JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
MINISTRY OF COMMUNICATIONS, GOVERNMENT OF PAKISTAN

PAKISTAN TRANSPORT PLAN STUDY IN THE ISLAMIC REPUBLIC OF PAKISTAN (Phase II)

Draft Final Report

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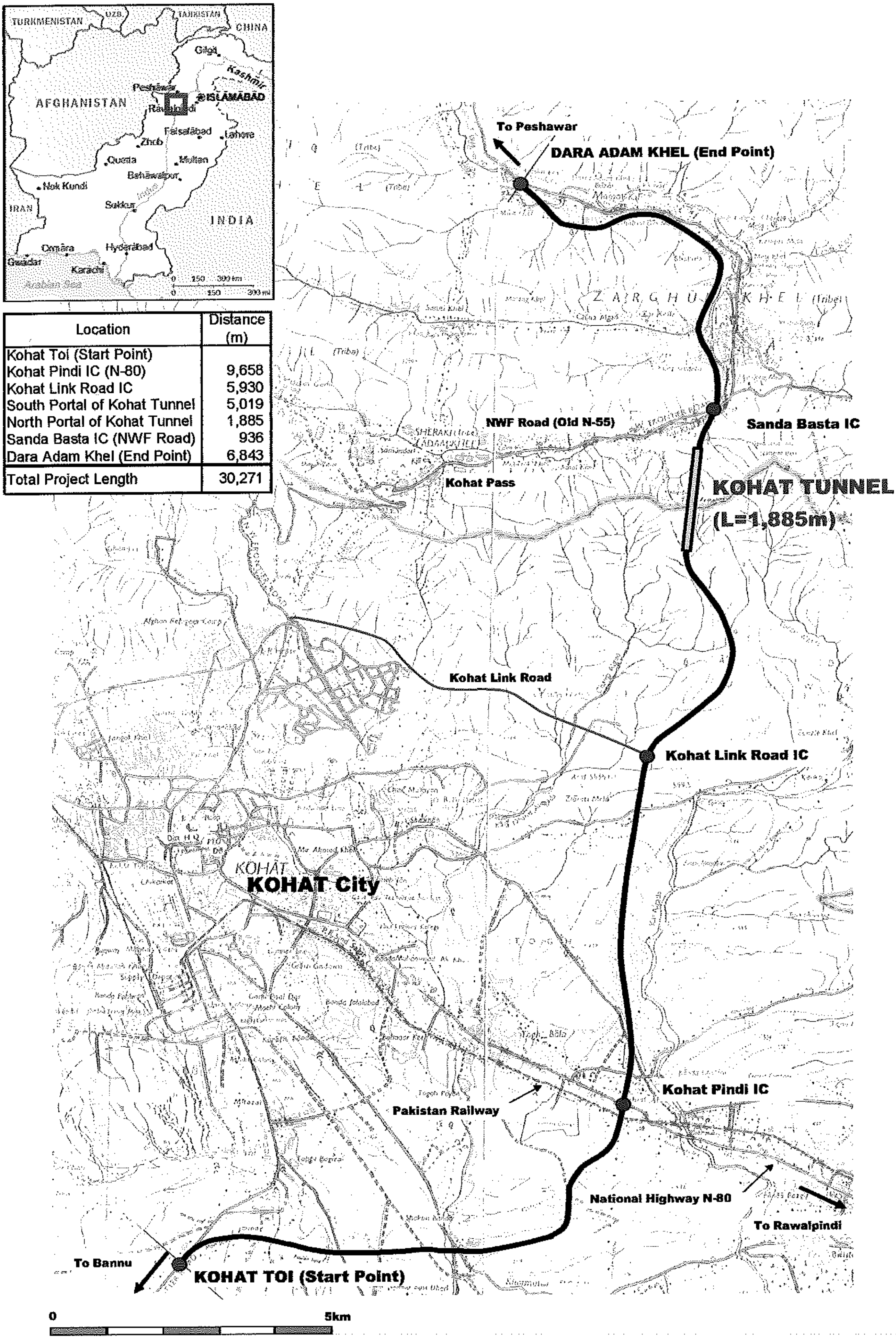
ON KOEI CO., LTD.
EC CORPORATION



Location	Distance (m)
Kohat Toi (Start Point)	
Kohat Pindi IC (N-80)	9,658
Kohat Link Road IC	5,930
South Portal of Kohat Tunnel	5,019
North Portal of Kohat Tunnel	1,885
Sanda Basta IC (NWF Road)	936
Dara Adam Khel (End Point)	6,843
Total Project Length	30,271

2ND KOHAT TUNNEL AND ACCESS ROADS PROJECT | **LOCATION MAP**

KPT	Karachi Port Trust
LOS	Level of Service
MC&O	Management Contractor & Operator
MOC	Ministry of Communications
MOE	Ministry of Environment
MR	Resilient Modules
MTDF	Medium Term Development Framework
NATM	New Austrian Tunneling Method
NESPAK	National Engineering Services Pakistan
NHA	National Highway Authority
NO2	Nitrogen dioxide
NOx	Nitrogen Oxide(s)
NPV	Net Present Value
NTC	National Trade Corridor
NTRC	National Transport Research Center
NWFP	North West Frontier Province
O/D	Origin/Destination
OECF	Overseas Economic Cooperation Fund
PC	Precast Concrete
PCC	Portland cement concrete pavement
PCU	Passenger Car Unit
PDA	Post Decision Analysis
PEPA	Pakistan Environment Protection Agency
PGA	Peak Ground Acceleration
pH	hydrogen-ion concentration (pH is Germany)
PIA	Pakistan International Airlines
PIARC	Permanent International Association of Road Congress
PMD	Pakistan Meteorological Department
POL	Petroleum, Oil and Lubricants
PR	Pakistan Railways
PSDP	Public Sector Development Program
PTPS	Pakistan Transport Plan Study
RH	Relative Humidity
RMA	Road Maintenance Account
ROW	Right of Way
S/S	Sub Station
SCF	Standard Conversion Factor
SEA	Strategic Environmental Assessment
SO2	Sulphur dioxide
SOP	Standard Operation Procedures
SOP	Survey of Pakistan
SOx	Sulphur Oxide(s)
SPM	Suspended Particulate Matter
STD	Sexually Transmitted Disease
SVC	Supervisory and Control
SWH	Surface Water Hydrology
TCM	Travel Cost Method
TPM	Total Particle Matter
TRB	Transportation Research Board
TTC	Travel Time Costs

Abbreviations /Acronyms

AADT	Annual Average Daily Traffic
AAQA	Ambient Air Quality Standards
AASHTO	American Association of State Highway and Transportation Officials
ADB	Asian Development Bank
ADT	Average Daily Traffic
B/C	Benefit/Cost Ratio
CAD	Computer aided design system
CBR	California Bearing Ratio
CCTV	Close Circuit Television
CDWP	Central Development Working Party
CESA	Cumulative Equivalent Single Axle Load
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
COMSAK	Committee for Safety Action for Kohat Tunnel
D.G.	Director General
D/D	Detailed Design
DBST	Double Bituminous Surface Treatment
DFO	District Forest Officer
ECNEC	Executive Committee of the National Economic Council
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EL	Elevation
EMMP	Environment Management & Monitoring Plan
EMP	Environmental Management Plan
EPA	Environment Protection Agency
ESA	Equivalent Single Axle
F	Fluorine
FATA	Federally Administered Tribal Areas
FONSI	Finding of Non-Significant Impact
FR	Frontier Region
FY	Fiscal Year
GDP	Gross Domestic Product
GOP	Government of Pakistan
GOJ	Government of Japan
GPS	Global Positioning System
HAZCHEM	Hazardous Chemical Material
HCM	Highway Capacity Manual
HGVs	Heavy Goods Vehicles
HIV/AIDS	Human Immunodeficiency Virus/ Acquired Immune Deficiency Syndrome
HPS	high-pressure sodium
I.E.C.	International Electro-Technical Commission
IBRD	International Bank for Reconstruction and Development
IC	Interchange/Intersection
IEE	Initial Environmental Examination
IUCN	International Union for the Conservation of Nature and Natural Resources
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency

UPS	Un-interrupt able power supply
US-SCS	U.S. Soil Conservation Services
VOC	Vehicle Operating Costs
W/O	Without
WAPDA	Water and Power Development Authority
WHO	World Health Organization
WPCHB	West Pakistan Code of Practice for Highway Bridges

SUMMARY

1. The Final Report of PTPS Master Plan Study was submitted in March 2006. In this report, the 2nd Kohat Tunnel Construction Project was recommended as one of the priority projects to be selected for the next medium Term Development Framework (MTDF), or in parallel with the current MTDF, in view of their contribution to national economy, alleviation of traffic congestion and safety improvement.

The Condition of the Existing Kohat Tunnel and Access Road

2. The existing tunnel (1st Kohat Tunnel) and both access roads were completed and became operational in June, 2003. Up to now, no accident has been recorded in the tunnel by the severe vehicle checking by NHA monitoring and management. Traffic volume at the Kohat tunnel was increased by 12.4% from 2004 to 2005. For the period from January to May, the increase rate was 21.8% from 2005 (Jan-May) to 2006 (Jan-May).

3. The existing tunnel was constructed as a 2-lane (single carriageway road) at 2.2% up grade to the north. The design speed of the Kohat tunnel is 60 km/hour. Vehicle running speed has been controlled at 40km/hour and overtaking is not allowed in the tunnel for safety. However, the actual travel speed is 16.7 km/hour and it takes 7-8 minutes for the northbound traffic forming platoons behind slow-moving trucks, which cannot be broken up since passing maneuvers are not possible. The travel speed for the south bound traffic is 30.9 km/hour, that is less than the controlled speed, even though down-grade traffic.

4. Taking the above situation into consideration, the feasibility study of 2nd Kohat Tunnel Construction Project was selected by JICA as the most appropriate priority project in view of urgency, technical complexity, and the fact that the 1st Kohat Tunnel is named as the Pakistan-Japan friendship tunnel.

5. The feasibility study was commenced from the end of April, 2006. Hereinafter, major conclusions and recommendations of the study are introduced.

Traffic Analysis

6. The current traffic passing through the Kohat tunnel is 7,370 veh/day and it will continue to increase at high percentage. Future traffic volume was forecast based on the analysis of the PTPS traffic survey, NHA's toll collection data, and supplemental traffic surveys carried out in the study. The future tunnel traffic is estimated to be 14,050 veh/day in 2015 and 24,340 veh/day in 2025.

7. The capacity analysis based on Highway Capacity Manual (Transportation Research Board, National Research Council, USA) revealed that the level of service of the existing Kohat Tunnel is already LOS of "D" level in a peak hour, and will experience LOS of "E" level within a few years.

8. The traffic on the Access Road in the south of the Kohat Link Road IC, located 4.6 km south of the tunnel (nearly the mid point of the entire Project length), will be 80% of the tunnel traffic and experience LOS of "D" level in 2013.

Preliminary Design

Access Road

9. New 2-lane access road is designed beside the existing two lane access road within the already acquired ROW. Northern access road is 7,780m in length and southern access road is 20,607m in length.

10. In the design of southern access road, transition curves are employed in its horizontal alignment. Four intersections and ten bridges are planned.

Tunnel

11. The location of south portal is shifted from the original plan proposed in the design stage of the 1st tunnel, to the western direction by 40m from the economical and technical view points. The distance between two tunnels will be 30m centre-to-centre. The location of north portal is same as the original plan. It is proposed to lower the elevation of the south portal because of technical reasons. As a result, the grade of the 2nd tunnel will be 2.4%, 0.2% steeper than the 1st tunnel. Since the 2nd tunnel will be used for the southbound traffic in down grade, this grade will not affect traffic flow and safety.

12. The same tunnel opening and cross section as the 1st tunnel is adopted.

Tunnel Facility Works

13. For the tunnel facilities such as ventilation, lighting, power supply and emergency facilities, the same systems employed in the 1st tunnel will be adopted from economical and easy maintenance view points.

14. Since the planned tunnel portal will be located just behind the existing control room, it is necessary to relocate the existing control room and substation prior to starting tunnel excavation.

15. Two tunnels will be connected by two cross passages, which will be used for evacuation of tunnel users in case of accidents in the tunnels.

Environmental Study

16. The results of the IEE showed no major environment impacts were observed. Moreover, there do not appear to be any resettlement issues as the necessary ROW is already acquired by NHA. Based on the EIA law in Pakistan, this project would require a full scale EIA. However, considering that the project has the same nature as the widening project, NHA has to discuss with NWFP EPA whether an EIA will be necessary.

Construction Plan and O&M Plan

17. As the tunnel construction works is on the critical path in the construction schedule, the plan of tunnel excavation from both portals is recommended. New Austrian Tunneling Method (NATM) will be applied for tunnel excavation and support. For the widening of the access road, construction method of hard rock excavation keeping traffic on the existing access road was examined. Excavation in association with controlled blasting and a hydraulic breaker is recommended.

18. Three years of construction schedule is considered to be most realistic and reasonable. Due to the technical complexity of the project, construction works are recommended to be conducted by a qualified international contractor.

19. NHA has contracted the operation and maintenance of the 1st Kohat Tunnel and Access Roads to a private company as Maintenance Contractor & Operator (MC&O) since its opening in May 2003 under overall supervision of NHA. As the current operation and maintenance system has worked well, the present system of operation and maintenance will be applied expanding the scope of works of MC&O to cover both tunnels

Cost Estimates

20. On the basis of the preliminary design and established unit prices, the project cost was estimated at approximately 6,332 million Pakistan rupees using ICB conditions at mid 2006 prices. At the same time, future operation and maintenance cost was estimated based on the operation record of the existing tunnel.

Project Evaluation

21. The economic evaluation was made by the conventional discounted cash flow methodology, and EIRR of the Project is confirmed as 16.6%. The major economic

benefits quantified were the vehicle operation cost saving and travel time saving. The results of sensitivity analysis also show the robustness of the strong feasibility of the Project.

22. Financial evaluation was carried out by calculating the revenue based on the current toll rates of the existing tunnel. The result shows FIRR of 4.7%. The investment cost cannot be covered by the future toll revenue. However, annual operation and maintenance costs will be sufficiently covered by the toll revenue.

23. These result indicated that the Project is feasible and sustainable.

Project Implementation Plan

24. The need to upgrade the Indus Highway to 4-lane highway is further heightened under the National Trade Corridor program. Stage-wise construction scheme of the Project (postpone the construction of the section in the south of the Kohat Link Road IC) was examined to attain higher EIRR, but the increment is so small as to be negligible (0.7% only).

25. Therefore, it is recommended to construct the 2nd Kohat Tunnel and Access Roads between Kohat Toi and Dara Adam Khel at once.

26. Implementation schedule is prepared on the basis that the Project will be implemented with foreign financial assistance. The estimated opening of the 2nd Kohat Tunnel will be at the earliest at the beginning of 2013.

Recommendation

(1) Construction of the 2nd Kohat Tunnel is viable from the macro-economic perspective. It will contribute to the development of the regional economy as well as national economy and have great significance in terms of developing a part of the National Trade Corridor. Moreover, at the earliest possible opening of the 2nd Kohat Tunnel in 2013, the tunnel traffic should have reached the capacity of the 1st Kohat Tunnel. Therefore, the Project should be an urgent project to be implemented at the earliest opportunity.

(2) Prior to undertaking the next step of implementation, NHA has to discuss with NWFP EPA whether an EIA is required for the Project. If required, NHA should prepare the EIA and receive Environmental Clearance from the EPA of NWFP. NHA/MOC should send this project to the screening process in the Government and expedite the application for financial assistance to appropriate donor agency/country, as soon as this feasibility study is completed. Since the 1st Kohat Tunnel and Access Roads Project was financed by JBIC, JBIC will be one of the most possible sources.

(3) Fortunately, no major accident has ever been experienced in Kohat tunnel since its opening, however, the Pakistan Government is requested to continue to take the following actions to keep and ensure smooth and safe highway operation.

- to reinforce control systems to eliminate truck overloading
- to establish education systems for drivers to keep safe driving with good driving manners.

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Chapter 1. INTRODUCTION

1.1 Background of the Study

1.1.1 General

The Islamic Republic of Pakistan is located north-east of the Arabian Sea and extending towards the Himalayas on the border of China. The country has land area of 796,000 km2 and consists of four provinces, two territories, and the Pakistan part of Kashmir. The distance between Islamabad (the capital of Pakistan) and Karachi having two important international ports is about 1,200 km in a straight line. The transport system in Pakistan plays an important role in unification of theses regions in terms of political and economic activities.

The government of Pakistan has requested the government of Japan to provide technical assistance in carrying out a comprehensive transport development study titled "the Pakistan Transport Plan Study in the Islamic Republic of Pakistan", PTPS. The government of Japan agreed to conduct the study and has entrusted its execution to the Japan International Cooperation Agency, JICA.

Pakistan Transport Plan Study in the Islamic Republic of Pakistan (PTPS) consists of two phases. The first phase was carried out from June 2005 to March 2006, in which the major task was to formulate a short-term plan (2005/06-2009/10) and a master plan (2005/06-2024/25) for the development strategy of national transport system of Pakistan. The activities and results in the first phase of PTPS are summarized as follows.

1. The Study Team analyzed the present conditions of transport sector including road, railway, port and airport, focusing on infrastructure, transportation (passenger and freight), legal framework, organization, administration, financial situation, and environmental consideration. The problems and issued were identified.
2. Nation-wide traffic surveys were carried out in July and August, 2005. The traffic surveys consists of the roadside O/D interview survey and traffic count survey at 100 sites over the country and other supplemental surveys. The present vehicle O/D tables were produced from the traffic surveys.
3. The socio-economic framework targeting the year 2010 and 2025 was prepared. The future traffic demand for road, rail, port and airport was estimated based on the framework. Traffic volumes on roads and railways were calculated from the future O/D tables for passenger and freight transport. Using the result of the forecast, demand and supply analysis was carried out for all transport modes.
4. The transport policies and the development strategies were established, and development plans and short-term investment plans were formulated for road, rail, port and airport sectors.
5. The Study Team held two seminars about traffic surveys, demand analysis and other technical matters for the National Transport Research Center (NTRC), and opened a seminar about the results of PTPS for stakeholders.
6. The Study Team conducted survey for the restoration of transport infrastructure in the northern area in particular of the Jhelum Valley Road damaged by the earthquake in October 8, 2005.

Among the priority projects defined in the Master Plan, the 2nd Kohat Tunnel and Access Road Construction Project (hereinafter referred to as "the Project") was selected for technical transfer of feasibility study in the second phase of PTPS.

The 2nd phase of PTPS commenced at the end of April 2006, and the feasibility study as well as technical transfer on the Project continued until September 2006 at the site in Pakistan.

This draft final report presents all the study results and findings obtained in the Feasibility Study on the 2nd Kohat Tunnel and Access Roads Project (hereinafter referred to as "the Study").

1.1.2 Objectives of the Study

The major objectives of the Study are:

- To conduct Feasibility Study for the 2nd Kohat Tunnel and Access Road; and
- To pursue technology transfer to the counterparts on the Pakistan side in the course of the Feasibility Study.

In essence, the Study aims at determination of the optimum scope of the 2nd Kohat Tunnel and Access Roads construction through various studies and comparison among conceivable alternatives.

1.1.3 Study Area

The study area is shown in Figure 1.1.1 below.

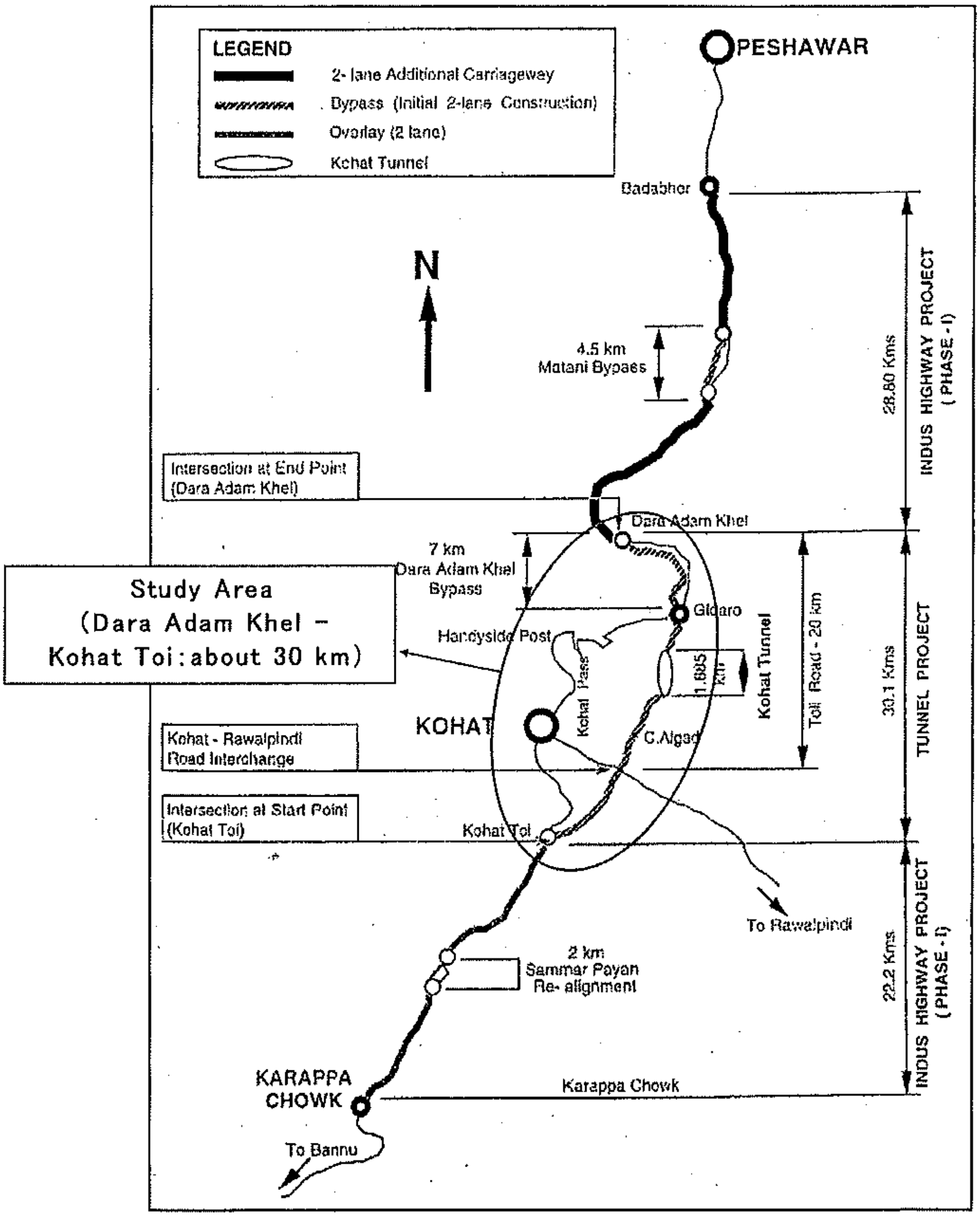


Figure 1.1.1 Study Area

1.2 Work Schedule

1.2.1 Overall Work Flow and Schedule of the Study

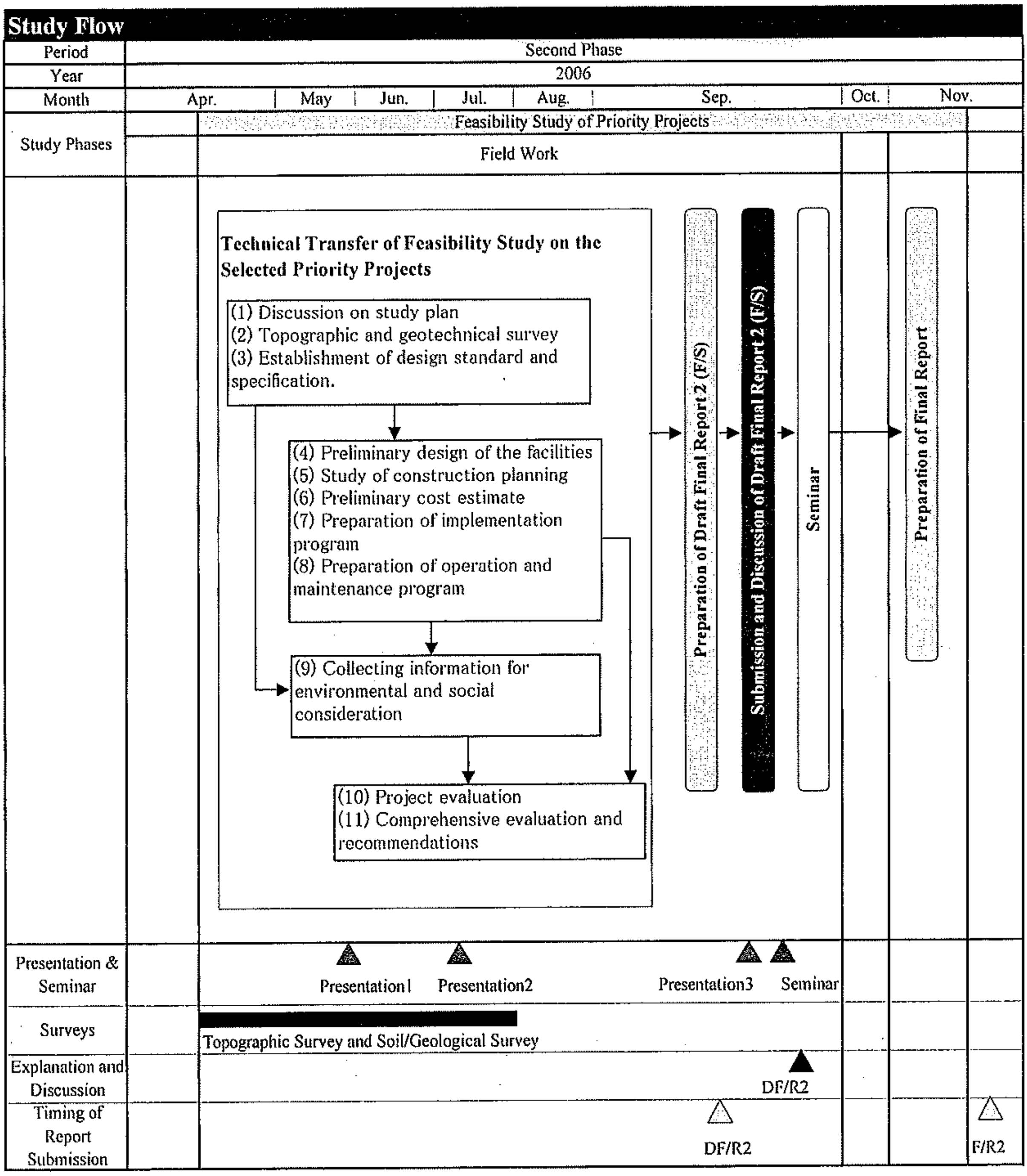


Figure 1.2.1 Overall Work Flow of the Study

1.2.2 Presentations

The Study Team held three presentations on the Study to NHA and NTRC and other stakeholders as part of technical transfer, which were summarized in the following table.

	1st Presentation	2nd Presentation	3rd Presentation
Date	29 May, 2006	6 July, 2006	14 September, 2006
Venue	NHA Auditorium	NHA Auditorium	NHA Auditorium
Subjects	- Work Plan and Methodology of the Feasibility Study - Introduction of Japanese Technology in Tunnel Construction - Brief Comments on Rods vs. Railway Tunnel	- Progress of the FS Study / Traffic Forecast / Highway Capacity - Highway and Pavement Design - Tunnel Geology - Tunnel Design - Tunnel Facility	-

1.3 Organization of the Study

1.3.1 Organization of the Study

The Study has been carried out by the Study Team under supervision of Japan International Cooperation Agency (JICA) and with cooperation of counterparts under Ministry of Communication (MOC). The organization chart of the Study is presented in Figure 1.3.1

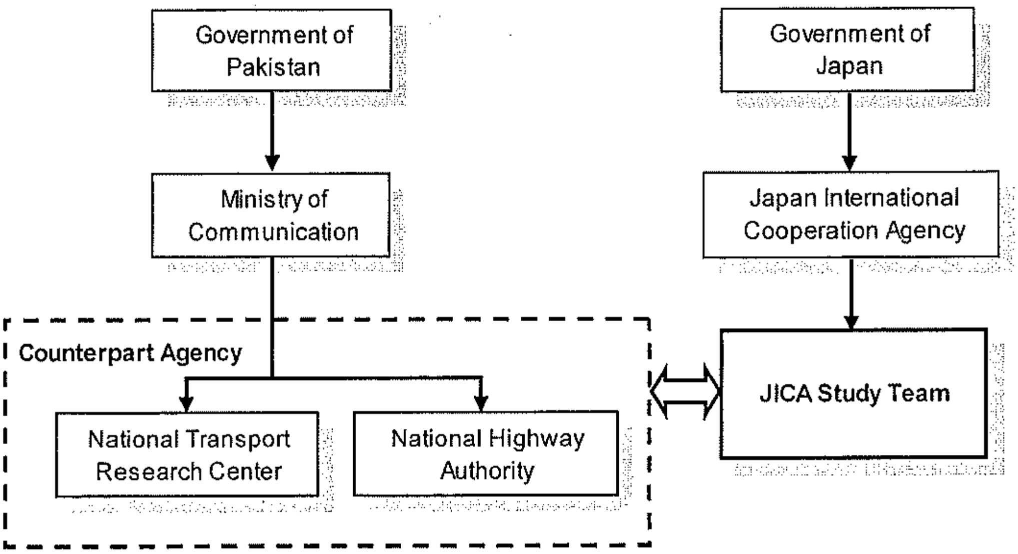


Figure 1.3.1 Organization Chart of the Study

1.3.2 Counterpart

The Government of Pakistan nominated the National Highway Authority (NHA) and the National Transport Research Centre (NTRC) as the Pakistani counterpart for the Study.

The Study Team collaborated closely with the personnel of NHA and NTRC and conducted many works and investigations with the assistance of relating agencies and entities of Pakistan.

The members of the counterpart (NHA) for the Study are listed below;

Mr. Raja Nowsherwan	Member Planning
Mr. S.A.Latif	General Manager, Planning Contact Person (NHA Head Office)
Mr. Muhammed Naseem Khattak	Chief Operation Officer Contact Person (NHA Kohat Tunnel O & M Office)
Mr. Asim Amin	General Manager (Design) Highway design
Mr .Jehanzeb Niazi	Assistant Director (Planning) Highway planning
Mr. Sjjad Medhi	Director (Materials) Geologist / Slope disaster prevention planning
Mr.Jhangir Larik	Assistant Director (Design) Tunnel engineer / Construction planning (including bridges)
Mr. Shabir	Cost Estimate Specialist Tunnel facility engineer / Cost estimate specialist

The members of the counterpart (NTRC) for the Study are listed below;

Mr. Muhammad Kazim Idris	Chief of NTRC
Mr. Bashir Ahmed	Deputy Chief of NTRC PTPS FS Coordinator (NTRC)
Mr. Muhammad Naeem	Deputy Chief of NTRC PTPS FS Deputy Coordinator (NTRC)
Mr. Khizer Javed	Research Officer Traffic demand analysis / Traffic demand forecast
Mr. Masoud Bakht	Assistant Chief Economic / Financial analysis
Mr. Shahbaz Latif Mirza	Research Officer Social / Natural environmental specialist

1.3.3 Study Team

The members of the Study Team for the Study are listed below;

Mr. Minoru Shibuya	Team Leader / Comprehensive transport planning
Mr. Koichi Tanuma	Deputy team leader /Road planning/Road facility planning
Mr. Shogo Uchida	Traffic demand analysis / Traffic demand forecast
Mr. Atsutoshi Sakata	Geologist/Slope disaster preventing planning
Mr. Shigeru Konda	Highway engineer / Highway planning
Mr. Makoto Kubota	Tunnel engineer / Construction Planning
Mr. Kuniaki Nishijima	Tunnel facility engineer / Cost estimate specialist
Mr. Masahito Homma	Economic / Financial analysis
Mr. David Gordon Lees	Social environmental specialist
Mr. Hironori Kuroki	Natural environmental specialist
Ms. Michiko Matsumoto	Administrator / Topographic and geological survey

Chapter 2. PRESENT TRANSPORTATION SYSTEM

2.1 General

Pakistan has a population of approximately 160 million and is the sixth most populated country in the world. Real GDP was Rs.6,548 billion (by 2004/2005 estimate), and per capita income was estimated at $736 in 2004/2005. Pakistan borders on India to the east, Afghanistan to the north-west, China to the north, Iran to the west-south, and Arabian Sea to the south. Roughly, there are three types of geographical areas in Pakistan. Northern part of Pakistan is mountainous area where three of the world's great mountain ranges (the Hindukush, the Karakorams and the Himalayas) meet. Punjab and Sindh, eastern part of Pakistan along the Indus River and its tributaries, are very fertile and populated areas. Balochistan covers a large part of Pakistan in the west, where dry and hilly desert stretches and population density is very small.

Road transport is the dominant mode of inland transport, carrying 91% of passengers and 96% of cargos in the whole country. The total length of roads is approximately 258,000 km. The Pakistan Railways (PR) has 11,515 km of tracks and 7,791 km of route network with 633 stations. The total route-kilometres, 1,043 km have double track and 285 km long section between Lahore and Kanewal is electrified.

During the 1990s, road transport volumes grew at 5% per year for passengers and 12% per year for freight in terms of passenger-km and ton-km, respectively. The growth rate of freight transport was high in the early 1990's.

Around 95% of imports and exports are handled through the Karachi Port and Port Qasim. Another deep-sea port is now under construction in Gwadar. The Karachi Port handles about 30 million tons of cargo, while the Port Qasim handles about 11 million tons. Approximately 60% of the imported cargo is transported inland from the two ports by road and rail to the upcountry. The Indus, Chenab, Jhelum, Ravi, and Sutlej Rivers flow through the territory of Pakistan, but inland water transport is very limited.

There are 44 airports including five international airports located in Islamabad, Karachi, Lahore, Peshawar, and Gwadar. PIA (Pakistan International Airlines) is the national flag carrier, while Aero Asia, Shaheen Air International, Royal Airlines, and Airbule are private airlines in Pakistan. Passenger km by air is a tenth of that by rail, and a hundredth of that by road.

The Indus, Chenab, Jhelum, Ravi, and Sutlej rivers flow through the territory of Pakistan, but inland water transport is very limited.

2.2 Existing Road Networks

The entire road network in Pakistan has a total length of approximately 258,000 km: 8,900km of national highways (national highways, motorways and strategic roads) and 92,600 km of provincial roads and 156,500 km of other roads (district, municipal and cantonments roads). Approximately 60% of the network is paved. The total road length has increased by 50,355 km in the last 10 years since 1994/1995. However the increase since 1999/2000 has been only been 9,660 km. The recent trend is that the length of "high type roads" is increasing while that of "low type roads" remains unchanged. This implies that the strategy for road development has been shifted from the road network expansion to the capacity increase of the existing networks.

The road density in Pakistan is 0.32 km/km^2 and the Medium Term Development Framework (MTDF) 2005-2010 proposes to enhance this to 0.42 km/km^2 through the construction of 80,000 km of new roads. The road density in Punjab and Sindh is relatively high at 0.51 and 0.57 km/km^2, while it is extremely low in Balochistan at 0.12 km/km^2 as shown in Table

2.2.1. On the other hand, the road length per population is the highest in Balochistan and it is the lowest in Punjab.

Table 2.2.1 Road Length and Density by Province

	Pakistan	Punjab	Sindh	NWFP	Balochistan
Total Road Length (km)	258,214	106,140	79,834	30,049	42,191
Percentage of Paved Road	63%	78%	69%	46%	13%
Area (km^2)	796,095	206,250	140,914	101,741	347,190
Road Density (km/km^2)	0.32	0.51	0.57	0.30	0.12
Population (million)	148.72	85.33	32.99	23.26	7.14
Road Length per Mil. People (km)	1,736	1,244	2,420	1,292	5,909
Number of Registered Vehicles	4,974,000	2,920,984	1,457,323	430,429	165,264
Road Length per 1,000 Vehicles	52	36	55	70	255

Source: PTPS Final Report, JICA Study Team

2.3 National Highway Networks

There are fourteen national highways (8,600 km), five motorways (767 km), and two strategic roads (207 km) as listed in Table 2.3.1 and shown in Figure 2.3.1. N-5 is the longest and the most important national highway. In view of its high importance, N-5 has been improved to a dual carriageway road. The improvement works is almost completed except for the sections between Karachi and Hyderabad, Peshawar and Torkham and other small sections. The other national highways are 2-lane roads except for the Badabher-Peshawar section of N-55.

