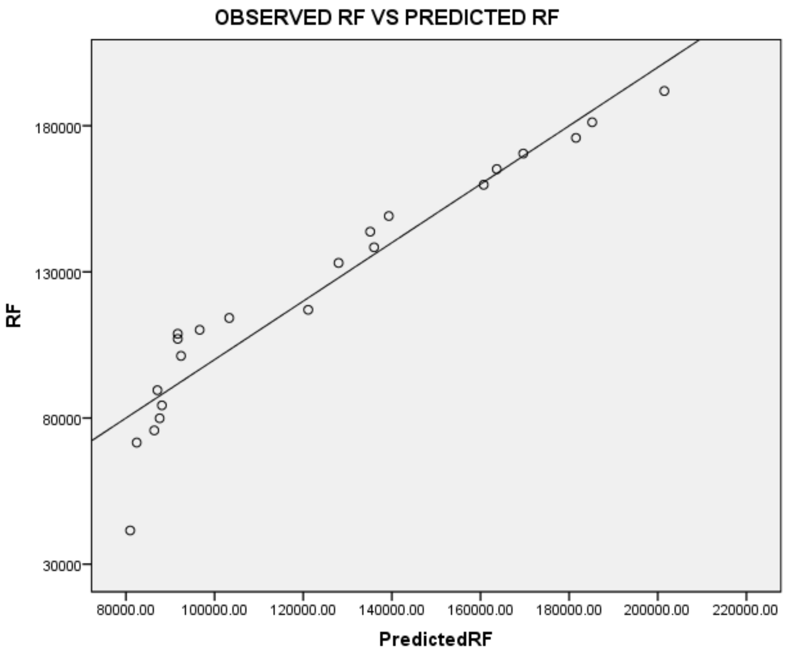


Figure 5.5: Statistics of regression models – 4

c. Equation of regression model:

Unstandardized coefficients of constant and independent variable GDP (USD) were 58904.718 and 453.222 respectively, as indicated in Figure 5.5. Thus, the regression model equation can be expressed as:

$$RF = 58904.718 + 453.222 * GDP\ (USD) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(5.4)}$$

Or,

Pakistan road freight = 58904.718 + 453.222 * (Pakistan GDP in USD)

This shows that with an increase of 1 Billion USD in Pakistan GDP, the estimated increase in Pakistan road freight would be 453.222 Million Ton kms.

d. Analysis of regression model

The scatter plot between Pakistan road freight (RF) and Pakistan GDP in USD [GDP (USD)] indicated a positive linear correlation as shown in Figure 5.5. Therefore, linear regression analysis was conducted to examine the relationship between predictor GDP (USD) and outcome RF. The regression model produced $R = 0.954$, indicating a strong positive relationship between RF and GDP (USD) and $R^2 = 0.910$, indicating 91 % of the variation in outcome is explained by variation in predictor. The t-stats i.e. $t = 14.238 > 2.3060$ with Sig. (P value) = $0.000 < 0.05$ (95% Confidence level), indicated a significant linear relationship between RF and GDP (USD) at 0.05 level of significance. The F stats i.e. $F = 202.727$, Sig. (P value) = $0.000 < 0.05$ further confirmed the independent variable to be significant. Therefore, each of the road freight (RF) data is positively and significantly correlated with Pakistan GDP in USD [GDP (USD)], demonstrating more the Pakistan GDP in USD more will be its road freight.

e. Validation of regression model:

The final step in the model-building process is to validate the selected regression model to check whether the model's predictive performance deteriorates substantially when applied to data that were not used in model estimation. As mentioned earlier, 25% of the total data i.e. 5 years data was used for model validation. Mean Squared Prediction Error (MSPE) was calculated for validation data and compared with Mean Squared Error (MSE) of original model based on regression data as shown in Table 5.7. Since MSPE is fairly close to MSE for the developed model and the difference between them is 28.03% < 35%, therefore it satisfy the validation and the model has potentially reasonable prediction.

Years	Road freight (RF) (Observed Yi) (Million Ton Kms)	Pakistan GDP (Billion USD)	Road freight *(Predicted Y^i)* Using Developed Model:	$(Y_i - Y^{\wedge}_i)^2$	Number of cases in the validation data set (n)	Mean Squared Prediction Error (MSPE) = $\sum (Y_i - Y^{\wedge}_i)^2 / n$	Mean squared error (MSE) (From ANOVA Table)	Percentage difference of MSPE from MSE (%)
PredictedRF = 58904.718+453.222* GDP(USD)								
1993	53719	51.48	82236.59	813252743	5	200889577	156910345	28.03
1999	95246	62.97	87444.11	60869529				
2005	116327	109.5	108532.53	60753809				
2011	154456	213.587	155707.05	1565114				
2017	186540	304.567	196941.18	108184605				
		$\sum (Yi - Y^{\wedge}i)^2 =$		1044625801				

Table 5.7: Validation of Regression model – 4

5.3.5. Prediction of freight traffic expected CPEC alignments in cpec scenario

Prediction of freight traffic, which would be expected on different CPEC alignments in CPEC Scenario in the analysis year 2025, was carried out in three different ways by using different combinations of above regression models. Summary of these three methods along with the combinations of regression models is given below in Table 5.8 followed by its detail:

S/ no.	Methods	Combinations of regression models	Dependent / outcome variables	Independent / predictor variables	Relationships established
1.	Method 1	Model 2	Road freight (RF) (million tons kms)	Pakistan trade in USD [PT(USD)]	*Between no. Of trucks on road and pakistan trade in usd*
		Model 1	No. of trucks on road (TOR) (Numbers)	Road freight (RF) (million tons kms)	
2.	Method 2	Model 3	Road freight (RF) (million tons kms)	Pakistan trade in tons [PT(Tons)]	*Between no. Of trucks on road and pakistan trade in tons*
		Model 1	No. of trucks on road (TOR) (Numbers)	Road freight (RF) (million tons kms)	
3.	Method 3	Model 4	Road freight (RF) (million tons kms)	GDP in USD [GDP(USD)]	*Between no. Of trucks on road and pakistan gdp in usd*
		Model 1	No. of trucks on road (TOR) (Numbers)	Road freight (RF) (million tons kms)	

Table 5.8 : Methods for prediction of freight traffic expected in CPEC scenario

5.3.5.1. Method 1 – calculation of number of trucks on road from Pakistan trade in USD

In this method, number of trucks on road was calculated from Pakistan trade in USD by using combination of regression model 1 and 2 in two steps. The data that was used in this method is given in Table 5.9.

To predict the freight traffic expected on CPEC alignments from China and other countries, the hypothesis was taken into consideration i.e. "If even 5% worth of the China's total trade volume (in USD or Tons) goes through CPEC, our current spare capacity cannot handle it" (Shiekh, 2016). For this analysis, time series data on China total trade in USD was collected for the last 19 years i.e. 2000 to 2019 from internet and was extended further to year 2025 by following the trend line as shown in Table 5.10. After estimating the China total trade in the year 2025, 5% of it was assumed to be shifted on CPEC. This 5% trade was considered as an addition to Pakistan trade in the year 2025 and expressed in Million USD. Using equation (5.2) of regression model 2, Pakistan road freight (RF) was calculated for this additional trade from China [PT (USD)] and expressed in Million Tons Kms as shown in Table 5.9. This road freight (RF) data was further used in equation (5.1) of regression model 1, and additional number of trucks on road in Pakistan (TOR) due to 5% trade shift from China on CPEC was calculated in the year 2025, as shown in Table 5.10.

Years	Road freight (RF) (million ton kms)	Pakistan trade in USD [PT(USD)] (Million USD)	Number of trucks on road in Pakistan (TOR) (No.)
1992	41536	16156	75800
1993	53719	16754	84200
1994	71596	15367	92000
1995	75770	18531	98300
1996	79900	20512	104200
1997	84345	20214	110300
1998	89527	18746	117100
1999	95246	17211	121000
2000	101261	18878	127400
2001	107085	19931	132300
2002	108818	19475	145200
2003	110172	23380	146700
2004	114244	27905	149200
2005	116327	34989	151800
2006	117035	45032	151800
2007	133066	47516	173300
2008	138413	59018	177800
2009	143761	52510	181900
2010	149108	54000	200500
2011	154456	65224	209500
2012	159803	68536	230500
2013	165151	69410	220500
2014	170498	70183	240000
2015	175846	69493	252000
2016	181193	65472	263800
2017	186540	73332	276200
2018	191888	84007	280000

Table 5.9: Time series data used in method 1

Trade year	Export (Billion USD)	Import (Billion USD)	Total trade (import & export) (Billion USD)	Total trade (import & export) (Million USD)
2000	360	188	548	548000
2001	378	203	581	581000
2002	445	246	691	691000
2003	567	346	913	913000
2004	749	459	1208	1208000
2005	926	533	1459	1459000
2006	1140	639	1779	1779000
2007	1380	710	2090	2090000
2008	1430	856	2286	2286000
2009	1201	1005	2206	2206000
2010	1577	1396	2973	2973000
2011	1898	1743	3641	3641000
2012	2048	1818	3866	3866000
2013	2209	1949	4158	4158000
2014	2342	1959	4301	4301000
2015	2355	1983	4338	4338000
2016	2097	1587	3684	3684000
2017	2263	1843	4106	4106000
2018	2494	2134	4628	4628000
2019	2837	2476	5313	5312737
2020	2902	2496	5399	5398568
2021	3033	2619	5652	5651914
2022	3163	2743	5905	5905260
2023	3293	2866	6159	6158606
2024	3423	2989	6412	6411952
2025	3553	3112	6665	6665298

Table 5.10: Shift of Chinese trade under CPEC scenario

To determine the additional number of trucks, AADT of CPEC alignments for the year 2021 was used. Percentage of number of trucks on CPEC alignment was calculated as compared to total number of trucks on road in Pakistan in the year 2021. Finally, additional number of trucks on CPEC alignments expected in the year 2025 was determined, by using the percentage of trucks on each section as shown in Table 5.11 to 5.17

Route	Trucks on routes (Year: 2018-19) (Max. AADT)] [Source: NTRC]	Number of trucks on road (TOR) in Pakistan (Year : 2018) [Source: Pakistan Economic Survey 2019-20 (NTRC)]	Percentage of trucks on each route w.r.t to trucks on road (Pakistan)
	Numbers	Numbers	%
Central	7228	280000	2.5814
Eastern	14315	280000	5.1125
Western	8135	280000	2.9054
Khunjerab	2476	280000	0.8843

Table 5.11: Trucks percentage (%) on CPEC alignment as compared to trucks on road (TOR) in Pakistan

China Total Trade (2025) (million USD)	Assume 5 % of China Trade Shift on CPEC (million USD)	Equation 1 Constant	Pakistan trade = 5% China trade (Million USD)	Road freight (RF) using Equation 1 (million ton kms)
Equation 1: RF = 556622.277 + 1.644 * PT(USD)				
6665297.74	333264.89	556622.277	333264.89	1104509.752

Table 5.12: Road freight to Pakistan from China model 2 (Method 1)

Equation 2 constant	Road freight (RF) using equation 1 (million tons kms)	Additional trucks on road (TOR) using equation 2 (numbers)	Remarks
Equation 2: TOR = - 11895.329 + 1.451 * RF			
-11895.329	1104509.75	1590748	Year : 2025

Table 5.13: Additional number of trucks in Pakistan model 1 (Method 1)

Percentage of trucks on central alignment	Trucks on road (TOR) [from Equation 2] (numbers)	Additional trucks on central alignment	Remarks
2.5814	1590748	41064	Year : 2025

Table 5.14: Additional number of trucks on Central alignment (Route 1) in CPEC scenario

Percentage of trucks on Eastern alignment	Trucks on road (TOR) [from Equation 2]	Additional trucks on Eastern alignment	Remarks
5.1125	1590748	81327	Year : 2025

Table 5.15: Additional number of trucks on Eastern alignment (Route 2 & 3) in CPEC scenario

Percentage of trucks on western alignment	Trucks on road (TOR) [from equation 2]	Additional trucks on western alignment	Remarks
2.9054	1590748	46217	Year : 2025

Table 5.16: Additional number of trucks on Western alignment (Route 4) in CPEC scenario

Percentage of Trucks on Eastern Alignment	Trucks on road (TOR) [from equation 2]	Additional trucks on eastern alignment	Remarks
0.8843	1590748	14067	Year : 2025

Table 5.17: Additional number of trucks on Burhan Khunjerab alignment in CPEC scenario

5.3.5.2. Method 2 – calculation of number of trucks on road from Pakistan trade in tons

In this method, number of trucks on road was calculated from Pakistan trade in Tons by using the combination of regression model 1 and 3 in two steps. The data, which was used in this method, is given in Table 5.18.

To predict the freight traffic expected on CPEC from China and other countries, in this method again first hypothesis of this chapter (already discussed) was taken into consideration. Time series data on China total trade in twenty feet equivalent units (TEUs) was collected for the last 20 years i.e. 2000 to 2020 from web and was extended further up to year 2025 by following the trend line as shown Table 5.19. Since pay load of one TEU is equal to 24 Tons (Elarum)[Exports of Petrochemical Products]," 2016). China total trade in tons was calculated after multiplying number of TEUs with 24. After estimating the China total trade in the year 2025, 5% of it was assumed to be shifted on CPEC. This 5% trade was considered to be additional trade to Pakistan trade in the year 2025 and expressed in million tons. Using equation (5.3) of regression model 3, Pakistan road freight (RF) was calculated for this additional trade from China [PT(USD)] and expressed in million tons kms. This road freight (RF) data was further used in equation (5.1) of regression model 1, and additional number of trucks on road in Pakistan (TOR) due to 5% trade shift from China on CPEC was calculated in the year 2025

Years	Road freight (RF) (million ton kms)	Pakistan trade in tons (million tons)	Number of trucks on road in Pakistan (TOR) (no.)
1993	53719	22.17	84200
1994	71596	22.57	92000
1995	75770	23.10	98300
1996	79900	23.58	104200
1997	84345	23.48	110300
1998	89527	37.65	117100
1999	95246	37.99	121000
2000	101261	38.70	127400
2001	107085	39.57	132300
2002	108818	40.01	145200
2003	110172	40.99	146700
2004	114244	41.94	149200
2005	116327	48.05	151800
2006	117035	53.84	151800
2007	133066	55.20	173300
2008	138413	63.68	177800
2009	143761	65.26	181900
2010	149108	68.29	200500
2011	154456	68.08	209500
2012	159803	63.33	230500
2013	165151	64.16	220500
2014	170498	67.77	240000
2015	175846	73.88	252000
2016	175846	73.8752	252000
2017	181193	83.4174	263800
2018	186540	89.9333	276200

Table 5.18: Time series data used in method 2

Trade year	China total trade [20 feet equivalent units (million TEUs)]	Payload of one twenty feet equivalence unit (TEU) (tons)	China total trade (million tons)
2000	41.000	24	984
2001	44.726	24	1073
2002	55.718	24	1337
2003	61.898	24	1486
2004	74.725	24	1793
2005	67.246	24	1614
2006	84.811	24	2035
2007	103.823	24	2492
2008	115.942	24	2783
2009	108.800	24	2611
2010	131.989	24	3168
2011	146.442	24	3515
2012	159.337	24	3824
2013	174.394	24	4185
2014	185.136	24	4443
2015	193.734	24	4650
2016	197.849	24	4748
2017	222.155	24	5332
2018	233.201	24	5597
2019	242.300	24	5815
2020	236.932	24	5686
2021	257.071	24	6170
2022	267.964	24	6431
2023	278.857	24	6693
2024	289.751	24	6954
2025	300.644	24	7215

Table 5.19 : Container port traffic of Pakistan from 2001 to 2020 in TEUs

To determine the additional number of trucks, again percentage of number of trucks on CPEC alignments as compared to total number of trucks on road in Pakistan was used,. Additional number of trucks on CPEC alignment expected in the year 2025 was finally determined by calculating trucks on road in Pakistan (TOR) as shown in Table 5.20 to 5.25.

China total trade (2025) (million tons)	**Assume 5 % of china trade shift on CPEC (million tons)**	**Equation 1 constant**	**Pakistan trade = 5% China trade (million tons)**	**Road freight (RF) using equation 1 (million ton kms)**
Equation 1: RF = 42609.204 + 1683.974 * [PT(Tons)]				
7215.45	360.77	42609.204	360.77	650141.04

Table 5.20: Road freight using model 3 (method 2)

Equation 2 constant	**Road freight (RF) using equation 1 (million ton kms)**	**Additional trucks on road (TOR) using equation 2 (Numbers)**	**Remarks**
Equation 2: TOR = - 11895.239 + 1.451 * RF			
-11895.329	650141.04	931459	Year : 2025

Table 5.21: Additional number of trucks in Pakistan using model 1 (method 2)

Percentage of trucks on Central alignment	**Trucks on road (TOR) [from equation 2] (numbers)**	**Additional trucks on Central alignment (numbers)**	**Remarks**
2.5814	931459	24045	Year : 2025

Table 5.22: Additional number of trucks on Central alignment (Route 1) in CPEC scenario

Percentage of trucks on Eastern alignment	**Trucks on road (TOR) [from equation 2] (Numbers)**	**Additional trucks on Eastern alignment (Numbers)**	**Remarks**
5.1125	931459	47621	Year : 2025

Table 5.23: Additional number of trucks on eastern alignment (Route 2 & 3) in CPEC scenario

Percentage of trucks on Western alignment	Trucks on road (TOR) [from equation 2] (Numbers)	Additional trucks on Western alignment (Numbers)	Remarks
2.9054	931459	**27062**	Year : 2025

Table 5.24: Additional number of trucks on western alignment (Route 4) in CPEC scenario

Percentage of trucks on Burhan Khunjerab alignment	Trucks on road (TOR) [from equation 2] (Numbers)	Additional trucks on Burhan Khunjerab alignment (Numbers)	Remarks
%	Numbers		
0.8843	931459	8237	Year : 2025

Table 5.25: Additional number of trucks on Burhan Khunjerab alignment in CPEC scenario

5.3.5.3. Method 3 – calculation of number of trucks on road from Pakistan GDP in USD

In this method, number of trucks on road was calculated from Pakistan GDP in USD by using the combination of regression model 1 and 4 in two steps. The data, which was used in this method, are given in Table 5.26 and 5.27.

To predict the freight traffic expected on CPEC from China and other countries, in this method, second hypothesis of this chapter (already discussed) was taken into consideration that "the current 5.5 % Pakistan Annual GDP Growth (2025) will boost upto 7-8% or more when CPEC would be completely operationalized and the huge amount of trade from China and other countries would start using this corridor". PCW suggested that GDP growth of Pakistan will be amongst the top 10 nations in next 10 years till 2030. They also suggested that GDP % will reach 7.5% till 2025 if CPEC becomes operational (World in 2050, PCW UK 2017). For this analysis, time series data on Pakistan GDP and GDP annual growth was collected for the last 28 years i.e. 1991 to 2019 from different sources. This data was extended upto year 2025 using statistical tools. It was assumed that Pakistan GDP annual growth will rise after CPEC opening i.e. 2021(till the end of year) due to increase of trade and investment in the country from outside. After calculating Pakistan total expected GDP in the year 2025 by incorporating increase in the annual GDP Growth upto 7.5%, this GDP value was used in equation (5.4) to calculate road freight in million ton kms which was further used in equation (5.1) to calculate number of trucks on road in Pakistan.