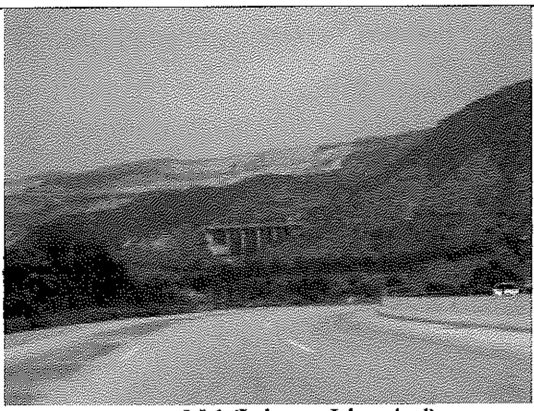
Table 2.3.1 National Highways, Motorways and Strategic Roads

No.	Route	Length (km)
National Highways (8,113 km)		
N-5	Karachi - Hyderabad - Multan - Lahore - RWP - Peshawar – Torkham	1,819
N-10	(Makran Coastal Highway) Liari - Ormara - Pasni - Gwadar – Gabd	653
N-15	Mansehra - Naran - Jalkhad - Chilas Road	240
N-25	Karachi - Nela - Khuzdar - Kalat - Quetta – Chaman	813
N-35*1	(KKH) Hassanabdal - Abbottabad - Thakot - Gilgit – Khunjrab	806
N-40	Lakpss (near Quetta) - Dalbandin – Taftan	610
N-45*2	Nowshera - Dir – Chitral	309
N-50	D.I. Khan - Zhob - Kuchlad (near Quetta)	531
N-55	**(Indus Highway) Kotri - D.G. Khan - D.I. Khan - Kohat – Peshawar**	**1,264**
N-65	Sukkur - Sibi - Saryab (Quetta)	385
N-70	Multan – D.G. Khan - Loralai - Qila Saifullah	447
N-75	Islamabad - Satra Mile - Lower Topa – Kohala	90
N-80*3	Turnol - Fatehjang – Kohat	146
N-85	Hoshab – Panjgur – Nag – Basima – Surab	487
Motorways (711 km)		
M-1	Islamabad - Peshawar Motorway	155(58)
M-2	Lahore - Islamabad including 32 km links & Lahore Bypass	367
M-3	Pindi Bhattian - Faisalabad Motorway	53
M-9	Karachi - Hyderabad Motorway	136
Strategic Roads (207 km)		
S-1	Gilgit - Skardu Road	167
S-2	Kohala - Muzafarabad Road	40
Total		**9,518**

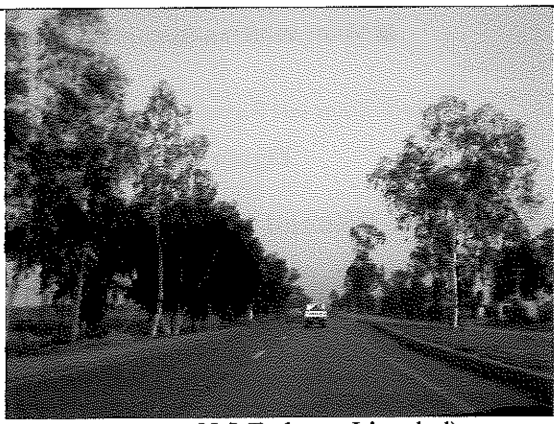
Source: PTPS Final Report, JICA Study Team

Source: PTPS Final Report, JICA Study Team

Figure 2.3.1 National Highways and Motorways Network



M-1 (Lahore – Islamabad)



N-5 (Peshawar-Islamabad)

The road section between Rawalpind and Lahore along N-5 has the heaviest traffic in Pakistan as far as inter-city transport is concerned. According to the PTPS Traffic Survey, the traffic volume between Lahore and Gujranwala was the highest at 22,760 vehicles a day, followed by the Gujranwala to Gujrat section at 19,900. As a whole, the traffic volume on N-5 range from 7,000 to 20,000 vehicles, while other national highways have a smaller traffic volumes ranging from 1,000 to 4,000 vehicles, except for some sections. The traffic volume on N-55 ranges from 1,300 at the Jacobabad-Hyderabad section to 7,450 vehicles near Peshawar.

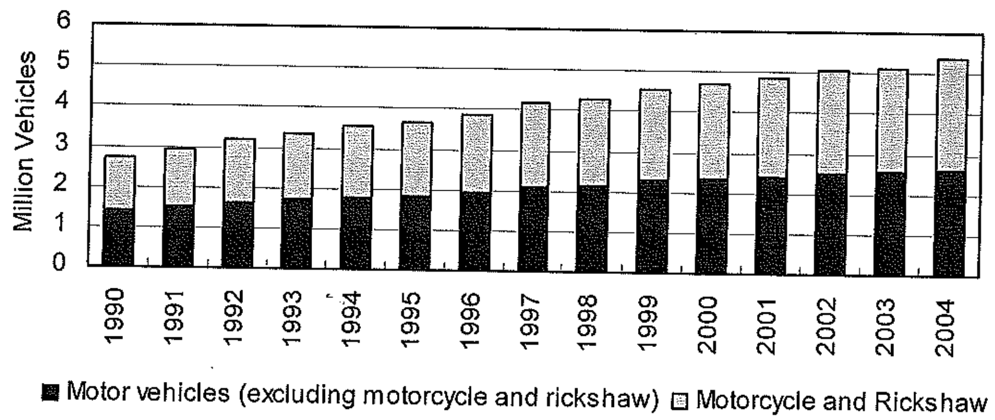
There are many topographic obstacles on the national highways. For example, the Kohat Tunnel has only two -lanes and the actual vehicle speed is only 15-30 km /hour. N-70 has a very dangerous mountainous section between D.G. Khan and Fort Munro. The Khushalgarh Bridge over the Indus River on N-80 is old and narrow. The Lowari Rail Tunnel Project is underway to overcome topographical obstacles on N-45. The Malakand Tunnel (N-45) and the Lakpass Tunnel (N-25) are also planned to improve road transport. Many new bridges over the Indus River and other big rivers are proposed.

2.4 Traffic Demand Forecast on National Highway Networks

2.4.1 Motor Vehicles

The number of registered motor vehicles has been gradually increasing (recently at an annual rate of 4.3%), and was projected to reach 5.4 million in 2004/2005 as shown in Figure 2.4.1. Half of the registered motor vehicles are motorcycles and rickshaws, and their proportion has been increasing slowly.

The share of cars increased from 21% in 1995/1996 to 37%, while the percentage of trucks decreased from 48% to 37%. Trucks still obstruct the stable flow of cars on many national highways due to the slow speed of trucks on 2-way/2-lane roads. Most trucks run at a speed of only 40–50km/hreven under free flow environment.

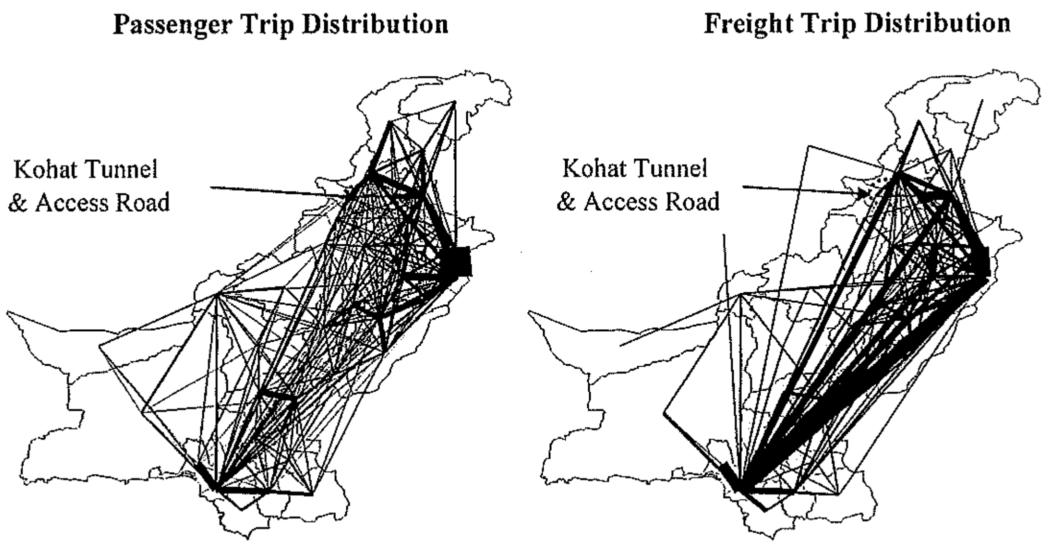


Source: Economic Survey 2004-2005

Figure 2.4.1 Number of Registered Vehicles

2.4.2 Traffic Demand Forecast

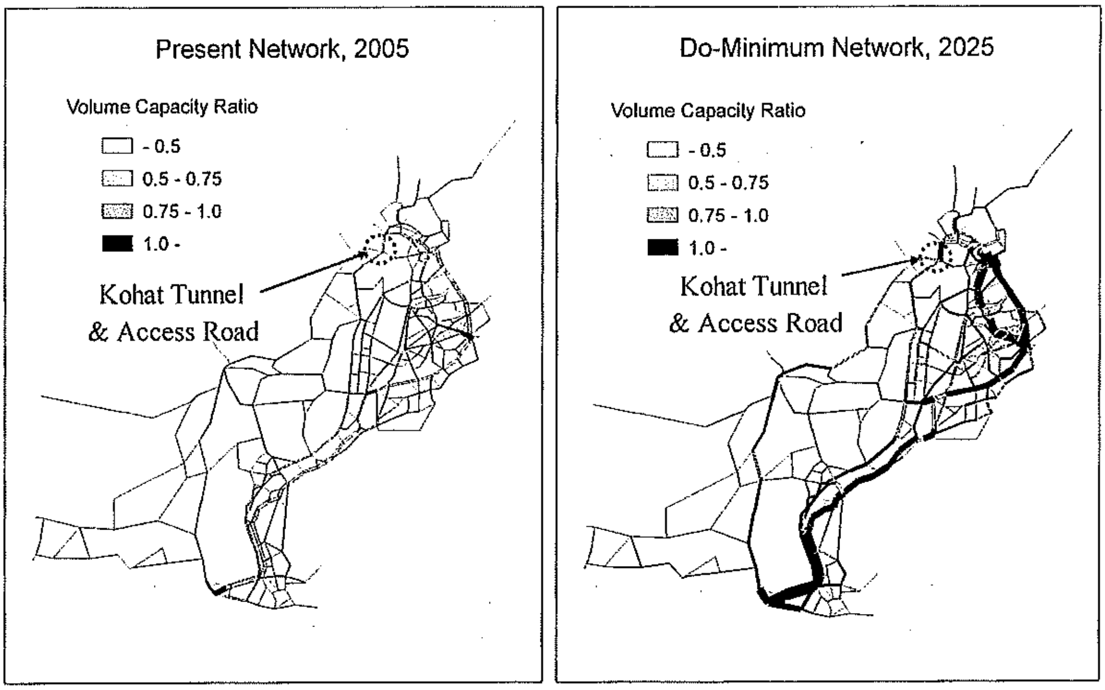
Figure 2.4.2 illustrates the projected trip distribution (Future OD Matrices) in PTPS by the JICA Study Team.



Source: PTPS Final Report, JICA Study Team

Figure 2.4.2 Desired Line of Road Transport Project (2025/2026)

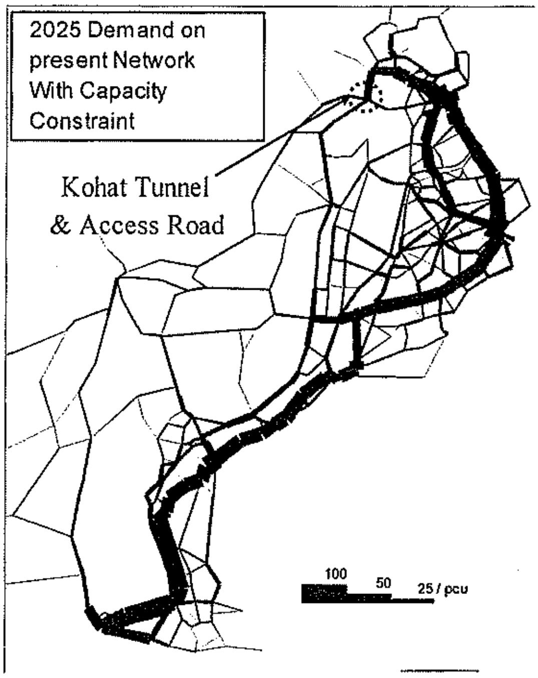
Figure 2.4.3 depicts the results of traffic assignment on the present network for 2005 and "Do-Minimum" network for 2025.



Source: PTPS Final Report, JICA Study Team

Figure2.4.3 Results of Traffic Assignment for 2005 and 2025

Figure 2.4.4 shows the traffic assignments according to the 2025 demand in two cases; one with constrained capacity and the other with unconstrained capacity. The former case indicates a considerable diversion from congested highways to others. If the road capacity is unlimited, road users choose the shortest paths. Thus a considerable number of vehicles running between Karachi and Peshawar will choose N-55 instead of N-5 in the unconstrained capacity case.



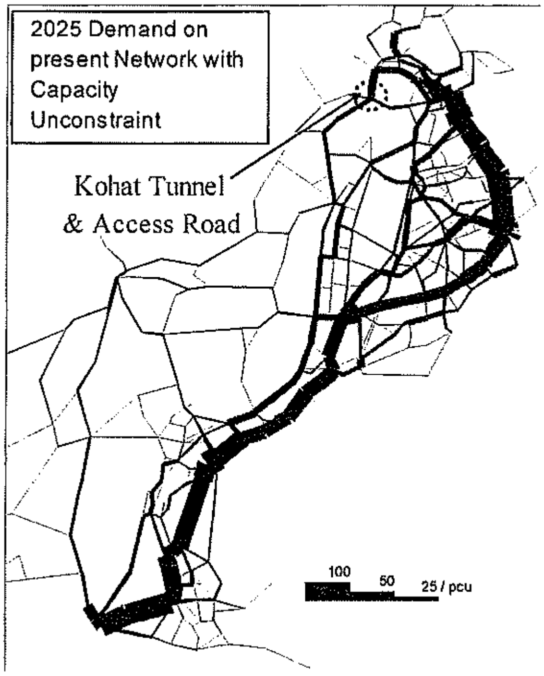


Figure 2.4.4 Assigned Traffic according to 2025 Demand on Current Network

The master plan for road network was proposed based on the result of the demand-supply analysis. Various factors such as regional development and natural resource exploitation were considered in formulating the plan. Required projects for the planned network were identified. N-5 will be the most important corridor as most of the traffic concentrates on this route. N-55 is expected to reduce excessive traffic burden on N-5 as an alternative north-south trunk route.

2.5 Road Administration and National Highway Authority (NHA)

Administration of roads of difference categories by the respective government agencies responsible for the construction and maintenance of the road is as summarized in Table 2.5.1. Ministry of Communication (MOC) is responsible for the national road sub-sector. The National Highway Authority (NHA) is responsible for administration of national highways, motorways and strategic roads.

Table 2.5.1 Administrative Classification of Roads

Classification	Administration	Length	Function
National Highways Motorways Strategic Roads	• National Highway Authority (NHA), Ministry of Communications	9,000km	Constituting the main transport corridors and providing inter-provincial linkages and connections to the neighbouring countries
Provincial Roads	• Communication and Works Department (C&WD), • Works and Services Department (WSD), and • Frontier Highway Authority (FHA)	101,000km	Providing access to the economic and population centres in the four provinces
District Roads	• District Government	94,000km	Providing access to villages and remote areas
Municipal and Cantonment Roads	• Municipal Government and Army	54,000km	Providing access to villages and remote areas

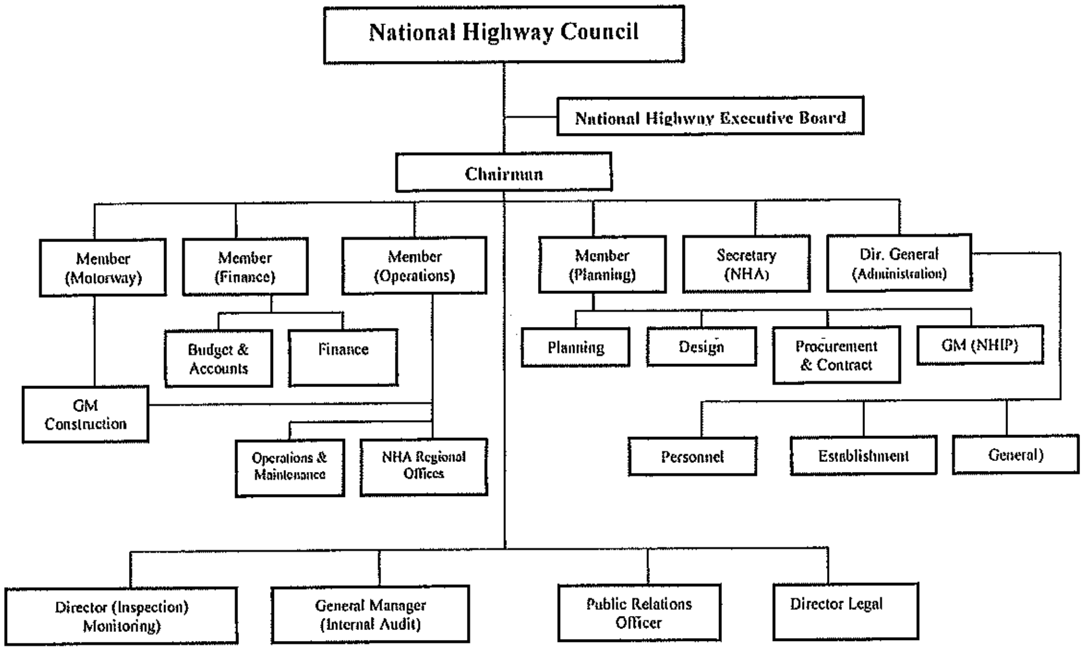
Source: PTPS Final Report, JICA Study Team

Tolls are collected at toll plazas on both the National Highways and the Motorways. Toll plazas were introduced by NHA in 1999. Toll revenue is an important source of maintenance work.

NHA was established by the National Highway Act of 1991 as a semi-autonomous organization under the Ministry of Communications (MOC) with responsibilities to plan, promote, organize and implement programmes for construction, development, operation, repair and maintenance of national highways, motorways and strategic roads.

NHA's organizational set up comprises six core-wings: Motorway, Construction Planning, Operation, Finance and Administration. The organization chart of NHA is shown in Figure 2.5.1.

The 2001 Amendment removed the Boards power to approve projects costing more than Rs.50 million. For projects over Rs.50 million the NHA Executive Board is required to make recommendations to the Central Development Working Party (CDWP) and the Executive Committee of the National Economic Council (ECNEC) for approval.



Source: NHA

Figure 2.5.1 Organization of NHA

2.6 Other Transport Systems

2.6.1 Railways

The Pakistan Railways network is comprised of 7,791 route-kilometres; 7,346 km of broad gauge and 445 km of metre gauge. There are 625 stations in the network, 1,043 km of double-track sections (in total) and 285 km of electrified sections. Figure 2-x illustrates the network of the Pakistan Railways. Major stream of railway traffic is the main corridor of Peshawar- Rawalpindi- Lahore- Karachi section. The Pakistan Railway carried 78.2 million passengers and 6.4 million tonnes of cargos in 2004-2005. Passenger km by rail was 24.2 billion with the average travel distance of 310 km, while freight traffic in tonne-km was 5.5 billion with the average transport distance of 863 km in 2004-2005.

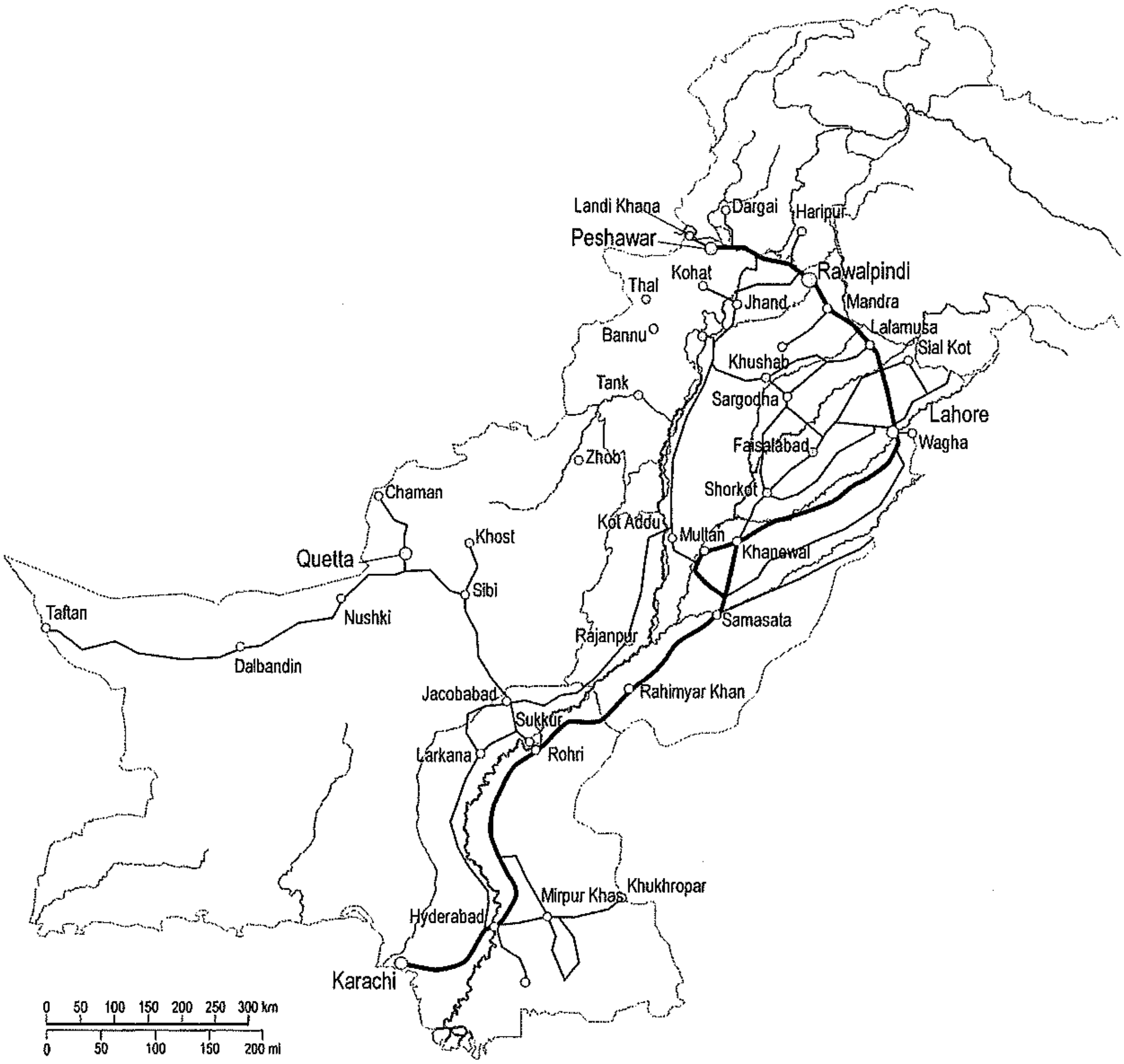


Figure 2.6.1 Pakistan Railways Network

Source: JICA Study Team

2.6.2 Air Transport

The air routes of Pakistan mainly connect five major cities: Karachi, Lahore, Islamabad, Peshawar, and Quetta. The busiest lines are Karachi–Lahore and Karachi–Islamabad. Domestic flights in Pakistan carried 3.28 million passengers and 56,300 tons of cargo in 2005/2006. Passenger traffic on domestic flights reached a peak volume of 4.5 million in 1995/2006, and then decreased rapidly to 2.5 million in 2001/02. Since 2001/2002, the passenger traffic has been increasing at an annual rate of 7.7%.

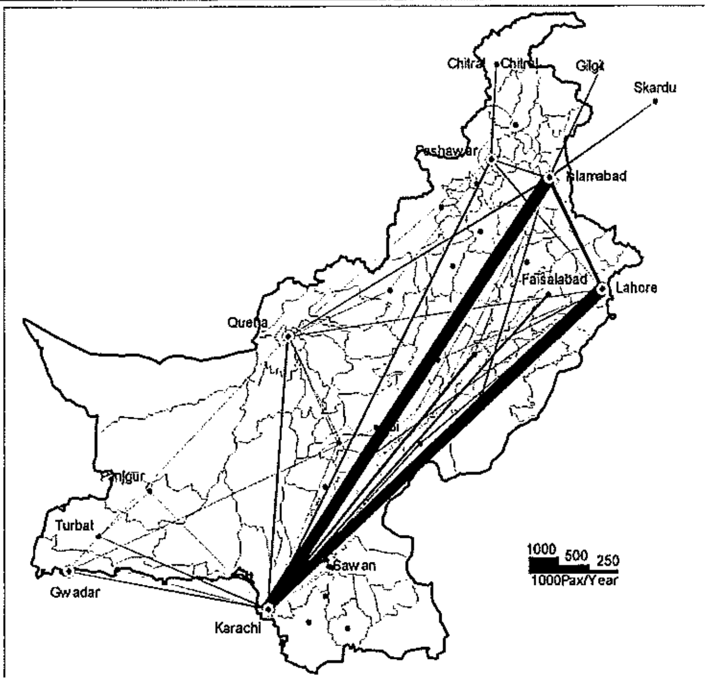


Figure 2.6.2 Air Traffic Volume

Source: JICA Study Team

2.6.3 Port

There are three deep seaports in Pakistan. Karachi Port is the premier port of Pakistan, handled 28.6 million tonnes (22.1 million imports and 6.5 million exports) in 2004-2005. Port Qasim is the second deep seaport of Pakistan, located to the east of Karachi Port. Port Qasim handled 21.3 million tonnes of cargo in 2004-05. Gwadar Port is strategically important, located at the mouse of Persian Gulf near the Iranian border. The development of the port is underway.

Chapter 3. ROAD DEVELOPMENT PLAN

3.1 On-going and Committed Road Projects

The following Table 3.1.1 shows a list of on-going and new projects having been committed by authorized agencies.

Table 3.1.1 List of Ongoing and Committed Projects

No.	Project Name	No.	Project Name
	Ongoing Projects	250	Bridge over River Chenab at Shershah
10	Makran Coastal Road (Balochistan)	260	Interchange at Khangah Dogran on M-2
20	Islamabad – Peshawar Motorway (M-1)	270	Interchange at Sial More on M-2
30	Pindi- Bhattan Motorway (M-3)	280	Lala Musa – Gulyana Thotha Rai Bahadur Road
40	Karachi Northern Bypass	290	Nowshera – Chakdara, Dir-Chitral N-45
50	Lyari Expressway	470	N-5 Rehabilitation Project
60	Islamabad-Muzaffarabad Road	540	Kalat –Quetta – Chaman Section (N-25)
72	**Indus Highway Project (Phase-III), (N-55)**	551	Peshawar-Torkhan Dual Carriageway
80	Mansehra – Naran – Jalkhad Road	552	Malana Junction-Sarai Gambia Dualization
100	Rahim Yarkharn Bahalwalpur (N-5)	**553**	**Badabher – Dara Adam Khel (N-55), ADB**
110	Okara Bypass	554	Sarai Gambia-Bannu-Miran Shah-Ghulam Road
120	Karian – Rawalpindi (N-5)	**650**	**Kohat Tunnel and Access Road (N-55), JBIC**
130	Chablat Nowshera (N-5)	670	Karao-Wad Section, JICA
140	Lowari Tunnel & Access Road		***Committed Projects***
150	Bridge on River Jhelum at Azad Pattan AJK	480	Rehabilitation of 518km of N-5, WB
160	Improvement of N-65 Dera Allah Yar Nutal Section	530	Gujranwala-Hafizabad-Pindi Battian, WB
170	Improvement of N-65 Nutal-Sibi-Dhadar Section	561	Hub – Uthal Section N25, ADB
180	Improvement of KKH (N-35), NWFP	562	Multan – Muzaffargarh, ADB
190	D.I.Khan Mugharl Kot Section (N-50)	563	Khanozai-Mughalkot N50, ADB
200	Improvement of N-70 Qila Saifullar Loralai Bewata	564	Hassanabdal-Abbotabad-Mansera, ADB
210	Ratodero-Shahdakot-Khuzdar Section (M-8)	565	Sukkur-Jaccobabad, ADB
220	Gwadar – Khuzdar Road (M-8)	566	Tarnol-Fatejangh-Jand, ADB
230	Khori-Quba Seed Khan Section	567	Qila Saifullah – Loralai –Wiagum Rud, ADB
240	Realignment of N65 near Jaccobabad	570	Malakand Tunnel/Bypass, ADB

Source: PTPS Final Report, JICA Study Team

As to National Highway N-55 (Indus Highway), the Government of Japan assisted in implementation of the Indus Highway Project (Phases I and II) and the 1st Kohat Tunnel and Access Roads construction. ADB has assisted in a dual carriageway construction of Badabher – Dara Adam Khel road.

3.2 National Road Development Plan

3.2.1 New Road Projects in MTDF

There are 54 road projects in the Medium Term Development Framework (MTDF), consisting of 5 motorway projects, 12 bridge projects, 4 bypass projects, 2 tunnel projects, and others (see Table 3.2.1). The total project cost is estimated at about Rs. 330 billion.

As to the National Highway N-55, improvement of the Dadu-Ratodero (150 km) and improvement and widening of the Ratodero–Sehwan section (200 km) are listed up.

Table 3.2.1 List of New Projects in MTDF

No.	Name[1)]	Type[2)]	Cost
310	Improvement of Quetta Western Bypass	I	225.5
340	Five Bridges on Gilgit Skardu Road, S-1	N	214.7
350	Noshki- Dalbadin Section (165 Km) (N 40) Balochistan	I	1,986.0
360	Jhalkhad- Chillas Road (63 Km) N-15	I	1,827.3
370	KKH-Skardu Road S-1 (167 Km)	I	4,000.0
380	Ghaggar Phatak Bridge to Kotri N-5	N	2,850.0
390	Jand-Kohat National Highway N-80 (46 Km)	I	1,000.0
400	Link Road from M-1 GT Road to Hazara Road Bypassing Hassanabdal	N	500.0
335	Bridge over River Indus at Larkana	N	2,500.0
410	Dhakpattan Bridge (P.M directive)	N	520.0
415	**Dadu Ratodero (150 Km) Fence+Ser. Rd N-55**	I	3,750.0
330	Bridge over River Indus at Chund (Riwaz)	N	700.0
420	Other Projects (Interchanges on M-2,Urban Areas Development etc)	N	3,000.0
450	Widening & Improvement of Hosahb-Nag-Bsima Surab (459 Km)	I, W	12,100.0
460	Karachi-Hub-Dureji-Kakar Motorway (M-7) 270 Km	N	18,000.0
491	Bridge between Kotri Bridge and Sajjawal Bridge	N	2,500.0
492	Bridge between Kotri Bridge and Dadu Moro	N	2,500.0
493	Bridge between Kandhkot and Ghotki	N	2,500.0
494	Ravi cum Road bridge over Indus linking Chachran with Mithanokot	N	2,500.0
495	Bridge over Indus linking Taunsa and Leiah	N	2,500.0
496	Bridge over Indus at Kalur Kot	N	2,500.0
497	Bridge over Indus linking Mianwali with Isa Khel	N	2,500.0
500	ITS & Corridor Management along the Corridor		6,000.0
830	Ratodero-Rajanpur Motorway Section (M-6), 270 Km	N	21,600.0
520	N-5 (Gujranwala-Kharian-Sara e Alamghir, 98 Km) service road along with fence	I	4,200.0
600	Lakpass-Noshki Section (120 Km), N-40	I, W	3,600.0
640	Improvemant of N-65 Quetta- Dhadhar Section (127 Km)	I, W	6,350.0
580	National Highway N-45 (Chakdara-Dir, Kalkatak- Chitral) 120 Km	I, W	6,000.0
590	Murree- Kohala-Muzaffarabad-Chakothi (S-2)Road N-75, 120 Km	I, W	6,000.0
610	Hydrabad-Khokhrapar (222 Km)	I, W	8,880.0
620	Chakdara- Kalam Road (130 Km)	I, W	6,500.0
630	Khwaza Khela- Besham Road (66Km)	I, W	3,300.0
690	**Ratodero-Sehwan (200 Km) N-55**	I, W	6,000.0
660	N-70 (D.G Khan-Sakhi Sarwar-Bewata, 165km) incl. Ghazi Ghat Bridge.	I, W	6,200.0
680	Bridge over River Indus at Khushalgrah (N-80)	N	3,500.0
700	Rehab/Improv/Widening of KKH (Mansehra-Khunjarab, 712km)	I, W	18,500.0
810	Faisalabad-Multan Motorway M-4	N	22,080.0
820	Periodic Overlay on M2 & Realignment of Slat Range	I	11,840.0
510	Khanewal-Lodharan-Uch Sharif-Mithankot-Rajanpur Motorway M-5	N	42,000.0
840	Karachi-Hyderabad Motorway M-9 (136km)	W	7,000.0
850	Peshawar Northern Bypass (26km)	N	3,078.1
860	Rawalpindi Bypass (28km) & Tarnol Interchange N-5	N	3,489.1
870	Lakpass Tunnel (N-25)	N	570.5
890	Shahdara Flyover N-5	N	4,500.0

1) Names are not necessarily the same as indicated in MTDF.
2) I: Improvement, N: Construction, W: Widening, D: Dualization
Source: MTDF, NHA, JICA Study Team

3.2.2 Proposed Projects in PTPS

(1) Proposed Projects in PTPS

The Medium Term Development Framework (MTDF) published in May 2005 sets an ambitious goal for Pakistan to be a developed, industrial, just and prosperous country within 25 years, by attaining a 7 - 8 percent annual economic growth rate. In order to achieve the goal, development of infrastructure in the transport sector is prerequisite. A demand and supply analysis in PTPS indicated that the present road network will not meet the future transport demand if Pakistan achieves the target economic growth, even if all ongoing and committed projects are completed.

Economic growth is given the top priority under the current national development plan and transportation has to shoulder an important role to support high economic growth. One of the main policies of the Master Plan in PTPS is to develop a transport system to support people's economic and social activities so as to reduce regional disparities and realize the optimal modal share between road and railway.

The implications of the analysis on the road planning in PTPS are summarized as follows.

- M-7 and a new road between Hyderabad and Sukkur along the Nara Canal can be used as new shortcut roads of N-5.
- **The road capacity of N-5 and N-55 in Sindh Province should be expanded as early as possible. Construction of new roads or dualization of N-55 can be considered.**
- The road capacity of N-5 and M-2 between Rawalpindi and Lahore should also be expanded. Access control of N-5 and traffic control in urban areas are important because construction of new roads along this corridor may be difficult.
- Construction of new bridges on the Indus, Jhelum, Chenab, Ravi and Sutlej Rivers is necessary. River crossing demand is very high in Punjab Province.
- M-4 will significantly reduce the detour rate between Multan and Faisalabad, and can be given high priority.

The implementation plan of the Master Plan was prepared by each transport sub-sector in the short term (FY2005/2006 - 2009/2010), medium term (FY2010/2011 - 2014/2015) and long term (FY2015/2016 - 2024/2025). The identified projects were evaluated and prioritized primarily based on the Economic Internal Rate of Return (EIRR). Secondly, the projects were examined from the viewpoints of balanced growth among regions, profitability, network integration, international linkage, social equity/poverty and environmental issues. Finally, based on the comprehensive evaluation results, the projects were classified into short, medium and long terms, also considering the possible budget envelope.

A list of proposed projects (motorway, highway, tunnel, bridge and urban bypass projects) in PTPS is shown in Table 3.2.2. Widening of N-55 to a dual carriageway road and construction of the Second Kohat Tunnel are among the projects listed.

(2) Priority Projects in PTPS

The following priority projects in PTPS have been selected for the next MTDF (or in parallel with the current MTDF) in view of their contribution to national economy, alleviation of traffic congestion, and safety improvement:

- Capacity Expansion of Karachi – Lahore Railway Corridor.
- **The Second Kohat Tunnel.**
- M-13 (Lahore – Sialkot Motorway) Construction.
- M-16 (Hyderabad –Nawabshah – Khaipur Desert Road) Construction.
- Murree – Muzaffarabad Road Improvement.
- Bridge Construction in Punjab.
- Karachi Southern Bypass.
- Qasim Port Access.
- Lahore Strategic Peripheral Route Development.
- Lahore Multi-modal Terminal Construction.
- Bypass Construction.

It is recommended to carry out feasibility studies and plan the implementation program for these projects as soon as possible.

Table 3.2.2 List of Proposed Projects in PTPS

Code	Name	Type	Cost
	Motorways		
951	M11 (Chakwal – Shorkot, 289km, 4-lane)	N	29,645
952	M12 (Lahore – Faisalabad, 137km, 4-lane)	N	8,673
953	M13 (Lahore – Sialkot, 136km, 6-lane)	N	12,575
954	M14 (Sialkot – Bhatian, 180km, 4-lane)	N	11,395
955	M15 (Quetta – Khuzdar, 327km, 4-lane)	N	32,143
956	M16 (Hyderabad – Ratodero, 287km, 6-lane)	N	29,336
957	M17 (Bargah – Rajanpur, 280km, 4 lanes)	N	20,526
958	M18 (Khairgarh Fort – Shorkot, 276km, 4-lane)	N	20,273
959	M19 (Khuzdar – Bela, 228km, 4-lane)	N	19,087
	Total		183,653
	Highways		
985	**N55 Dualization (Kohat – D.I.Khan)**	W	14,230
986	**N55 Dualization (D.I.Khan – D.G.Khan)**	W	9,600
987	**N55 Dualization (Rajanpur – Ratodero)**	W	11,630
959	**N55 (Dadu - Kotri) 4-lane**	W	10,000
974	N65 Dualization	I	23,645
1002	Lahore Peripheral Road	N	24,299
	Total		93,404
	Tunnel		
655	**Second Kohat Tunnel (N-55)**	N	6,000
	Sub-total		6,000
	Bridges		
961	Bridge on River Chanab at Garh Maharaja, District Jang	N	1,000
962	Bridge on River Sultaj to link Chistan Burewala Road	N	500
963	Bridge on River Chanab near Head Mohammadwala	N	600
964	Jhelum, Gatalian Mirpur Bridge	N	1,250
330	Bridge on River Chanab at Chund	N	700
966	Bridge on River Ravi near Qutab Shahara	N	500
967	Bridge on River Ravi at Syedwala	N	600
968	6-Lane Bridge (4-lanes for roadway and two lanes for LRT Lahore – Shahdrah)	N	950
969	Victoria Bridge Linking Malikwal - Pind Dadan Khan.	N	1,000
982	Bridge on River Indus (Khanote – Hala old)	N	2,500
983	Bridge on River Indus (Dault pur – Shehwan)	N	2,500
	Total		16,360
	Urban Bypasses in Punjab Province		
1011	Chakwal	N	1,380
1012	Bhakkar	N	850
1013	Khushab	N	1,275
1014	Mianwali	N	850
1015	Jhang	N	1,200
1016	Toba Tek Singh	N	960
1017	Mandi Bahauddin	N	1,290
1018	Sialkot	N	1,800
1019	Multan	N	1,900
1020	D.G.Khan	N	2,125
1021	Layyah	N	750
1022	Muzaffargarh	N	1,176
1023	Rawalpindi	N	8,000
1024	Lahore	N	16,900
1025	Gujranwala	N	3,430
1026	Bahawalpur	N	920
1027	Bahawalnagar	N	341
1028	Rahim Yar Khan	N	219
1029	Khan Pur	N	170
	Total		45,536

Note: I: Improvement, N: Construction, W: Widening, D: Dualization
Source: PTPS Final Report, JICA Study Team

Currently, 10 motorways (M1 - M10) with a total length of 2,667 km are under operation or have been planned already. In addition to these, nine motorways totalling 2,140 km were proposed by PTPS (Figure 3.2.1). As the highway network configuration has been almost completed, the main stream of road investment is "widening and improvement" rather than "new construction" (Figure 3.2.2). In connection with the highway development, 17 new bridges were proposed to be constructed on the Indus River and its tributaries in addition to the existing 48 bridges (Figure 3.2.3). Urban bypasses were also proposed for 37 cities, in addition to the existing 65 bypasses (Figure 3.2.4).

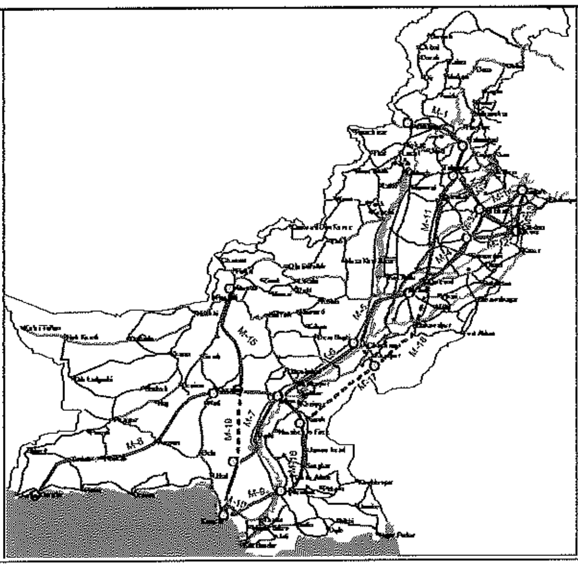


Figure 3.2.1 Proposed Motorway Network

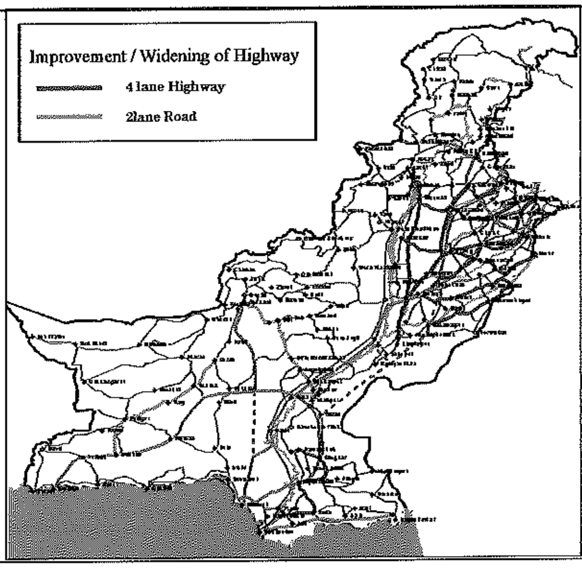
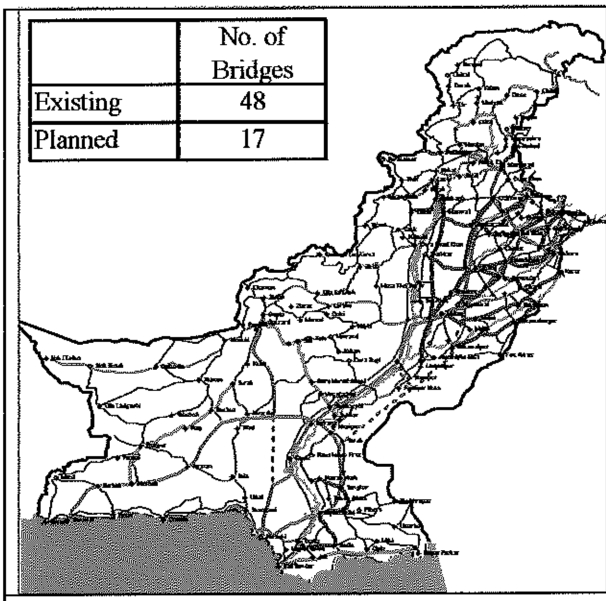
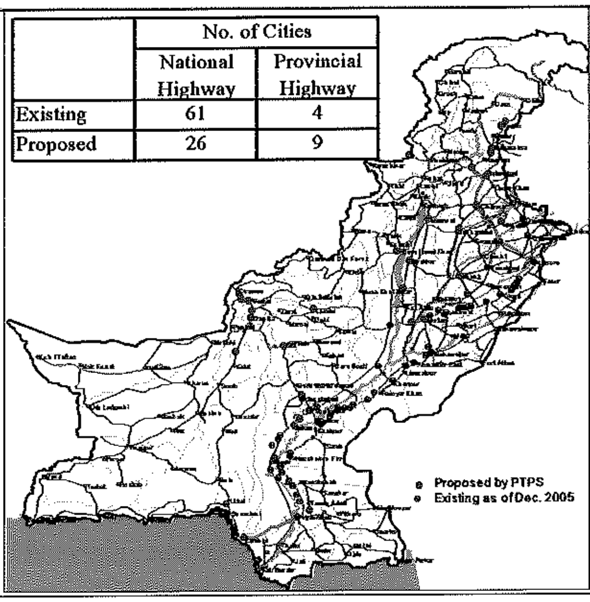


Figure 3.2.2 Highway Improvement and Widening



	No. of Bridges
Existing	48
Planned	17

Figure 3.2.3 Existing and Proposed Bridge



	No. of Cities	
	National Highway	Provincial Highway
Existing	61	4
Proposed	26	9

Figure 3.2.4 Existing and Proposed Bypass

(3) Non-investment Projects

The action plan for legislative, institutional and enforcement improvement recommended for the road sector in the Master Plan is as summarized in Table 3.2.3. These actions are essential for developing a rational plan and effective use of infrastructure.

Table 3.2.3 Recommended non-Investment Projects for Road Sector in PTPS

Sector	Project	Policy			Strategy						
		Support economic & Social Activities	Support regional Balanced growth	Realize optimal modal share	Financially realizable Master Plan	Transparent prioritization	Pursuit safety	Inter-modal facilities	Cross-border Facilities	Institutional capacity enhancement	Environmental consideration
General	Adoption of Quake Resistant Design Standard						■				
Road	Establishment of Highway Research and Training Center		■		■					■	
Road	Implementation and Enforcement of Traffic Safety Improvement Measures						■				
Road	Implementation and Enforcement of Anti-overloading Measures			■			■				
Road	Database Building on Traffic Accidents						■				
Road	Road Development Account and Capitalization of NHA Debt		■		■						
Road	Introduction of Road Tax	■			■						

Source: Extracted from PTPS Final Report, JICA Study Team

3.2.3 National Trade Corridor (NTC) Program

Pakistan's national road transportation system mainly depends on the North-South links. The existing North-South links are N-5 on the east bank and N-55 on the west bank of River Indus. N-5 serves for the life of Pakistan as it connects to approximately 80% of the urban population. N-55 acts as an alternative route to N-5 and has a high potential for future expansion.

Pakistan has common borders with four countries and the main overland trade routes with these countries are:

- Taftan in Balochistan (Pakistan-Iran boarder).
- Chaman in Balochistan (Pakistan-Afghanistan boarder at South).
- Torkham in NWFP (Pakistan- Afghanistan boarder at North).
- Sust (Gilgit) in N.A. (Pakistan-China boarder)
- Wagah in Punjab (Pakistan-India oarder)

The World Bank introduced to the Prime Minister of Pakistan the concept of North-South National Trade Corridor (NTC) in August 2005. This corridor plays a pivotal role in the transit trade to Afghanistan and the landlocked Central Asian countries.

A Task Force was established under the Deputy Chairman, Planning Commission with representatives from the Ministries of Communications/NHA, Railways, Ports &

Shipping/KPT, CBR and the World Bank.

Pakistan is geographically placed at a strategic location in South Asia. It is adequately linked by road with neighbouring countries and this ideal location has offered Pakistan the most attractive transit route to the inland countries. The two Karachi ports are linked to Charman through N-25 and to Torkham via N-5 and N-55. The Gwadar Port will be connected to the Central Asian states by the Khuzdar - Ratodero Motorway (M-5, N-25, N-55 and N-5). M-8 will link Gwadar with N-25 at Khuzdar and Indus Highway (N-55) at Ratodero. The National Highway N-35 (Karakoram Highway) will link N-5 at Hasanabadal to Khunjrab at the border with China.

The construction of the infrastructure to the required international standards is a prerequisite to achieve the targets. NHA is finalizing the route plan of NTC from Karachi to Torkahm at the Afghan border (refer to the implementation plan in Table 3.2.4).

Table 3.2.4 Route Plan of National Trade Corridor (NTC)

	Route / Section	Length (km)	Scope of Work	Estimated Cost (Mil. Rs.)	Financed by	Implementation Period
M7	Karachi - Dureji - Dadu	250	2-lane carriageway + 4-lane structures	18,000	GOP	2006-10
N-55	Dadu - Ratodero	150	2-Lane additional carriageway	11,250	GOP & GOJ	2007-10
N-55	Ratodero - Shikarpur	44	Converted to 4-lane Expressway	3,750	GOP & PPP/ADB	2008-09
N-65	Shikarpur -Sukkur	37	Converted to 4-lane Expressway	2,775	GOP & ADB	2007-09
N-5	Sukkur - Khaniwal	495	Converted to 4-lane Expressway	37,500	GOP & WB	2007-10
M-4	Khaniwal - Faisalabad	184	Construction of 4-lane Expressway	22,000	GOP & PPP-Malaysia	2007-10
M3	Faisalabad - Pindi Bhattian	54	Completed and open to traffic			-
M-2	Pindi Bhattian - Islamabad	243	Completed and open to traffic			
M-1	Islamabad - Peshawar	154	To be completed by 2006 (6-Lane) Two sections (37km+21km) were opened			-2007
	Peshawar Northern Bypass	34	Construction of 4-lane Expressway	3,078	GOP & PPP	2006-09
N-5	Peshawar - Torkhan Expressway	51	Construction of 4-lane Expressway	8,600	GOP & ADB	2006-09
N-5	Guranwala - Dina Expressway	100	Upgrading of ACW a& ECW	6,000	GOP & WB	2008-10
	Pindi Bhattian - Hafizabad - Wazirabad	100	Construction of 4-lane Expressway	6,600	GOP & WB	2007-09
	Four Bridges Over River Indus		Construction of 4 Bridges	12,000	GOP & WB	2008-11

Source: NTRC /NHA

3.2.4 Indus Highway (N-55) Improvement Program

The Indus Highway (N-55) Project, 1,264 km in total length, which constitutes the north-south link on the west bank of Indus River, was initiated in late 1980s. There was only one route (N-5) linking the northern and southern parts of the country. The Indus Highway provides an additional or an alternative route for N-5 reducing the overburdened traffic on it. The most important contribution of the project is the reduction in distance between Karachi and Peshawar by 500 km compared to the N-5 route.

The Government of Japan extended three loans (Jyen41,781 million in total) through OECF/JBIC for the improvement and construction of 761 km (approximately 60% of the total length) of Indus Highway from 1989 to 2003.

Table 3.2.5 Japanese Loans for Indus Highway Project

Item	Phase 1	Phase 2	Phase 2B
Loan Amount	Jyen 8,299 million	Jyen33,482 million	
Loan Agreement Signed	March 1989	January 1991	August 1993
Loan Completion	August 2000	May 2000	January 2003

Note: Post-Evaluation Report of JBIC on Indus Highway Project, 2004

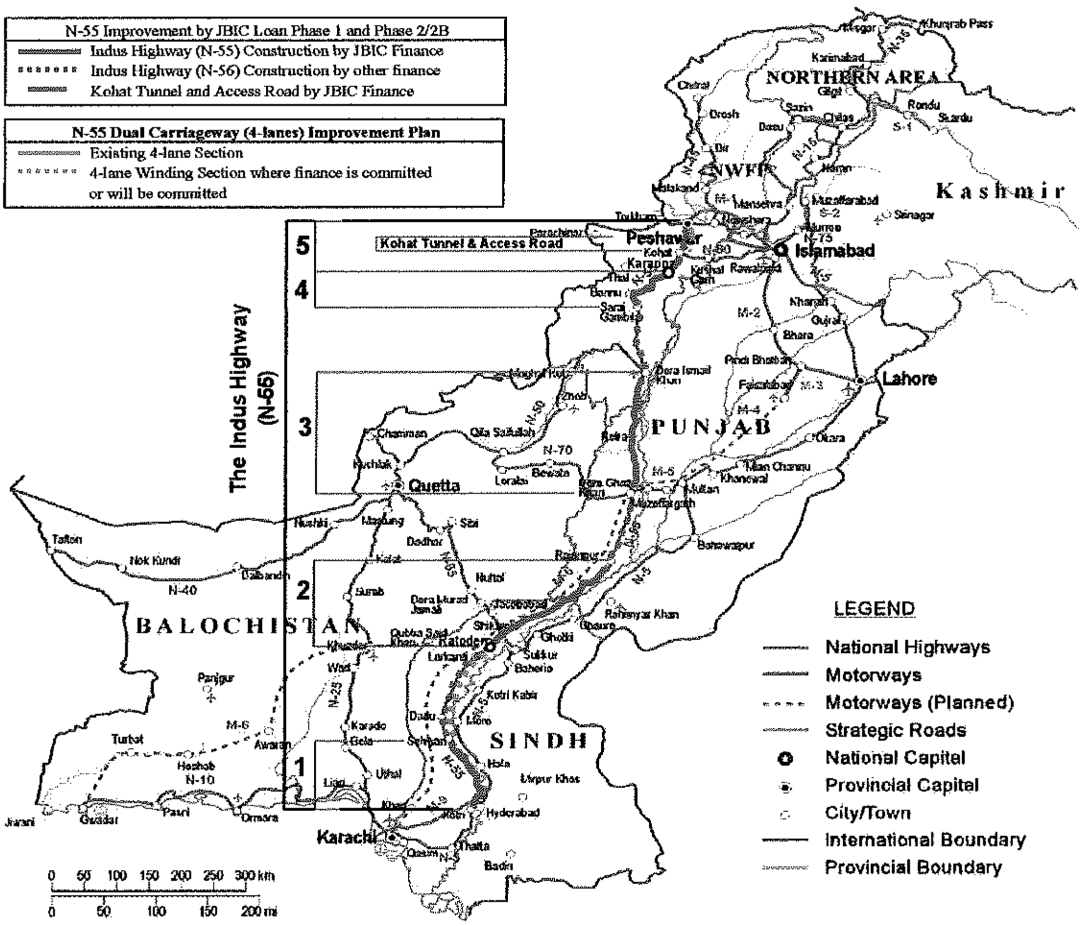
The sections listed in the following Table 3.2.6 and Figure 3.2.5 were improved with JBIC assistance to 2-lane standard roads, except for the 29 km long section near Peshawar which has 4 lanes.

Table 3.2.6 Indus Highway Project with JBIC Loans

No.	Section	Length (km)	Scope of Work	Completion Year
1	Janshoro (Kotri) - Sehwan	133	Improvement /Widening	1999
2	Ratodero - Rajampur	270	Improvement /Widening	1999
3	D.G.Khan - D.I.khan	211	Improvement /Widening	2001
4	Sarai Gambila - Karappa	96	Bypass Construction	1998
5	Karappa - Peshawar	51	Improvement /Widening (22km) Additional lanes (29km)	1996
	Total	761		

Source: Post-Evaluation Report of JBIC on Indus Highway Project, 2004

NHA has planned to improve by widening the Indus Highway to a dual carriageway road in line with the traffic increase and the strategic importance of N-55 including NTC. JBIC will finance the improvement and construction of additional two lanes for the Sehwan - Ratodero section (200 km).



Source: JICA Study Team

Figure 3.2.5 Indus Highway Construction with JBIC Loans

NHA has planned to upgrade the Indus Highway to a dual carriageway road in line with the traffic increase and the strategic importance of N-55 including NTC. The upgrading proposed to JBIC and ADB for their financial assistance is summarized in Table 3.2.7.

Table 3.2.7 Present Situation and Proposed Upgrading of the Indus Highway

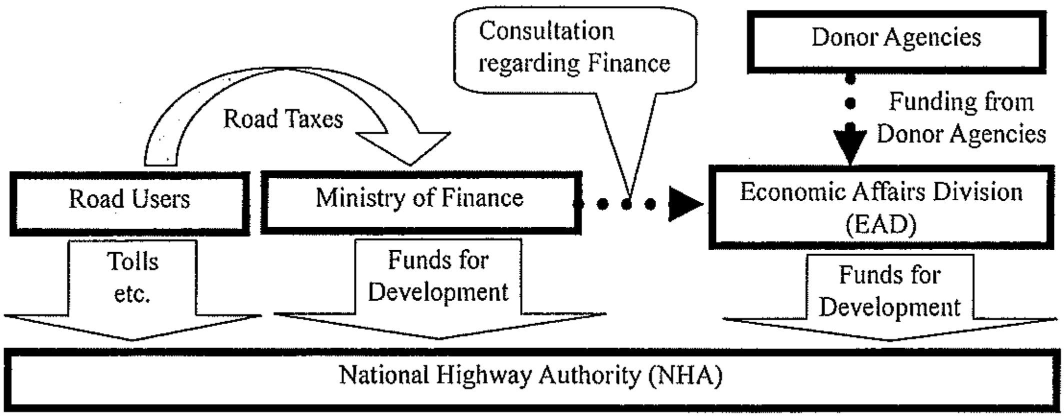
Section		Length (km)	Present Width	Finance	Completion	Proposed Upgrading	
						Scope	Expected Donor
Janshoro (Kotri)	- Sehwan	134	2-lane	JBIC	1999		
Sehwan	- Ratodero	199	2-lane			ACW	JBIC
Ratodero	- Shikarpur	44	2-lane			ACW & ECW	ADB
Shikarpur	- Rajanpur	226	2-lane	JBIC	1999	ACW	JBIC
Rajanpur	- D.G. Khan	106	2-lane			ECW	GOP
D.G. Khan	- Malana Junction	206	2-lane	JBIC	2001	ACW	JBIC
Malana Junction	- Serai Gambila	117	2-lane			ACW	ADB
Serai Gambila	- Karappa Chowk	93	2-lane	JBIC	1998	ACW	JBIC
Karappa Chowk	- Kohat Toi	26	2-lane	JBIC	1996		
Kohat Toi	- Dara Adam Khel	30	2-lane	JBIC	1996		
Dara Adam Khel	- Peshawar (Bada Ber)	28	4-lane	JBIC	1996		
Total		1209					

Note: ACW: Addiitonal Carriageway, ECW: Improvement of Existing Carriageway

3.3 Financial Situation of National Highway Authority

3.3.1 Financial Resources for National Highways

NHA (National Highway Authority) is funded in the following manner:



Sources: Interview with NHA

Figure 3.3.1 Flow of Funds for the NHA

NHA collects tolls from road users and borrows money or issues bonds after consultation with the Ministry of Communications (MOC). In 1991, the government decided that the road development should be switched from grants to loans.

The biggest components of the "Road Taxes" (Figure 3.3.1) are the surcharges on petroleum, oil and lubricants (POL) from road users. The following table shows the funding sources for NHA.

Table 3.3.1 Funding to the NHA

(Unit: Million Rs.)

Fiscal Year	Type of Funding					Total
	Loan for Development Fund	Grants for				
		Maintenance	Administration	Others	Sub-Total	
1991/92	5,152	378	6		384	5,537
1992/93	9,498	410	16		426	9,924
1993/94	8,084	430	17		447	8,530
1994/95	7,406	452	16		468	7,874
1995/96	6,100	356	15		371	6,471
1996/97	7,183	521	11		532	7,715
1997/98	9,952	600	20		620	10,572
1998/99	17,325	605	20		625	17,950
1999/00	16,364	660	21		681	17,045
2000/01	10,312	482	22		504	10,816
2001/02	10,900	760	23		783	11,683
2002/03	15,263	800	30	3	833	16,096
2003/04	16,243	825	32	3	860	17,103
2004/05	15,562	N.A.	N.A.	N.A.	N.A.	15,562

Source: PTPS Final Report, and additional information from NHA

3.3.2 Financial Outlook of NHA

(1) Financial Status of NHA

NHA has engaged in commercial activities since 2001 and is now preparing the commerce-based financial statements. Based on the draft financial statements (un-audited), the JICA study team has prepared Table 3.3.2 showing the financial status of NHA.

Table 3.3.2 Financial Status of NHA

(Unit: Rs.Million.)

FY	1998/99	1999/00	2000/01	2001/02	2002/03	Data Source
(1) Revenues						
Grants in Aid from Government	**625**	**681**	**504**	**783**	**833**	
Maintenance Grants	605	660	482	760	800	Data From NHA
Establishment Grants	20	21	22	23	30	
Other Grants	0	0	0	0	3	
Grants from Foreign Donors	3	3	2	2	2	
Toll Income	**184**	**1,022**	**2,186**	**2,220**	**2,570**	Financial Statement (Draft)
Others	121	355	241	369	591	
Total	**933**	**2061**	**2933**	**3374**	**3996**	
(2) Expenditures Maintenance & Restoration	621	756	1,051	2,355	1,406	Financial Statement (Draft)
Financial and other Charges	28	1,522	367	240	712	
Others	748	2,874	1,913	1,333	666	
Total	**1,397**	**5152**	**3,331**	**3,928**	**2,784**	
(3) Surplus before Depreciation (1)-(2)	-464	-3,092	-398	-555	1,211	Financial Statement (Draft)
(4) Depreciation Charges	771	1,305	1,342	1,207	972	
Surplus (3)-(4)	-1,235	-4,397	-1,740	-1,761	239	

Source: Prepared by JICA Study Team with NHA Financial Statement (Draft) and Other Documents from NHA

According to Table 3.3.2, NHA continued to run at a loss until the fiscal year 2001/2002. Even though there was a surplus in the fiscal year 2002/2003, this is due to the financial support received from the government. Accordingly, since NHA does not have enough financial resources for loan repayments and interest payments, NHA owed a total amount of Rs. 103 billion from loans at the end of the fiscal year 2002/2003 as shown in Table 3.3.3 below:

Table 3.3.3 Loans of NHA at the End of FY 2002/03

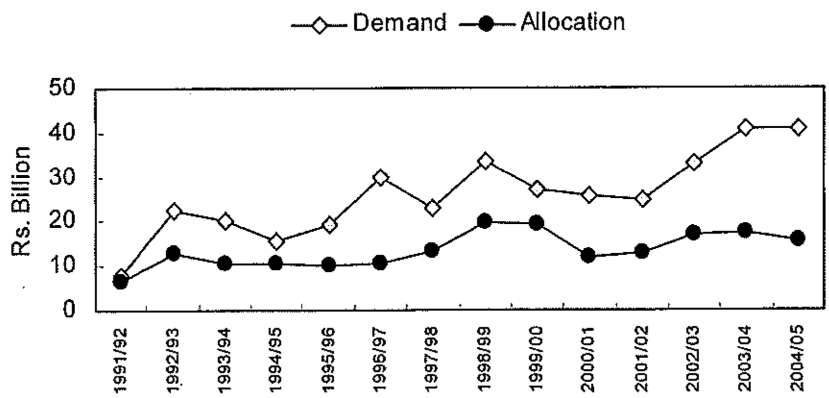
(Unit: Rs Million)

Lenders	Details	Amounts
Government of Pakistan	Cash Development Loans from the Government	68,082
Foreign Re-lent Loans	IBRD	6,274
	OECF/JBIC	13,688
	International Development Association	78
	Asian Development Bank	232
	Islamic Development Bank	324
Foreign Direct Loans	Turk Exim Bank (for work on the M1)	934
	Dawwoo (for work on the M2)	13,447
Total		103,061

Source: NHA Financial Statement (Draft)

(2) Fund and Expenditure for Development

For the construction and improvement of national highways, NHA has received funds from the Government through the Public Sector Development Program (PSDP). However, the allocations made available to NHA fell short of demand, as illustrated in Figure 3.3.2.



Source: NHA

Figure 3.3.2 Demand and Allocation of PSDP

(3) Road Maintenance Account (RMA)

Toll revenue is the major resource of fund for maintenance of the national highway network. In addition, the Federal Government provides an annual Maintenance Grant to NHA. The Maintenance Grant amounted to Rs. 825 Million in 2003/04.

In 2003/04, the total fund raised for maintenance was Rs. 3,774 million, 78% of which was the revenue generated, the remainder being the maintenance grant from the Federal Government, as shown in Table 3.3.4. However, the total fund for maintenance was insufficient to meet the increasing expenditure.

Table 3.3.4 Maintenance Fund and Expenditure

Fund (Unit: Million Rs.)

Source	2001/02	2002/03	2003/04	2004/05	2005/06	Total
Maintenance Grant	760	800	825	829		3,214
Net Revenue Generated	2,024	2,432	2,949	3,704		11,109
Total Fund	2,784	3,232	3,774	4,533		14,323

Expenditure

Province	2001/02	2002/03	2003/04	2004/05	2005/06	Total
Punjab	1,660	191	3,932	N.A		5,783
Sindh	548	320	821	N.A		1,689
NWFP	134	119	1,244	N.A		1,497
Balochistan	311	510	1,036	N.A		1,857
Total Expenditure	2,653	1,139	7,033	N.A		10,826

Source: NHA RAMD (Road Asset Management Unit

3.4 Road Safety and Overloading

3.4.1 Road Safety

Table 3.4.1 summarizes the accidents reported by NTRC. The accident data in 2001 shows 4,527 fatal and 6,060 non-fatal accidents resulting in 5,421 deaths and 12,942 injuries,

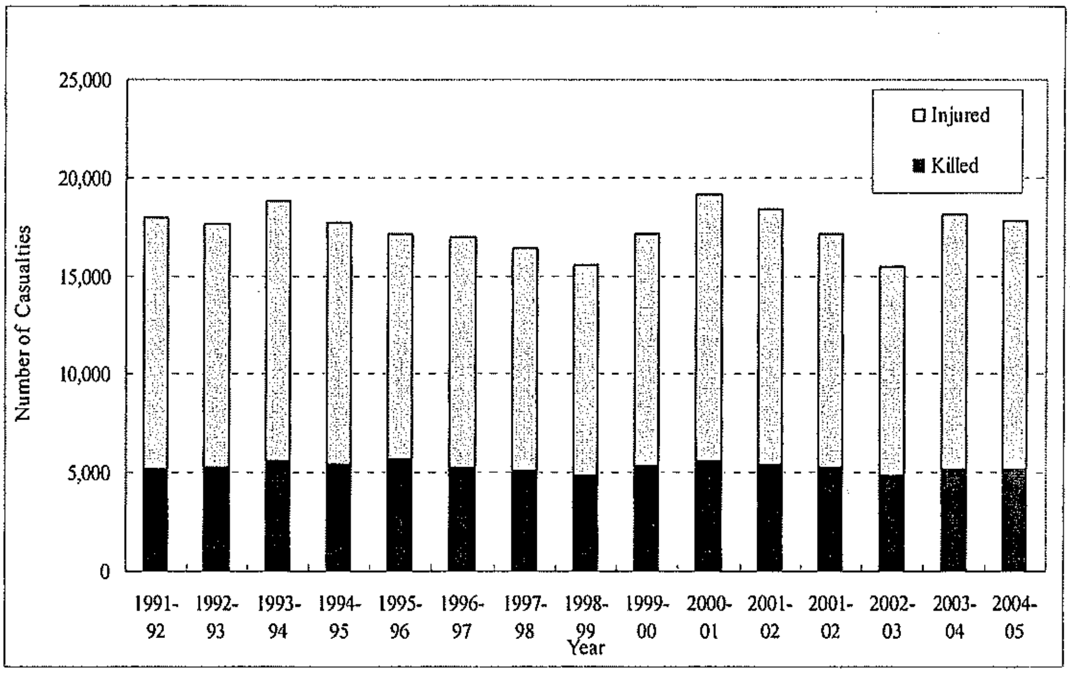
Table 3.4.1 Traffic Accident Statistics

Year	Fatal	Non-Fatal	Others	Total	Killed	Injured	Total
1996	4,383	5,369	2,938	12,690	5,301	11,697	16,998
1997	4,407	5,249	2,737	12,393	5,141	11,229	16,370
1998	3,620	4,317	418	8,355	4,196	9,817	14,013
1999	4,637	5,635	449	10,721	5,371	11,797	17,168
2000	4,629	6,114	409	11,152	5,627	13,479	19,106
2001	4,527	6,060	338	10,925	5,421	12,942	18,363

Source: Accident Statistics (1991-2001), NTRC

A road safety study conducted by NHA in 1998-1999 estimated 7,000 fatalities, 140,000 injuries and 1,400,000 property damage cases based on sample surveys carried out in four provinces, but a recent study by the ADB indicated that the road traffic accidents involved over 10,000 fatalities per year (over 30 per 10,000 vehicles) and 150,000 injuries. These are higher than the figures in Southeast Asia though better than those in India and Bangladesh.

Traffic accidents are also recorded by the Federal Bureau of Statistics. Despite a doubling of vehicle numbers, the number of fatal accidents and fatalities remains the same over a 15-year period (Figure 3.4.1). These data indicated that about 5,000 people are killed annually on the roads in Pakistan.



Source: PTPS Final Report, JICA Study Team

Figure 3.4.1 Number of Casualties in Traffic Accidents

3.4.2 Overloading

Overloading by trucks is one of the most typical phenomena in Pakistan. An Axle Load Study of the National Highways conducted by NTRC in 1995 showed that 43% of rear axle loads exceed the 12-tonne limit (the legal axle-load limit mandated by the Road Safety Act 2000). Figure 3.4.2 shows allowable load limits for national highways as per the National Highway Safety Ordinance-2000.

Allowable Axle Loads

The National Highways Safety Ordinance 2000 stipulates maximum axle loads and tyre pressures:

- Front axle – 5 tones
- Single axle - 12 tones
- Tandem axle – 22 tones
- Tridem axle – 33 tones
- Tyre pressure rear axle 120 psi
- Tyre pressure – front axle 100 psi

These regulations were passed in 2000 but an agreement was reached between NHA and the transport industry to allow some concessions on National Highways but not on motorways. The current situation for the various configurations is shown below.

Truck Type	Allowed on National Highways	Concession Granted by NHA in 2002	Allowed on Motor Ways
2 AX SINGLE (BEDFORD)	17.5	20	17.5
2 AX SINGLE (HINO / NISSAN)	17.5	23	17.5
3 AX TANDEM	27.5	32	27.5
3 AX SINGLE	29.5	32	29.5
4 AX SINGLE TANDEM	39.5	42	39.5
4 AX TANDEM SINGLE	39.5	42	39.5
4 AX SINGLE	41.5	44	41.5
5 AX SINGLE TRIDEM	48.5	51	48.5
5 AX TANDEM TANDEM	49.5	52	49.5
5 AX SINGLE SINGLE TANDEM	51.5	54	51.5
5 AX TANDEM SINGLE SINGLE	51.5	54	51.5
6 AX TANDEM TRIDEM	58.5	61	58.5
6 AX TANDEM SINGLE TANDEM	61.5	64	61.5

National Highway Safety Ordinance 2000 is being now amended after the steering committee held in Karachi in August 2005 to provide for the greater punishment of the originator of the overloading.

Figure 3.3.2 Concept of National Highway Audinance-2000

Chapter 4. GENERAL CONDITION OF THE PROJECT AREA

4.1 Socio-economic Conditions

4.1.1 Overview of Social Indicators in Pakistan

Pakistan is experiencing economic growth but poverty is still widespread throughout the country. It is difficult to state definitively which province is the poorest. For all practical purposes, NWFP and Balochistan are ranked equally the same in terms of poverty level. There are a number of factors which characterize poverty in Pakistan:

- Education: the proportion of literate household heads in poor households was almost half that in non-poor households.
- Poor households on average had 75% more children than non-poor households. In general these children do not receive any education
- Over one third of poor households were headed by aged persons who were dependent on pensions and similar forms of social support.
- Poor persons have few physical assets, such as land or livestock
- Poor rely on casual employment, such as day labour in agriculture, construction, trade and transport. Poverty is high among self-employed, such as street vendors
- Inequality in land ownership makes the poorest sections of rural society more vulnerable to poverty shocks.
- Environmental degradation is a cause of poverty in Pakistan, particularly in health effects.
- Waterborne diseases are widespread because 17% of urban and 47% of the rural population do not have clean drinking water.
- Poor are more vulnerable to disease as they have limited income to spend on health, and sickness reduces their productivity.

Poverty is usually taken to mean lack of food, clothing, and shelter (housing) essential for a reasonable standard of living. There are many "standard of living" measures but the most important variables remain income and expenditure. Living standard is not determined by income and consumption alone, but also by other non-economic aspects such as life expectancy, mortality, access to clean drinking water, education, health, sanitation, electricity and security which are measures of well being. NWFP is lacking in social services as it has shortages of water, sanitation, clinics and schools.

There is little documentation on the gender dimensions of poverty but incidence of poverty among women in Pakistan is higher compared with men, and is characterized by low endowment of land and productive assets, unemployment, discrimination in the labour market, and limited access to economic options and political processes. Income or consumption related vulnerability is likely to be high in female headed households clustered around the poverty line.

The government recognizes that sustained growth is critical for poverty reduction but growth alone is not enough. A sustained economic growth policy must be accompanied by other poverty alleviation measures such as investment in education, health and other human development activities, integrated small public works programs in both urban and rural areas, and other social safety net measures. Expenditures on roads and highways constitute the major share in community services. This has grown 250% in three years from Rs.6.34 billion in 2001-02 to Rs.16.6 billion in 2004-05. This will contribute to mitigating poverty in rural areas.

The Government of Pakistan has adopted the Millennium Development Goals which includes halving poverty by the year 2015. The government has stated that improvement in transport infrastructure through the provision of better road conditions is a major factor in poverty alleviation.

4.1.2 Key Social Indicators in NWFP

NWFP has relied mainly on roads for communications in the past as there is no well developed rail system, apart from the rail link through the Khyber Pass to Landi Kotal. NWFP has an extensive rural road network and the poor sector of the population may benefit most from any road improvement project.

NWFP is regarded as one of the poorest provinces. The Kohat tunnel project will pass through Kohat District and the Tribal areas. Information on the tribal areas is limited although the main place impacted by the road scheme is Dara Adam Khel town which is a well developed urban centre.

Kohat district is based on Kohat town which is an important armed forces centre. Comparison of socio economic indicators for Kohat and NWFP in general are given below.

Table 4.1.1 Socioeconomic Indicators for NWFP and Kohat District

Socio-economic Indicator	North West Frontier Province	Kohat
Population	17,744,000	563,000
Annual Population Growth Rate	2.8%	3.3%
Persons / Household	8.0	7.4
Unemployment Rate	26.8%	38.4%
Drinking water supply inside house	35.3%	57.63%
Electric lighting	72%	86%
Wood used for cooking	83.7%	77%
Gas used for cooking	9.8%	11%
Illiterate – all population	65%	56%
Illiterate – male population	50%	35%
Illiterate – female population	81%	76%
Number of primary schools – male	10,692	503
Number of primary schools - female	6,188	286
Number of hospitals	123	7

Source: "Socio-economic Indicators at District Level NWFP", Federal Bureau of Statistics, GOP 2002

The population growth rate in Kohat is slightly higher than the province average. Unemployment is higher indicating lower job opportunities. In general supply of electricity, drinking water and cooking fuel in Kohat is higher than the province average. Illiteracy levels are lower than average and the number of schools and hospitals is slightly higher than the average. In general discussions with residents, all were in favour of a new tunnel and Kohat ring road as it will benefit local people. After discussions with local government officers the EPA, Wildlife Department and Forestry Department all stated that they had no objection to the scheme.

4.2 Topography and Geology

4.2.1 General Topography

On the east bank of the Indus River in the northwest of Pakistan, the Potohar Plateau with an elevation between 400 m and 700 m above sea level spreads from north to south. The area of the Potohar Plateau has the shape of a distorted trapezoid. Its north edge extends from the junction of the Indus River and the Kabul River in the west to Rawalpindi City in the east along the Highway No.5. The Salt Range with an elevation between 1,000 m and 1,500 m above sea level forms the base of the trapezoid in the south, and the Indus and Jhelum Rivers form its west and east edges respectively. The Potohar Plateau is characterized by many hills, terraces and alluvial plains. The hills consist of Tertiary formations and terraces consist of Quaternary deposits partially covered with Aeolian losses.

On the west bank of the Indus River, branches of the Hindu Kush Mountains ranging in elevation from 2,000 m to 3000 m flow from north to south along the border with Afghanistan. The Project area is located on the Adam Khel Mountain which is one of these branches. It extends from east to west at an elevation between 1,000 m and 1,200 m and forms a watershed between the Peshawar Basin (EL=600 m) in the north and the Kohat Basin (EL=500m) in the south.

The 2nd Kohat Tunnel and Access Road will be constructed in parallel with the 1st Kohat Tunnel and Access Road on their east side. This 30 km long highway connects the above two basins.

4.2.2 General Geology

A geological map of North-West Frontier Province and Northern Punjab Province is shown in Figure 4.2.1, and the stratigraphy of the Potohar Plateau is illustrated in Table 4.2.1. As shown in these table and figure, the Adam Khel Mountain consists of Samana-Sak formation of Upper Palaeocene, Lockhart formation of Middle Palaeocene, and Patara formation of Lower Palaeocene. All of these formations are marine sediments and comprise sandstone, shale, limestone and their alternation. They are complexly folded and faulted by the Himalayan Orogenic Movement during the Tertiary age.