To determine the number of trucks expected in the year 2025, once again percentage of number of trucks on CPEC Alignments as compared to total number of trucks on road in Pakistan was used. Total number of trucks on CPEC Alignments in CPEC scenario (year 2025) was finally determined by calculating number of trucks on road in Pakistan (TOR) as shown in Table5.28 to 5.33

Years	Road freight (RF) (million ton kms)	Pakistan GDP (GDP) (Billion USD) [Source: The World Bank	Number of trucks on road in Pakistan (TOR) (No.)
1993	53719	51.48	84200
1994	71596	51.89	92000
1995	75770	60.64	98300
1996	79900	63.32	104200
1997	84345	64.43	110300
1998	89527	62.19	117100
1999	95246	62.97	121000
2000	101261	73.95	127400
2001	107085	72.31	132300
2002	108818	72.31	145200
2003	110172	83.24	146700
2004	114244	97.98	149200
2005	116327	109.50	151800
2006	117035	137.26	151800
2007	133066	152.39	173300
2008	138413	170.08	177800
2009	143761	168.15	181900
2010	149108	177.41	200500
2011	154456	213.59	209500
2012	159803	224.65	230500
2013	165151	231.15	220500
2014	170498	244.36	240000
2015	175846	270.56	252000
2016	181193	278.66	263800
2017	186540	304.57	276200
2018	191888	314.57	280000

Table 5.26 : Time series data used in method 3

Year	Pakistan GDP Annual Growth (%)	Pakistan GDP (Billion USD)
1991	5.10	45.45
1992	7.70	45.45
1993	1.80	51.48
1994	3.70	51.89
1995	5.00	60.63
1996	4.80	63.32
1997	1.00	64.43
1998	2.60	62.19
1999	3.70	62.97
2000	4.30	73.95
2001	2.00	72.3
2002	3.20	72.31
2003	4.80	83.24
2004	7.40	97.98
2005	7.70	109.5
2006	6.20	137.26
2007	4.80	152.39
2008	1.70	170.08
2009	2.80	168.15
2010	1.60	177.166
2011	2.70	213.587
2012	3.50	224.65
2013	4.40	231.219
2014	4.70	244.361
2015	4.73	270.556
2016	5.53	278.66
2017	5.55	304.57
2018	5.84	314.57
2019	1.90	320.54
2020	-0.40	319.26
2021	1.00	322.46
2022	4.50	336.97
2023	6.00	357.18
2024	6.50	380.40
2025	7.50	408.93

Table 5.27 : Pakistan GDP in 2025 in USD

Pakistan forecasted GDP (2025) due to CPEC (i.e. annual GDP growth boosted to 7.5% in 2025) (billion USD)	Equation 1 Constant	Pakistan GDP (2025) (billion USD)	Road freight (RF) using equation 1 (million ton kms)	Remarks
Equation 1: RF =58907.718+453.222*GDP(USD)				
408.93	58907.718	408.93	244243.79	Year : 2025

Table 5.28: Road freight using model 4 (Method 3)

Equation 2 Constant	Road freight (RF) [Using Equation 1] (million ton kms)	Trucks on road (TOR) Using equation 2 (Numbers)	Remarks
Equation 2: TOR = - 11895.329 + 1.451* RF			
-11895.329	244243.79	342502	Year : 2025

Table 5.29: Trucks on road using model 1 (Method 3)

Percentage of trucks on central alignment	Trucks on road (TOR) [from Equation 2] (Numbers)	Additional trucks on central alignment (Numbers)	Remarks
2.5814	342502	8841	Year : 2025

Table 5.30: Additional Number of Trucks on Central Alignment Route 1 in CPEC Scenario (Numbers)

Percentage of trucks on eastern alignment	Trucks on road (tor) [from equation 2 (Numbers)]	Additional trucks on eastern alignment (Numbers)	Remarks
5.1125	342502	17510	Year : 2025

Table 5.31: Additional Number of Trucks on Eastern Alignment (Route 2 & 3) in CPEC Scenario

Percentage of trucks on western alignment	Trucks on road (TOR) [from Equation 2] (Numbers)	additional trucks on western alignment (Numbers)	Remarks
2.9054	342502	9951	Year : 2025

Table 5.32: Additional number of trucks on western alignment (Route 4) in CPEC scenario

Percentage of trucks on bk alignment	Trucks on road (TOR) [from equation 2] (Numbers)	Additional trucks on Burhan Khunjerab alignment (Numbers)	Remarks
0.8843	342502	3029	Year : 2025

Table 5.33: Additional number of trucks on Burhan Khunjerab alignment in CPEC scenario

5.4.CHAPTER SUMMARY AND CONCLUSIONS

In this chapter, estimation of freight traffic expected on Different routes of CPEC Alignments in CPEC scenario was carried out adopting modelling strategies. The most successful strategy was then used for estimation, which was carried out by statistical modeling using three different methods and the expected freight traffic was calculated. Summary of results is as shown in Table 5.34. From results of analysis, it is concluded that in Pakistan, freight traffic is significantly related to trade and economy.

Sr No.	Routes	Percentage of trucks	Method 1 using PT(USD)	Method 2 Using PT (TONS)	Method 3 Using Pakistan GDP(USD)
			trucks/day	trucks/day	trucks/day
1	Burhan Khunjerab Alignment	0.8843	14,067	8,237	3,029
1	Central Alignment (Route 1)	2.5814	41,064	24,045	8,841
2	Eastern Alignment (Route 2 & 3)	5.1125	81,327	47,261	17,510
3	Western Alignment (Route 4)	2.9054	46,217	27,062	9,951
	Total trucks on roads of Pakistan under CPEC scenario		182,675	106,605	39,331

Table 5.34 : Summary of results of freight traffic estimation in CPEC scenario

6. TRUCK FREIGHT TRAFFIC MANAGEMENT AND ENHANCEMENT OF CPEC UNDER VISION 2025

6.1.INTRODUCTION

Capacity analysis of CPEC alignments in chapter 4 provided an estimate of number of trucks that can be accommodated by these alignments in CPEC scenario as a “route” for LOS “C”. Transportation management and enhancement plan would become a dire need if Pakistan’s infrastructure plan to accommodate the influx of China, as China has become of the great economies in the past years, keeping operational integrity and accommodate the influx from China to other countries and vice versa. Although Pakistan is also keen on improving its trade (exports in the long term) but to accommodate any percentage of China trade would be a great accomplishment of CPEC. This part of the research will provide a comprehensive outlook of Chinese trade on existing as well as improved infrastructure of Pakistan including roads and railways (especially roads). The basic idea is to keep the operational integrity under check and provide way forward to the policy makers as well as Government. The main question that will be answered would be how CPEC is performing under the trade load i.e Trucks (Truck freight Traffic Management Plan) and what improvements would be required in the future (CPEC truck freight capacity enhancement plan). Furthermore, LOS “C” is most commonly used as lower limits for any transportation projects that is why most of the analysis was done under LOS “C” to avoid congestion related problems in future.

6.2. TRUCK FREIGHT TRAFFIC ON CPEC ROUTES UNDER INCREASED CAPACITY OF RAILWAYS IN 2025

The basic assumption that was taken for this assignment was that all the trade that is being shifted from China to Pakistan will eventually travel to the Gwadar port and vice versa. Under this assumption, different scenarios were formulated to provide an insight of how trucks may be managed. According to the plan of CPEC, the road infrastructure starts from Khunjerab till Gwadar in Pakistan. CPEC traverses through a number of routes as already stated in Chapter 4. According to the analysis, routes/ Options such as Khunjerab – Burhan and Hoshab – Gwadar sections will be the common routes and will acts as bottlenecks for the traffic on CPEC routes. All three alignments eventually fall to these points directly or indirectly which makes them a threat to the operational Integrity of the system. One more aspect of management of CPEC routes and alignments is railways. Railways share can play a vital role in improving the operational capability of road infrastructure. Pakistan railways have been underperforming in terms of freight hauling as it only takes 4% share from the overall trade of Pakistan, which in turns push almost 96% of the freight load on roads. Improvements of railway infrastructure under CPEC scenario will be a vivacious step in country's freight load transfer. If ML-1 project is completed in year 2025 and same configuration of freight trains are loaded on the system, almost **25.38 %** of the freight load will be carried by Pakistan railway (Usama, 2020). The load capacity under CPEC scenario is given in the table 6.1

		Total freight of pakistan		**Freight share on existing roads**		**Freight share on existing railways**		**Freight share on roads after railway enhancement**	**Share on railways after railway enhancement**
Methods		2021 MTK)	2025 (MTK)	2021 (MTK)	2025 (MTK)	2021 (MTK)	2025 (MTK)	2025 share 74.62% (MTK)	2025 share 25.38% (MTK)
1	PT (USD)	1021210	1104510	980361	1060329	408484	441804	824185	280325
2	PT (Tons)	562090	650141	539607	624135	224836	260056	485135	165006
3	GDP (Million USD)	205052	244244	196849	234474	82021	97698	182255	61989

Table 6.1: Freight calculations on routes after railway enhancement

Under the effect of railway enhancement under vision 2025 of CPEC the roads freight share will lower by 25.38% as mentioned above and it will in turn decrease the load on roads of Pakistan. This will make the road load less and the number of trucks/ day under the percentage of existing road freight will lower and can be calculated by using already done statistical modelling. The decreased number of trucks per day on road are shown in Table 6.2

Sr No.	Routes	Percentage of Trucks	Method 1 using PT(USD)	Method 2 Using Data of PT (TONS)	Using Data of Pakistan GDP(USD)
			trucks/day	**trucks/day**	**trucks/day**
1	Burhan Khunjerab Alignment	0.8843	10470	6120	2233
2	Central Alignment (Route 1)	2.5814	30564	17864	6519
3	Eastern Alignment (Route 2 & 3)	5.1125	60532	35380	12912
4	Western Alignment (Route 4)	2.9054	34400	20106	7338

Table 6.2: Number of additional trucks of each of CPEC alignment after improvement of railways under railway vision 2025

6.3.ANALYTICAL FRAMEWORK FOR ESTIMATION

Analytical framework for estimation of percentage of China’s trade to be handled by CPEC alignment is described in Figure 6.1.

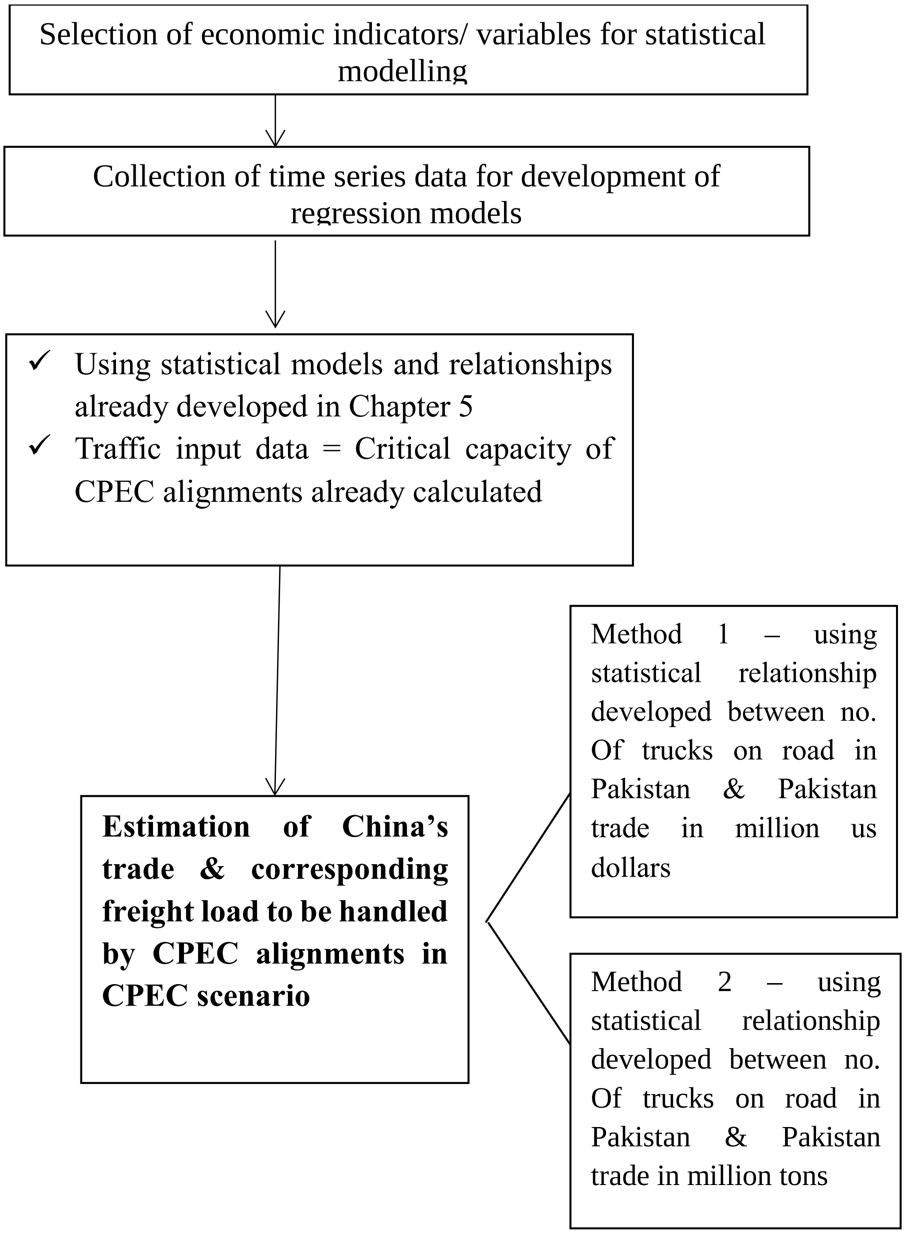


Figure 6.1: Analytical framework for estimation of percentage of China's trade to be handled by CPEC alignment

6.3.1. Enhancement of existing CPEC routes to find the critical capacity under vision 2025

Number of additional trucks that can be handled by each alignment was compiled as per the existing infrastructure and two more options were formulated under enhanced road Infrastructure in the year 2025. Each section is considered as an option and three different options were formulated as follows

- **Route 1**

Khunjerab – Burhan – Hakla – Dera Ismail Khan – Dera Ghazi Khan – Rajanput – Ratodero – Khuzdar – Besima – Hoshab – Gwadar.

- **Route 2**

Khunjerab – Burhan – Islamabad – Kallar Kahaar – Salem – Pindi Bhattian – Faisalabad – Gojra – Gojra – Multan – Sukkur – Hyderabad – Karachi – Gwadar.

- **Route 3**

Khunjerab – Burhan – Islamabad – Kallar Kahaar – Salem – Pindi Bhattian – Faisalabad – Gojra – Gojra – Multan – Sukkur – Ratodero – Khuzdar – Besima – Hoshab – Gwadar.

- **Route 4**

Khunjerab – Burhan – Hakla – Dera Ismail Khan – Zhob – Quetta – Kalat – Besima – Sorab – Hoshab – Gwadar.

All these routes are classified on the basis of CPEC long, medium and short term plan. Some of the routes are common among all making them the most important as they will define the capacity of CPEC alignments. However, all the sections considered in above routes can be enhanced according to the vision 2025 and CPEC plan by Pakistan government. Some options were formulated according to each route already established. Options are shown in Tables 6.3 to 6.6

After the formulation of options, additional number of trucks for each alignment were compared to determine and formulate the critical capacity matrix of each of the CPEC alignments as shown in Tables 6.7 to 6.10

Sr No.	Section Name	Option 1	Option 2	Option 3
1	Khunjerab – Raikot	2E	2E	2E
2	Raikot – Thakot	2E	2E	2E
3	Thakot – Mansehra	2E	2E+2N	2E+2N
4	Mansehra – Havelian	4E	4E	4E
5	Havelian – Burhan	6E	6E	6E
6	Burhan – Hakla	6E	6E	6E
7	Hakla – Dera Ismail Khan	4E	4E	4E+2N
8	Dera Ismail Khan – Dera Ghazi Khan	2E	2E+2N	2E+2N
9	Dera Ghazi Khan – Ratodero	2E	2E+2N	2E+2N
10	Ratodero – Khuzdar	2E	2E+2N	2E+4N
11	Khuzdar – Hoshab	2E	2E+2N	2E+2N
12	Hoshab – Gwadar.	2E	2E+2N	2E+4N

Table 6.3: Enhancement option for Route 1

E= Existing Lanes

N=New Lanes

Sr No.	Section Name	Option 1	Option 2	Option 3
1	Khunjerab – Raikot	2E	2E	2E
2	Raikot – Thakot	2E	2E	2E
3	Thakot – Mansehra	2E	2E+2N	2E+2N
4	Mansehra – Havelian	4E	4E	4E
5	Havelian – Burhan	6E	6E	6E
6	Burhan – Islamabad	6E	6E	6E
7	Islamabad – Kallar Kahaar	6E	6E	6E
8	Kallar Kahaar – Salem	6E	6E	6E
9	Salem – Pindi Bhattian	6E	6E	6E
10	Pindi Bhattian – Faisalabad	4E	4E	4E
11	Faisalabad – Gojra	4E	4E	4E
12	Gojra – Multan	4E	4E	4E
13	Multan – RYK	6E	6E	6E
14	RYK – Sukkur	6E	6E	6E
14	Sukkur – Hyderabad	4E	4E+2N(M)	4E+2N(M)
15	Hyderabad – Karachi	6E	6E	6E
16	Karachi – Gwadar	2E	2E+2N	2E+2N

Table 6.4: Enhancement option for Route 2

Sr No.	Section Name	Option 1	Option 2	Option 3
1	Khunjerab – Raikot	2E	2E	2E
2	Raikot – Thakot	2E	2E	2E
3	Thakot – Mansehra	2E	2E+2N	2E+2N
4	Mansehra – Havelian	4E	4E	4E
5	Havelian – Burhan	6E	6E	6E
6	Burhan – Islamabad	6E	6E	6E
7	Islamabad – Kallar Kahaar	6E	6E	6E
8	Kallar Kahaar – Salem	6E	6E	6E
9	Salem – Pindi Bhattian	6E	6E	6E
10	Pindi Bhattian – Faisalabad	4E	4E	4E
11	Faisalabad – Gojra	4E	4E	4E
12	Gojra – Multan	4E	4E	4E
13	Multan – RYK	6E	6E	6E
14	RYK – Ratodero	6E	6E	6E
14	Ratodero – Khuzdar	2E	2E+2N	2E+4N
15	Khuzdar – Hoshab	2E	2E+2N	2E+2N
16	Hoshab – Gwadar	2E	2E+2N	2E+4N

Table 6.5: Enhancement option for Route 3

Sr No.	Section Name	Option 1	Option 2	Option 3
1	Khunjerab – Raikot	2E	2E	2E
2	Raikot – Thakot	2E	2E	2E
3	Thakot – Mansehra	2E	2E+2N	2E+2N
4	Mansehra – Havelian	4E	4E	4E
5	Havelian – Burhan	6E	6E	6E
6	Burhan – Hakla	6E	6E	6E
7	Hakla – Dera Ismail Khan	4E	4E	4E+2N
8	Dera Ismail Khan – Zhob	2E	2E+2N	2E+2N
9	Zhob – Quetta	2E	2E+2N	2E+2N
10	Quetta – Kalat	2E	2E+2N	2E+2N
11	Kalat – Surab	2E	2E+2N	2E+2N
12	Surab – Hoshab	2E	2E+2N	2E+2N
13	Hoshab – Gwadar.	2E	2E+2N	2E+4N

Table 6.6: Enhancement option for Route 4

Options	Years	Khunjerab-Raikot	Raikot-Thakot	Thakot-Mansehra	Mansehra-Havelian	Havelian-Burhan	Burhan-Hakla	Hakla-DI Khan	DI Khan-DG Khan	DG Khan-Ratodero	Ratodero-Khuzdar	Khuzdar-Hoshab	Hoshab-Gwadar	Critical/ Bottle Neck Capacity	Critical/ Lowest Truck Capacity Section
Option 1		2E	2E	2E	4E	6E	6E	4E	2E	2E	2E	2E	2E		
	2021	10852	10494	10261	28277	48766	22698	15687	0	1570	0	1338	791	0	DD
	2025	10584	10366	8922	27452	48686	22460	15399	0	1033	0	854	332	0	DD
Option 2		2E	2E	2E+2N	4E	6E	6E	4E	2E+2N	2E+2N	2E+2N	2E+2N	2E+2N		
	2025	10584	10366	19385	27452	38405	22460	15399	24701	24273	18403	24168	22455	10366 15399	Raikot-Thakot Hakla DI Khan
Option 3		2E	2E	2E+2N	4E	6E	6E	4E+2N	2E+2N	2E+2N	2E+4N	2E+2N	2E+4N		
	2025	10584	10366	19385	27452	38405	22460	36220	24701	24273	36703	24168	36800	22460	Burhan-Hakla

Table 6.7: Options matrix showing max trucks/day that can be accommodated on CPEC Central alignment (Route 1)