The central part of the mountain consists of limestone named Kohat Limestone. The southern access road is located on a flood plain and hills of the Kohat Basin. There exist many small composite fans at the foot of the mountain. The flood plain is covered with gravel partially accompanied by clay. Most rivers are influenced by a seasonal semi-dry climate, therefore there is no running water in the river channel except in the monsoon season from July to August. Hills consist of basement rock but sometimes they are covered with Soan formation of Pleistocene. The northern access road is constructed at the foot of the mountains and in a narrow valley plain. Therefore, this road passes through basement rocks and alluvial gravels. According to the geological map of Pakistan, the Indo-Pakistan plate moved from south to north and collided with the Eurasian plate during the Eocene age. As a result, rapid upheaval of the Himalaya Mountains and Tibet Highland began at the north edge of the Indian Sub-continent, while large scale subsidence occurred at the south edge of the collision. Thick Tertiary formations are deposited in this subsidence area where the Indus River flows from north to south at present. The Project area is located on the south edge of the Himalayan Fold Belt formed by the orogenic movement.

Table 4.2.1 Stratigraphy of Potohar (Potwar) Plateau

Era	Period	Epoch	Geological Formation	Lithology
Cenozoic	Quaternary	Holocene	Alluvial Plain Deposit	River Deposit Unconsolidated gravel, sand, silt, and clay
		Pleistocene	Aeolian Terrace Deposit	Potohar Silt and Losses. Yellowish brown, unconsolidated silt and strongly cemented red silt
			Upper Siwalik Group (Soan Formation)	Fresh Water Clastic Sediment. Conglomerate, sand stone and clay stone
	Tertiary	Pliocene	Middle Siwalik Group (Soan Formation)	Fresh Water Clastic Sediment. Cyclic alternation of clay, sand stone and gravel.
		Miocene	Lower Siwalik Group (Chinji, Nagri Formation)	Fresh Water Clastic Sediment. Red clay and sand stone
		Eocene	Rawalpindi Group (Muree , Kamlial Formation)	Fresh Water Clastic Sediment. Alternation of sandstone and shale.
		Oligocene		
		Palaeocene	UpperPalaeocene (Patala Formation)	Marine Sediment. Shale with limestone and sandstone
			Middle Palaeocene (Lock hart Formation)	Marine Sediment. Medium grained nodular limestone.
			Lower Palaeocene (Hangu Forrmation)	Marine Sediment. Sandstone
Mesozoic	Cretaceous		Upper Cretaceous (Kawagrah Formation)	Marine Sediment. Fine grained limestone with shale.
	Jurassic		Middle Jurassic (Samana Suk Formation)	Marine Sediment. Limestone
Pre-Cambrian (Basement)			Salt Range Formation.	Marine Sediment (Evaporite Sediment) Rock salt, gypsum and marl

Bedrock of Human Prehistory in Pakistan, Syed Muhammad Ashfaque, Pakistan Study Centre, University of Karachi (1994)

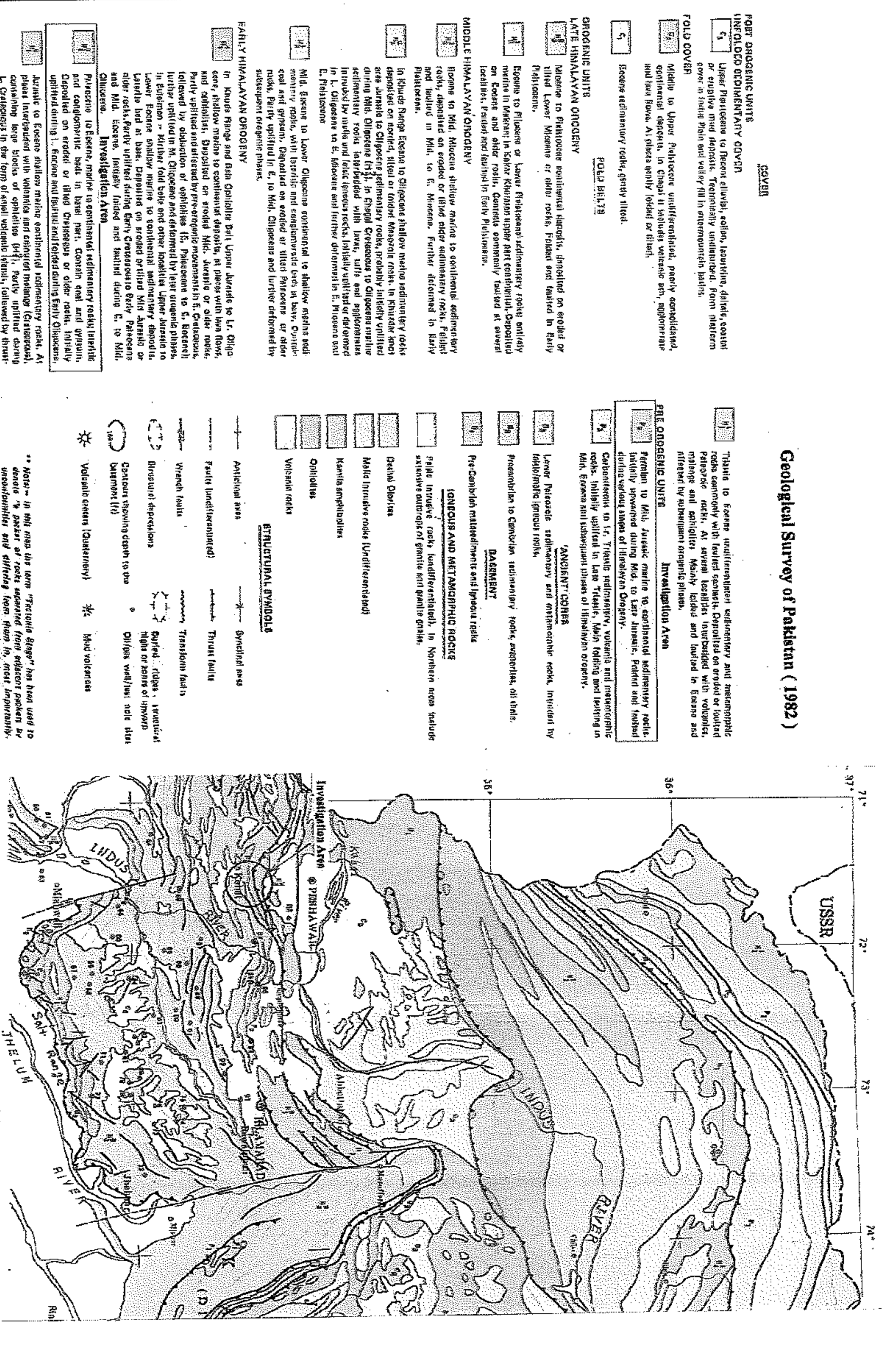


Figure 4.2.1 Geological Map of Pakistan

Chapter 5. EXISTING KOHAT TUNNEL AND ACCESS ROADS

5.1 Background

The National Highways N-5 and N-55 on the north-south axis are the major trunk road transport corridors in Pakistan. N-55 (Indus Highway) runs on the west bank of the Indus River from Kotri to Peshawar through D.G. Khan, D.I. Khan and Kohat over a total length of 1,264 km.

The Government of Pakistan (GOP) through NHA implemented the Indus Highway Construction Project. The Government of Japan extended three loans (Jyen 41,781 million in total) through OECF/JBIC for the construction of 761 km (60%) of the Indus Highway from 1989 to 2003. However, the road section crossing the steep mountainous terrain at Kohat Pass was the bottleneck of the Indus Highway, particularly caused by heavy vehicles that can run only at a speed of 10-30 km/hour maximum due to steep gradients and sharp bends (see following photographs).

Kohat Pass (Aug.2006)

Kohat Pass (Aug.2006)

The Kohat Tunnel study was initiated in 1973 and several studies were conducted since then. The latest feasibility study of the Kohat Tunnel and Access Roads (Kohat Toi-Dara Adam Khel Section) was conducted in 1990 as a part of the Indus Highway Project and the detailed design was conducted in 1990-1991. GOJ extended loans totalling Jyen 12,618 million in 3 phases for the construction of the Kohat Tunnel and Access Road including consultancy services (Table 5.1.1).

Table 5.1.1 Japanese Loans for Kohat Tunnel and Access Road Project

Item	Phase 1	Phase 2	Phase 3
Loan Amount	Jyen 5,437 million	Jyen 4,032 million	Jyen 3,149 million
Loan Agreement Signing	November 1994	July 2001	February 2003
Loan Completion	January 2001	Not yet completed	June 2006

Note: Post-Evaluation Report of JBIC on Kohat Tunnel Construction Project, 2005

In September 1996, NHA awarded a contract for consultancy services on Kohat Tunnel and Access Road Project to Pacific Consultants International (PCI), Mouchel Consulting Ltd. in association with Engineering Associate (EA) and NESPAK. The consultant reviewed the design of the Kohat Tunnel and Access Road including the tunnel route in 1998. Subsequently NHA awarded a contract for the construction of the 1st Kohat Tunnel (a bidirectional 2-lane tunnel) and Access Road to Taisei Corporation (Japanese firm) in June 1999. The construction was started in August 1999 and completed in April 2003 with a construction period of 45 months.

5.2 Construction of the 1st Kohat Tunnel and Access Roads

5.2.1 Outline of Facilities

The total length of the Project is 30.630 km: 28.745 km of access roads and 1,885 m of tunnel. The Project included 5 major interchanges/intersections, 11 bridges and allied facilities (Administration Building, Tunnel Control Room, Emergency Area Building, and Main Toll Plaza). Main features of the 1st Kohat Tunnel and Access Roads Projects are as outlined in Table 5.1.2 (also refer to the photographs in the next page).

Table 5.2.1 Summary of 1st Kohat Tunnel and Access Roads Project

Item	South Section	North Section
• Access Roads		
- Design Speed	90 km/hour	80 km/hour
- Length (28.745 km)	20.985 km	7.760 km
- Carriageway Width	7.30 m (2 lanes)	7.30 m (2 lanes)
- Shoulder Width	3.00 m (both sides)	3.00 m (both sides)
- Pavement	AC Pavement	AC Pavement
- Bridges (654 m)	7 Nos. (364 m in total)	4 Nos.(290 m in total)
- Underpasses (Vehicular)	8 Nos.	5 Nos.
• Intersections/Interchanges	Kohat Toi (Start Point) N-80 (Rawalpindi Road) IC * Kohat Link Road IC	Dara Adam Khel (End Point) NWF (Sanda Basta) Road IC
• Allied Facilities	Administration Building Tunnel Control Room Main Toll Plaza * Toll Plaza for Kohat Link Road	Emergency Area Building
• Tunnel		
- Length	1,885 m	
- Total Width	9.40 m	
- Carriageway Width	7.30 m (2-lanes)	
- Shoulder Width	0.30 m (both sides)	
- Walkway Width	0.75 m (both sides)	
- Vertical Clearance	5.10 m	
- Gradient	2.2% (ascedeing to northbpund)	
- Pavement	Concrete pavement (t=30 cm)	
- Emergency Areas	5 Nos.	
- Ventilation	Jet Fans (10 Nos.)	
- Other Facilities	Emergency phones, Luminaries, CCTV camera, etc.	

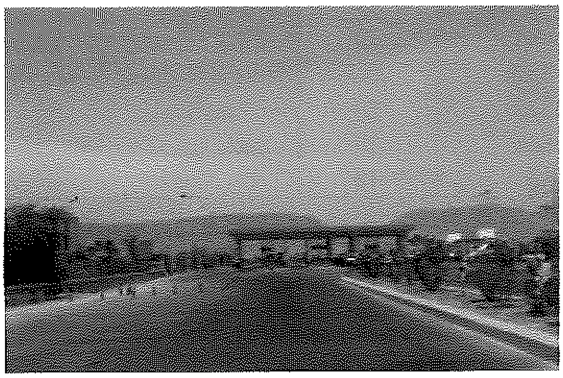
Note: * Constructed by NHA's own funding

NHA constructed the Kohat Link road (7.0 km in length) connected to the Kohat Tunnel Access Road at Sta.15+575. About 40% of the traffic uses this link road for access to/from Kohat Town instead of N-80 IC at Sta.9+645.

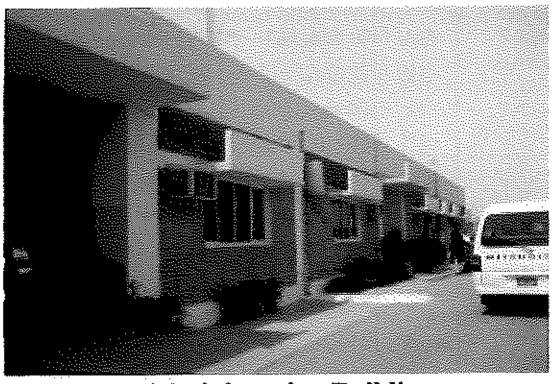
NHA then constructed a new toll plaza at Sta.17+400 to combine the Main Toll Plaza at Sta.10+600 and the Kohat Link Road Toll Plaza at Sta.15+575. Operation of the new toll plaza was initiated by NHA in July 2006.

Kohat Toi Intersection (Start Point)

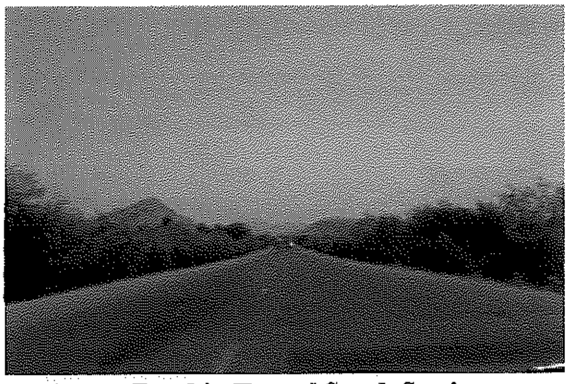
Dara Adam Khel Intersection (End Point)



Main Toll Plaza at Sta.10+600

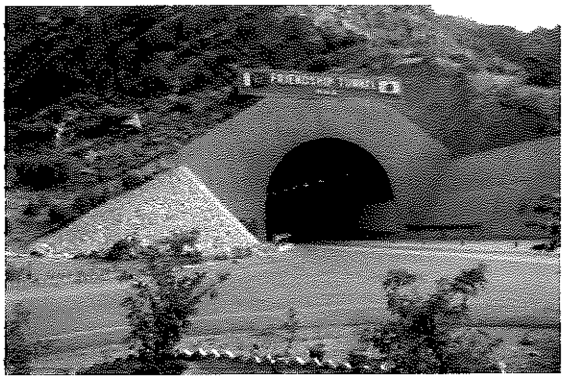


Administration Building

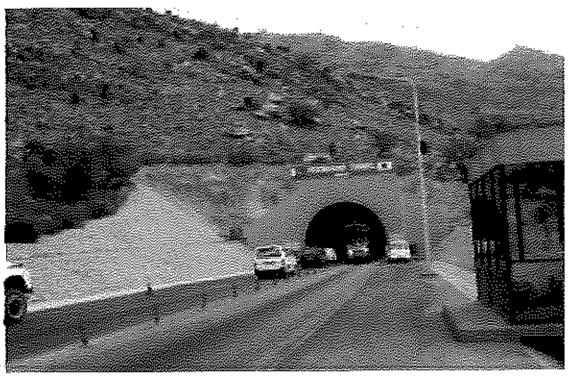


Access Road in Tunnel South Section

Access Road in Tunnel North Section



Kohat Tunnel South Portal



Kohat Tunnel North Portal

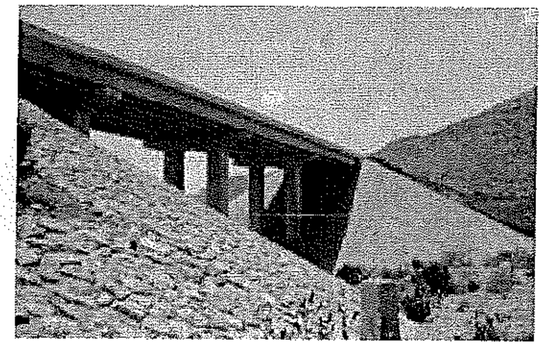
5.2.2 Bridge Construction

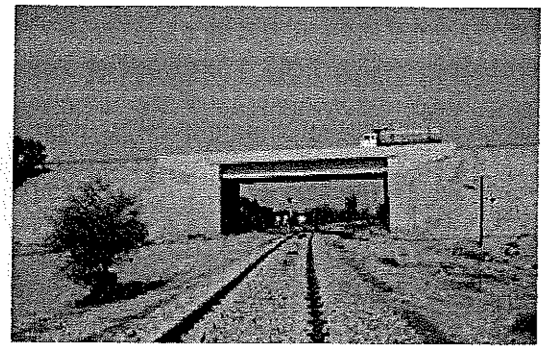
Eleven bridges listed in Table 5.2.2 were constructed under the Project. Of these, Bridge No.4 was constructed with a dual carriageway (4-lane bridge) while the others were constructed as 2-lane bridges. Seven bridges cross over rivers and five over roads, railways and tracks. Nine bridges are of PC girder type and two of RC girder type. Cast-in-palace piles (dia.750 mm and 900 mm) foundation applied for the bridges except Bridge No.8 for which spread foundation was adopted.

Table 5.2.2 List of Bridges under 1st Kohat Tunnel and Access Roads Project

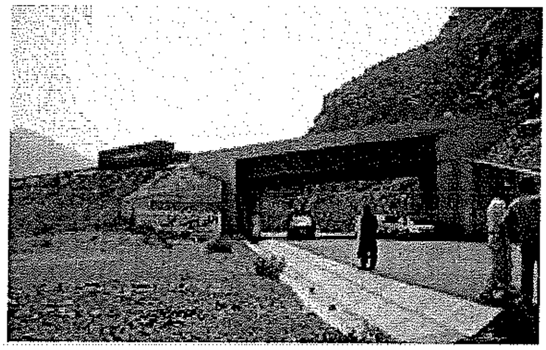
No.	Station (at center)	Type	Length (m)	Span	Pile Length (m)	Remarks (Crossing over)
1	2+736.245	PC Girder	120	4 - 30 m Span	16	Jerma Minor/Kohat Toi
2	4+735.415	PC Girder	50	2 - 25 m Span	14	Chagai Algad
3A	9+454.363	PC Girder	20	1 - 20 m Span	20	Railway
3B	9+645.760	PC Girder	30	1-30 m Span	21.5	National Highway N-80
9	14+800.000	RC Girder	12	1-12 m Span	20	Bazi Khel Road
10	16+585.000	RC Girder	12	1-12 m Span	20	A track
4**	19+205.000	PC Girder	120	4-30 m Span	18	Chanzi Algad
			Kohat Tunnel			
5	18+920.415	PC Girder	50	2 - 25 m Span	20	Osti Khel Algad
8	19+082.700	PC Girder	20	1 - 20 m Span	Spread Fd.	NWF Road
6A	21+260.525	PC Girder	180	6-30 m Span	12	Osti Khel Algad & Panderi Algada
7	25+388.915	PC Girder	40	2-20 m Span	20	Mullah Khel Algad
	Total:		654	m		

Notes. 1. * River bridges
2. ** constructed as a dual carriageway (4-lane bridge)


Bridge No.4 (L=120 m, Pier Height=30 m)


Bridge No.3A (L=20 m)

Bridge No.3B (L=30 m)


Bridge No.8 (L=20 m)

5.2.3 Civil Works Cost

The final civil works cost was Rs.5,114 million. Earthworks accounted for 26.9%, the tunnel and its facilities 33.5%, pavement 11.4% and structures (bridges and box culvers) 11.5% of the total cost as summarized in Table 5.2.3.

Table 5.2.3 Summary of Civil Works Cost of 1st Kohat Tunnel and Access Roads

Unit (Rs Mil.)

Bill No.	Description	South Section		North Section		Tunnel		Total	
		Amount	Share	Amount	Share	Amount	Share	Amount	Share
Bill No.1	Earthworks	879	17.2%	497	9.7%			1,376	26.9%
Bill No.2	Sub-Base and Base Course	295	5.8%	119	2.3%			414	8.1%
Bill No.3	Surfacing	125	2.4%	43	0.8%			168	3.3%
Bill No.4A	Structures - Box Culverts	146	2.9%	56	1.1%			202	3.9%
Bill No.4B	Structures - Bridges	289	5.7%	101	2.0%			390	7.6%
Bill No.4C	Structures - Pipe Culverts	12	0.2%	5	0.1%			17	0.3%
Bill No.5	Drainage and Erosion Works	41	0.8%	300	5.9%			341	6.7%
Bill No.6	Ancillary Works	126	2.5%	95	1.9%			221	4.3%
Bill No.7A	Tunnel Civil Works					1,139	22.3%	1,139	22.3%
Bill No.7B	Facilities Works					573	11.2%	573	11.2%
Bill No.7C	Building Works					43	0.8%	43	0.8%
Bill No.8	Sub-Soil Investigation	6	0.1%					6	0.1%
Bill No.9	Provisional Sum	56	1.1%					56	1.1%
Bill No.10	Indirect Cost (Engineer's Facilities)							168	3.3%
Total		1,975	38.6%	1,216	23.8%	1,755	34.3%	5,114	100.0%

Source: Final Statement of Civil Works Contract, Kohat Tunnel and Access Road Project

5.3 Operation and Maintenance of the Existing Kohat Tunnel and Access Roads

5.3.1 Management and Operation Organization

NHA has contracted with the Management Contractor & Operator (MC&O), a private company (M/S.AXS Pakistan (Pvt) Ltd.), for the operation and management of the Kohat Tunnel and Access Roads since its opening in June 2003. The current organization of the tunnel operation and management is as shown in Figure 5.3.1. The organization is headed by the Chief Operating Officer of NHA stationed in the Kohat Administration Office. The head of the MC&O is the Operations Manager, who is supported by an Administration Officer and an Assistant Operations Manager.

5.3.2 Operation and Maintenance Cost

The current contract amount is Rs. 442 million for a 5-year period. This is within the toll revenues. Seventy six percent (76%) is for staff salaries, 8% for vehicles and 16% for operation and maintenance (electricity consumption charge, replacement of lights, etc.).

Table 5.3.1 Summary of Operation and Maintenance Cost for 1st Kohat Tunnel

Item	Description	Amount	
		(Rs.)	(%)
1	Staff Salaries	335,883,660	76.0
2	Tunnel Vehicles	35,353,000	8.0
3	Operation and Maintenance	70,921,281	16.0
	Total	442,157,941	100.0

Source: NHA Kohat Tunnel Operation & Maintenance Office

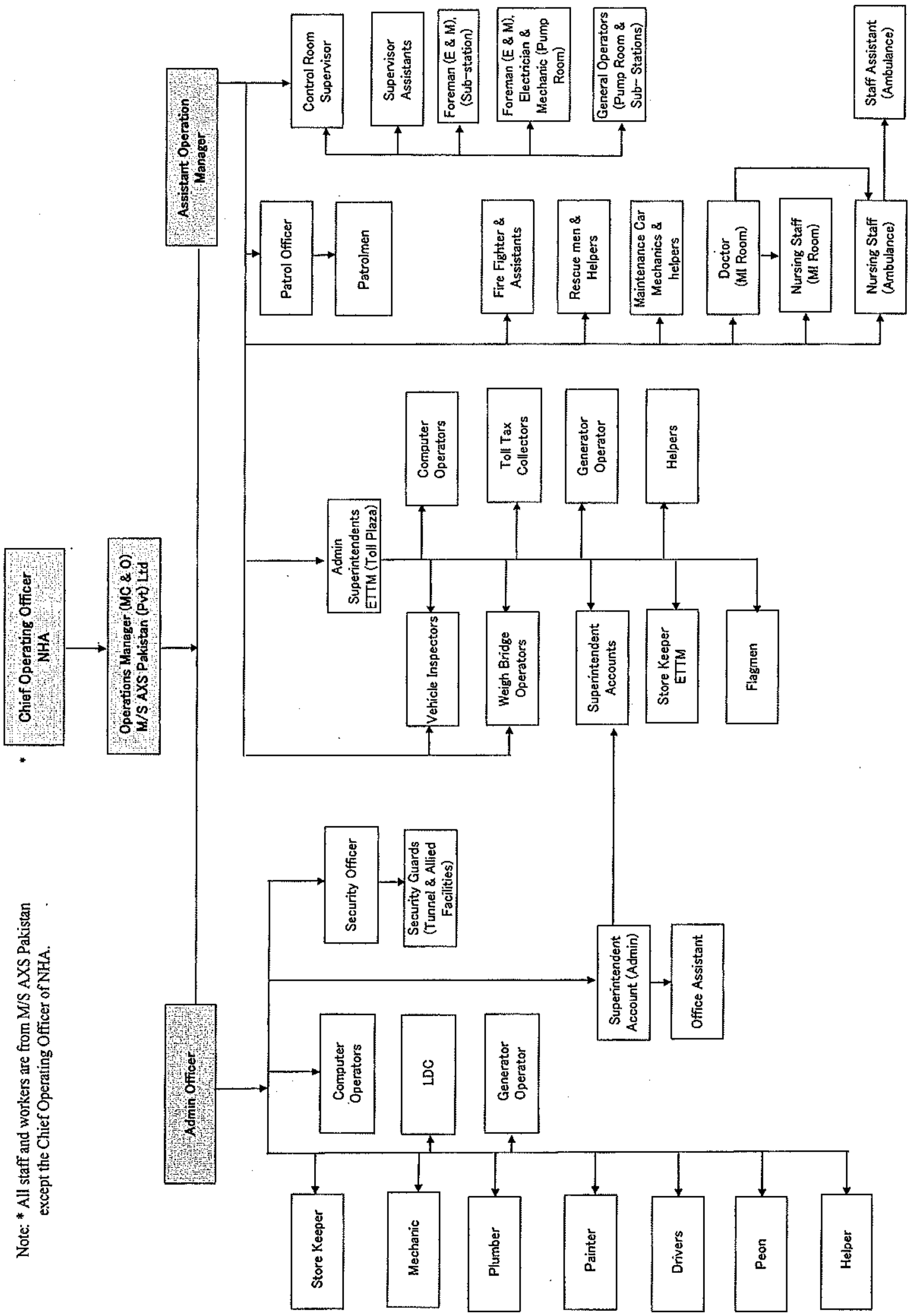


Figure 5.3.1 Organization of Kohat Tunnel Operation and Maintenance Office

A substantial part (approximately 86%) of the operation and maintenance item shown in Table 5.3.1 is for electricity charge. The monthly charge is approximately Rs. 1 million of which 83% is for lighting of tunnel and operation of jet fans as indicated in Table 5.3.2. Electric power is supplied directly by a separate power line. Two generators are kept on standby in the control room for backup in case of blackout.

Table 5.3.2 Electricity Consumption in May 2006

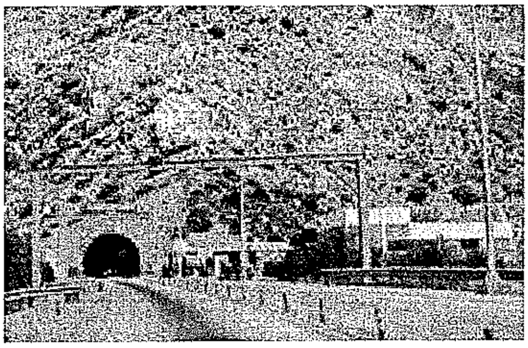
Item	Description	Amount	
		(Rs.)	(%)
1	Tunnel	843,532	82.5
2	Toll Plaza	49,375	4.8
3	Administration Building	74,769	7.3
4	Staff Resident Camp	32,240	3.2
5	North Emergency Building	22,013	2.2
	Total	1,021,929	100.0

Source: NHA Kohat Tunnel Operation & Maintenance Office

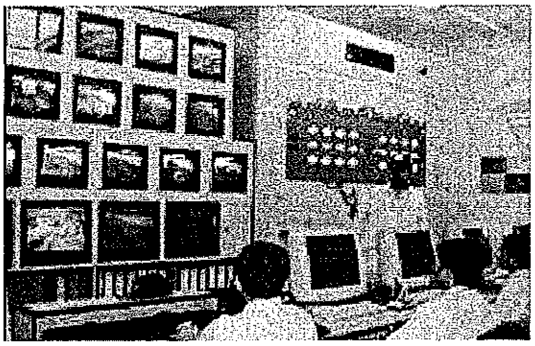
5.3.3 Operation and Maintenance Facilities

The following facilities have been provided for operation and maintenance of the tunnel and access roads:

- Administration Building
- Control Room (including CCTV monitoring, control boards, etc.)
- North Emergency Building
- Toll Plazas and weigh bridges
- Seizing barriers and vehicle inspection points
- Ventilation and lighting facilities including standby generators
- Emergency facilities for tunnel (emergency parking areas, press alarm buttons, emergency phones, fire extinguishers, etc.)
- Information and sign boards.



Control Room at South Portal



CCTV Monitoring and Control Board

There are 10 jet fans for ventilation and the operation (activating numbers) is controlled by CO percentage and visibility rate automatically. Eleven Hi-resolution CCTV cameras are installed at about 180m intervals for monitoring the tunnel inside and 5 cameras for the emergency areas for 24 hours/day.

The tunnel operation is classified into normal, partial and emergency modes. The normal operation means when two-way is secured. The partial operation is one-way traffic at regular time intervals from both sides escorted by a patrol car, which is required in times of tunnel system maintenance, earthquakes and after emergencies. The control system is basically in auto mode for these operations. The emergency mode in the tunnel includes vehicles collision, vehicle breakdown, fire, excess CO, poor visibility, power failure, terrorism, etc. In an emergency case, the tunnel is closed immediately for all vehicles and tunnel facilities are run in the manual mode and planned actions are taken.

5.3.4 Standard Operation Procedures (SOP)

Training of the MC&O was carried out by Japanese tunnel operation and maintenance experts prior to the opening of the tunnel to public traffic. The 1st version of the Standard Operating Procedures Manual (SOP) for the tunnel was developed jointly by the personnel involved. Japanese experts then revised it after 3 months of physical operation by incorporating the remedies for troubles encountered and improvements suggested by the MC&O. Further revision of SOP has been made recently and is waiting for formal approval by NHA.

Preventive maintenance has been planned on a weekly, monthly and yearly basis. Fire and rescue exercises are carried out periodically.

5.3.5 Staff and Vehicles

The MC&O has supplied 377 officers, supervision staff and working staff in total. These staffs are assigned for the Administration Building, Toll Plaza, Control Room, Substation, North Administration Building, Weigh Bridge, MI Room and Pump Room as detailed in Table 5.3.3. These staffs and workers work in two shifts for 24 hours.

Table 5.3.3 Operation and Maintenance Staff

Item	Description	Number	%
1	Operation Manager and Officers	5	1.3
2	Administration Building	75	19.9
3	Toll Plaza	73	19.4
4	Control Room	54	14.3
5	Substation	21	5.6
6	North Administration Building	60	15.9
7	Weigh Bridge	54	14.3
8	MI Room (Doctor and nursing staff)	10	2.7
9	Pump room	25	6.6
	Total	377	100.0

Source: NHA Kohat Tunnel Operation & Maintenance Office

There are 21 vehicles (as listed in Table 5.3.4) for the tunnel and access road operation and maintenance. Approximately 30% of vehicles are for administration use. Broken-cars, if any, in the tunnel (a few incidents daily) are moved out by towing tractors. Fire vehicles are kept on standby for emergency.

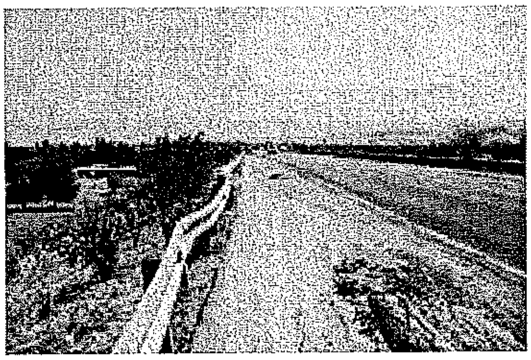
Table 5.3.4 Operation and Maintenance Vehicles

Item	Description	Number	%
1	Administration & Staff Car	6	28.6
2	Patrol Car	3	14.3
3	Ambulance	2	9.5
4	Fire Vehicle	2	9.5
5	Maintenance Vehicle and Sky Lift	2	9.5
6	Coach for Shift Duty	3	14.3
7	Water Tanker	1	4.8
8	Towing Tractor / Recovery Vehicle	2	9.5
	Total	21	100.0

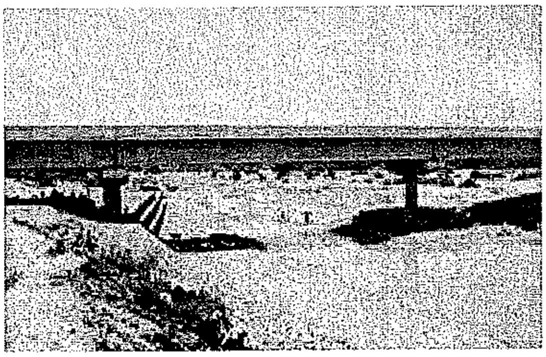
Source: NHA Kohat Tunnel Operation & Maintenance Office

5.3.6 Physical Repair and Maintenance of Road Facilities

Maintenance of the road facilities is carried out under contracts using the maintenance budget of NHA. NHA has executed shoulder repairs, bridge scouring repair, slope protection works, guard rail replacement, etc. since opening of the tunnel and access roads. Shoulders damaged at many locations by passage of vehicles have been reconstructed by NHA with cement concrete pavement or asphalt concrete pavement. The foundations of Piers 3 and 4 of Bridge No.1 which had been scoured by floods in the last rainy season have been protected with gabions by NHA. NHA has spent Rs.22 million for the shoulder repair and Rs.9 million for the scouring protection works since opening of the access road. Cut slope protection works (by grouted riprap) are underway at Sta.18+200 - Sta.18+600.



Shoulder / Guard Rail Damages



Scouring Repair Works by Gabion for Bridge No.1

5.4 Current Problems of the Existing Kohat Tunnel and Access Road

5.4.1 Vehicle Running Speed and Level of Service

The control speed of vehicles for the tunnel south section access road is 90km/hour and that for the north section is 80km/hour (same as the design speed). The 1st Kohat Tunnel was constructed as a 2-lane road (single carriageway) at a 2.2% gradient. The design speed of vehicles in the Kohat Tunnel is 60 km/hour. Vehicle running speed has been controlled at 40 km/hour and overtaking is not allowed in the tunnel for safety reason.

However, the actual travel speed is 16.7 km/hour and it takes 7-8 minutes (Table 5.4.1) for the north bound (up-grade) traffic as the travel speed in the tunnel depends on heavy vehicles.

Table 5.4.1 Travel Speed in Tunnel

From South Portal to North Portal (Up-grade)

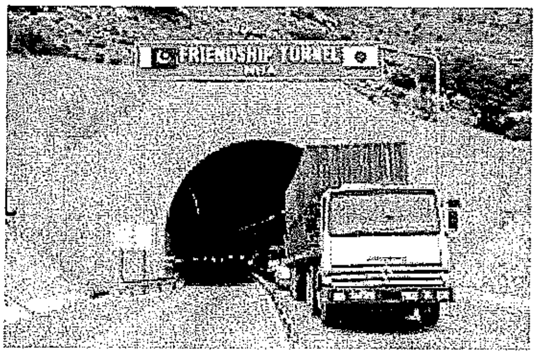
No.	Time			Speed
	In	Out	Time	(km/hour)
1	11:20:00	11:28:00	0:08:00	14.1
2	11:36:00	11:44:00	0:08:00	14.1
3	11:55:00	11:59:15	0:04:15	26.6
4	12:15:00	12:20:27	0:05:27	20.8
5	12:30:00	12:42:37	0:12:37	9.0
6	12:50:00	12:54:00	0:04:00	28.3
7	13:03:00	13:10:00	0:07:00	16.2
8	13:21:00	13:29:49	0:08:49	12.8
9	13:40:00	13:48:16	0:08:16	13.7
10	13:57:00	14:07:13	0:10:13	11.1
Average			0:07:40	16.7

From North Portal to South Portal (Down-grade)

No.	Time			Speed
	In	Out	Time	(km/hour)
1	11:30:00	11:34:00	0:04:00	28.3
2	11:49:00	11:52:55	0:03:55	28.9
3	11:02:00	11:05:56	0:03:56	28.8
4	12:23:00	12:26:55	0:03:55	28.9
5	12:45:00	12:48:34	0:03:34	31.7
6	12:58:00	13:01:00	0:03:00	37.7
7	13:14:00	13:17:35	0:03:35	31.6
8	13:34:00	13:37:48	0:03:48	29.8
9	13:51:00	13:54:49	0:03:49	29.6
10	14:10:00	14:13:21	0:03:21	33.8
Average			0:03:41	30.9

Notes: 1. Tunnel Length is 1.885km
2. Survey by the JICA Study Team on 20th June 2007

The travel speed for the south bound traffic is 30.9 km that is less than the controlled speed, even though it is down-grade traffic. The current level of service (LOS) in the tunnel section is "D", in accordance with Highway Capacity Manual (HCM) of Transportation Research Board, National Research Council, USA. Traffic flow in the tunnel is stable not only for the north bound traffic but also for the south bound traffic.



Slow Movement of Traffic at North Portal

Slow Movement of Traffic in Tunnel due to Heavy Trucks

The current ADT figure is approximately 7,400 vehicles but it will increase at high rates (refer to Chapter 7). The current LOS of the Kohat Link Road - Dara Adam Khel section is estimated at "C" but will drop to "D" level in the near future.

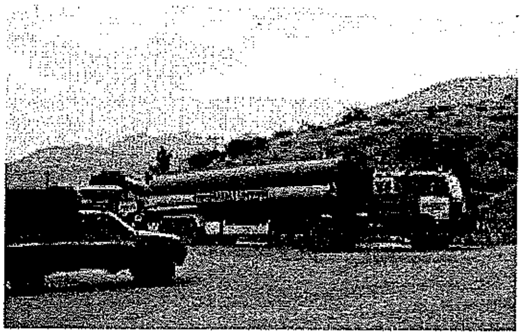
5.4.2 Public Complain on Auto-emission

The ventilation capacity (jet-fans) of the tunnel is sufficient and it is well-controlled by a computer-assisted system based on visibility and CO content, both of which are well below the admissible levels according to regulation. However, the public has complained of auto emission associated with forced slow travel speed in the tunnel. The emission problem was caused by slow movement of heavy vehicles due to overloading, insufficient vehicle maintenance and low quality fuel. However, those problems are not easy to solve even with NHA's continuous efforts to overcome them.

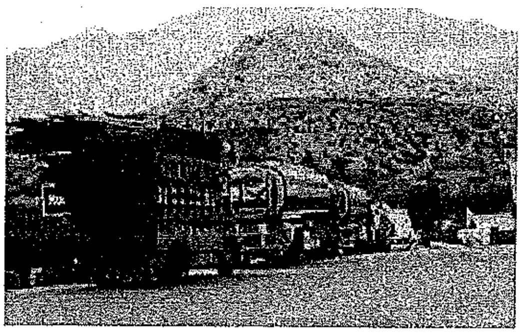
The best solution would be to construct the 2nd tunnel to increase the travel speed and reduce the travel time in the tunnel. It will increase satisfaction of the users while reducing complaints.

5.4.3 Safety in Tunnel

NHA has monitored safety aspects and maintained the tunnel on a 24-hour basis. Sufficient equipment and control systems, including CCTV, communication systems and other facilities and personnel, have been introduced. Vehicles carrying dangerous items like oil and out-sized materials are not allowed to enter the tunnel. These vehicles use the Kohat Pass road (see following photos).



Oil-tankers Passing on Kohat Pass Road

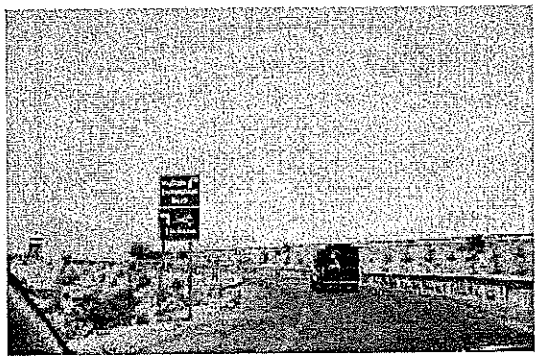


Trucks Carrying Oil and Over-sized Materials passing on Kohat Pass Road

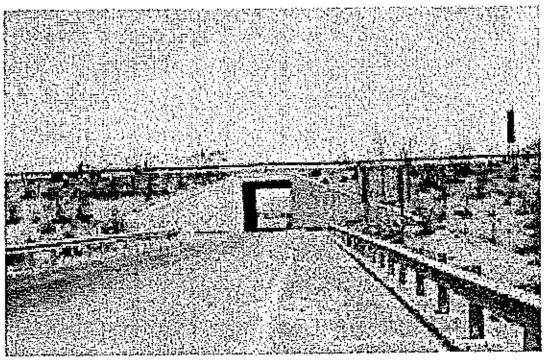
The maintenance and emergency procedures have been standardised and staff are well trained. Fortunately no car collision and fire have occurred in the tunnel since its opening However, there are risks in the case of fire and other unexpected incidents in the tunnels because there are no evacuation tunnels.

5.4.4 Kohat Link Road

The traffic flow between Kohat Town and Peshawar in the original plan was through the N-80 Interchange (Kohat-Rawalpindi Road IC) at Sta.9+645. NHA constructed the Kohat Link Road (L=7.0 km) at Sta.15+575 to provide a short-cut between Peshawar and Kohat and to reduce the passage of heavy vehicles through the Kohat Town centre. This Link Road contributes to minimizing traffic jam in the Kohat Town centre. Approximately 40% of the traffic goes to Kohat Town through the Kohat Link Road and 60% goes further to the south.



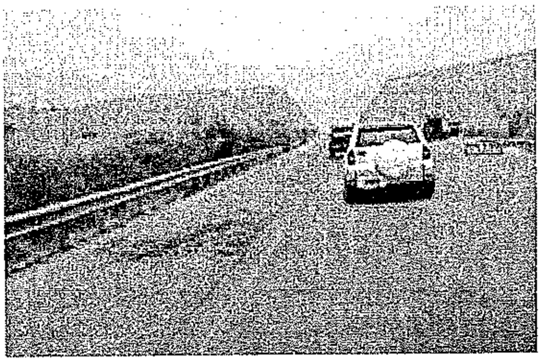
Kohat Link Road On-Ramp, No proper On-ramp for South



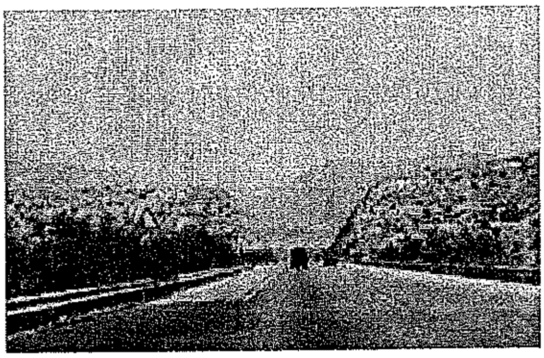
Kohat Link Road Off-Ramp, Narrow Box-culvert for Underpass

NHA has constructed a new toll plaza that started operation in July 2006 at Sta.17 + 400 combining the existing Main Toll Plaza at Sta.10 + 600 and the Kohat Link Road Toll Plaza at Sta.15 + 575. This arrangement will provide a function of bypass road (ring-road) for Kohat Town traffic as vehicles from/to the northern part of Kohat Town are allowed to pass the southern part of the Kohat Tunnel Access Road without payment. However, the current layout of the interchange facility between the Access Road and the Kohat Link Road is inappropriate to accommodate bypass traffic.

5.4.5 Damage of Shoulders



Damage of Shoulders



Repair of Damaged Shoulders

Many parts of the shoulders have been damaged by passage of heavy vehicles on them. The west side shoulder has been damaged over a length of 1,000 m and the east side shoulder over a length of 800 m. As the existing shoulder width is 3.0 m, that is not much different from the carriageway width of 3.65 m, some drivers misunderstand that it is a 4-lane road or they simply use shoulders as a convenient overtaking lane. As the pavement structures between the carriageway (AC 26-27cm thick) and the shoulders (DBST) are substantially different, the latter have been damaged by the passage of heavy vehicles. NHA has repaired the damaged shoulders either by replacing them with cement concrete or asphalt pavement using the maintenance budget provided by the head office.

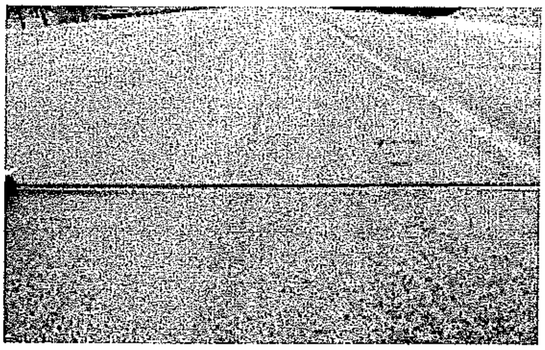
If additional two lanes are constructed, this kind of failure will be reduced substantially as overtaking can be done on the carriageway which has sufficient pavement strength. Heavy vehicles will be regulated to use the left lane and light vehicles the right lane.

5.4.6 Rutting and Pavement Failure

Pavement failure occurring earlier than the planned design life of roads is one of the major problems for the road administration. The major damages are rutting, pavement deterioration (cracking) and base failure due to heavy traffic, overloading, insufficient drainage, use of inappropriate materials, and substandard construction.

No major pavement failures have been observed on the 1st Kohat Tunnel Access Road since its opening in 2003 except for the above shoulder damage, because thick pavement (21-22cm AC base and 5cm AC wearing) was applied. However, minor rutting is seen and it might develop to serious condition in future. Besides, it is necessary to carefully monitor the development of cracks from the view point of medium- to long-term stability of asphalt concrete because the applied bitumen content during the construction was at the lowest value (3.5%) of the Standard Construction Specifications of NHA, taking resistance to rutting into account.

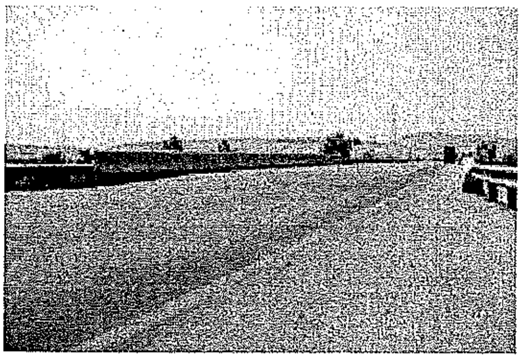
Minor Rutting (Depth 5-10mm)



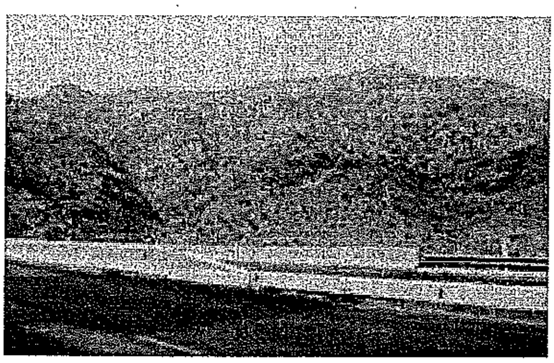
Rutting (Depth 15-20mm)

5.4.7 Settlement of Bridge Approaches

Settlement of bridge approaches was observed because no bridge approach slabs were provided for abutments. Though the settlement is 20-30 cm, it requires careful monitoring and periodical repair for safety to ensure the structures and pubic traffic.



Settlement of Bridge Approach (Bridge No.3)



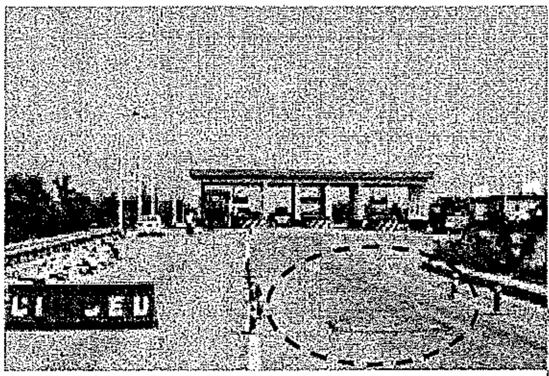
Settlement of Bridge Approach (Bridge No.4)

5.4.8 Overloading

Overloading of trucks is one of the major reasons for slow movement of vehicles in the tunnel. As overtaking is not allowed in the tunnel and a share of heavy vehicles is approximately 25%, the driving speed of heavy vehicles controls that of all other vehicles. Overloading also causes earlier pavement failure.

The Kohat Operation and Maintenance Office started overloading control utilizing weigh bridges at the Main Toll Plaza in July 2006 in accordance with the National Highways Safety Ordinance 2000.

A computer-assisted system is used. The gross weight of vehicles is measured when they pass on a weigh bridge installed at approximately 100 m before the toll gate and the recorded data are transmitted to the computer. Extents of overloading and imposed fines are indicated on an electrical board (see following photographs). Fines are collected by the operation and maintenance staff.



Weigh Bridge at Main Toll Plaza

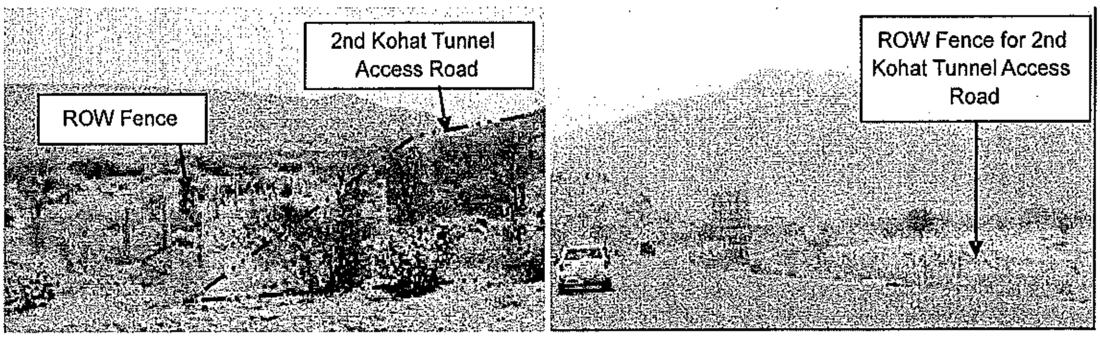
Computer Assisted Overloading Control and Fines Imposing System

5.4.9 The 2nd Tunnel and Access Roads in the Original Plan

The basic plan (the original plan) for the 2nd tunnel and access roads was made in the 1st Kohat Tunnel and Access Roads Project. Intersections and interchanges were constructed with 4 lanes. Bridge No.4 at Sta.19+200 was also constructed as a dual carriageway (a 4-lane bridge). The right of way (ROW) necessary for the future 2-lane winding was already secured on the east side (right hand side) for future 2-lane widening.

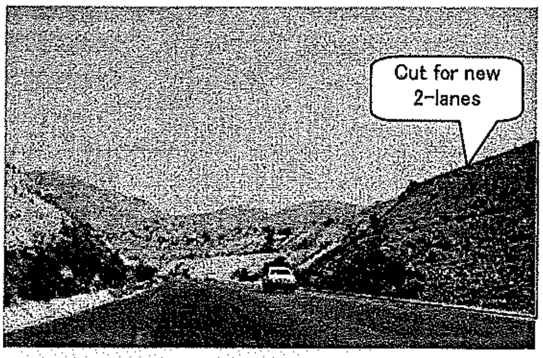
However, there are the following problems in the original plan to be considered for planning the 2nd Kohat Tunnel and Access Roads Project.

- New two-lane road is necessary to be designed utilising the 50 m wide ROW, which has been secured already through the Project road (see following photos).

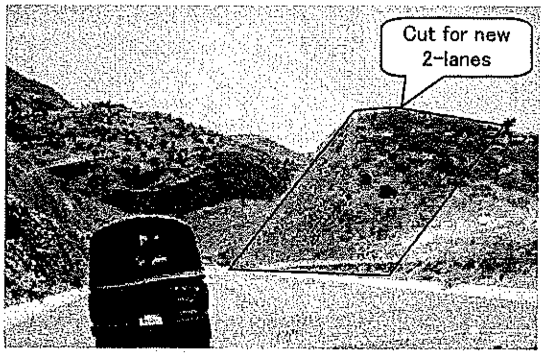


Existing ROW Fence for the 2nd Kohat Tunnel Access Road

- Road geometry in the original design did not use transition curves.
- High-cuts (H=20-30m) which may disturb the existing traffic during construction exist at several locations (see following photos).

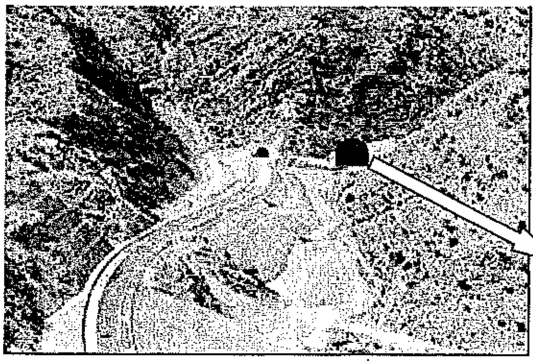


High Cut in South Section
At Sta.18+100 -Sta.18+700



High Cut in North Section
At Sta.23+850 -Sta.23+975

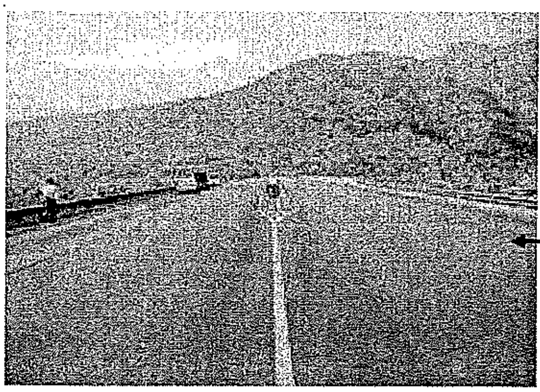
- Insufficient traffic capacity at intersections in the original design.
- The originally proposed position of the south portal is 70 m to the east of the 1st Kohat Tunnel. However, as there is a steep creek on the right (see following photos), it may face mud-flow during the heavy rains. The position 30-40 m to the east would be more stable but this would require moving the existing tunnel control room.



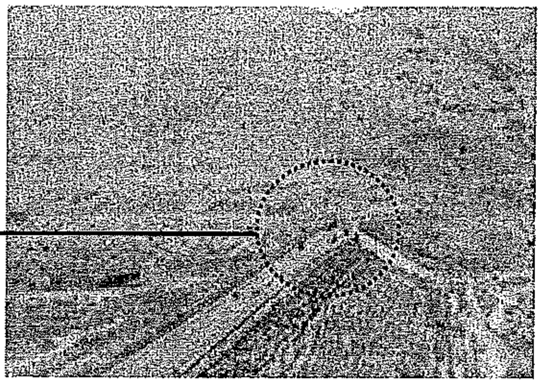
South Portal

A Steep Creek at South Portal (Right) in the Original Plan

- No approach concrete slabs were provided to prevent settlement of bridge approaches.
- It is better to use Bridge No.4 (L=120 m) already constructed as a 4-lane bridge for the 2nd Kohat Tunnel Access Road (see following photographs).

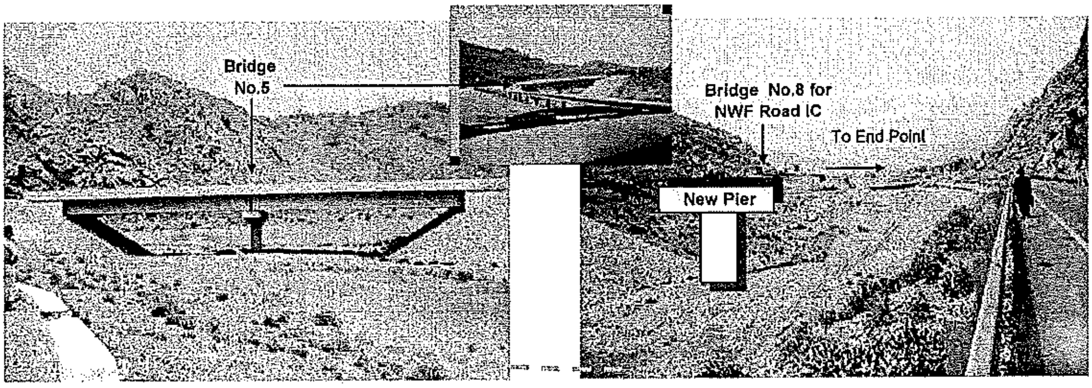


Bridge No.4 already constructed as a 4-lane bridge



Bridge No.4 already constructed as a 4-lane bridge

- Constructions of the new Bridge No.5R at Sta.18+935 at the river bend.



Bridge No.5 at Sta.18+935 Direction (Towards Up-stream) | **Bridge No.5 at Sta.18+935 Direction (Towards Down-stream)**

- The design of the bridges for the 1st Kohat Tunnel Access Road was conducted in 1990 and the applied seismic force was 0.05g - 0.07g (see Figure 5.4.1) in Zone III. NHA has reviewed the Peak Ground Acceleration (seismic force) and seismic zone after the earthquake at Muzaffarabad on October 8, 2005. The new PGA (0.26g for the Project area) shall be used for the design of bridges under the 2nd Kohat Tunnel and Access Roads Projects.

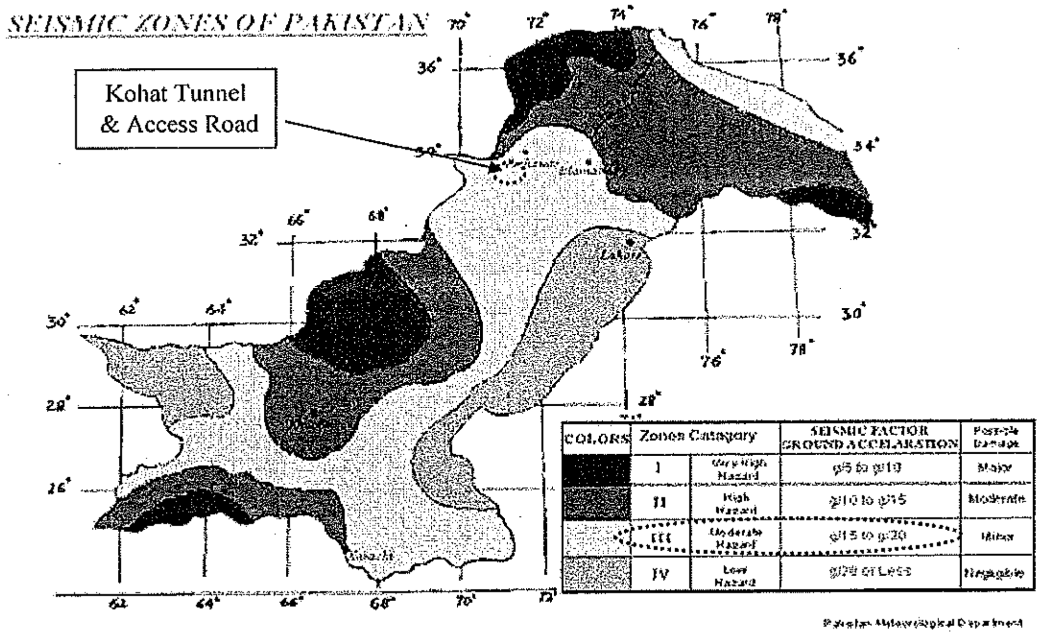


Figure 5.4.1 Old Seismic Force Zoning for Project Area under Review

Chapter 6. ENGINEERING SURVEY AND ANALYSIS

6.1 General

In order to obtain necessary engineering data and information of the Study area, the following field surveys were carried out by the local consultants and engineers.

1) Topographic survey
2) Hydrological survey
3) Geological survey
4) Materials survey

6.2 Topographic Survey

For preliminary engineering design, the following topographic surveys were carried out;

1) Control points survey using Global Positioning System (GPS)
2) Ground survey using Total Station

6.2.1 Control Points Survey

In advance of the ground survey, 18 control points were established in the Project area by using Global Positioning System (GPS).

6.2.2 Ground Survey Using Total Station

Ground survey was carried out along the Project Road covering the area necessary for the alignment study and design as listed below.

- Detailed topographical survey along the N-55 between Kohat Toi to Dara Adam Khel excluding the middle part of the Kohat tunnel (1.5 km)
- Survey on the intersections at Kohat Toi and Dara Adam Khel and three interchanges on the N-55 between Kohat Toi to Dara Adam Khel
- Survey on portals for both end of the Kohat Tunnel to cover the portal area of the tunnel including the control center at the south portal
- Topographic survey for an Alternative Route between STA17+500 and STA20+000 (Kohat Tunnel south portal, approximately 2.5 km) selected by the Engineer

Total Station was used for the survey to obtain the survey data in digital form.

Elevation and co-ordinates of survey spots for the topographic mapping was measured by radiation method based on the traverse points based on traverse points established from the co-ordinates of the GPS stations. The data shows the following items.

- Ground details including carriageways, shoulders, pavement edges, inner and outer shoulders, embankment and cut edges and trees, drains, slope protection work, guard rail, toll plaza, irrigation channels, ROW, property lines, building lines, central reserves, and median barriers.
- Overhead and ground utilities including electrical, telephone poles and cables, storm water drainage, sewerage, water supply, gas pipelines, optical fibre cables, trees and all other means of services. The heights and depths of utility lines crossing the carriageway shall be determined.
- Buildings, bridges, tunnels, pipe and box culverts, underpasses and other developments.

The recorded data from the total stations were downloaded onto the computers and the topographic maps with contours were prepared using AutoCAD system. These digital maps contain the three-dimensional properties and can be used to produce the three dimensional digital terrain modelling of the surveyed area.

6.3 Hydrological Study

6.3.1 General

A hydrological study was carried out to confirm or obtain the information on the design discharge, flood water level and scouring depth for the cross drainage structures, especially for river bridges (listed in Table 6.3.1), which had been used for the design of the 1st Kohat Tunnel and Access Road and their effectiveness for the design of the 2nd Kohat Tunnel Access Road.

The scope of work for the hydrological survey covered the follows activities:

- Field Survey
- Data Collection and Processing
- Hydrological Analysis
- Evaluation of Data and Analysis.

Table 6.3.1 List of River Bridges

Bridge No.	Station (at center)	Bridge Length (m)	Span	Remarks (Name of River)
1 R	2+736.245	120	4 - 30m Span	Kohat Toi (Jerma Minor)
2 R	4+735.415	50	2 - 25m Span	Chargai Algada
5 R	18+935.415	80	25m+30m+25m	Osti Khel Algad
6A R	21+260.525	180	6-30m Span	Osti Khel Algad & Panderi Algada
7 R	25+388.915	40	2-20m Span	Mullah Khel Algad

Another objective of the study is to evaluate the affects of creeks located on the right and left sides of the planned tunnel south portal.

The study was carried out by local engineers under the guidance and supervision of the JICA Study Team. The following methodology was adopted for the study:

- Rainfall data for the Kohat and Peshawar Stations are collected from Pakistan Meteorological Department (PMD) for periods of 1951-2005 and 1950-2005 respectively. Other meteorological data on temperatures, wind and humidity are also collected.
- Topographic maps produced by the Survey of Pakistan (SOP) on as a scale of 1:50,000 and 1:250,000 are used for estimating catchments areas.
- Hydro-meteorological data are obtained from PMD. Discharge data are mostly available at the Irrigation Department of NWF Province and Surface Water Hydrology (SWH) of the Water & Power Development Authority (WAPDA).
- River cross sections are obtained from topographic survey and river profiles are obtained from 1:50,000 maps.
- Processing and analysis of the above data by appropriate methods.

6.3.2 Climate

The climate of the Project area is hot and arid which can be divided into the following four seasons based on temperature and rainfall:

- Cold weather season: December - March
- Hot weather season: April - June

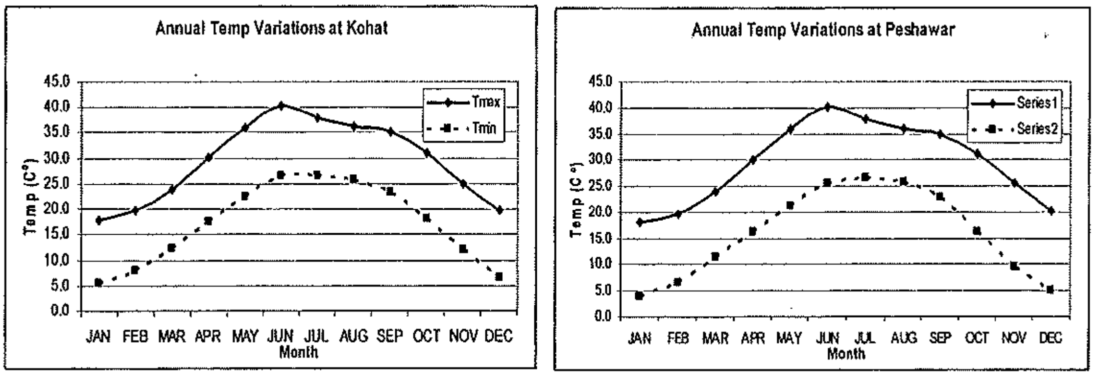
- Monsoon season: July - September
- Post-monsoon or Autumn season: October - November

(1) Temperature

The monthly mean of daily maximum and minimum temperatures at Kohat for the period of 1954 to 2005 and at Peshawar for the period of 1950 to 2005 is as follows:

	Kohat	Peshawar
• **Mean Max. Temperature (C°):**	**40.3 (in June)**	**40.2 (in June)**
• **Mean Min. Temperature (C°):**	**5.5 (in January)**	**4.1 (in January)**

The temperature variations in the Project area (Kohat and Peshawar) are shown in Figure 6.3.1. Temperatures start risings in January, reached the maximum in June and then declines until December.



Source: JICA Study Team

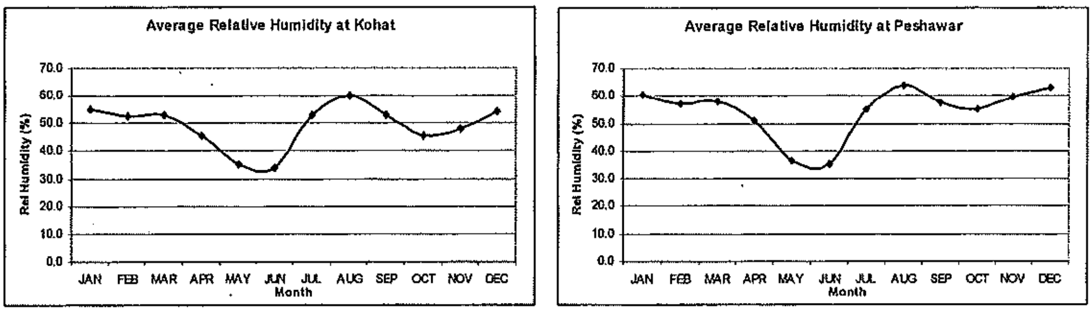
Figure 6.3.1 Annual Temperature Variations in the Project Area

(2) Relative Humidity

The average monthly relative humidity (RH) at Kohat (1954 - 2005) and Peshawar (1950 - 2005) is given below.

	Kohat	Peshawar
• **Mean Max. RH (%):**	**60 (in August)**	**64 (in August)**
• **Mean Min. RH (%):**	**34 (in June)**	**35 (in June)**

The relative humidity at Kohat and Peshawar, shown in Figure 6.3.2, is stable from January to March, decreases until June, increases sharply until August, decreases until October, then starts increasing again in November and December.



Source: JICA Study Team

Figure 6.3.2 Average Relative Humidity in the Project Area

6.3.3 Rainfall

The monthly rainfall data of the Kohat station are available for the period of 1954 to 2005 and those of the Peshawar station for the period of 1950 to 2005. The average annual rainfall at Kohat and Peshawar is 572 mm and 423 mm respectively. The minimum annual rainfall of 234 mm occurred in 1986 and the maximum annual rainfall of 1003 mm occurred in 2003 at Kohat. The minimum annual rainfall of about 174 mm occurred in 1952 and the maximum annual rainfall of 905 mm occurred in 2003 at Peshawar. The monthly average, monthly minimum and monthly maximum rainfalls at Kohat and Peshawar are summarised in Table 6.3.2 and graphed in Figure 6.3.3.

Table 6.3.2 Average Annual Rainfall (1950-2005) in the Project Area

Unit: mm

Month	Kohat			Peshawar		
	Average	Minimum	Maximum	Average	Minimum	Maximum
JAN	30.9	8.8	46.0	33.7	19.6	33.0
FEB	45.9	29.1	135.0	46.5	52.6	131.5
MAR	80.3	38.3	103.0	76.5	44.5	66.0
APR	54.6	18.7	85.0	52.0	19.0	129.0
MAY	37.4	3.9	13.0	24.8	5.1	23.0
JUN	24.9	21.1	55.0	11.3	0.0	10.0
JUL	79.0	25.4	210.0	44.4	0.3	156.0
AUG	107.6	40.5	182.0	57.1	0.5	114.0
SEP	49.5	6.4	108.0	24.6	20.8	111.0
OCT	27.2	8.2	10.0	17.7	0.5	70.0
NOV	11.8	18.2	31.0	13.7	0.0	42.0
DEC	22.3	15.1	25.0	20.6	10.9	19.0
Total	571.9	233.7	1,003.0	423.0	173.8	904.5

Source: Pakistan Meteorological Department (PMD)

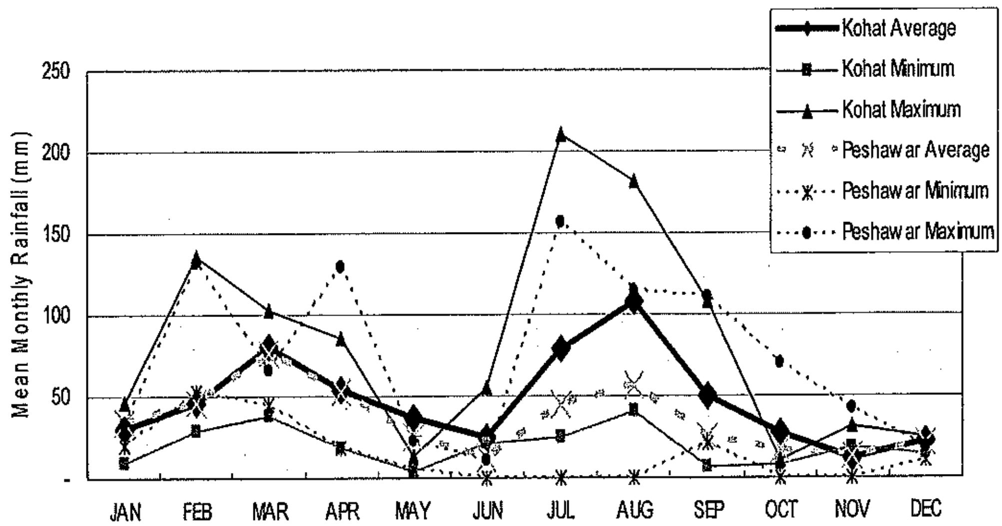


Figure 6.3.3 Average Monthly Rainfall at the Project Area

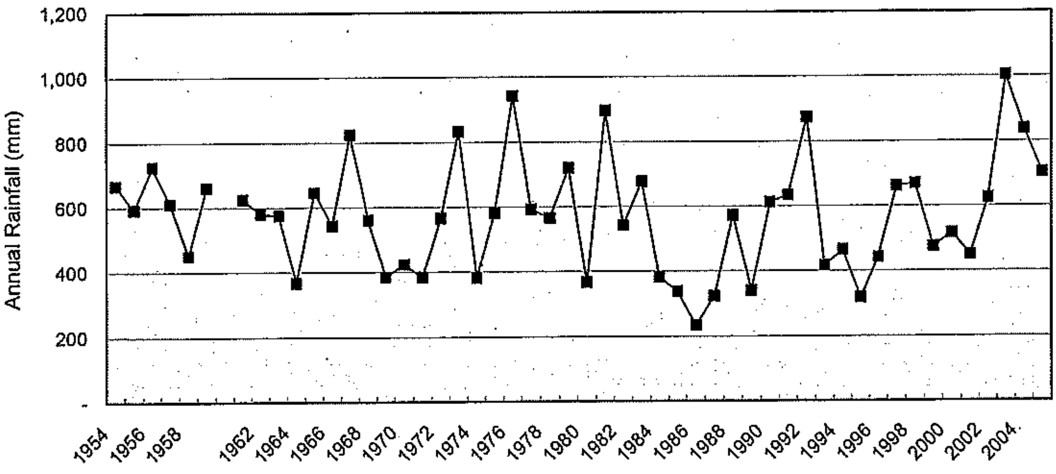
The annual rainfall at Kohat varies mostly from 400 mm to 900 mm (see Table 6.3.3). The highest monthly rainfall between 1950 and 2005 was 419.6 mm in August 1976. No significant increasing or decreasing trend was noticed in the last 50 years.