Options	Years	KH-R	RT	TM	MH	HB	BI	IK	KS	SPB	P B - Fsd	Fsd-Gojra	Gojra-Multan	Multan-RYK	RYK-Sukkur	Sukkur-Hyderabad	Hyderabad - Karachi	Karachi-Gwadar	Critical/ Bottle Neck Capacity	Critical Section
Option 1		2E	2E	2E	4E	6E	6E	6E	6E	6E	4E	4E	4E	6E	6E	4E(H)	6E	2E		
	2021	10852	10494	10261	28277	48766	22798	40708	23558	67208	39352	41274	24382	22809	23886	27921	40901	0	0	KG
	2025	10584	10366	8922	27452	48686	22390	40367	23114	66684	38196	40466	23321	21556	23457	26961	40358	0	0	KG
Option 2		2E	2E	2E+2N	4E	6E	6E	6E	6E	6E	4E	4E	4E	6E	6E	4E+2N(M)	6E	2E+2N		
	2025	10584	10366	19385	27452	38405	22390	40367	23114	66684	38196	40466	23321	21556	23457	45513	40358	31105	10366 21556	(Raikot-Thakot) (Multan-Rahim Yar Khan)
Option 3		2E	2E	2E+2N	4E	6E	6E	6E	6E	6E	4E	4E	4E	6E	6E	4E+2N(M)	6E	2E+2N		
	2025	10584	10366	19385	27452	38405	22460	40367	23114	66684	38196	40466	23321	21556	23457	45513	40358	31105	21556	Mul-RYK

Table 6.8: Options matrix showing max trucks/day that can be accommodated on CPEC eastern alignment (Route 2)

Options	Years	Kh-Ra	Ra-Tha	Tha-M	Man-Hav	Hav-Bur	BI	IK	KS	SP	PF	FG	GM	MR	RR	RK	KH	HG	Critical/ Capacity	Critical Capacity section
Option 1		2E	2E	2E	4E	6E	6E	6E	6E	6E	4E	4E	4E	6E	6E	2E	2E	2E		
	2021	10852	10494	10261	28277	48766	22798	40708	23558	67208	39352	41274	24382	22809	23886	0	1334	791	0	KG
	2025	10584	10366	8922	27452	48686	22390	40367	23114	66684	38196	40466	23321	21556	23457	0	854	382	0	KG
Option 2		2E	2E	2E+2N	4E	6E	6E	6E	6E	6E	4E	4E	4E	6E	6E	2E+2N	2E+2N	2E+2N		
	2025	10584	10366	19385	27452	38405	22390	40367	23114	66684	38196	40466	23321	21556	23457	18403	24168	22455	10366 18403	Raikot-Thakot Ratodero- Khuzdar
Option 3		2E	2E	2E+2N	4E	6E	6E	6E	6E	6E	4E	4E	4E	6E	6E	2E+4N	2E+2N	2E+4N		
	2025	10584	10366	19385	27452	38405	22460	40367	23114	66684	38196	40466	23321	21556	23457	33927	24168	36800	21556	Multan-RYK

Table 6.9: Options matrix showing max trucks/day that can be accommodated on CPEC eastern alignment (Route 3)

Options	Years	Kh-Ra	Ra-Tha	Tha-M	Man-Hav	Hav-Bur	BH	HD	DZ	ZQ	QK	KS	SH	HG	Critical/ bottle neck capacity	Critical/ lowest truck capacity section
Option 1		2E	2E	2E	4E	6E	6E	4E	2E	2E	2E	2E	2E	2E		
	2021	10852	10494	10261	28277	48766	22698	15687	3738	2991	0	0	4004	791	0	QK
	2025	10584	10366	8922	27452	48686	22460	15399	3470	2779	0	0	3989	382	0	QK
Option 2		2E	2E	2E+2N	4E	6E	6E	4E	2E+2N	2E+2N	2E+2N	2E+2N	2E+2N	2E+2N		
	2025	10584	10366	19385	27452	38405	22460	15399	26645	24158	20031	21249	24688	22455	10366 15399	Raikot-Thakot Hakla -DI Khan
Option 3		2E	2E	2E+2N	4E	6E	6E	4E+2N	2E+2N	2E+2N	2E+4N	2E+2N	2E+2N	2E+4N		
	2025	10584	10366	19385	27452	38405	22460	36220	26645	24158	37266	21249	24688	36800	21249	Kalat Surab

Table 6.10: Options matrix showing max trucks/day that can be accommodated on CPEC western alignment (Route 4)

As already stated, Burhan to Khunjerab section is common among all the CPEC alignment. To overcome the bottleneck created introduction of truck freight traffic controller in the shape of truck/ trailer Park/ Freight village is necessary for optimum utilization of CPEC. Diversion of CPEC alignment into three routes after Burhan have individual critical capacities and that will define the CPEC capacity above 90% efficiency. After the completion of Havelian dry port. A trailer Park/ freight village concept can be introduced at the same location hence increasing the efficiency and adequacy of three alignments of CPEC. Under this assumption that freight village at Havelian Dry Port will be functional and the bottleneck of Burhan Khunjerab will be managed efficiently, the new defining/critical capacities will change accordingly. Scenarios based on selection of routes were made without choosing the common sections of the road to take out the maximum capacity of CPEC.

	Central alignment (Route 1)	**Eastern alignment (Route 2)**	**Eastern alignment (Route 3)**	**Western alignment (Route 4)**
Option 1	0	0	0	0
Option 2	15,399 trucks/day Hakla - D.I Khan	21,556 trucks/day Multan - Rahim Yar khan	18,403 trucks/day Ratodero - Khuzdar	15,399 trucks/day Hakla - D.I Khan
Option 3	22,460 trucks/day Burhan - Hakla	21,556 trucks/day Multan - Rahim Yar khan	21,556 trucks/day Multan - Rahim Yar khan	21,249 trucks/day Kalat-Surab

Table 6.11: Critical Capacities of CPEC alignments under developed options

As it can be assessed from the table 6.11, Option 1 have no spare capacity to accommodate any new trucks. In addition, different common sections were encountered during analysis but in this case only one was considered and maximum capacity of each route was calculated by adding all capacities. These number of trucks were used to calculate the percentage of trucks on CPEC alignments as a whole as a percentage of China’s Trade.

6.4.CPEC CAPACITY AS A PERCENTAGE OF CHINA TRADE

The modal split between road and railways is considered important for CPEC but will it be enough for the road infrastructure as per CPEC plan? China Pakistan Economic Corridor (CPEC) is anticipated to add huge volume of freight traffic/ trade from China to Pakistan that will considerably increase the traffic or freight load on its current road infrastructure. China is planning to shift some percentage of its trade on CPEC. How much would be the percentage? It is neither known nor shared by Chinese government with Pakistan. Although people of different line of work from both countries have made estimates about it but the precise volume/ percentage is still uncertain. Nevertheless, it is vital for Pakistan to know the trade management capacity of its existing/ planned road infrastructure to deal with the trade projected from China. However, the major problem that was highlighted in the analysis of existing capacity of CPEC alignments that Khunjerab to Burhan section of the infrastructure being common route will acts as a bottleneck. To use the three alignments of CPEC through Pakistan in an efficient way making full use of the available infrastructure, assuming that the CPEC infrastructure will only be used by trucks under CPEC scenario. To evaluate the capacity of CPEC alignments as a percentage of China's trade, different strategies were adopted in this estimation process and are discussed in this part of the research study.

6.4.1. Estimation of China's trade & corresponding freight load to be handled by CPEC alignments in CPEC scenario

To analyze and estimate the trade of China as a percentage on CPEC alignments, already established relations between economic indicators and trade of Pakistan were used. Using the reverse method and critical capacity that can be handled by CPEC alignments under LOS"C" in the analysis year 2025 estimation of trade of China that can be accommodated was calculated as a percentage of China's total trade. Two methods were used to estimate the percentage of China's trade to be handled by CPEC Alignment in the year 2025 if used in full Capacity.

6.4.1.1. Method 1 - using relationship between number of trucks on road & Pakistan trade in million us Dollars

Statistical Models were reformed and using ratio and proportion method, which was used in calculating the percentage of China's trade that can be accommodated on CPEC alignments. As determined in Chapter 4 using statistical models, when 5% of China's trade in Million Tons was assumed to be shifted on CPEC, the number of additional trucks on CPEC alignments in analysis year 2025 were calculated. Using additional number of trucks/ under the condition of LOS "C" additional trade to be handled by CPEC alignment in the year 2025 was found, which when compared with the China's total trade in Million Tons, the percentage was calculated as shown in Table 6.12 and 6.13

China total trade (2025) (Already estimated/ forecasted)	Assumed 5 % of China trade shifted on CPEC (2025)	Additional trucks on cpec alignment for 5 % China trade, shifted on CPEC (2025)	Maximum capacity of CPEC alignments under condition of LOS "C" (2025)	Additional trade handled by CPEC alignment in 2025,	Percentage of China trade to be handled by CPEC alignment in 2025
million USD	million USD	numbers	numbers	million USD	(%)
6665297.74	333264.89	182675	55358	100992.80	1.52

Table 6.12: Percentage of China trade to be handled by CPEC alignments for Option 2 using Pakistan trade in USD

Improvements in infrastructure has allowed to increase the capacity and under two different scenarios. The amount of truck to be handled as a percentage of China's Trade was found to be 1.25% and 1.79% using both options under the plan and policies yet finalized.

China total trade (2025) (already estimated/ forecasted)	Assumed 5 % of China trade shifted on CPEC (2025)	Additional trucks on CPEC alignment for 5 % China trade, shifted on CPEC (2025)	Maximum capacity of CPEC alignments under condition of LOS "C" (2025)	Additional trade handled by CPEC alignment in 2025,	Percentage of China trade to be handled by CPEC alignment in 2025
million USD	million USD	numbers	numbers	million USD	(%)
6665297.74	333264.89	182675	65265	119066.71	1.79

Table 6.13: Percentage of China trade to be handled by CPEC alignments for Option 3 using Pakistan trade in USD

6.4.1.2. Method 2 - using relationship between number of trucks on road & Pakistan trade in million tons

As determined in Chapter 4 using statistical models, when 5% of China's trade in Million Tons was assumed to be shifted on CPEC, the number of additional trucks on CPEC alignments in analysis year 2025 were calculated. Using additional number of trucks/ under the condition of LOS "C" additional trade to be handled by CPEC alignment in the year 2025 was calculated, which when compared with the China's total trade in Million Tons, the percentage was calculated as shown in Tables 6.14 and 6.15

China total trade (2025) (already estimated/ forecasted)	**Assumed 5 % of China trade shifted on CPEC (2025)**	**Additional trucks on CPEC alignment for 5 % China trade, shifted on CPEC (2025)**	**Maximum capacity of CPEC alignments under condition of LOS "C" (2025)**	**Additional trade handled by CPEC alignment in 2025,**	**Percentage of China trade to be handled by CPEC alignments in 2025**
million tons	million tons	numbers	numbers	million tons	(%)
7215.45	360.77	106965	55358	186.71	2.59

Table 6.14: Percentage of China trade to be handled by CPEC alignments for option 2 using Pakistan trade in tons

China total trade (2025) (already estimated/ forecasted)	**Assumed 5 % of China trade shifted on CPEC (2025)**	**Additional trucks on CPEC alignment for 5 % China trade, shifted on CPEC (2025)**	**Maximum capacity of CPEC alignments under condition of LOS "C" (2025)**	**Additional trade handled by CPEC alignment in 2025,**	**Percentage of China trade to be handled by CPEC alignments in 2025**
million tons	million tons	numbers	numbers	million tons	(%)
7215.45	360.77	106965	65265	216.02	3.05

Table 6.15: Percentage of China trade to be handled by CPEC alignments for option 3 using Pakistan trade in tons

6.5.IMPACT OF TRUCK TRAFFIC AFTER TRADE SHIFT

After the calculation of truck freight traffic in CPEC scenario under vision 2025, the impact of this increase in truck freight traffic on the service life of infrastructure of CPEC has to be taken under consideration. For the ease of analysis, it was assumed that under vision 2025 the infrastructure of CPEC is rehabilitated to improve the design/ service life till 2035 i.e. 10 years.