Table 6.3.3 Monthly Rainfall (1954-2005) at Kohat Station

Unit: mm

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1954	107.4	103.6	41.4	17.3	48.8	56.6	134.3	62.7	45.7	40.4	7.9	0.0	666.1
1955	0.0	3.0	8.4	3.0	38.9	7.6	49.0	392.7	73.9	5.1	0.0	10.4	592.0
1956	2.3	26.9	178.6	31.5	0.0	59.2	246.9	51.1	99.3	25.1	1.3	1.3	723.5
1957	50.8	0.8	112.8	104.4	52.1	9.4	45.7	76.5	40.6	37.8	53.1	26.7	610.7
1958	18.0	7.1	67.6	18.8	5.1	7.9	85.3	59.2	59.2	1.5	4.6	115.6	449.9
1959	69.8	95.3	33.0	65.3	31.8	2.3	79.0	46.2	110.0	41.4	71.6	15.2	660.9
1960	15.0	1.0	114.6			18.0	109.7	68.0	80.2	1.3	0.0	44.7	
1961	110.0	26.2	16.3	94.7	28.2	46.7	73.7	68.3	41.1	84.3	33.0	2.5	625.0
1962	13.2	37.6	61.7	36.8	55.6	37.1	74.2	95.3	60.2	13.0	19.3	75.4	579.4
1963	0.0	38.9	130.0	114.3	64.5	9.1	25.1	28.2	50.8	57.9	23.4	32.8	575.0
1964	45.2	17.3	47.2	46.0	31.0	54.6	38.9	20.1	35.3	8.1	0.0	23.9	367.6
1965	21.1	76.7	48.5	201.2	80.8	28.7	56.1	46.7	38.6	13.0	28.2	5.1	644.7
1966	0.0	98.8	101.3	126.7	37.3	19.0	33.8	21.6	24.1	81.0	0.0	0.0	543.6
1967	0.0	50.5	239.5	38.6	18.0	15.2	119.9	92.5	11.9	61.0	22.1	154.7	823.9
1968	44.7	22.1	92.7	37.6	49.8	39.6	32.8	136.1	7.1	79.8	10.9	7.4	560.6
1969	0.0	52.8	38.1	36.1	43.7	18.3	59.7	58.9	30.0	46.0	0.0	0.0	383.6
1970	16.3	38.6	59.7	23.6	18.5	36.1	67.6	122.9	33.8	0.5	0.0	6.3	423.9
1971	4.8	29.5	21.1	84.1	18.0	38.1	106.2	55.9	19.8	3.6	0.3	2.5	383.9
1972	42.9	82.8	48.3	59.4	26.9	11.4	30.0	141.7	34.0	40.1	13.7	34.8	566.0
1973	7.4	66.0	115.3	14.0	66.3	6.6	115.3	308.1	109.2	9.1	0.0	15.2	832.5
1974	5.3	36.6	25.6	61.4	30.7	0.0	25.4	42.0	112.0	0.0	0.0	42.4	381.4
1975	4.9	59.0	88.4	65.2	73.7	14.5	134.0	116.8	21.1	0.0	0.0	3.3	580.9
1976	14.9	93.6	38.1	67.2	50.2	20.9	102.1	419.6	78.8	56.3	0.0	0.0	941.7
1977	56.3	14.2	8.0	70.3	65.6	4.9	81.9	103.5	91.1	70.0	12.8	13.5	592.1
1978	21.4	6.1	216.3	23.5	1.3	6.4	156.2	87.1	31.2	6.3	7.6	2.8	566.2
1979	41.3	41.9	34.4	14.5	69.8	8.7	94.0	356.2	14.8	13.2	17.7	11.2	717.7
1980	53.2	79.8	67.1	9.9	4.4	9.2	26.7	14.0	63.4	8.4	26.7	4.6	367.4
1981	29.7	35.4	364.9	36.8	21.2	0.8	100.8	249.9	19.9	30.2	5.8	0.0	895.4
1982	55.4	25.0	200.7	28.4	28.4	18.0	41.3	56.0	30.1	8.9	38.6	11.8	542.6
1983	36.3	46.9	91.5	195.2	42.9	14.0	19.5	146.8	36.5	42.8	3.0	1.0	676.4
1984	1.3	14.8	43.0	16.8	16.0	10.0	71.4	158.1	14.9	1.3	25.6	7.7	380.9
1985	34.5	1.5	31.7	51.2	29.0	24.2	17.7	76.9	5.1	5.8	10.5	48.8	336.9
1986	8.8	29.1	38.3	18.7	3.9	21.1	25.4	40.5	6.4	8.2	18.2	15.1	233.7
1987	0.0	23.5	64.1	5.2	39.2	36.3	67.0	57.0	23.0	7.0	0.0	1.0	323.3
1988	16.8	16.6	131.0	33.0	34.0	34.0	124.0	61.0	59.0	13.5	0.0	49.0	571.9
1989	16.3	8.0	42.1	10.0	9.2	19.2	61.0	90.0	52.0	1.0	2.0	30.0	340.8
1990	38.0	92.0	77.5	68.0	6.0	6.0	105.0	69.0	53.0	13.0	9.0	76.0	612.5
1991	20.0	77.0	125.0	128.2	117.0	35.0	51.0	55.0	17.4	7.0	0.0	1.0	633.6
1992	68.0	59.0	113.0	102.0	113.0	19.0	44.0	231.0	83.0	18.0	9.0	14.0	873.0
1993	11.0	7.0	139.5	34.0	15.0	18.0	134.0	22.0	17.0	7.0	12.5	0.0	417.0
1994	5.0	46.0	52.0	60.0	35.0	7.0	92.0	20.0	48.0	32.0	12.0	57.0	466.0
1995	8.0	32.0	49.0	61.0	5.0	14.0	52.0	41.0	24.0	18.0	5.0	9.0	318.0
1996	35.0	43.0	60.0	17.0	31.0	50.0	34.0	107.0	9.0	55.0	1.0	0.0	442.0
1997	7.0	18.0	19.0	129.0	92.0	24.0	88.0	102.0	31.0	100.0	9.0	42.0	661.0
1998	27.0	163.5	72.5	71.0	52.6	10.5	89.5	69.5	79.5	33.0	0.0	0.0	668.6
1999	122.0	27.0	67.0	4.0	30.5	14.0	84.0	66.0	29.0	8.0	24.0	0.0	475.5
2000	45.5	23.5	33.0	12.5	69.0	32.0	85.0	104.0	51.5	49.0	0.0	12.0	517.0
2001	0.0	0.0	36.5	64.5	19.6	66.2	98.0	71.5	61.5	29.0	0.0	3.5	450.3
2002	2.0	56.0	34.0	22.0	8.0	85.0	14.0	241.0	63.0	53.0	2.0	45.0	625.0
2003	46.0	135.0	103.0	85.0	13.0	55.0	210.0	182.0	108.0	10.0	31.0	25.0	1003.0
2004	76.5	59.0	18.0	51.0	0.0	82.0	154.0	140.0	117.0	47.0	37.0	56.0	837.5
2005	133.0	143.0	115.0	15.0	65.0	13.0	42.0	44.0	119.0	10.0	4.0	0.0	703.0
Average	30.9	45.9	80.3	54.6	37.4	24.9	79.0	107.6	49.5	27.2	11.8	22.3	571.9

Source: Pakistan Meteorological Department (PMD)



6.3.4 Estimate of Design Discharge

(1) Design Criteria and Methodology (US-SCS Method)

The design discharges with a 50 year return period was adopted in this study for the planned bridges and south portal creeks. Due to the absence of flood discharge data, the synthetic triangular hydrograph technique was applied. The U.S. Soil Conservation Services (US-SCS) approach was used to synthesize flood hydrograph by using the Curve Number method. The US-SCS Unit Hydrograph Method was used to estimate the peak discharge at the bridge locations. This method requires the following information about the catchments.

- Maximum 24-hour rainfall for the design return period
- Length of nullah (dry stream) measured along the longest path from the head to the site
- Slope of nullah (dry stream)
- Catchment area
- Antecedent soil moisture condition
- Soil group
- Cover complex classification.

The length and slope of streams and the catchment areas were determined from available G.T. Sheets on 1:50,000 scale. The Curve Number was determined from information gathered from the field visit and from G.T. Sheets.

The maximum discharge is calculated from the following formulae:

S	=	1000/CN - 10
Q	=	$(P-0.2S)^2/(P + 0.8S)$
tc	=	1/7700 x (L/S^0.5)^0.77
ΔD	=	0.133 x tc
tp	=	D/2 + 0.6 x tc
Qp	=	484 x A x Q/ tp

Where,

S	=	Potential maximum retention in inches
CN	=	Curve number
Q	=	Volume of runoff in inches
P	=	Maximum 24-hour rainfall in inches of required return period
L	=	Length of longest stream in feet
H	=	Difference of elevation in feet
tc	=	Time of concentration in hours as per Kirpich's equation
tp	=	Time to peak in hours
ΔD	=	Unit storm duration in hours
Qp	=	Peak rate of flow in cusecs
A	=	Catchment area in sq. miles

(2) Rational Method

For the two small creeks at the South portal, the rational method was used as their catchment areas are smaller than 10 sq. miles. The peak discharge was calculated by the following equation:

q = CiA

Where,

q = Discharge (ft3/sec)
i = Rainfall intensity (in/hr)
A = Watershed area in acres
C = Runoff coefficient.

The rainfall intensity was estimated by using the Mononobe's formula. The estimated rainfall intensity for the west and east creeks of the tunnel south portal are 4.09 in/hr and 4.06 in/hr respectively. The "C" value adopted for the catchments is 0.8.

(3) 24-hour Annual Maximum Rainfall

To estimate the design discharges, the one day annual maximum rainfall at Kohat for the period of 1951 to 2005 (55 years) shown in Table 6.3.4 has been used.

Year	One day (24-hr) Annual Maximum Rainfall (mm)	Year	One day (24-hr) Annual Maximum Rainfall (mm)	Year	One day (24-hr) Annual Maximum Rainfall (mm)
1951	45	1971	29	1991	56
1952	29	1972	72	1992	102
1953	69	1973	83	1993	52
1954	51	1974	45	1994	26
1955	93	1975	49	1995	21
1956	94	1976	118	1996	40
1957	74	1977	37	1997	52
1958	54	1978	100	1998	48
1959	58	1979	112	1999	38
1960	35	1980	37	2000	40
1961	55	**1981**	**120**	2001	51
1962	34	1982	40	2002	108
1963	27	1983	39	2003	66
1964	24	1984	39	2004	75
1965	37	1985	22	2005	75
1966	31	1986	18		
1967	**178**	1987	36		
1968	46	1988	42		
1969	49	1989	50		
1970	41	1990	35		

Source: Pakistan Meteorological Department (PMD)

Table 6.3.4 Maximum One Day Rainfall (1951-2005) in the Project Area

The maximum one day rainfall of 178 mm occurred in March 1967. The next highest value of 120 mm was recorded in 1981. A frequency analysis of 55-year time series was carried out using the Weibull's plotting position formula and the Gumbel's extreme value type-I distribution. The plotted data and the related line are shown in Figure 6.3.4 and the results of frequency analysis are summarized in Table 6.3.5.

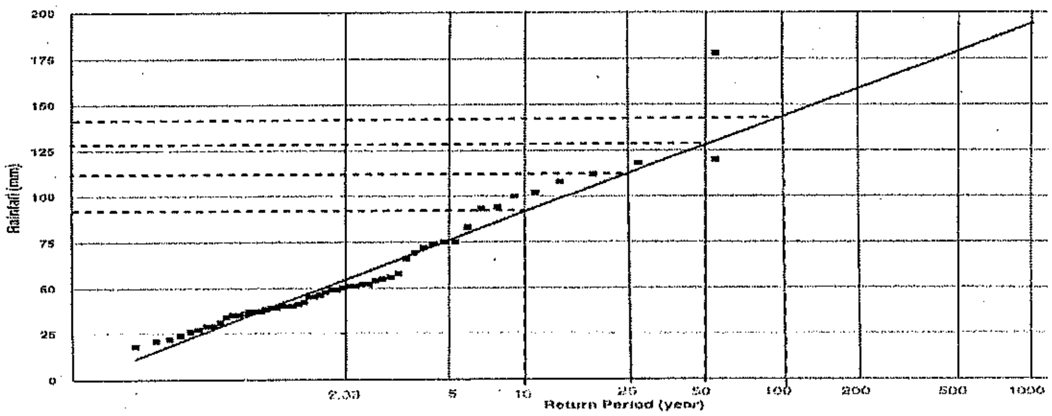


Figure 6.3.4 Frequency Analysis of One-Day Annual Maximum Rainfall

Table 6.3.5 Probable Rainfall by Return Period

Return Period Year	Probable Rainfall Inches	Probable Rainfall mm	Conversion One day to 24 hours Rainfall	Remarks (1st Kohat Design)
10	3.6	91	103	107
25	4.4	112	127	128*
50	5.04	128	145	155
100	5.64	143	162	175

Note: * for 20 year return period

For converting the one day rainfall to 24-hour rainfall, a multiplication factor of 1.13 was used as found in various studies in Pakistan and in the Manual for Estimation of Probable Maximum Precipitation by the World Meteorological Organization.

No substantial difference is seen in the probable rainfall between the 1st Kohat Tunnel and Access Road and this survey.

(4) Catchment Characteristics

The catchment characteristics of the bridges under study and the two creeks on the South portal of the tunnel were derived from the Survey of Pakistan maps of 1:50,000 and 1:250,000 scale. The catchment characteristics including catchment area, length of stream, slope, time of concentration, hydrograph time step ΔD and lag time for all the locations are given in Table 6.3.6.

Table 6.3.6 Catchment Characteristics

Bridge No.	Stream Name	Catchment Area (sq km)	Catchment Area (sq mile)	Length 'L' ft	Slope 'S'	Sq. Root of 'S'	Tc hr	d hr	Lag Time hr	Remarks* Catchment Area (sq mile)
1	Kohat Toi (Jerma Minor)	1,500.0	579.2	354,600	0.01189	0.1090	13.42	1.79	8.05	378.0
2	Chargai Algad	99.0	38.2	65,620	0.01056	0.1028	3.83	0.51	2.30	30.5
5	Bosti Khel	29.0	11.2	45,280	0.01900	0.1378	2.30	0.31	1.38	10.6
6A	Bosti Khel Algad & Panderi	99.0	38.2	88,600	0.01745	0.1321	3.98	0.53	2.39	-
7	Malla Khel Algad	116.0	44.8	108,770	0.01388	0.1178	5.09	0.68	3.05	46.5
South Portal Creek (West)		2.5	1.0	2,560	0.43030	0.6560	0.08	0.01	0.05	-
South Portal Creek (East)		2.7	1.0	2,800	0.54710	0.7397	0.07	0.01	0.04	-

Note: * from the design review report of the 1st Kohat Tunnel and Access Road

The catchment areas are almost same between the 1st Kohat Tunnel Access Road and this study except for the Kohat Toi River (as shown in the above table).

(5) Design Discharge

By using the estimated catchment parameters and rainfall, the flood hydrographs for the design return period (50 years) were synthesized through a worksheet computer program. A summary of the design discharge is shown in Table 6.3.7. There is no substantial difference between the 1st Kohat Tunnel and Access Road except Kohat Toi (Jerma Minor) in the design discharge for the rivers where bridges are constructed. The design discharge (55-57 m^3/sec) of creeks located at the tunnel south portal is relatively large against the catchment areas because of steep slopes. Sufficient drainage capacity should be provided both for water and debris flows. Protection against scouring is necessary for the lower part of embankments.

Table 6.3.7 Design Discharge

Site		Name of Main River / Stream	50 Year Peak Discharge (cumecs)	Remarks* 1st Kohat Design (cumecs)
Bridge No. 1	2+736.245	Kohat Toi (Jerma Minor)	5,030	1,600
Bridge No. 2	4+735.415	Chargai Algada	460	378
Bridge No. 5	18+920.415	Bosti Khel	158	243
Bridge No. 6A	21+260.525	Bosti Khel & Panderi Algada	520	-
Bridge No. 7	25+388.915	Malla Khel Algada	615	656
South Portal (West)		a creek	57	-
South Portal (East)		a creek	55	-

Note: * from the design review report of the 1st Kohat Tunnel and Access Road

It is noticed that there is a large difference between the discharge estimated by this study and that by the 1st Kohat Tunnel and Access Roads Project. This is originated from different catchment areas estimated by both studies (refer to Table 6.3.6). However, as a flood water storage function of the Tanda Dam, which is located at upstream of the Kohat Toi River is counted, the new bridge length will not be necessary to change from the existing bridge length.

6.3.5 Hydraulic Study

(1) Flood Water Level

To calculate the flood water levels, the cross sections and river slopes were obtained from the topographic survey data carried out under this FS Study. Table 6.3.8 shows the flood water levels computed on a mathematical model called HEC-RAS.

Table 6.3.8 Flood Water Level

Site		Name of River	River Bed Elevation (m)	FWL Elevation (m)	Remarks (FWL)* 1st Kohat Design (m)
Bridge No. 1	2+736.245	Kohat Toi (Jerma Minor)	444.0	456.7	449.8
Bridge No. 2	4+735.415	Chargai Algada	437.1	441.3	441.4
Bridge No. 5	18+920.415	Bosti Khel	691.8	693.5	692.8
Bridge No. 6/	21+260.525	Bosti Khel & Panderi Algada	672.9	674.9	-
Bridge No. 7	25+388.915	Malla Khel Algada	631.6	637.2	634.1

Note: * from the design review report of the 1st Kohat Tunnel and Access Road

(2) Scour Depth

The design scour depth of the river bed for the bridges on the 1st Kohat Tunnel Access Road Project is as follows (Table 6.3.9):

Table 6.3.9 Design Scour Depth of River Bridges on the 1st Kohat Tunnel Access Road

Site		Name of River	Scour Depth (m)	Scour Depth from HFL	
				Abutment (m)	Pier (m)
Bridge No. 1	2+736.245	Kohat Toi (Jerma Minor)	3.3	4.9	6.6
Bridge No. 2	4+735.415	Chargai Algada	2.7	4.1	5.4
Bridge No. 5	18+920.415	Bosti Khel	1.8	2.6	3.5
Bridge No. 6A*	21+260.525	Bosti Khel & Panderi Algada	-	-	-
Bridge No. 7	25+388.915	Malla Khel Algada	2.5	3.7	4.9

Notes: 1. From the design review report of the 1st Kohat Tunnel and Access Road
2. * No scour depth analysis for Bridge No.6A in the original design report

Since the scour depth for Bridge No.6A is not available in the design report of the 1st Kohat Tunnel and Access Roads (this bridge was not included in the original design list), its scour depth analysis was conducted in this study. The Lacey's method was used for score depth analysis. The discharge concentration 'q' was increased by 20% to cater for the curve in the nullah/stream and variation in discharge concentration over the cross section. The D50 required for the analysis was determined from the particle size distribution of the bed material. Two test pits were excavated at the bridge location to identify the particle size distribution at laboratory.

The formulae and computation results of scour depth computation are shown in Table 6.3.10 for piers and Table 6.3.11 for abutments of Bridge No.6A.

Table 6.3.10 Scour Depth Calculation for Piers of Bridge No.6A

Description	Formula	US Costmary Unit	Metric Unit
Discharge	Q	18,364.00 cusecs	520.00 cumecs
Width of flow	B	251.00 ft	76.46 m
Discharge Concentration	q = Q/B	73.20 cusecs/ft	6.80 cumecs/m
20 % increase in Discharge Consent.	$q_{1.2}$	87.85 cusecs/ft	8.16 cumecs/m
Median grain size	D_{50}	0.07 mm	0.07 mm
Lacey's Silt Factor	$f = 1.76 (D_{50})^{1/2}$	2.00	2.00
Scour Depth	$R = [(q^2/f)]^{1/3}$	15.68 ft	4.78 m
F.O.S	F_S	1.75	
Scour Depth	$R = F_s \times [(q^2/f)]^{1/3}$	27.45 ft	8.37 m
Minimum Channel Elevation	MCE	2,207.59 ft	672.84 m
Water Surface Elevation	WSE	2,214.22 ft	674.86 m
Scour Extents	S=WSE-R	2,186.77 ft	666.49 m
Difference of Scour Elevation and Min. Channel Elevation	MCE-S	20.82 ft	**6.34 m**

Table 6.3.11 Scour Depth Calculation for Abutments of Bridge No.6A

Description	Formula	US Costmary Unit	Metric Unit
Discharge	Q	18,364.00 cusecs	520.00 cumecs
Width of flow	B	250.90 ft	76.46 m
Discharge Concentration	q = Q/B	73.20 cusecs/ft	6.80 cumecs/m
20 % increase in Discharge Consent.	$q_{1.2}$	87.85 cusecs/ft	8.16 cumecs/m
Median grain size	D_{50}	40.00 mm	40.00 mm
Lacey's Silt Factor	$f = 1.76 (D_{50})^{1/2}$	11.13	11.13
Scour Depth	$R = [(q^2/f)]^{1/3}$	8.85 ft	2.70 m
F.O.S	F_S	1.75	1.75
Scour Depth	$=Fs \times [(q^2/f)]^1$	15.49 ft	4.72 m
Minimum Channel Elevation	MCE	2,210.08 ft	673.64 m
Water Surface Elevation	WSE	2,219.99 ft	676.66 m
Scour Extents	S=WSE-R	2,204.50 ft	671.94 m
Difference of Scour Elevation and Min. Channel Elevation	MCE-S	5.58 ft	**1.70 m**

As scouring to a considerable depth will occur, appropriate scouring protection works are necessary for all river bridges. It is necessary to reduce the current foundation elevation for the piers of Bridge No.1 as the actual scouring depth occurred is larger than that calculated in the original design.

6.4 Geological Survey

6.4.1 Boring Investigation

(1) Result of Drilling Work

Drilling work was carried out at the sites of the north portal, south portal, bridge No.4 and bridge No.1. A location map is shown in Figure 6.4.1 and the quantity of works in Table 6.4.1. Rotary boring machine was used for rock drilling at BH No.1 and BH No.2, and percussion machine was utilized for gravel drilling. Results of boring are shown in the form of drilling logs in Appendix.

Table 6.4.1 Quantity of Boring Work

BH No.	Elevation (m)	Location	Drilling Depth (m)	SPT (Times)	Type of Boring
1	726.20	North Portal	15.0	0	Rotary
2	672.00	South Portal	15.0	0	Rotary
3	597.00	Bridge No.4	16.0	4	Percussion
4	447.00	Bridge No.1	25.0	2	Percussion
-	-	Total	71.0	6	-

a) BH No.1 (North Portal, EL=726.20m)

The boring site is located at 30 m eastward from the existing road centreline which is aligned on a gentle monoclinal slope consisting of weathered shale and covered with thin talus deposit. On the slope, there are many big boulders of limestone having a diameter of 2 m to 3m. The geological cross section is shown in Figure 6.4.2 and the drilling results are as follows:

Depth (m)	Thickness (m)	Formation
0.00~1.00	1.00	Top Soil (Clayey Silt with Gravel)
1.00~3.50	2.50	Talus Deposit (Gravel with Silt)
3.50~5.50	2.00	Highly weathered Shale
5.50~15.00	9.50	Weathered Shale

b) BH No.2 (South Portal, EL=672.00m)

The boring site is located at the bottom of the narrow valley, at 70 m to the east of the existing road centreline. The valley faces steep slopes consisting of limestone and is filled with debris flow deposit. The geological cross section is shown in Figure 6.4.3 and the drilling results are as follows:

Depth (m)	Thickness (m)	Formation
0.00~2.00	2.00	Debris Flow Deposit (Gravel)
2.00~6.15	4.15	Weathered Fine Limestone
6.15~6.45	0.30	Fractured Zone (Rubble)
6.15~15.00	8.50	Weathered Fine Limestone

c) BH No.3 (Bridge No.4, EL=597.00m)

The boring site is located in the river bed, at 10m eastward from the edge of the Bridge No.4. This site is on the surface of a small fan or alluvial cone formed by a by seasonal river. The river channel is obscure and shallow and alluvial gravel with a 10 - 20 cm diameter is found in the channel. The geological cross section is shown in Figure 6.4.4 and the drilling results are as follows:

Depth(m)	Thickness(m)	Formation
0.00~4.50	4.50	Fan Deposit (Gravel)

4.50~11.60	5.15	Highly Weathered Shale
11.60~11.80	0.20	Highly Weathered Sandstone
11.80~16.00	4.20	Weathered Shale

d) BH No.4 (Bridge No.1, EL=447.00m)

The boring site is located on the central part of the channel of the Kohat River which is the biggest seasonal river in the basin. Therefore, there is no running water in the channel except in the monsoon season. The geological cross section is shown in Figure 6.4.5 and the Drilling results are as follows:

Depth (m)	Thickness (m)	Formation
0.00~0.50	0.50	Alluvial Gravel
0.50~2.00	1.50	Alluvial Stiff Clay
2.00~8.50	5.40	Alluvial Gravel with Silt
8.50~9.50	1.00	Diluvial Hard Clay
9.50~1450	5.00	Diluvial Gravel with Clay
14.50~25.00	10.50	Dilivial Gravel

(2) Result of Standard Penetration Test (SPT)

The standard penetration test was carried out for BH No.3 and BH No.4. The results of SPT are as follows:

BH No.	Depth (m)	Formation	N Value (time/30cm)
3	0.00~4.50	Alluvial Gravel (AF)	(30~50)
3	6.15~6.45	Weathered Shale	60
3	8.15~8.45	Weathered Shale	81
3	9.15~9.45	Weathered Shale	R
3	11.00~11.30	Weathered Shale	R

BH No.	Depth (m)	Formation	N Value (time/30cm)
4	0.00~0.50	Alluvial Gravel (AG1)	(20~30)
4	1.15~1.45	Alluvial Stiff Clay (AC)	7
4	2.00~8.50	Alluvial Gravel (AG2)	(30~50)
4	8.50~9.50	Diluvial Hard Clay (DC2)	41
4	9.50~14.50	Diluvial Gravel (DG2)	(30~50)
4	14.50~25.00	Diluvial Gravel (DG3)	(50<)

Note : ( )= Estimated Value, R= Rebound

(3) Rock Quality Designation (RQD)

The RQD value of rock shows that the rate of total drilling core is 10 cm in length in one meter. This value is used as an indicator for evaluation of rock condition. Following is a comparison between the RQD value and rock classification:

Table 6.4.2 Rock Quality Designation (RQD)

RQD (%)	RQD (%)	Rock Classification
0 ~ 25	Very Poor	D ~ CII
25 ~ 50	Poor	CII ~ C I
50 ~ 75	Fair	C I ~ B
75 ~ 90	Good	B ~
90 ~ 100	Excellent	A ~ B

By Deere, 1967

As shown in the table below, the RQD value of BH No.2 ranges from Poor to Fair at various depths, but the RQD value at the depth between 7m and 9m is Very Poor.

Depth(m)	RQD(%)	Depth(m)	RQD(%)
2~3	59	7~8	21
3~4	49	8~9	14
4~5	64	9~10	74
5~6	31	10~11	43
6~7	54	11~12	37

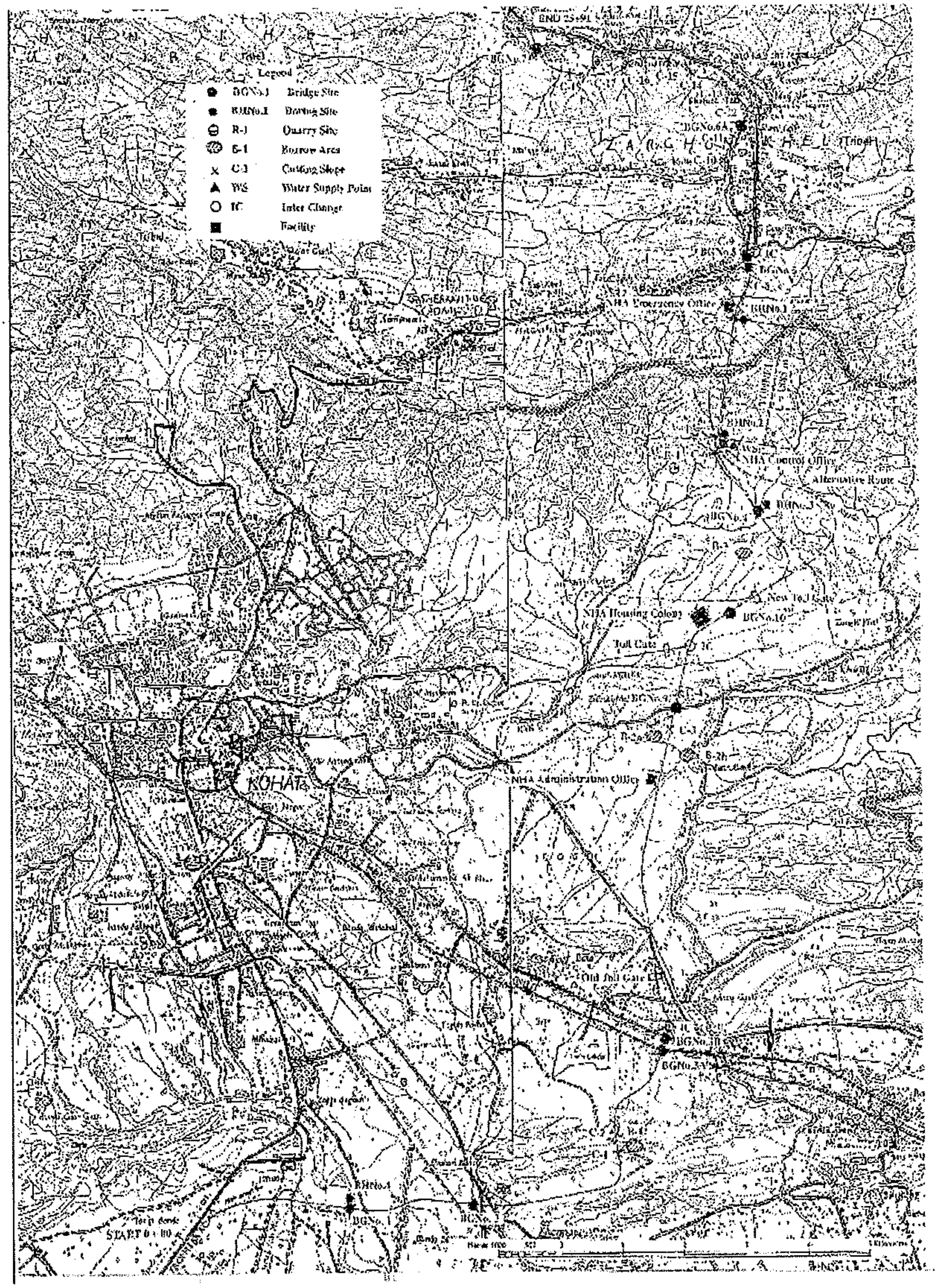


Figure 6.4.1 Location Map of Geological Survey

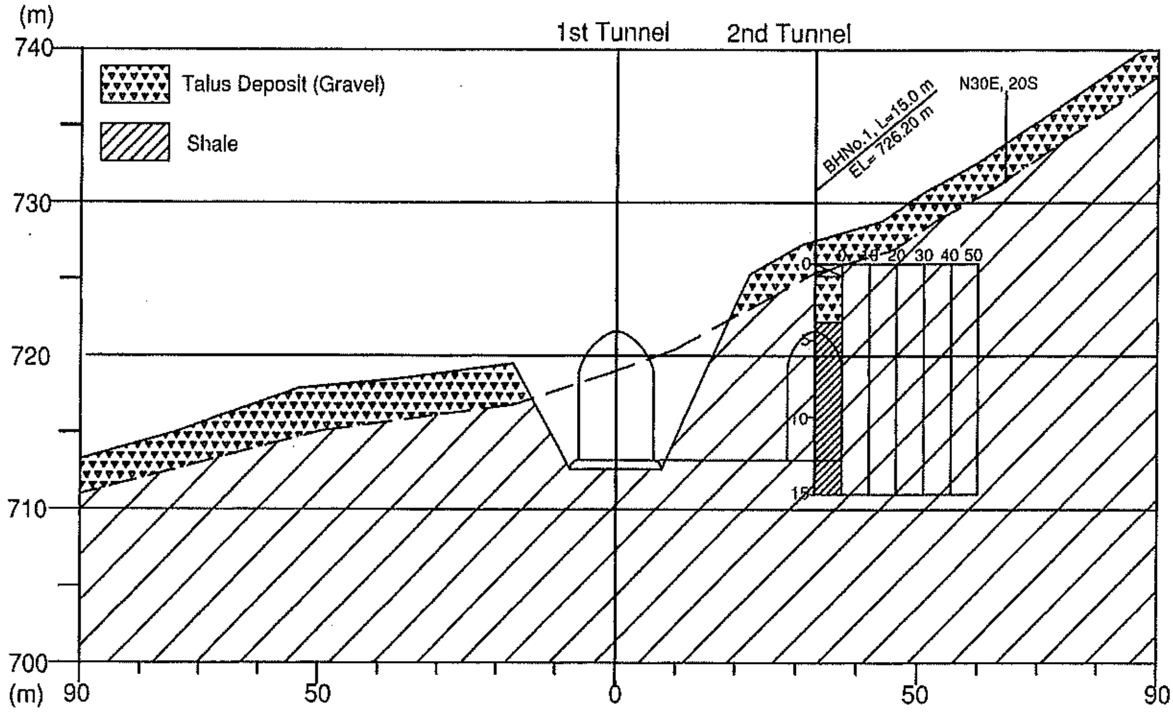


Figure 6.4.2 Geological Cross Section of North Portal

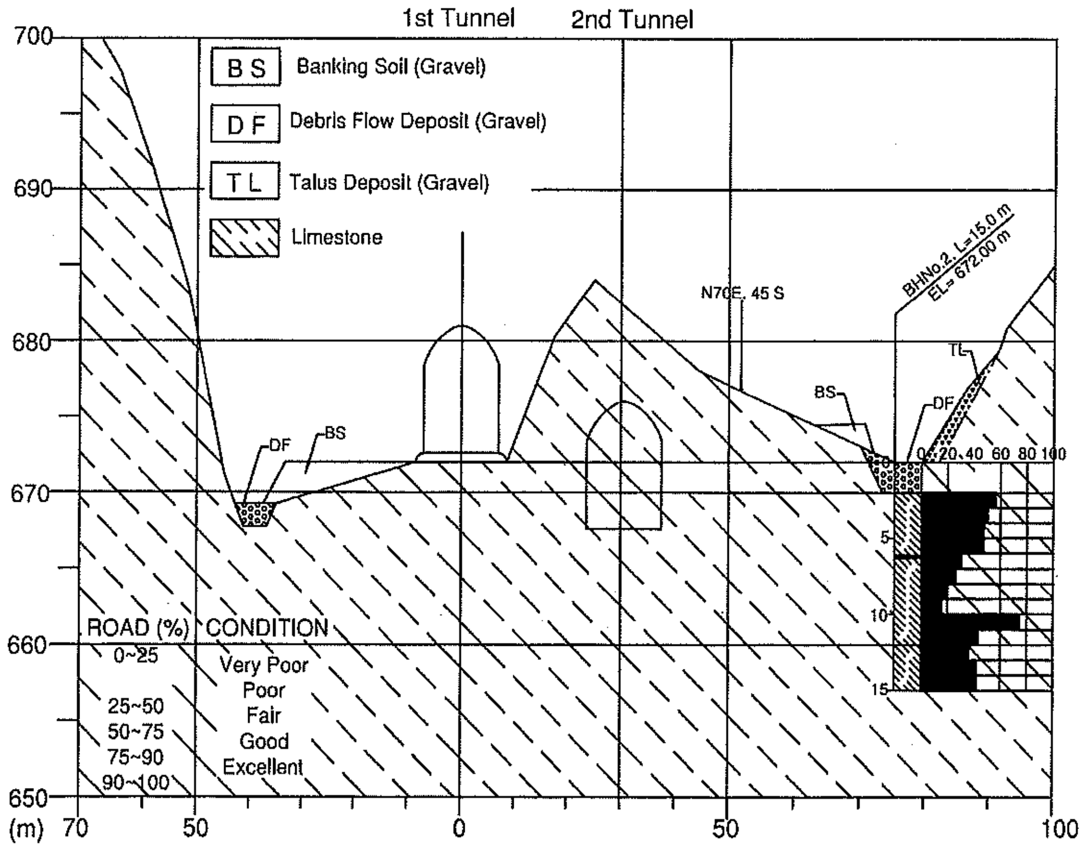


Figure 6.4.3 Geological Cross Section of South Portal

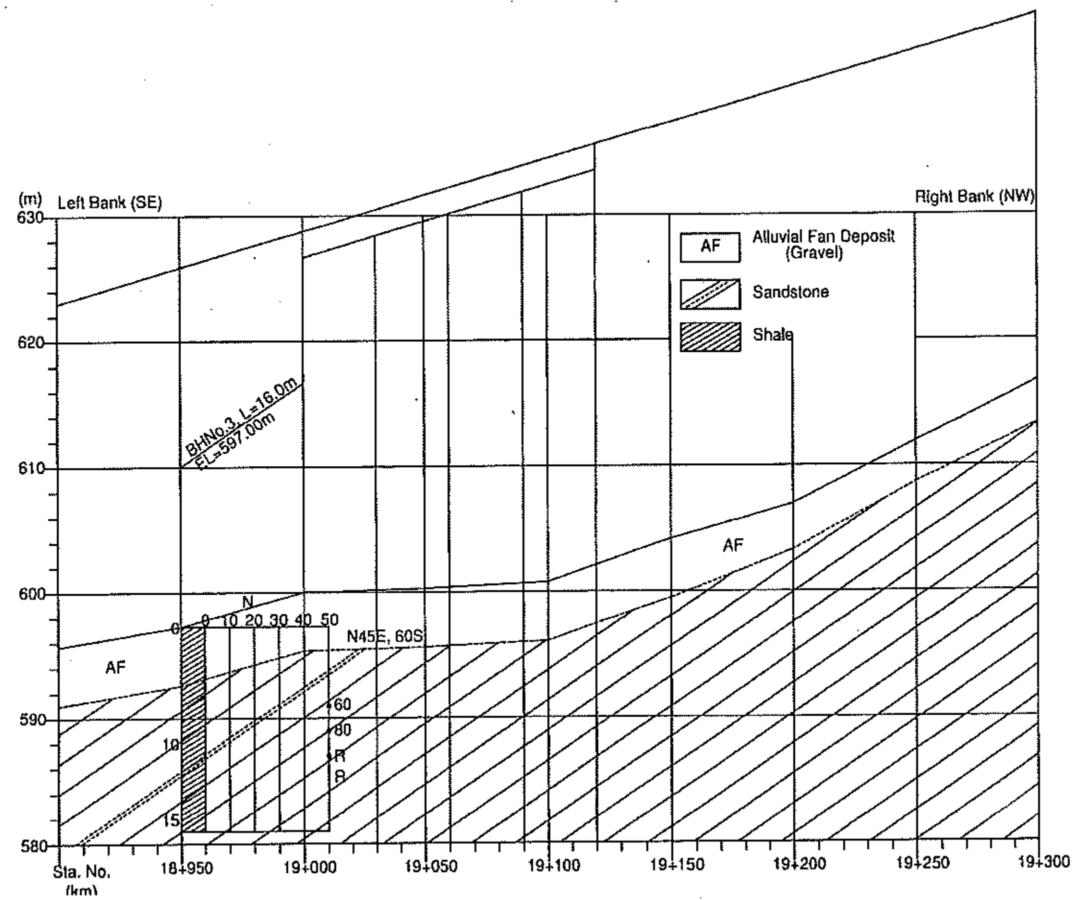


Figure 6.4.4 Geological Profile of Bridge No.4

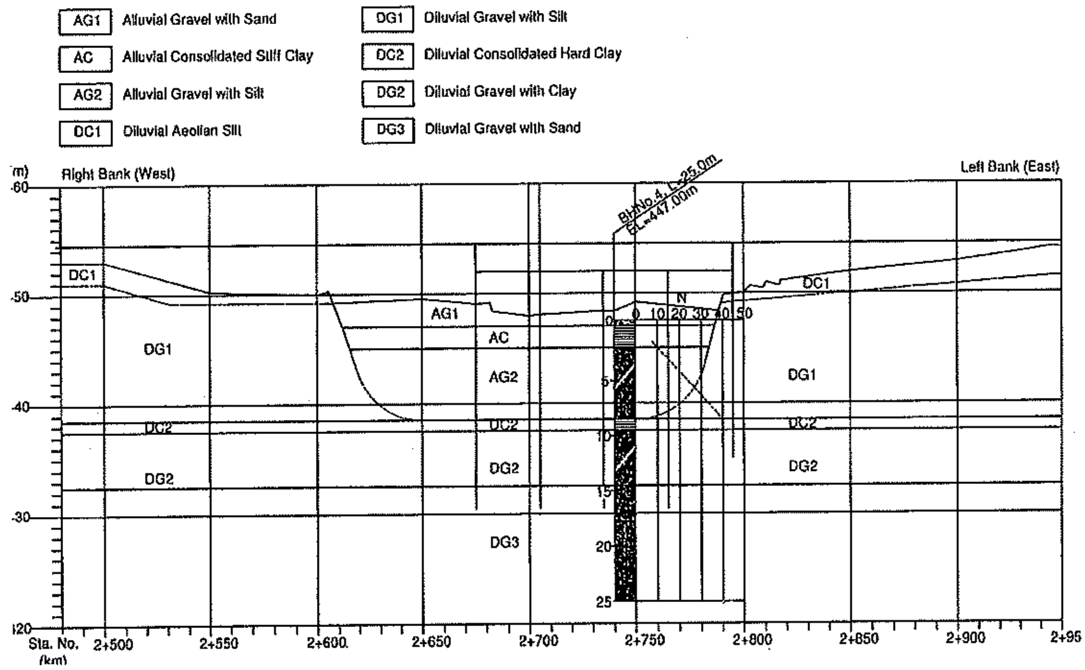


Figure 6.4.5 Geological Profile of Bridge No.1

6.4.2 Laboratory Test

Soil tests were carried out for samples taken from BH No.3 for the Bridge No.4 and from BH No.4 for the Bridge No.1. Rock test was carried out for the limestone taken from BH No.2 for the south portal. The items and quantities of laboratory tests are shown in Table 6.4.3.