Equivalent single axle load (ESAL) are considered to calculate the impact of truck traffic on the road infrastructure. ESALs were calculated for a specific service life of the designed facility. For the analysis the equivalent single axle load was calculated using the following equation

$$ESAL = (ADT)_0(T)(T_f)(G)(D)(L)(365)(Y) \quad \textbf{.....................(6.1)}$$

Where,

ESAL	=	Equivalent 18 kip single axle load
T	=	percentage of trucks
T_f	=	truck factor
G	=	Growth rate
D	=	Directional distribution factor
L	=	Lane distribution factor
Y	=	Design Life

For the analysis, critical section from each alignment of CPEC were selected and ESALs of each was calculated accordingly. Total 4 sections were considered and ESALs were calculated using eq 6.1 (Huang, 2004) as shown in Table 6.18

				Truck factors (EALF)	**Growth rate**	**Design life**	**GY table 6.13 (Huang ,2004)**	**Direction factor**	**Lane distribution factor**	**ESALS**
	Central Align	lanes	AADT	T_f	G	Y		D	L	
2025 after improvement	Burhan - Hakla	6	22460	0.52	0.03	10	11.5	0.4	0.7	**13726564**
2025 after trade shift	Burhan - Hakla	6	30564	0.52	0.03	10	11.5	0.4	0.7	**18679372**

Table 6.18: Comparison and ESALs calculation for increased traffic

As shown in table, the ESALs were calculated using the ESAL equation and increase in ESALs were calculated. After determining the increase in ESALs, the decrease in service life was also determined using eq 6.1. Decrease in service life is based on the truck traffic on each critical section of CPEC. Framework for calculation of decrease in design life is only done for one section and can be used to calculate decrease in design life of all the sections under CPEC. Summary of ESALs and decrease in design life of critical sections of each CPEC route was determined as shown in table 6.19.

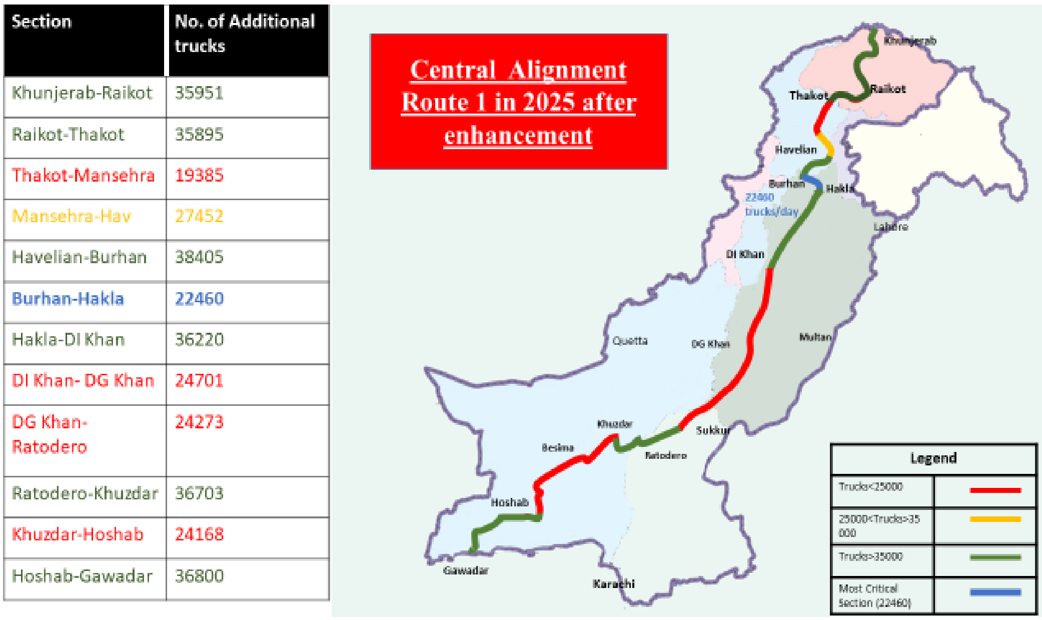
Alignment	**Section**	**Design ESALs**	**Service life**	**ESALs (after trade shift)**	**Decrease in service life (years)**
Khunjerab Burhan	Raikot Thakot	9158172	10	9255412	0.2
Central Alignment	Burhan Hakla	13726564	10	18679372	2.1
Eastern Alignment	Multan RYK	13174079	10	36994495	6.2
Western Alignment	Kalat Surab	18783978	10	30409376	2.8

Table 6.19: Calculation for decrease in service life

The decrease in design life shows the impact of increased traffic on CPEC infrastructure, which in turn dictate the maintenance and rehabilitation plans and activities.

6.6.DEVELOPMENT OF THEMATIC MAPS

Thematic maps were developed to interpret the traffic condition and are shown in table 6.2 to 6.6



Section	No. of Additional trucks
Khunjerab-Raikot	35951
Raikot-Thakot	35895
Thakot-Mansehra	19385
Mansehra-Hav	27452
Havelian-Burhan	38405
Burhan-Hakla	22460
Hakla-DI Khan	36220
DI Khan- DG Khan	24701
DG Khan-Ratodero	24273
Ratodero-Khuzdar	36703
Khuzdar-Hoshab	24168
Hoshab-Gawadar	36800

Figure 6.2: Thematic map of Central alignment (Route 1)

Section	No. of Additional trucks
Khunjerab-Raikot	35951
Raikot-Thakot	35895
Thakot-Mansehra	19385
Mansehra-Hav	27452
Havelian-Burhan	38405
Burhan-Islamabad	22460
Islamabad-KallarK	40367
KallarK-Salem	23114
Salem-PindiBhatia	66684
PindiBhatia-Fsd	38196
Fsd-Gojra	40466
Gojra-Multan	23321
Multan-RYK	21556
RYK-Sukkur	23457
Sukkur Hyderabad	45513
Hyderabad-Khi	40358
Khi-Gwadar	31105

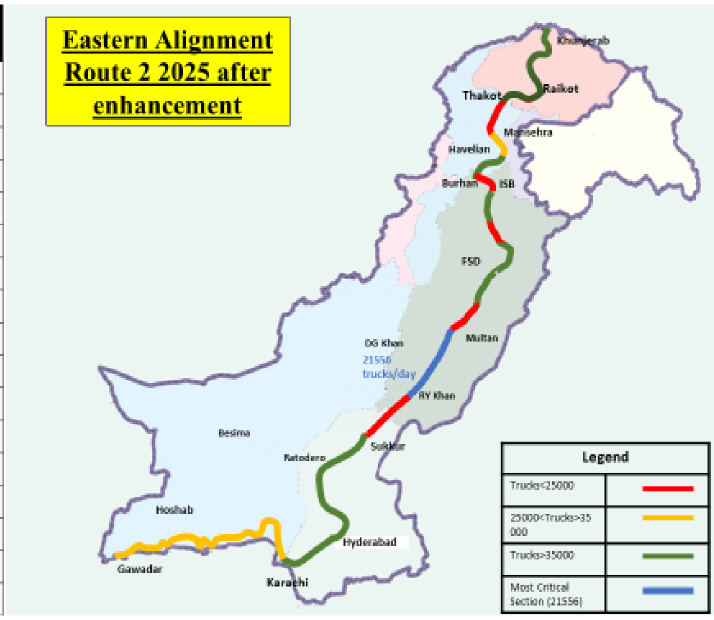


Figure 6.4:Thematic map for eastern alignment (Route 2)

Section	No. of Additional trucks
Khunjerab-Raikot	35951
Raikot-Thakot	35895
Thakot-Mansehra	19385
Mansehra-Hav	27452
Havelian-Burhan	38405
Burhan-Islamabad	22460
Islamabad-KallarK	40367
KallarK-Salem	23114
Salem-PindiBhatia	66684
PindiBhatia-Fsd	38196
Fsd-Gojra	40466
Gojra-Multan	23321
Multan-RYK	21556
RYK-Ratodero	23457
Ratodero-Khuzdar	33927
Khuzdar-Hoshab	24168
Hoshab-Gwadar	36800

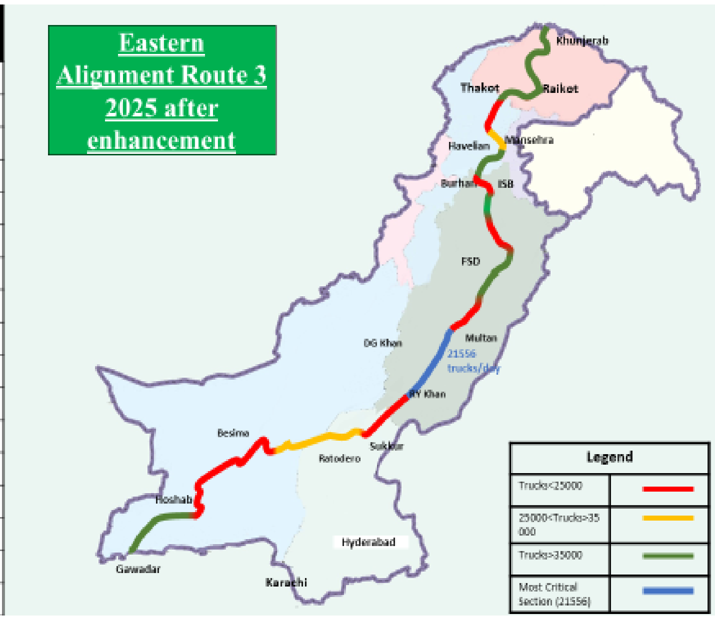


Figure 6.5: Thematic Maps for eastern alignment (Route 3)

Section	No. of Additional trucks
Khunjerab-Raikot	35951
Raikot-Thakot	35895
Thakot-Mansehra	19385
Mansehra-Hav	27452
Havelian-Burhan	38405
Burhan-Hakla	22460
Hakla-DI Khan	36220
DI Khan- Zhob	26645
Zhob-Quetta	24158
Quetta-Kalat	37266
Kalat-Surab	21249
Surab-Hoshab	24688
Hoshab-Gwadar	36800

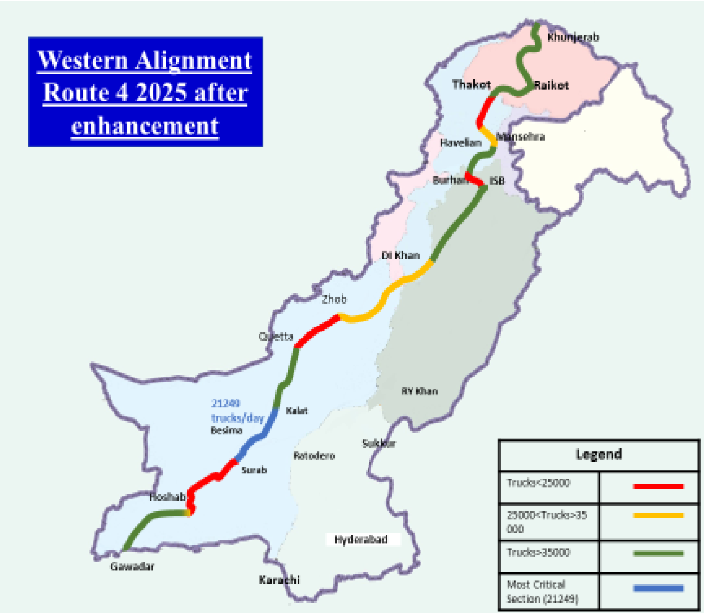


Figure 6.6: Thematic Maps for western alignment (Route 4)

6.7.CHAPTER SUMMARY AND CONCLUSIONS

Estimation of percentage of China's trade to be handled by CPEC routes in CPEC scenario was carried out in two different methods i.e. estimation using trade in Million USD and estimation using trade in Million Tons. Considering the Maximum freight load carrying potential of CPEC alignment in the analysis year 2025 in CPEC scenario. China's trade could be accommodated if trade considered in terms of million USD was found to be 2% and 2.39 % for option 2 and 3 respectively. In method 2, China's trade that could be accommodated if trade is considered in million tons was found to be 3.47% and 4.08% for option 2 and 3 respectively. The ESAL calculation was done to determine the decrease in service life using the critical sections, the results showed that as the trade is shifted from China to Pakistan the rehabilitation and maintenance activities will have to be in time to keep the facilities operational. As per the plans and policies under development by govt officials it is worth identifying that along the route of CPEC many common routes i.e bottlenecks were encountered which will decrease the operational integrity of the CPEC as shown in figure 6.7.

Traffic increase under CPEC scenario will eventually cause the decrease in service life of road infrastructure. To estimate/ predict the service life of infrastructure framework was established. Equivalent single axle truck (ESALs) were calculated using the design life of the established CPEC infrastructure and decrease in design life was calculated for critical sections of different routes. In case of increased traffic, decrease in design life of Khunjerab Burhan section, central alignment, western alignment and eastern alignment were 0.2, 2.1, 2.8 and 6.2 years respectively. Maintenance and rehabilitation of the CPEC infrastructure can be planned using the same framework. In view of this, freight village concept will play a vital role in this scenario to decrease the load. Two of the most important junction on CPEC are Burhan, which can be extended, and freight village can be provided at Havelian Dry Port. However, non-existence of any SEZ or Dry Port near Hoshab or Besima will create huge problems when CPEC will become functional. Improvement of the section is recommended with development of freight village at this junction either at Hoshab or Surab to efficiently control the flow of traffic. It is also to be noted that small freight villages may also be provided at junctions like DI Khan and Ratodero which might act as traffic controllers at a smaller scale. Making CPEC a overall efficient transportation system helping to achieve the goal it was intended to accomplish. Thematic maps were made that will help in establishing the maintenance and rehabilitation plan and policies of extension of road infrastructure in long term plans.

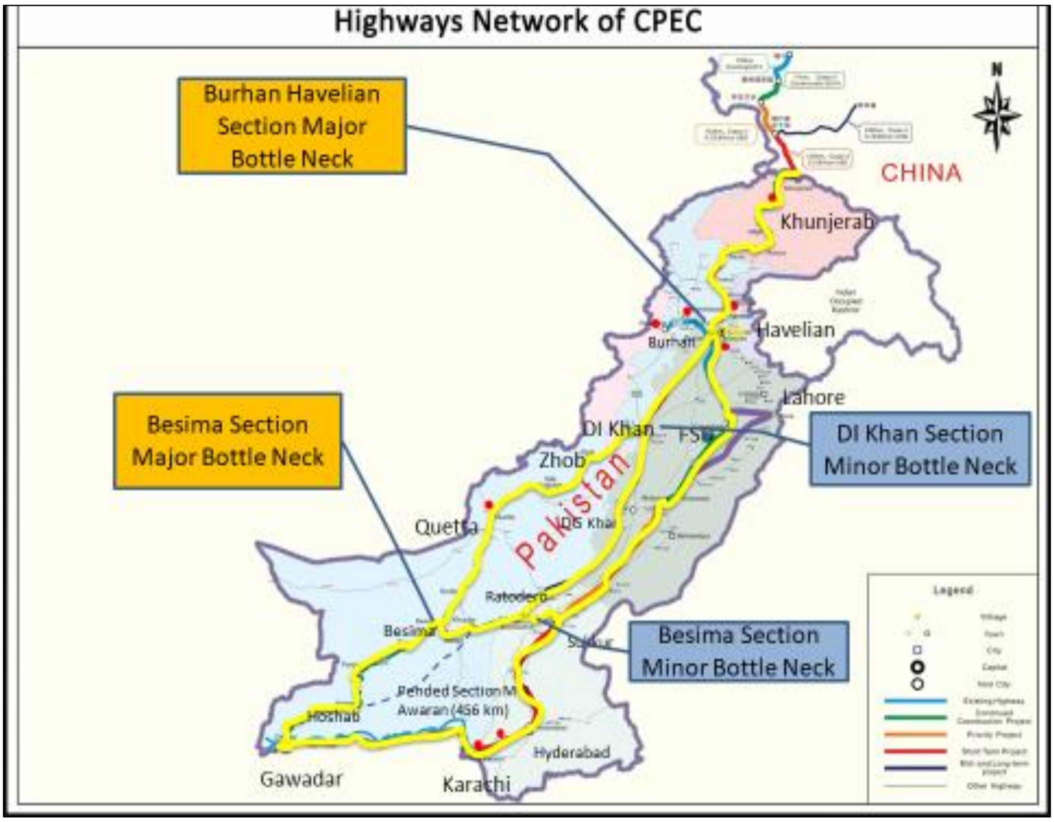


Figure 6.7: Major and minor bottlenecks of CPEC alignments

CHAPTER 7

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. SYNOPSIS OF THE RESEARCH

The research study focused on capacity analysis of CPEC alignments under the scenario that CPEC is fully active and trade shift from different parts of the world to China is in full swing. The study began with extensive literature review that covered state of the art and practice regarding capacity and LOS analysis of different facilities of Road infrastructure, capacity analysis of a Country as a whole, statistical analysis and prediction of freight traffic. The literature review highlighted the gaps in current practice and provided guidance for the improvement of the suggested framework. A critical framework was developed for the research design. Capacity analysis of existing CPEC alignments including all the routes was carried out using Highway capacity manual (HCM 2010) and for the proposed alternatives using multilane highways to freeway methodologies. Maximum possible alternatives were explored and number of trucks that could be accommodated by each alternative in CPEC scenario were determined. Results were summarized in a form of matrix under the conditions of LOS "C". Most Critical sections from all the routes were selected using HCM methodology of capacity analysis which in turn provided the basis for improvement/ enhancement of road infrastructure to make it feasible to accommodate the influx of truck freight traffic from China to Gwadar and vice versa. After the identification of most vulnerable section, enhancement of alignments was done under vision 2025 and Government policy and plans. In the next phase, statistical modelling was done for estimation of the freight traffic expected in CPEC scenario was carried out and it was used to estimate the percentage of China's trade that could be handled by CPEC alignments as an efficient system under CPEC scenario.

7.2. RESEARCH FINDINGS AND CONCLUSIONS

7.2.1. Major conclusions and findings from the literature review

1. Limited research studies have been carried out on social, trade and industrial aspects of CPEC but not many substantial studies have been carried out on

transportation, and logistics features.

2. Very few studies have been carried out at national or international level on capacity analysis of Pakistan infrastructure dealing with CPEC and its incoming freight load.

3. Evidences of the relationship between economic indicators and freight load exist in the past literature.

4. Freight management and enhancement plan need to be formulated if CPEC has to work efficiently.

7.2.2. Capacity and LOS analysis of CPEC alignments

i. Existing highway sections including two-lane two way sections, multi lane highways and Freeway sections were analysed and critical section from each alignment was identified

ii. Different critical sections from each route was identified i.e, Ratodero Khuzdar and DI Khan DG khan section from Central Route 1, Makran Coastal Highway from Eastern Route 2, Sukkur to Khuzdar section from Eastern Route 3 and Quetta – Kalat section from Western Route 4

iii. Total number of additional trucks that could be accommodated by CPEC alignment using existing condition came out to be zero. Enhancement of route was done keeping in view the demand of freight load in 2025. The total number of additional trucks on Central alignment Route 1 was 15,399 trucks/day, Eastern Alignment Route 2 was 21, 556 trucks/day, Eastern alignment route 3 was 21,556 trucks/day and for Western alignment route 3 is 15,399 trucks/day.