Table 6.4.3 Quantities of Laboratory Tests

Soil						Rock	
BH No.	NMC	GS	LL	PL	Grain size	Bulk Density	Compression
No. 1	-	-	-	-	-	-	-
No. 2	-	-	-	-	-	2	2
No. 3	3	-	3	3	3	-	-
No. 4	2	2	9	9	11	-	-
Total	5	2	12	12	14	2	2

Note: NMC = Natural Moisture Content
GS = Specific Gravity
LL = Liquid Limit
PL = Plastic Limit

(1) Results of Soil Tests

As shown in Table 6.4.4, the weathered shale at BH No.3 with a N value between 60 and R is composed of consolidated hard clay. The mean value of liquid limit of all the three samples is LL=30%, and their mean value of plasticity index is SI=10. At BH No.4, a 1.5 m thick stiff alluvial clay (AC) layer is found at the depth from 0.50 m to 2.00 m, and a 1.0 m thick hard diluvial clay (DC2) layer is found at the depth from 8.50 m to 9.50 m. The values of liquid limits and plasticity index of stiff alluvial clay (AC) and hard diluvial clay (DC2) are as follows.

AC : LL=28.5%, PI=18.0

DC2 : LL=28.5%, PI=10.5

The materials have big strength in the dry condition and low permeability. On the other hand, some materials have low compressibility.

Table 6.4.4 Results of Laboratory Test for Soil

BH No.	Sample No.	Depth (m)	Soil Type	N Value (Times)	NMC (%)	GS	Atterberg Limit LL (%)	PL (%)	PI (%)	Grain Size Analysis Gravel (%)	Sand (%)	Silt (%)	Clay (%)
1	-	-	Rock	-	-	-	-	-	-	-	-	-	-
2	-	-	Rock	-	-	-	-	-	-	-	-	-	-
3	SPT1	6.15~6.45	Shale	60	8.2	-	32.6	21.1	11.5	-	8.4	40.4	51.2
3	SPT2	8.15~8.45	Shale	81	6.7	-	27.8	18.5	9.3	-	9.1	42.5	48.4
3	SPT3	9.15~9.45	Shale	R	6.6	-	30.0	19.9	10.1	-	10.3	43.0	46.7
4	SPT 1	1.15~1.45	Clay	7	18.5	-	28.5	10.5	18.0	-	8.6	35.0	55.0
4	DS 1	3.00~3.30	Gravel	-	-	-	28.2	17.0	11.2	56.4	12.1	10.0	21.5
4	DS 2	4.50~4.80	Gravel	-	-	-	23.2	14.0	9.2	56.7	14.9	14.0	14.4
4	DS 3	6.00~6.30	Gravel	-	-	-	23.2	13.1	10.1	52.6	16.2	15.0	16.2
4	DS 4	7.50~7.80	Gravel	-	-	-	21.5	12.9	8.6	59.9	13.9	16.0	10.2
4	DS 5	8.00~8.20	Gravel	-	-	2.673	21.7	14.0	7.7	66.0	20.4	9.0	4.6
4	SPT 2	8.30~8.60	Clay	41	19.2	-	28.5	18.0	10.5	-	-	36.0	64.0
4	DS 6	10.00~10.30	Gravel	-	-	-	25.6	16.0	9.6	50.7	17.7	14.2	17.4
4	DS 7	14.00~14.30	Gravel	-	-	2.676	21.9	14.7	7.2	70.0	18.0	5.8	6.2
4	DS 8	18.00~18.30	Gravel	-	-	-	-	-	-	99.7	0.3	-	-
4	DS 9	20.00~22.30	Gravel	-	-	-	-	-	-	99.8	0.2	-	-

Note: NMC = Natural Moisture Content , GS = Specific Gravity, LL = Liquid Limit , PL = Plastic Limit

Table 6.4.5 Results of Laboratory Test for Rock

BH No.	Sample No.	Depth (m)	Rock Type	Bulk Density (g/cm³)	Compressive Strength (Mpa)
2	C-1	2.69~2.86	Lime stone	2.691	53.03(540.75 kg f/ cm²)
2	C-2	7.59~7.70	Lime stone	2.795	36.89(376.17 kgf/cm²)

(2) Results of Rock Test

A compressive strength test was carried out for the limestone taken from BH No.2. The results of rock test shown in Table 6.4.5 indicate that the compressive strength of the limestone sample is 376 kg/cm2 ~ 541 khf/cm2. As reference, the general values of strength of rock are shown in Table 6.4.6.

Table 6.4.6 General Strength of Rock

Class	Rock Type	General Value
A	Fresh Hard Rock (Igneous Rock, Metamorphic Rock and Sedimentary Rock of Pre-Tertiary)	qu : > 800
		Vp : > 5000
B	Weathered Rock and Hard Tertiary Rock	qu : > 100~800
		Vp : > 3000~5000
C	Very Weathered Rock and Soft Tertiary Rock	qu : > 100
		Vp : ≒ 3000
D	Soil and Gravel	—

qu=Compressive Strength (kgf/cm^2)
Vp= Elastic Wave Velocity (m/s)
Ministry of Construction of Japan (1984)

6.5 Analysis of Cutting Slope and Settlement of Banking

6.5.1 Analysis of Cutting Slope

Investigation of cutting slopes was carried out for gradients, rock type, stability and existing protection. The cutting slope sites of the existing road are shown in Figure 6.4.1 Location Map. The results of investigation for the existing road and Project road are shown in Tables 6.5.1 and 6.5.2, indicating the gradient and protection works of cutting slopes by rock type as follows:

Formation	Gradient	Protection
Rock (All types of rock)	1 : 0.5	Nothing, Partial Rock Net
Fractured and Weathered Zone	1 : 0.5~0.7	Rock Net
Unconsolidated Deposit	1 : 1.0~1.2	Grouted Riprap

According to the above results, the gradient of cutting slope for all kinds of hard rock is 1:0.5 and there are no slope protections for hard rock, except for partial rock nets installed for cracky rock. The slope gradient for weathered rock ranges between 1:0.5 and 1:0.7, but it seems that protections for fractured zones, weathered zones and cracky rock are not in so good condition. The slope gradient for unconsolidated deposits like talus deposit, terrace deposit or residual soil is 1:1.0 to 1:1.2, and protection works for these zones consists mostly of grouted riprap. At present, most cutting slopes appear to be stable because they have been constructed only 3 years before. Rock falls occurred at many places where no protections for rock are provided, but there is no scattering of rocks on the road owing to enough clearance between slope and road. The new route is planned to be constructed in parallel to the existing route, therefore there is no problem to adopt the same gradient and same protection for cutting slopes of the new route. However, rock nets should be installed to cover all the cracky rocks, fractured zones and weathered zones in order to prevent rock falls.

6.5.2 Settlement of Embankment

A 30 m high embankment construction is planned between Sta. 18+800 and Sta. 21+000. This section is located on a composite fan beside the mountain foot. According to the test results of BH No.3, this site consists of alluvial fan gravel with a thickness of 4.5 m and weathered shale. The gravel is very dense and its N value is estimated to be 30 to 50. The N value of weathered shale is between 60 and rebound. Considering this formation, it can be said that the possibility of settlement is very low at this site.

6.6 Materials Survey

Materials survey for borrow materials and aggregate was carried out with field reconnaissance and information from the contractor who constructed the 1st Kohat Tunnel Access Roads. The material survey as described below and no laboratory test were conducted for the materials surveyed.

(1) Borrow Materials for Embracement

Borrow pits for banking soil are shown in Figure 6.4.1 Location Map and among which the following borrow pits were selected:

B1: Sta.No.7+100 Alluvial Terrace Deposit

B2: Sta.No.14+000 Alluvial Terrace Deposit

B3: Sta.No.18+500 Talus Deposit

Alluvial deposit consists of gravel of limestone and sandstone with a 2 - 5 cm diameter and yellowish brown fine sand and silt. Talus deposit consists of rubble of limestone and sandstone with a 5 - 10 cm diameter and reddish brown fine sand and silt. These formations are widely distributed along the southern part of the projected route. So it is considered that their available quantity is enough for the construction works. From the geo-technical point of view, the CBR value of these deposits could be expected to be more than 20.

(2) Coarse Aggregate

The proposed quarry for coarse aggregate is shown in Figure 6.4.1 Location Map. This site is located at the mountain foot at 1 km westward from Sta. 19+100. This formation consists of highly weathered sandy limestone which is easily broken by strikes of hammer. Therefore, laboratory test is required to confirm its strength.

(3) Fine Aggregate

River sand as fine aggregate is not distributed around the existing road. River sand is found on the east bank of the Indus River which is located at 80 km east of Peshawar City along the Highway No.5. This site is a junction of the Indus River and the Kabul River. The Indus River forms several sand banks upstream of the junction by its several meanders. These sand banks consist of fine sand which can be used as fine aggregate for the construction works.

Table 6.5.1 Cutting Slope of Existing Road

No.	Sta.No. (km)	Length (m)	Mean Height (m)	Cutting Site	Rock Type	Gradient	Existing Protection	Stability
C-1	7+340~7+480	140	13	Both Sides	Grey, Weathered,Sandstone	1 : 0.5	Rock net	Medium
C-2	7+710~7+800	90	3	E.Side	Brown, Talus Deposit (Gravel)	1 : 1.0	Nothing	Bad
C-3	14+415~14+625	210	7	Both Sides	Reddish Brown, Conglomerate	1 : 1.2	Groutred Riprap	Good
C-4	15+110~15+420	310	26	Both Sides	Fractured sandstone and shale	1 : 0.7	Rock net	Medium
C-5	17+780~18+110	330	31	Both Sides	Red Sandstone(lower) , Conglomerate(upper)	1 : 1	Groutred Riprap	Good
C-6	19+740~19+960	220	26	W.Side	Gray, SandyLimestone	1 : 0.5	Nothing	Medium
C-7	18+130~18+330	200	8	Both Sides	Brown, Talus Deposit (Gravel)	1 : 1	Groutred Riprap	Good
C-8	18+600~18+800	200	1	E.Side	Brown, Talus Deposit (Gravel)	1 : 1	Groutred Riprap	Good
C-9	19+180~19+220	40	4	W.Side	Gray, Fine Lime stone	1 : 0.5	Nothing	Medium
C-10	20+620~20+700	80	5	W.Side	Gray , Fine Limestone	1 : 0.5	Nothing	Medium
C-11	20+910~21+150	240	28	W.Side	TalusDeposit (upper), Fine Limes stone(lower)	1 : 0.5	Fence for Talus	Bad
C-12	21+360~21+690	330	30	Both Sides	Fractured Limestone with Fault	1 : 0.5	Nothing	Bad
C-13	32+280~22+400	120	10	Both Sides	Grey,Fine Lime stone	1 : 0.5	Nothing	Medium
C-14	23+030~23+080	50	3	Both Sides	Grey ,Fine Lime stone	1 : 0.5	Nothing	Medium
C-15	23+460~23+480	20	1	S.Side	Grey,Fine Lime stone	1 : 0.5	Nothing	Medium
C-16	23+550~23+630	80	16	S.Side	Grey , Fine Lime stone	1 : 0.5	Nothing	Medium
C-17	23+700~23+940	240	25	Both Sides	Fractured Fine Lime stone with Fault	1 : 0.5	Rock net (upper)	Bad
C-18	24+120~24+460	340	21	Both Sides	Fine and Sandy Lime stone	1 : 0.5	Rock net (upper)	Medium

Table 6.5.2 Cutting Slope of the Projected Road

No.	Sta. No. (km)	Length (m)	Height (m)	Cutting Site	Rock Type	Gradient	Proposed Protection
C-1	7+340~7+480	140	13	E. Side	Grey, weathered sandstone	1 : 0.5	Rock net with rock anchor (all over)
C-2	7+710~7+800	90	3	E. Side	Brown, talus deposit (gravel)	1 : 1.0	Grouted riprap (all over)
C-3	14+415~14+625	210	7	E. Side	Reddish brown conglomerate	1 : 1.2	Grouted riprap (all over)
C-4	15+110~15+420	310	26	E. Side	Fractured sandstone and shale	1 : 0.7	Rock net with rock anchor (all over)
C-5	17+780~18+110	330	31	E. Side	Red sandstone and conglomerate	1 : 1.0	Grouted riprap (lower), rock net (upper)
C-7	18+130~18+330	200	26	E. Side	Brown talus deposit (gravel)	1 : 1.0	Grouted riprap (all over)
C-8	18+600~18+800	200	3	E. Side	Brown talus deposit (gravel)	1 : 1.0	Grouted riprap (all over)
C-12	21+360~21+690	330	30	E. Side	Fractured limestone with fault	1 : 0.5	Rock net with rock anchor (all over)
C-13	22+280~22+400	120	6	E. Side	Grey, sandy limestone	1 : 0.5	Rock net with rock anchor (all over)
C-17	23+700~23+940	240	25	N. Side	Fractured limestone with fault	1 : 0.5	Rock net with rock anchor (all over)

6.7 Soil Characteristics along the Road Alignment

Table 6.7.1 shows a summary of the laboratory tests of soil along the Project route conducted by the 1st Kohat Tunnel and Access Roads Project during the design stage. The Study Team conducted site reconnaissance to confirm site conditions and soil type. The soil found at the site is not much diffidence from those in Table 6.7.1. The original ground has sufficient strength (the lowest CBR 5-6%) for embankment construction. No specific weak soil exists.

Table 6.7.1 Laboratory Test Results of Soil along the Project Road

Sample No	Location Station Km	Max Size	Analysis #10	(Pass %) # 40	# 200	Liquid Limit	P.I	Soil group with Group Index	Max. Dry Density gms/c.c	OMC %	CBR at 95 % Comp	Swell %
1	1+000	#4		100	85	43	21	A-7-6 (13)	1.93	11.0	6.4	0.5
2	3+000	#5		100	85	31	10	A-4 (8)	1.95	10.0	6.7	1.0
3	4+500	#6		100	88	27	8	A-4 (8)	1.92	11.0	5.4	0.5
4	6+000	#7		100	98	41	19	A-7-6 (123)	1.93	11.0	6.5	0.9
5	8+000	#8		100	95	29	9	A-4 (8)	1.92	11.0	4.9	0.4
6	10+000	6	20	13	10	N-P		A-1-a (0)	2.17	6.5	60.0	0.1
7	13+000	#4	100	98	80	29	9	A-4 (8)	1.97	10.0	8.0	0.3
8	14+000	3	37	31	28	28	8	A-2-4 (0)	2.16	6.2	30.0	0.2
9	19+500	6	22	20	20	N-P		A-1-b (0)	2.13	7.4	56.0	0.1
10	22+000	#4		100	90	32	10	A-4 (8)	1.89	11.0	6.9	0.4
11	24+000	6	32	22	15	N-P		A-1-a (0)	2.16	6.4	36.0	0.1
12	26+000	#4	100	98	75	29	10	A-4 (8)	1.96	10.0	5.9	0.1

Source: Design Review Report of the 1st Kohat Tunnel and Access Road Project

Chapter 7. Traffic Analysis

7.1 Present Traffic Condition

7.1.1 Available Data and Traffic Survey

(1) Toll Collection Data

NHA keeps ticket sales data, by which traffic volume at the Kohat Tunnel can be obtained, at two toll plazas near the tunnel. Yearly and monthly data were provided by NHA to the JICA Study Team. In the ticked sales data, vehicles are classified into four types: 1) Car/Jeep, 2) Hi-ace/Coach, 3) Bus, 2&3 Axle Trucks, and 4) Articulated Trucks. Buses and 2&3 Axle Trucks belong to the same category because the same toll rate is applied for those vehicles.

(2) PTPS Traffic Survey

The first phase of PTPS carried out a nation-wide traffic survey in which several survey sites were selected near the Kohat Tunnel.

(3) Traffic Survey, Phase II

In the second phase of the PTPS, a supplemental traffic count survey was carried out at four intersections along the access road of the Kohat Tunnel, as shown in Figure 7.1.1. The survey was designed as follows:

(4) Survey location and survey date

Survey Location

- IC-1: Kohat Toi Intersection (Start point of the Kohat Tunnel Access Road)
- IC-2: Kohat Pindi Interchange (with N-80: Kohat-Rawalpindi Road)
- IC-3: Kohat Link Road Interchange
- IC-4: Dara Adam Khel Intersection (End point of the Kohat Tunnel Access Road)

Survey Date and Time

- IC-1: 29-May (06:00 – 22:00, 16 hours)
- IC-2: 29-May (06:00 – 22:00, 16 hours)
- IC-3: 30-May -31 May (06:00 – 06:00, 24 hours)
- IC-4: 30 May (06:00 – 22:00, 16 hours)

a) Vehicle Classification

Vehicles were classified into six types as follows, according to the vehicle types for toll plazas of NHA.

1 Car, Jeep, Land Cruiser/Pajero, Suzuki Van/ Pick up
2 Wagon (up to 24 seats), Hilux (Single/Double Cabin), Milk Truck M-3000, Coaster & Mini Bus (up to 24 seats), Mini Truck/Tanker built on Mazda T-3500 chassis and equivalent
3 Buses greater than 25 seats
4 Rigid Trucks (2-Axle)
5 Rigid Trucks (3-Axle)
6 Articulated Trucks/Vehicles

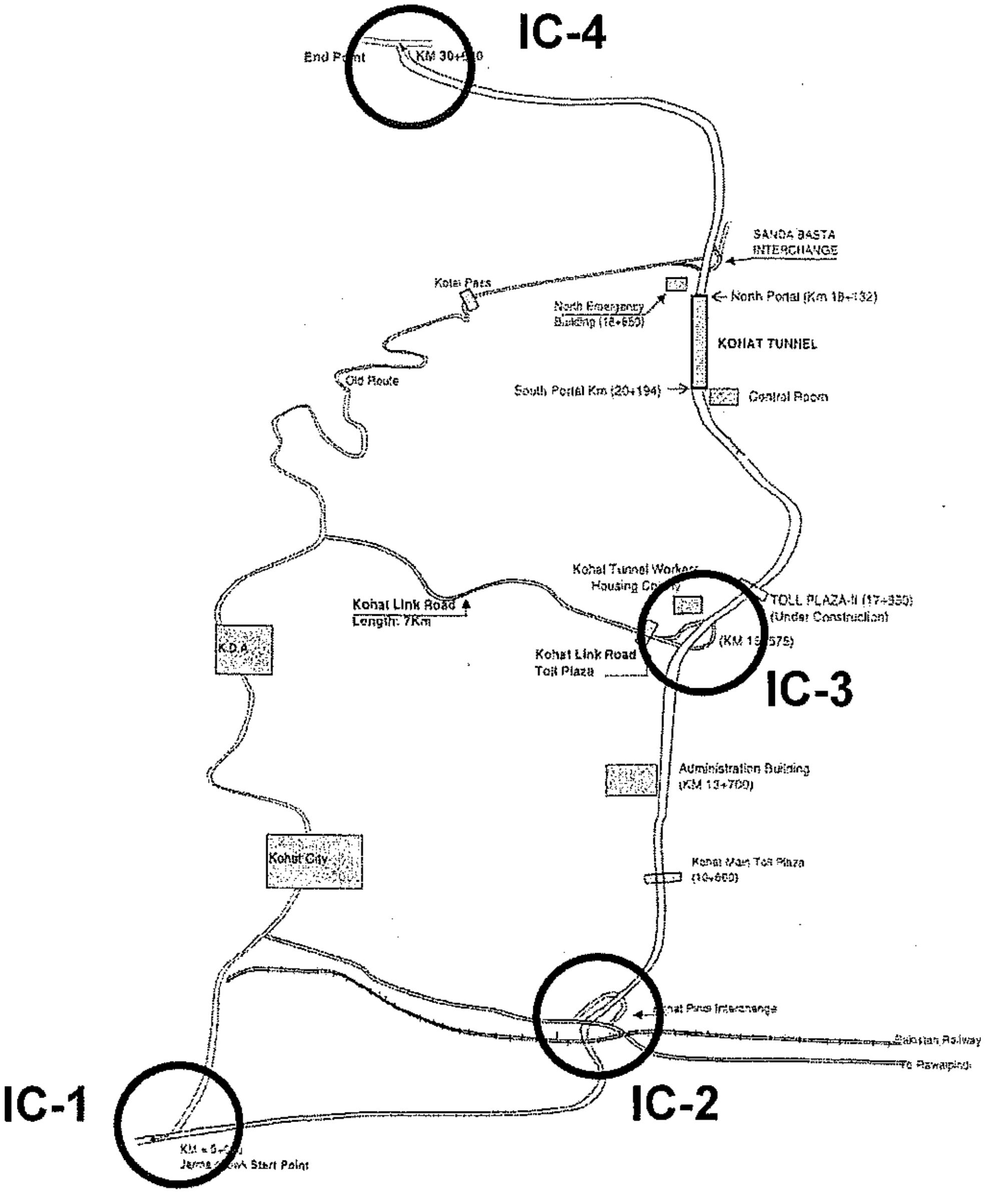
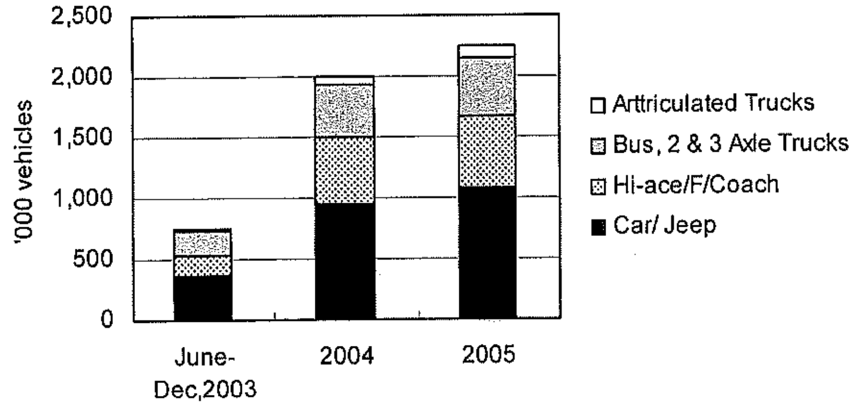


Figure 7.1.1 Survey Sites of the PTPS Traffic Survey near the Kohat Tunnel

7.1.2 Traffic Volume

(1) Yearly Traffic

Figure 7.1.2 illustrates the yearly traffic volume at Kohat Tunnel. Traffic volume at the Kohat Tunnel was 2.0 million vehicles in 2004 and 2.2 million in 2005, increased by 12.4%. The annual average daily traffic works out to be 5,487 veh/day in 2004 and 6,159 in 2005.

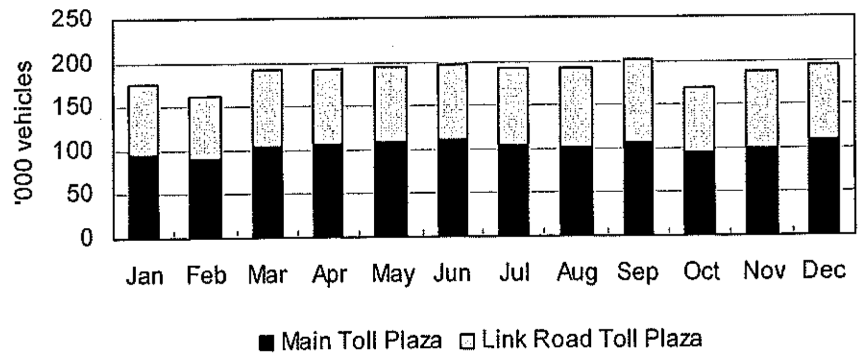


Source: NHA

Figure 7.1.2 Yearly Traffic Volume at Kohat Tunnel

(2) Monthly Traffic

Seasonal and monthly variations of the traffic volume are not significant as shown in Figure 7.1.3. The monthly traffic volume was highest in September at 1.09 times AADT, while it was lowest in October at 0.89 times AADT.

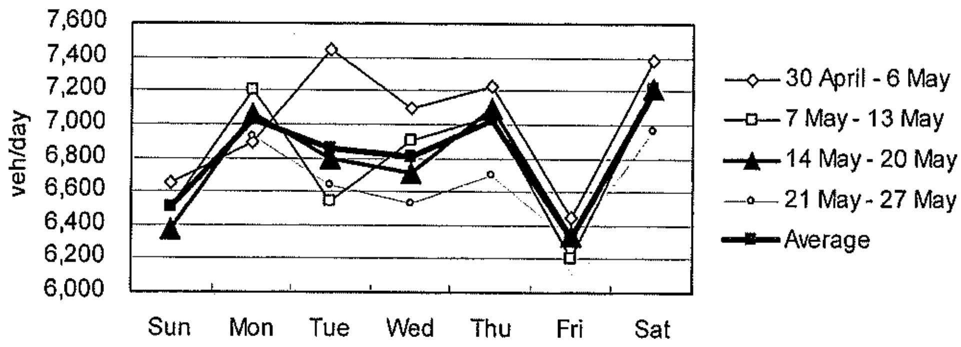


Source: NHA

Figure 7.1.3 Monthly Traffic Volume of Kohat Tunnel in 2005

(3) Daily Traffic

Daily traffic volume of the Kohat Tunnel varies from 6,300 to 7,200 vehicles per day (veh/day) according to the day of the week as shown in Figure 7.1.4. It is observed that weekend traffic volumes, on Friday and Sunday, are lower than weekday volumes. Peak traffic is observed on Saturday.



Source: NHA

Figure 7.1.4 Daily Traffic Volume of Kohat Tunnel in May 2006

(4) Hourly Traffic

Hourly traffic volumes at the intersections on the Access Road were illustrated in the figures from 7.1.5 to 7.1.8. The morning peak and the afternoon peak at the Kohat Tunnel are observed at 8:00-9:00 and 16:00-17:00, respectively. The ratio of the morning peak traffic to the daily traffic was 7.1%, while that of the afternoon peak traffic was 6.5%, respectively on 29 May, 2006. The morning peak is mainly contributed to the traffic from Kohat to Peshawar, while the afternoon peak is mainly contributed to the traffic from Peshawar to Kohat.

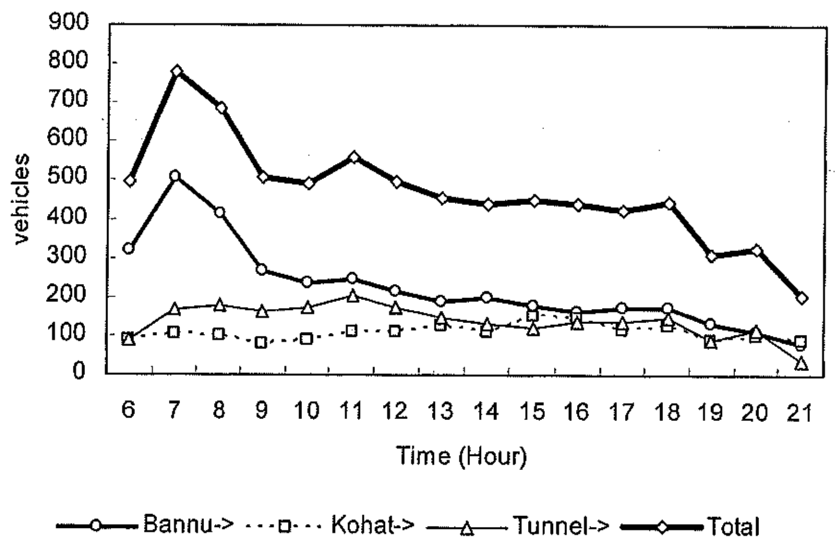


Figure 7.1.5 Hourly Traffic Volume at the Kohat University Intersection (IC-1)

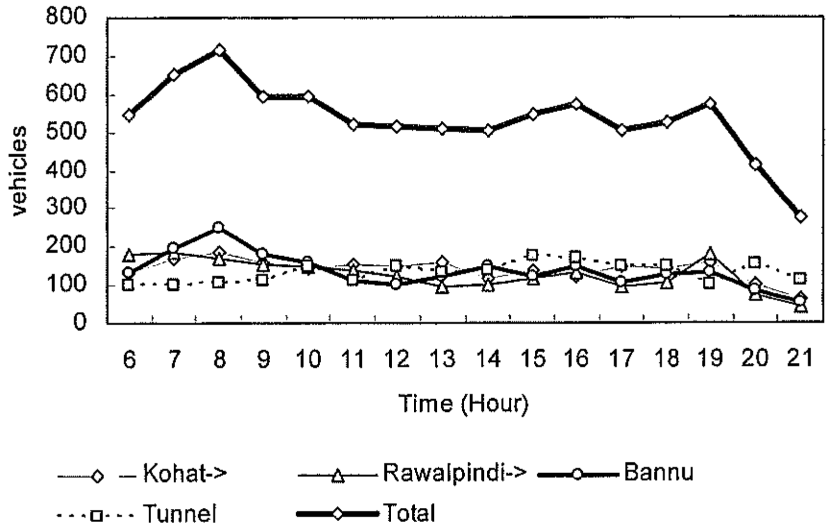


Figure 7.1.6 Hourly Traffic Volume at the Karim Abad Intersection (IC-2)

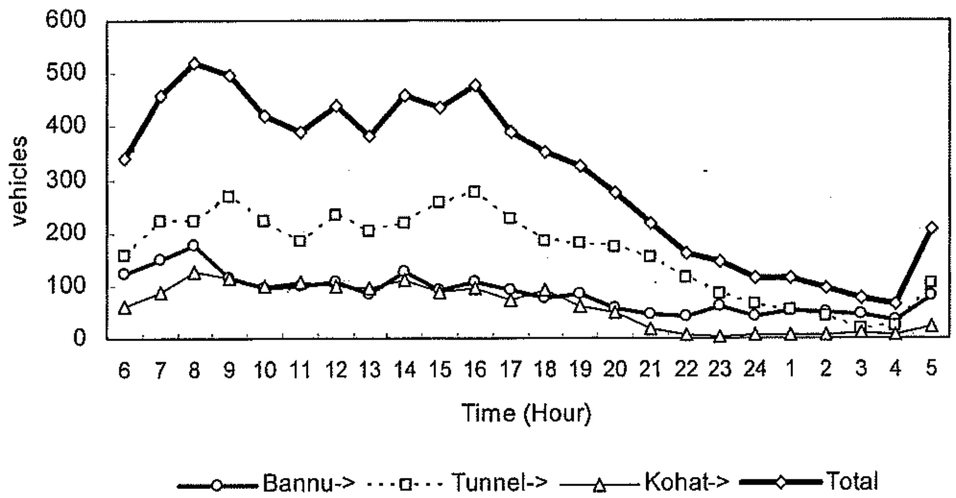


Figure 7.1.7 Hourly Traffic Volume at IC-3

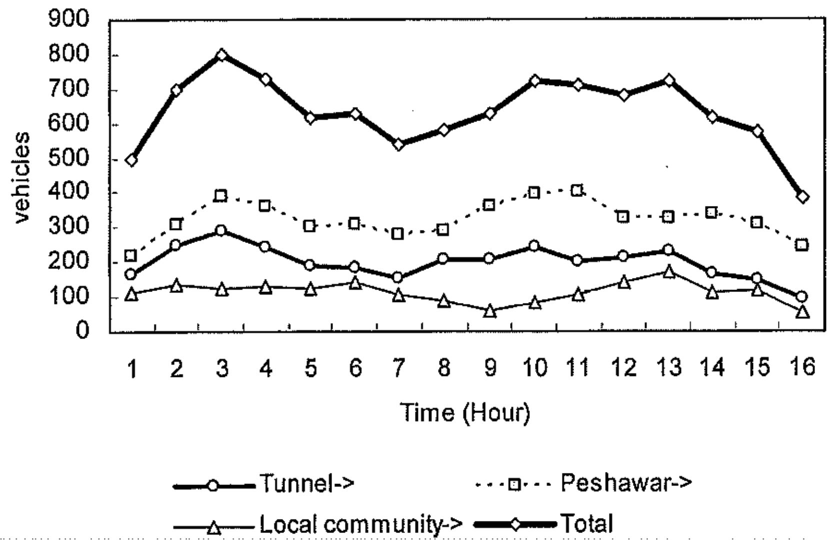


Figure 7.1.8 Hourly Traffic Volume at IC-4

(5) Traffic volume at Intersections

Figure 7.1.8 illustrates traffic volumes at the four intersections where the traffic count surveys were conducted. At the intersection (IC-1) of the start-point of the Kohat Tunnel Access Road, the major traffic directions are Bannu – Kohat City and Bannu – Kohat Tunnel. Traffic movement between Kohat City and the Kohat Tunnel is very small: it was only 329 vehicles from 6:00 to 22:00 on 29 May, 2006. At the intersection (IC-2) of the Kohat Tunnel Access Road and Kohat-Rawalpindi Road, the major traffic movements are through traffic and turning movements are small relatively small. At the intersection (IC-3) of the Kohat Tunnel Access Road and the Link Road, 44% of the traffic from/to the Kohat Tunnel uses the Link Road. At the intersection (IC-4) of the end-point of the Kohat Tunnel Access Road, four fifth of the traffic are between Peshawar and the Kohat Tunnel.

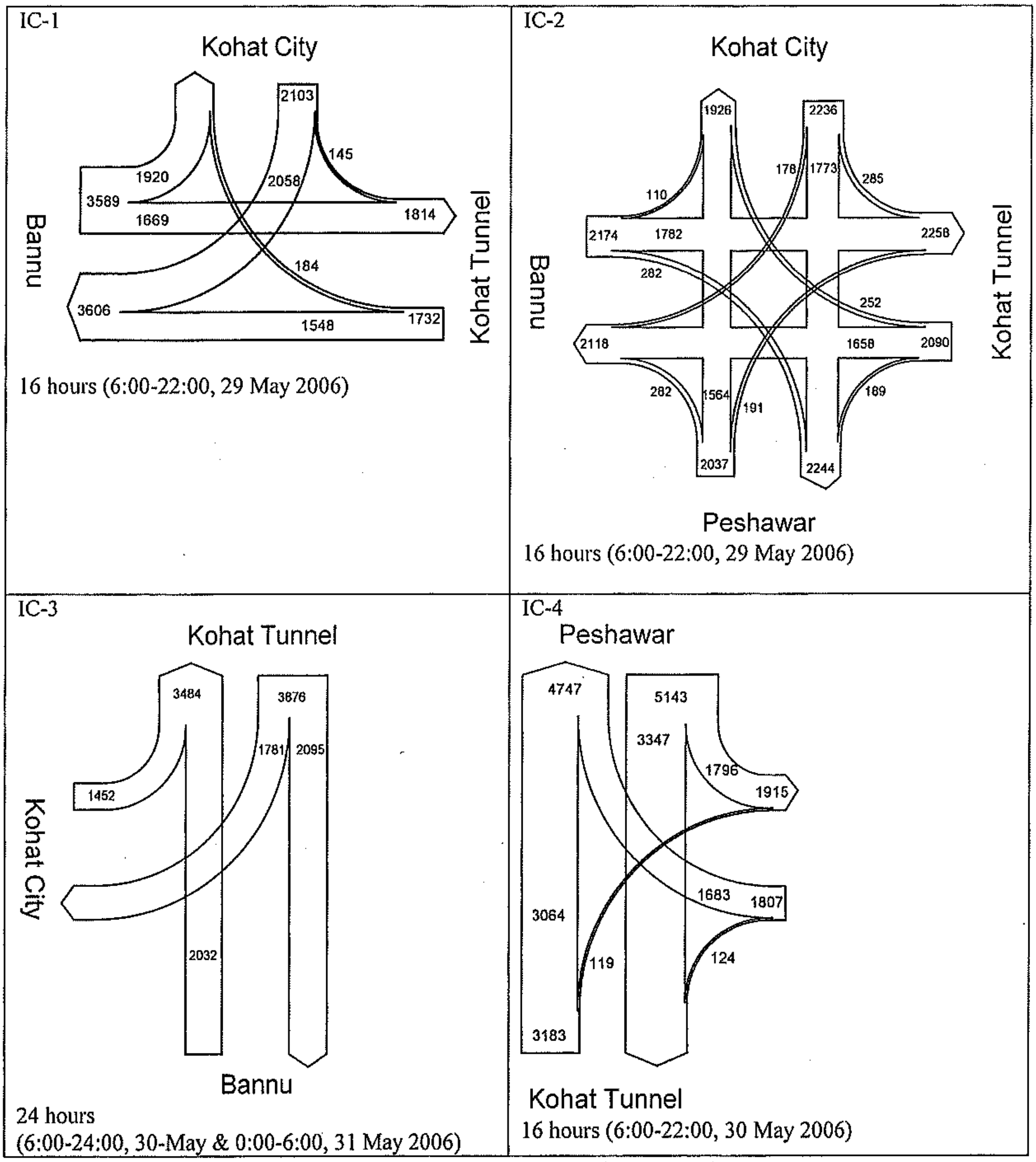


Figure 7.1.9 Traffic Flow at the Selected Intersections

7.2 Traffic Demand Forecast

7.2.1 Forecast in the PTPS Master Plan

(1) Socioeconomic Scenario

In the Medium Term Development Framework (MTDF), the Government set the target GDP growth rates over the MTDF period, starting at 7.0% in 2005/06, becoming higher year by year up to 8.2% in 2009/10. On the other hand, due to rising energy prices and the earthquake of October 8 2005, the economic growth rate in 2005/06 was 6.6%. PTPS applied moderate case as shown in Table 7.2.1: the economic growth rate will be 7% for the MTDF period, declining by 0.5% every five years after 2010/11.