7.2.3. Statistical modeling for estimation of freight traffic in CPEC scenario

i. Significant relationship exists between Pakistan freight load and its trade and economic indicators i.e. trade in USD , trade in Tons , GDP etc.

ii. Based on statistical models developed in this research study, it was found that with an increase of 1 Million USD in Pakistan trade, the expected increase in Pakistan road freight would be 1.644 Million Ton kms and for Pakistan trade in tons increase of 1 million tons would increase road freight for a value of 1785.809 million tons kms. Similarly, with an increase of 1 Billion USD in Pakistan GDP, the expected increase in Pakistan road freight would be 453.222 million ton kms.

iii. If a minimum of 5 % of the China's total trade is assumed to go shift to CPEC infrastructure in Pakistan, additional number of freight traffic in the analysis year 2025 is estimated to be 14,067 trucks/day, 41,064 trucks/day, 81,237 trucks/day and 46,217 trucks/day on route 1, 2, 3 and 4 respectively, if trade considered in terms of US dollar. Similarly, using the Pakistan trade in tons 8,237 trucks/day, 24,045 trucks/day, 47,261 trucks/day, 27,062 trucks/day on route 1, 2, 3 and 4 respectively.

iv. If Pakistan current annual GDP growth i.e. 5.5 % is boosted to 7.5 % due to CPEC in analysis year 2025, the additional number of freight traffic on CPEC alignment is estimated to be 3,029 trucks/day, 8,841 trucks/day, 17,510 trucks/day and 9,951 trucks/day on route 1, 2, 3 and 4 respectively.

7.2.4. Freight traffic management and CPEC capacity enhancement plan

i. Considering the maximum of critical freight load carrying potential of CPEC alignments in analysis year 2025 in CPEC scenario management will be required to accommodate and operate the CPEC infrastructure

ii. After the calculation of number of additional trucks under the management plan options were formulated to further enhance and improve the capacity of CPEC alignments to accommodate more trucks and provide a more efficient solution to trade shift from China, under the scenario of introduction of freight village/ trailer park options were formulated and maximum load carrying capacity of central alignment route 1 was 22,460 trucks/day, eastern alignment route 2 was 21,556 trucks/day, easter alignment route 3 was 21,556 trucks/day and western alignment route 4 was 21,249 trucks /day.

iii. Trade from China was distributed on road and railways accoridngly to lower the load on road infrstructure accoridng to the distribution described as 25.38% under vision 2025. The additional number of freight traffic on CPEC alignments in the analysis year 2025 is estimated to be 10,470 trucks/day, 30,564 trucks/day, 60,532 trucks/day and 34,400 trucks/day on Route 1, 2, 3 and 4 respectively, if trade considered in terms of US Dollar. Similarly, using the Pakistan trade in tons 6,120 trucks/day, 17,864 trucks/day, 35,380 trucks/day, 20,106 trucks/day on Route 1, 2, 3 and 4 respectively.

iv. After railway share, the additional number of freight traffic on CPEC alignment using Pakistan GDP in USD are estimated to be 2,233 trucks/day, 6,519 trucks/day, 12,912 trucks/day and 7,338 trucks/day on Route 1, 2, 3 and 4 respectively.

v. Statistical methods already developed were used to found that a total of 2% and 2.39% of China's trade could be accommodated if trade considered in terms of US Dollars using option 2 and option 3 respectively. 3.47% and 4.08% of China's trade could be accomodated on CPEC alignments in Pakistan when China's trade considered in terms of tons using option 2 and 3 respectively.

vi. Decrease in service life of infrastructure in terms of increased truck freight traffic from CPEC was estimated and came out to be 0.2 years for Khunjerab Burhan section, 2.1 years for Central alignment, 2.8 years for western alignment and 6.2 years for Eastern alignment.

vii. Thematic maps were made that will help in establishing the maintenance and rehabilitation plan and policies of extension of road infrastructure in long term plans.

7.3. RECOMMENDATIONS AND DIRECTION FOR FUTURE RESEARCH

i. Recommendations and direction for future research are added below:

ii. Introduction of freight village and its operational management can help in efficient, easy and in time interventions for the improvement with proper monitoring of traffic stream

iii. The proposed framework may be applied on CPEC's future potential development and policies and plans can be formulated.

iv. Trade handling capacity of Gwadar port may be worked out in order to compare it with the results of this study.

v. Research may be carried out to include the effect of SEZ's to be used as trailer park/ freight village to operate CPEC with more efficiency.
vi. Research should be carried out on comparative and benefit cost analysis of all three proposed routes of CPEC.
vii. Long term analysis of whole CPEC should be done for the analysis year as 2030, 2035 and 2040.

7.4. CONTRIBUTIONS THROUGH THIS RESEARCH

i. This study is one of the pioneer studies in Pakistan to carry out a detailed and multi-dimensional capacity analysis of complete CPEC and its result shall assist national and provincial highway agencies to cope up with the freight traffic expected in CPEC scenario efficiently.
ii. There is a severe lack of studies carried out on capacity and LOS analysis of complete CPEC under CPEC scenario and freight, this research study is one of the pioneer study in that regard.
iii. One of the very few studies at national level to establish statistical relation between freight load and economic indicators.
iv. One of the pioneer studies to estimate the percentage of China's trade that could be handled by CPEC alignments in CPEC Scenario

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Annex- A

Burhan-Islamabad Section																					
VOLUME (Traffic Data)														GEOMETRIC DETAILS AND SPEED							
Year	Growth Factor (Proportion)	Total Volume (AADT) (veh/day	Total Buses	Trucks	Total Trucks	Grand Total Volume Trucks (AADT) (veh/day)	Trucks Proportion	Buses Proportion	Total Trucks & Buses Proportion (P_T)	Total RVs	RVs Proportion (P_R)	Driver Population Factor (fp)	Peak Hour Factor (PHF)	Class of Facility	Measure of Effectiveness (MOE)	No. of Lanes (N)	Median Type	Lane Width (LW) (ft)	Shoulder Width (Right Lateral Clearance) (ft)	Terrain (Level, Rolling, Mountainous)
2019	0.03	20583	1977	6813	6813	20583	0.331	0.096	0.427	0	0.00	0.95	0.70	Class I	Density	3	Divided	12	6	Rolling
2020	0.03	21200	2036	7017	7017	21200	0.331	0.096	0.427	0	0.00	0.95	0.70	Class I	Density	3	Divided	12	6	Rolling
2021	0.03	21837	2097	7228	7228	21837	0.331	0.096	0.427	0	0.00	0.95	0.70	Class I	Density	3	Divided	12	6	Rolling
2022	0.03	22492	2160	7445	7445	22492	0.331	0.096	0.427	0	0.00	0.95	0.70	Class I	Density	3	Divided	12	6	Rolling
2023	0.03	23166	2225	7668	7668	23166	0.331	0.096	0.427	0	0.00	0.95	0.70	Class I	Density	3	Divided	12	6	Rolling
2024	0.03	23861	2292	7898	7898	23861	0.331	0.096	0.427	0	0.00	0.95	0.70	Class I	Density	3	Divided	12	6	Rolling
2025	0.03	24577	2361	8135	8135	24577	0.331	0.096	0.427	0	0.00	0.95	0.70	Class I	Density	3	Divided	12	6	Rolling

Burhan-Islamabad Section																				
VOLUME (Traffic Data)						**Heavy Veh Adjustment Factor (f_{HV})**														**Demand Flow Rate**
Year	**Grand Total Volume Trucks (AADT) (veh/day)**	**Hourly Volume; V (veh/hr)**	**Proportion of AADT during Peak hr (K factor)**	**Directional Split (50/50) (D factor) (Rural)**	**Peak Directional Hourly Volume; DDHV=AADT*K*D (veh/hr)**	**Base PCE Flow Rate (v) : v = V/PHF (veh/h)**	**Base PCE Flow Rate (v) (One Directional): v_d or v_o = v*0.5 (veh/h)**	**Terrain (Level, Rolling, Mountainous)**	**Total Buses**	**Buses Proportion**	**Total Trucks**	**Trucks Proportion**	**Trucks & Buses Proportion; (P_T)**	**Total RVs**	**RVs Proportion; (P_R)**	**PCE of Trucks & Buses; E_T**	**PCE of Recreational Vehs; E_R**	**f_{hv} = 1/(1+PT(ET-1)+PR(ER-1))**	**Demand Flow Rate; v=V/(PHF*N*fHV*f_{ID}) for (pc/h)**
2019	20583	858	0.10	0.5	1029	1225	613	Rolling	1977	0.096	6813	0.331	0.427	0	0.00	2.5	2	0.610	479
2020	21200	883	0.10	0.5	1060	1262	631	Rolling	2036	0.096	7017	0.331	0.427	0	0.00	2.5	2	0.610	493
2021	21837	910	0.10	0.5	1092	1300	650	Rolling	2097	0.096	7228	0.331	0.427	0	0.00	2.5	2	0.610	508
2022	22492	937	0.10	0.5	1125	1339	669	Rolling	2160	0.096	7445	0.331	0.427	0	0.00	2.5	2	0.610	523
2023	23166	965	0.10	0.5	1158	1379	689	Rolling	2225	0.096	7668	0.331	0.427	0	0.00	2.5	2	0.610	539
2024	23861	994	0.10	0.5	1193	1420	710	Rolling	2292	0.096	7898	0.331	0.427	0	0.00	2.5	2	0.610	555
2025	24577	1024	0.10	0.5	1229	1463	731	Rolling	2361	0.096	8135	0.331	0.427	0	0.00	2.5	2	0.610	571

Burhan-Islamabad Section							
LEVEL OF SERVICE							
VOLUME (Traffic Data)							
Year	Growth Factor (Proportion)	Grand Total Volume with CPEC Trucks (AADT) (veh/day)	FFS in Direction of Analysis (FFSd) (mph)	Demand Flow Rate in Direction of Analysis (v_d) (pc/h)	Demand Flow Rate in Opposing Direction (v_o) (pc/h)	Density (Demand Flow Rate/ Expected Speed)	Level of Service based on Density
2019	0.03	20583	62.0	479	479	8	A
2020	0.03	21200	62.0	493	493	8	A
2021	0.03	21837	62.0	508	508	8	A
2022	0.03	22492	62.0	523	523	8	A
2023	0.03	23166	62.0	539	539	9	A
2024	0.03	23861	62.0	555	555	9	A
2025	0.03	24577	62.0	571	571	9	A