Table 7.2.1 Prospect of Economic Growth Rate %

2005/06-2009/10	2010/11-2014/15	2015/16-2019/20	2020/21-2024/25	2025/26-2029/30
7.0 %	6.5 %	6.0 %	5.5 %	5.0 %

Source: PTPS

(2) Inter-zonal Traffic Demand

The JICA Study Team estimated the future inter-zonal traffic demand for passenger and freight in passenger-km and ton-km, respectively. Inter-zonal traffic is defined in PTPS as the traffic between traffic zones, which intends to express the major inter-city traffic in Pakistan. The increase ratio of inter-zonal traffic was estimated to be lower than that of GDP because it was assumed that major increase in traffic demand would occur in urban area instead of inter-city. Modal shift from road to rail for freight transport was another important assumption to estimate the inter-zonal traffic demand. Table 7.2.2 and 7.2.3 shows the forecast.

Table 7.2.2 Forecast of GDP and Inter-zonal Traffic Demand

Year	GDP	Inter-zonal Passenger demand (billion passenger-kms)			Inter-zonal Freight demand (billion ton-kms)				
						Modal shift case		Present share case	
	Rs. Billion	Total	Road	Rail	Total	Road	Rail	Road	Rail
2005/06	6,559	154	131	23	99	93	6	93	6
2010/11	9,199	212	186	27	133	123	10	125	8
2015/16	12,604	293	261	32	185	148	37	174	11
2020/21	16,867	389	351	38	248	181	67	234	15
2025/26	22,045	517	472	45	329	217	111	309	19

Source: PTPS

Table 7.2.3 Ratio of the Future Traffic Demand to the Present Demand

Year	GDP	Inter-zonal Passenger demand (passenger-kms)			Inter-zonal Freight demand (ton-kms)				
						Modal shift case		Present share case	
		Total	Road	Rail	Total	Road	Rail	Road	Rail
2005/06	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010/11	1.40	1.38	1.41	1.16	1.34	1.31	1.76	1.34	1.34
2015/16	1.92	1.90	1.99	1.37	1.86	1.58	6.40	1.86	1.86
2020/21	2.57	2.52	2.67	1.63	2.50	1.94	11.53	2.50	2.50
2025/26	3.36	3.35	3.59	1.95	3.31	2.33	19.13	3.31	3.31

Source: PTPS

(3) Traffic Assignment

The future O/D matrices were produced under the estimated increase in inter-zonal traffic of passenger and freight, and O/D was assigned to road network model using JICA STRADA. In the traffic assignment, traffic volume at the Kohat Tunnel (N-55 between Peshawar and Kohat) was calculated as shown in Table 7.2.4 and 7.2.5:

Table 7.2.4 PTPS Traffic Demand Forecast at the Kohat Tunnel (Modal shift case)

	2005/06	2010/11	2015/16	2020/25	2025/26
PCU	13,780	17,344	21,942	28,499	35,903
Increase Ratio	1.00	1.26	1.59	2.07	2.61
Annual Growth Rate	-	4.7%	4.8%	5.4%	4.7%

Source: PTPS

Table 7.2.5 PTPS Traffic Demand Forecast at the Kohat Tunnel (without modal shift case)

	2005/06	2010/11	2015/16	2020/25	2025/26
PCU	13,780	17,344	23,387	31,115	40,742
Increase Ratio	1.00	1.26	1.70	2.26	2.96
Annual Growth Rate	-	4.7%	6.2%	5.9%	5.5%
GDP Growth Rate		7.0%	6.5%	6.0%	5.5%

Source: PTPS

As can be seen in the results of the traffic assignments, the increase rate of traffic volume at the Kohat Tunnel was estimated to be lower than that of the total inter-zonal traffic demand due to difference in economic growth rate by region. PTPS assumed that the regional GDP in Punjab and Sindh would grow at higher rate than in NWFP and Baluchistan. The result shows that the traffic volume without modal shift after 2015/16 will increase at the same rate as GDP growth rate.

7.2.2 Review of Traffic Growth Rate

As has been mentioned, traffic volume at the Kohat Tunnel increased by 12.4% from 2004 to 2005. For the period from January to May, the increase rate was 21.8% from 2005 (Jan-May) to 2006 (Jan-May). On the other hand, Pakistan's economy has grown at 7.5%, 8.6% and 6.6% in the fiscal year 2003/04, 2004/05 and 2005/06, respectively (Economic Survey 2006). Traffic growth rate at the Kohat Tunnel has been significantly higher than GDP growth rate from its opening in 2003. From this, it is necessary to revise the traffic demand forecast in PTPS Phase-I, because the PTPS Phase-I estimated that traffic growth rate at the Kohat Tunnel would be lower than economic growth rate.

The rapid increase after the opening of the tunnel showed a drastic route diversion to the tunnel, and the steady increase in the last year implies that diversion from other routes to N-55 via the Kohat Tunnel is still under process. The trend in the diversion will weaken for the next several years, and come close to the growth rate estimated in PTPS Phase-I. From this, traffic increase rate at the Kohat Tunnel was assumed as follows:

Fiscal Year	Annual Traffic Growth Rate %
2006/07	12.0%
2007/08	10.0%
2008/09	9.0%
2009/10	8.0%
2010/11	7.5%
2011/12	7.0%
2012/13 – 2014/15	6.5%
2015/16 – 2019/20	6.0%
2020/21 – 2024/25	5.5%
2025/26 – 2029/30	5.0%

7.2.3 Traffic Demand Forecast for the Kohat Tunnel

(1) Impact of Khushalgarh Bridge Project

Construction of a new bridge at Khushalgarh in place of the existing narrow bridge is included in MTDF, as well as its access road Kohat – Jand – Fatehjang. Articulated trucks like container trucks can not pass through the existing bridge because there are cranks at the both ends of the bridge where large trucks can not make a turn. If the new Khushalgarh Bridge is constructed, a part of traffic between Kohat and Rawalpindi will be diverted from the Kohat Tunnel (N-55) to the Khushalgarh Bridge (N-80). On the other hand, a part of traffic between Peshawar and Rawalpindi will be diverted from N-5 or M-1 to the Kohat Tunnel – Khushalgarh Bridge. The former shift will decrease the traffic at the tunnel while the latter will increase. Using PTPS Traffic Model, traffic assignments were carried out to analyze this. The result showed that the difference of traffic volume would be small as shown in Table 7.2.6.

Table 7.2.6 Changes in Traffic Volume

(With K. Bridge Case – Without K. Bridge Case)/Without K. Bridge Case

2010	2015	2020	2025
0%	6%	4%	-3%

Source: PTPS

(2) Impact of the 2nd Kohat Tunnel

Increase in traffic capacity at the Kohat Tunnel and the Access Road will induce route diversion to some extent. This will occur when other alternative routes become to be congested. To evaluate the impact of the 2nd Kohat Tunnel and dualization of the Access Road, traffic assignments of PTPS Traffic Model were carried out. Without Kushalgarh Bridge Project, the increase in traffic at the Kohat Tunnel is not significant at 3% in 2020 and 5% in 2025. If the new Kushalgarh Bridge is open, a part of traffic using the existing Kohat Tunnel route would choose N-80, which would reduce traffic volume (especially that of trucks) at the Kohat Tunnel. The 2nd Kohat Tunnel will be able to regain the diverted traffic. In addition, the Kohat Tunnel – Khushargarh Bridge route would attract other traffics. It was computed that the 2nd Kohat Tunnel Project will increase traffic along the Access Road by 14% in 2020, and 4% in 2025.

Table 7.2.7 Changes in Traffic Volume by Kohat Tunnel

(With 2nd Tunnel Case – Without 2nd Tunnel Case)/Without 2nd Tunnel Case

	2010	2015	2020	2025
Without Kushalgarh Bridge	1 %	1 %	3 %	5 %
With Kushalgarh Bridge	4 %	14 %	14 %	4 %

Note: Traffic Volume is expressed in PCU
Source: PTPS

(3) Traffic Volume at the Kohat Tunnel

From the traffic survey, some basic data were calculated. Average Daily Traffic (ADT) of the Kohat Tunnel for the base year (2006) was calculated at 7,366 veh/day, or 10,872 Passenger Car Units (PCUs). Peak hour traffic volume was calculated at 520veh/h or 690 PCUs/h for both directions. Directional split of the peak hour was 58% for the direction from Peshawar to Kohat. Peak Hour Factor of the peak hour was 0.87. The percentages of buses and trucks in ADT were adopted for those in the peak hour traffic (buses: 2%; trucks: 26.5%).

Table 7.2.8 24 hours Traffic Volume of the Base Year (2006)

Vehicle Type	Car	Wagon	Large Bus	2-Axle Truck	3-Axle Truck	Articulated Truck	Total
veh/day	3,264	2,004	147	1,055	512	384	7,366
PCU/day	3,264	2,004	294	2,110	1,280	1,920	10,872
PCU	1.0	1.0	2.0	2.0	2.5	5.0	-

Source: PTPS

Applying the revised growth rate, the future traffic volume at the Kohat Tunnel, for the "without Khushalgarh Bridge Project" scenario was estimated as shown in Table 7.2.10. Since the impact of the bridge project probed to be neutral for the traffic demand forecast at the Kohat Tunnel, this result can be used for the "with case" and "without case" of the Kushalgarh Bridge Project. The future traffic volume in Table 7.2.9 is applied for the north section (Kohat Tunnel – Link Road).

Table 7.2.9 Future Traffic Volume at the Kohat Tunnel

Year	Growth Rate (%)	ADT (veh/day)	ADT (PCU/day)	Peak Hour Traffic Volume	Vehicular flow rate for peak-15 min
2006	12.0	7,366	10,872	520	598
2007	10.0	8,103	11,959	572	658
2008	9.0	8,832	13,036	624	717
2009	8.0	9,538	14,078	673	774
2010	7.5	10,254	15,134	724	832
2011	7.0	10,972	16,194	775	890
2012	6.5	11,685	17,246	825	948
2013	6.5	12,444	18,367	879	1,010
2014	6.5	13,253	19,561	936	1,075
2015	6.0	14,048	20,735	992	1,140
2016	6.0	14,891	21,979	1,051	1,208
2017	6.0	15,785	23,298	1,114	1,281
2018	6.0	16,732	24,695	1,181	1,358
2019	6.0	17,736	26,177	1,252	1,439
2020	5.5	18,711	27,617	1,321	1,518
2021	5.5	19,740	29,136	1,394	1,602
2022	5.5	20,826	30,738	1,470	1,690
2023	5.5	21,971	32,429	1,551	1,783
2024	5.5	23,180	34,213	1,636	1,881
2025	5.0	24,339	35,923	1,718	1,975

Source: PTPS

(4) Traffic Volume on the South Section of Access Road (Starting Point – N80 – Link Road)

Traffic volume on the Access Road between the Link Road and N80 is about 60% of that of Kohat Tunnel while the Link Road accounts for about 40%. The base year traffic volume on this section in ADT was calculated to be 4,127 veh/ day from the traffic survey as shown in Table 7.2.10. Traffic volume between N80 and the start point of the Access Road is almost the same.

Table 7.2.10 24 hours Traffic Volume of the Base Year (2006)

Vehicle Type	Car	Wagon	Large Bus	2-Axle Truck	3-Axle Truck	Articulated Truck	Total
veh/day	1,479	931	123	778	462	354	4,127
PCU/day	1,479	931	246	1,556	1,155	1,770	7,173
PCU	1.0	1.0	2.0	2.0	2.5	5.0	-

Source: PTPS

Applying the growth rates to the base year traffic, the average daily traffics work out to be 7,871 veh/day in 2015-16, 10,483 veh/day in 2020-21, and 13,636 in 2025-26.

There are an entering ramp and an exiting ramp at the junction (IC-3) between the Kohat Access Road and the Link Road. The entering ramp provides a connection from the Link Road to the Kohat Tunnel, while the exiting ramp provides it from the Kohat Tunnel to the Link Road. Ramps for the connection between the Link Road and the South section of the Kohat Access Road are not provided at present. It is proposed to provide such ramps so that the Kohat Access Road can function as a bypass road of Kohat City.

If the new ramps are provided, a part of traffic to the east and to the south of Kohat City will divert from the existing route, where congestion is very heavy due to economic activities along streets of the route, to the Access Road as a bypass. From the northern part of Kohat City to Bannu, travel time will reduce by 5 – 10 minutes. From the northern part of Kohat City to the direction of Khushalgarh, travel time will reduced by about 15 minutes. Toll payment will not be required for the bypass route.

To estimate diversion traffic, the following percentages were assumed:

- Percentage of traffic whose origin or destination is in the northern Kohat
- Percentage of traffic which will divert from the existing route to the bypass

From these assumptions, diverted traffic volumes were computed to be 1,760 veh/ day in the base year as shown in Table 7.2.11. **It was assumed that most of buses would not change their routes because they can not catch passengers along the bypass.** From this, traffic volumes on the new ramps are computed as shown in Table 7.2.12.

Table 7.2.11 Estimation of Diverted Traffic to the Access Road via Link Road

Original Route	Traffic volume of the base year (veh/day) *	Percentage of traffic whose origin or destination is in the northern Kohat (%)	Percentage of diversion traffic to the Access Road (%)	Diverted traffic to the Access Road of the base year (veh/day)
Kohat City ←→ Khushargarh (via IC-2)	3,870	40	80	1,240
Kohat City ←→ Bannu (via IC-1)	3,460	30	50	520
Original Route				1,760

Note*: Buses are excluded from traffic volumes
Source: PTPS

Table 7.2.12 Base Year Traffic between Link Road and Access Road (IC2 – IC3)

Vehicle Type	Car	Wagon	Large Bus	2-Axle Truck	3-Axle Truck	Articulated Truck	Total
East	758	357	15	53	28	29	1,240
South	367	68	6	64	13	2	520
Total	1,125	425	21	117	41	31	1,760

Source: PTPS

The future traffic volumes on the Access Road for the section of SP- N80 – Link Road are computed based on the base year traffic and the growth rates as shown in Table 7.2.13. If the new ramps are provided, traffic between N80 and Link Road will reach 14,900veh/day in 2020-21. Traffic on the new ramps will be about 5,800veh/day, or 2,650veh/day for each direction in 2025-26.

Table 7.2.13 Future Traffic Volume on the Access Road (SP- N80 – Link Road)

Year	Without New Ramp	With New Ramp		
	SP* - Link Road	N80 – Link Road	SP – N80	Ramp
2010-11	5,745	8,195	6,469	2,450
2015-16	7,871	11,228	8,863	3,357
2020-21	10,483	14,954	11,804	4,471
2025-26	13,630	19,452	15,355	5,815

Note: Both directions
Source: PTPS

7.3 Capacity Analysis

7.3.1 Tunnel

(1) Capacity of the Kohat Tunnel

The Kohat Tunnel is a two-lane road. The Highway Capacity Manual (HCM) 2000, published by Transportation Research Board (TRB), USA, regards the ideal capacity of a two-lane highway as 1,700pc/h in each direction or 3,200pc/h in both directions. On the other hand, the ideal capacity of 2,800pc/h in both directions, which is applied in HCM 1985, has been commonly used for a two-lane highway. Since the HCM 2000 does not give a methodology to adjust the ideal capacity to the actual capacity, and the ideal capacity of 3,200pc/h seems to be high, the HCM 1985 was applied for calculating the capacity of the Kohat Tunnel. Note that an ideal capacity of 2,500pc/h is commonly used in Japan.

In HCM 1985, the capacity of a two-lane road is calculated as a service flow rate for the level of service (LOS) F as follows:

$$SF_i = 2800\ (v/c)_i f_d f_w f_{HV}$$

Where,
SF_i = service flow rate for LOS i, veh/h in both directions
$(v/c)_i$ = maximum permissible v/c ratio for LOS i
f_d = adjustment factor for directional distribution
f_w = adjustment factor for narrow lanes and/or shoulders
f_{HV} = adjustment factor for heavy vehicles

In the detailed design (D/D) of the Kohat Tunnel Project, the capacity of the tunnel was calculated at 1,861veh/h using the above formula.

Table 7.3.1 Capacity of Tunnel Section in D/D

LOS	SF_i	Ideal Capacity	$(v/c)_i$	f_d	f_w	f_{HV}
A	61	2,800	0.04	0.97	0.76	0.744
B	233	2,800	0.16	0.97	0.76	0.706
C	466	2,800	0.32	0.97	0.76	0.706
D	886	2,800	0.57	0.97	0.76	0.753
E	1,861	2,800	1.00	0.97	0.91	0.753

Source: Kohat Tunnel D/D Report

The results of the traffic survey show that there are minor differences in the conditions of traffic flow which affects the adjustment factor, but the changes are not significant. Instead, it is necessary to review the calculation because of the following reasons.

Influences of a tunnel section were not considered in the D/D to compute the capacity. Narrow lanes and/or shoulders were considered as f_w, but this is not enough to reflect tunnel conditions such as low visibility, feeling of pressure, sudden change in environment at portals, and so on. Some traffic data in Japan shows that traffic capacity at a tunnel is about 80% of its access roads. The adjustment factors in Table above contribute only 88% ($f_d \times f_w$ = 0.97 × 0.91). In order to consider tunnel conditions, PTPS adopted 0.70 for f_w when LOS is from A to D. In addition, the adjustment factor for directional distribution was also revised to be 0.94 based on the result of the traffic survey.

Since the HCM 1985 was developed based on traffic conditions in USA, it is necessary to consider traffic conditions in Pakistan, especially for trucks. It is observed in Pakistan that trucks run at a crawl even in flat sections. The 2%-gradient in the Kohat Tunnel is a hard condition for Pakistani trucks. This means that passenger-car equivalents in the HCM 1985 should be adjusted. For this, PTPS adopted the following values to compute f_{HV}.

Table 7.3.2 Passenger-Car Equivalents for Trucks for the Kohat Tunnel

LOS	D/D	PTPS
A	2.0	2.5
B & C	2.2	2.7
D & E	2.0	2.5

Source: PTPS

From these review of parameters, the capacity of the Kohat Tunnel is computed to be 1,642veh/h in both directions as shown in the table below.

Table 7.3.3 Revised Capacity of the Kohat Tunnel

LOS	SF_i	Ideal Capacity	$(v/c)_i$	f_d	f_w	f_{HV}
A	52	2,800	0.04	0.94	0.70	0.707
B	200	2,800	0.16	0.94	0.70	0.680
C	401	2,800	0.32	0.94	0.70	0.680
D	745	2,800	0.57	0.94	0.70	0.709
E	1,642	2,800	1.00	0.94	0.88	0.709

Source: PTPS

(2) Demand and Capacity Analysis

Table below shows the results of the estimation of the v/c ratio and LOS for the Kohat Tunnel in the future. According to this, LOS has already become D in a peak hour this year. The Kohat tunnel will experience LOS of E for a decade from 2009-10 to 2021-22, and will reach the capacity in 2022-23. It should be noted that a peak hour rate of 7.1%, taken from the traffic count survey, was applied in computing hourly volume for the analysis. The relatively low rate of 7.1% means that the peak is moderate and therefore similar traffic volumes are observed during a daytime. In other words, the situation that LOS is E will continue over daytime in the near future.

Table 7.3.4 Demand & Capacity in the Kohat Tunnel

Year	Growth Rate (%)	ADT (veh/day)	Hourly Volume (veh/h)	Vehicle Flow Rate (veh/h)	v/c	LOS
2006-07	12.0	7,366	520	598	0.4	D
2007-08	10.0	8,103	572	658	0.4	D
2008-09	9.0	8,832	624	717	0.5	D
2009-10	8.0	9,538	673	774	0.5	E
2010-11	7.5	10,254	724	832	0.6	E
2011-12	7.0	10,972	775	890	0.6	E
2012-13	6.5	11,685	825	948	0.6	E
2013-14	6.5	12,444	879	1,010	0.7	E
2014-15	6.5	13,253	936	1,075	0.7	E
2015-16	6.0	14,048	992	1,140	0.8	E
2016-17	6.0	14,891	1,051	1,208	0.8	E
2017-18	6.0	15,785	1,114	1,281	0.9	E
2018-19	6.0	16,732	1,181	1,358	0.9	E
2019-20	6.0	17,736	1,252	1,439	1.0	E
2020-21	5.5	18,711	1,321	1,518	1.0	E
2021-22	5.5	19,740	1,394	1,602	1.1	E
2022-23	5.5	20,826	1,470	1,690	1.1	F
2023-24	5.5	21,971	1,551	1,783	1.2	F
2024-25	5.5	23,180	1,636	1,881	1.3	F
2025-26	5.0	24,339	1,718	1,975	1.3	F

Source: PTPS

7.3.2 Access Road

(1) Capacity of Access Road

Capacity of general sections of the Access Road is higher than that of the tunnel section. The same methodology for two-way segments applied in 7.3.1 can be also applied for the general sections. Different conditions of these sections than that of the tunnel section are:

- Passing is possible.
- Shoulder space is large enough.

The former affects v/c values while the latter affects fw. The same values can be applied for other parameters. From this, capacity of these sections was computed to be 1,866veh/h as shown in the table below.

Table 7.3.5 Service Flow Rates on General Section of Access Road

LOS	SF_i	Ideal Capacity	$(v/c)_i$	f_d	f_w	f_{HV}	E_T	E_B
A	279	2,800	0.15	0.97	1.00	0.707	2.5	1.8
B	483	2,800	0.27	0.97	1.00	0.680	2.7	2.0
C	770	2,800	0.43	0.97	1.00	0.680	2.7	2.0
D	1,194	2,800	0.64	0.97	1.00	0.709	2.5	1.6
E	1,866	2,800	1.00	0.97	1.00	0.709	2.5	1.6

Source: PTPS

(2) Demand and Capacity Analysis

a) Starting Point – N80 – Link Road

Volume to capacity ratios (v/c) were computed from flow rates of the peak hour and the capacity of 1,866veh/h. The flow rates were calculated as follows:

Flow Rate (veh/h) = AADT × K × PHF

Where, K = the ratio of designed hourly traffic volume to AADT (0.0706)
PHF = peak hour factor (0.92)

LOSs were determined from service flow rates in Table 7.3.5 and the flow rates.

Table 7.3.6 shows v/c and LOS of the Access Road from the Starting Point to the Link Road. The table indicates that traffic volume will not exceed the capacity. However, the v/c ratio between N80 and Link Road will reach 0.8 in 2023-24. LOS of this section will become E in 2020-21.

b) Link Road – Ending Point

Table 7.3.6 shows the results of the demand-capacity analysis for the section between Link Road and Ending Point of the Access Road. LOS will become E in 2016-27. The v/c ratio will reach 0.8 in 2019-20, and reach 0.9 in 2021-22. Traffic will reach the capacity in 2024-45.

It should be noted that traffic stream near the tunnel tends to be disturbed because vehicle speeds often change at the parcel of the tunnel. Therefore, even if the v/c ratio is less than 1.0, traffic congestion will occur when the v/c ratio is high, because capacity will decrease once disturbed traffic flow caused congestion.

Table 7.3.6 Future v/c and LOS of the Access Road (SP – N80 – Link Road)

K-Factor = 0.0706

Year	SP - N80				N80 - Link Road			
	AADT (veh/day)	Flow Rate (veh/h)	v/c	LOS	AADT (veh/day)	Flow Rate (veh/h)	v/c	LOS
2006-07	4,647	377	0.2	B	5,887	478	0.3	B
2007-08	5,112	415	0.2	B	6,476	525	0.3	C
2008-09	5,572	452	0.2	B	7,059	573	0.3	C
2009-10	6,017	488	0.3	C	7,623	619	0.3	C
2010-11	6,469	525	0.3	C	8,195	665	0.4	C
2011-12	6,922	562	0.3	C	8,769	712	0.4	C
2012-13	7,372	598	0.3	C	9,339	758	0.4	C
2013-14	7,851	637	0.3	C	9,946	807	0.4	D
2014-15	8,361	678	0.4	C	10,592	860	0.5	D
2015-16	8,863	719	0.4	C	11,228	911	0.5	D
2016-17	9,394	762	0.4	C	11,901	966	0.5	D
2017-18	9,958	808	0.4	D	12,615	1,024	0.5	D
2018-19	10,556	857	0.5	D	13,372	1,085	0.6	D
2019-20	11,189	908	0.5	D	14,174	1,150	0.6	D
2020-21	11,804	958	0.5	D	14,954	1,214	0.6	E
2021-22	12,453	1,011	0.5	D	15,777	1,280	0.7	E
2022-23	13,138	1,066	0.6	D	16,644	1,351	0.7	E
2023-24	13,861	1,125	0.6	D	17,560	1,425	0.8	E
2024-25	14,623	1,187	0.6	D	18,525	1,503	0.8	E
2025-26	15,355	1,246	0.7	E	19,452	1,578	0.8	E

Note: v/c = vehicle flow rate/1866
Source: PTPS

Table 7.3.7 Future LOS of the Access Road (South and North of the Tunnel)

K-Factor = 0.0706

Year	Growth Rate (%)	ADT (veh/day)	Hourly Volume (veh/h)	Vehicle Flow Rate (veh/h)	v/c	LOS
2006-07	12.0	7,366	520	598	0.3	C
2007-08	10.0	8,103	572	658	0.4	C
2008-09	9.0	8,832	624	717	0.4	C
2009-10	8.0	9,538	673	774	0.4	D
2010-11	7.5	10,254	724	832	0.4	D
2011-12	7.0	10,972	775	890	0.5	D
2012-13	6.5	11,685	825	948	0.5	D
2013-14	6.5	12,444	879	1,010	0.5	D
2014-15	6.5	13,253	936	1,075	0.6	D
2015-16	6.0	14,048	992	1,140	0.6	D
2016-17	6.0	14,891	1,051	1,208	0.6	E
2017-18	6.0	15,785	1,114	1,281	0.7	E
2018-19	6.0	16,732	1,181	1,358	0.7	E
2019-20	6.0	17,736	1,252	1,439	0.8	E
2020-21	5.5	18,711	1,321	1,518	0.8	E
2021-22	5.5	19,740	1,394	1,602	0.9	E
2022-23	5.5	20,826	1,470	1,690	0.9	E
2023-24	5.5	21,971	1,551	1,783	1.0	E
2024-25	5.5	23,180	1,636	1,881	1.0	F
2025-26	5.0	24,339	1,718	1,975	1.1	F

Note: v/c = vehicle flow rate/1866
Source: PTPS

7.3.3 Intersection

Currently, there is no signalized intersection along the Kohat Tunnel Access Road. A separate left-turn lane with a triangle island and unsignalized T-intersections compose an intersection at the start point of the access road (IC-1) and the end point (IC-4). Ramps connect the access road and minor roads without signals. To analyze unsignalized intersections and ramps, the HCM 2000 was referred. Gap acceptance theory is the underlying concept for computing capacity of minor roads at unsignalized intersections. The model is express as:

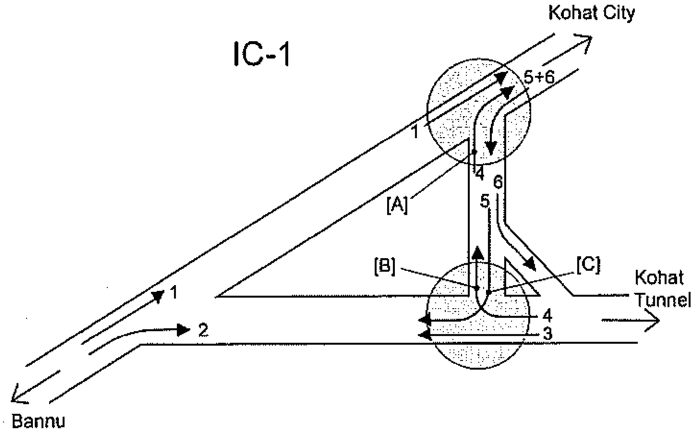
$$c_p = v_c \frac{\exp(-v_c t_c/3600)}{1-\exp(-v_c t_f/3600)}$$

where:
- c_p = potential capacity of minor movement (veh/h)
- v_c = conflicting flow rate (veh/h)
- t_c = critical gap (s)
- t_f = follow-up time (s)

(1) Present Performance

a) IC-1

For IC-1, the start point of the Kohat Tunnel Access Road, following three movements at the peak hour were analyzed:



[A] right-turn from the minor road to the major road

[B] right turn from the major road to the minor road

[C] right-turn from the minor road to the major road

Other movements are given priority at the intersection and the capacity is enough at present. For the selected three movements, v/c, queue length, and delay were estimated as shown in Table below. No problem was identified at IC-1 from the analysis.

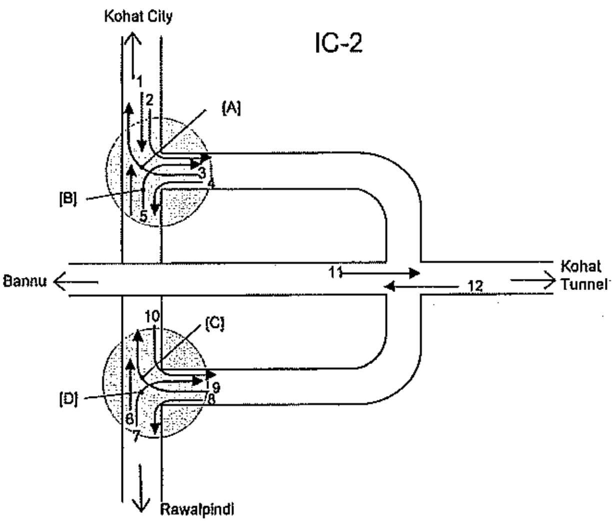
Table 7.3.1 Intersection Analysis for the Selected Movement at IC-1

	Peak flow rate (veh/h)	Conflicting flow rate (veh/h)	Movement capacity (veh/h)	v/c	Q95 (veh)	Delay (s)	LOS
[A]	20	384	602	0.0	0.1	11	B
[B]	175	377	608	0.3	1.2	13	B
[C]	20	255	1,259	0.0	0.0	8	A

Source: PTPS

b) IC-2

For IC-2, the interchange between the Access Road and N-80, the following four movements at the peak hour were analyzed. Currently, traffic volumes of these movements are very small.



[A] right-turn from the direction to Bannu via the ramp to N-80

[B] right-turn from N-80 to the direction to the Kohat Tunnel via the ramp

[C] right-turn from the direction to the Kohat Tunnel via the ramp to N-80

[D] right-turn from N-80 to the direction to Bannu via the ramp

Other movements are given priority at the intersection and the capacity is enough at present. For the selected four movements, v/c, queue length, and delay were estimated as shown in Table below. No problem was identified at IC-2 from the analysis.

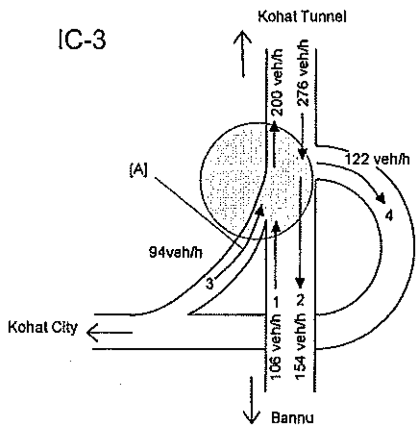
Table 7.3.2 Intersection Analysis for the Selected Movement at IC-1

	Peak flow rate (veh/h)	Conflicting flow rate (veh/h)	Movement capacity (veh/h)	v/c	Q95 (veh)	Delay (s)	LOS
[A]	12	394	548	0.0	0.1	12	B
[B]	12	211	1,318	0.0	0.0	8	A
[C]	13	404	462	0.0	0.1	13	B
[D]	7	197	1298	0.0	0.0	8	A

Source: PTPS

c) IC-3

The capacity of the interchange between the Access Road and the Link Road is enough, compared to traffic volume at present.



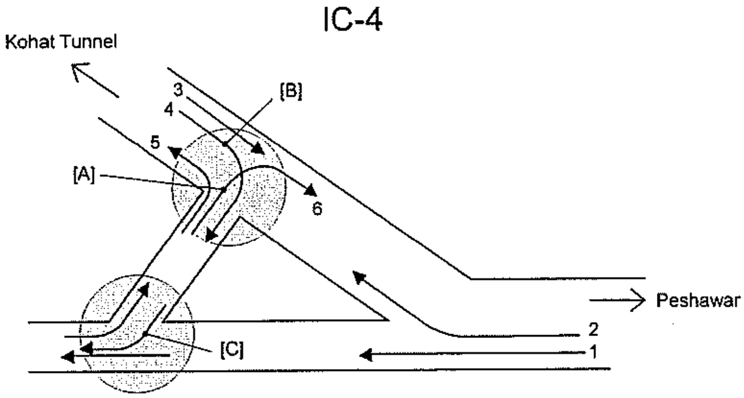
Since vehicles of the traffic movement of [A] have to stop at the end of the ramp, the intersection between the ramp and the Access Road was analyzed as unsignalized T-intersection. No problem was identified from the analysis.

Table 7.3.3 Intersection Analysis for the Selected Movement at IC-3

	Peak flow rate (veh/h)	Conflicting flow rate (veh/h)	Movement capacity (veh/h)	v/c	Q95 (veh)	Delay (s)	LOS
[A]	102	115	906	0.1	0.4	9	B

d) IC-4

For IC-4, the interchange at the end of the Access Road, the following three movements were analyzed.



[A] right-turn from the major road to the Access Road (to Peshawar)

[B] right-turn from the Access Road to the minor road

[C] the second right-turn after the right-turn of [B]

The result of the analysis shows that v/c is 0.4 and LOS is C for the traffic movement of [A]. This means that the movement [A] will be the first that reach the capacity under the current conditions. No problem was identified for other movements.

Table 7.3.4 Intersection Analysis for the Selected Movement at IC-3

	Peak flow rate (veh/h)	Conflicting flow rate (veh/h)	Movement capacity (veh/h)	v/c	Q95 (veh)	Delay (s)	LOS
[A]	142	624	385	0.4	1.7	20	C
[B]	12	264	1,312	0.0	0.0	8	A
[C]	14	244	696	0.0	0.1	10	B

Source: PTPS

(2) Future Performance

The future values of movement capacity, v/c, queue length, and delay were estimated based on the estimated traffic growth rate. Traffic volume will exceed the capacity for some traffic movements. At IC-1, v/c of movement [C] will exceed 1.0 in 2015. At IC-2, v/c of movement [C] will exceed 1.0 in 2023. At IC-4, v/c of movement [A] will soon exceed 1.0 in 2010. These intersections should be signalized before the year when v/c exceeds 1.0.

Table 7.3.5 Intersection Analysis at IC-1

Year	Annual Growth Rate %	IC-1-[A] Peak Flow Rate	Capacity	v/c	Q95	d	LOS	IC-1-[B] Peak Flow Rate	Capacity	v/c	Q95	d	LOS
2006	12.0	20	651	0.0	0.1	11	B	20	1,259	0.0	0.0	8	A
2007	10.0	22	618	0.0	0.1	11	B	22	1,227	0.0	0.1	8	A
2008	9.0	24	589	0.0	0.1	11	B	24	1,197	0.0	0.1	8	A
2009	8.0	26	561	0.0	0.1	12	B	26	1,168	0.0	0.1	8	A
2010	7.5	28	535	0.1	0.2	12	B	28	1,141	0.0	0.1	8	A
2011	7.0	31	510	0.1	0.2	13	B	31	1,114	0.0	0.1	8	A
2012	6.5	33	487	0.1	0.2	13	B	33	1,088	0.0	0.1	8	A
2013	6.5	35	464	0.1	0.2	13	B	35	1,062	0.0	0.1	9	A
2014	6.5	37	441	0.1	0.3	14	B	37	1,035	0.0	0.1	9	A
2015	6.0	39	418	0.1	0.3	15	B	39	1,007	0.0	0.1	9	A
2016	6.0	42	396	0.1	0.4	15	C	42	981	0.0	0.1	9	A
2017	6.0	44	374	0.1	0.4	16	C	44	953	0.0	0.1	9	A
2018	6.0	47	352	0.1	0.5	17	C	47	925	0.1	0.2	9	A
2019	6.0	50	330	0.2	0.5	18	C	50	896	0.1	0.2	9	A
2020	5.5	53	308	0.2	0.6	19	C	53	866	0.1	0.2	9	A
2021	5.5	56	288	0.2	0.7	20	C	56	838	0.1	0.2	10	A
2022	5.5	59	269	0.2	0.8	22	C	59	809	0.1	0.2	10	A
2023	5.5	62	250	0.2	1.0	24	C	62	780	0.1	0.3	10	B
2024	5.5	65	231	0.3	1.1	27	D	65	750	0.1	0.3	10	B
2025	5.0	69	212	0.3	1.3	30	D	69	720	0.1	0.3	11	B

Year	Annual Growth Rate %	IC-1-[C] Peak Flow Rate	Capacity	v/c	Q95	d	LOS
2006	12.0	148	608	0.2	1.0	13	B
2007	10.0	165	572	0.3	1.2	14	B
2008	9.0	182	540	0.3	1.5	15	C
2009	8.0	198	511	0.4	1.9	17	C
2010	7.5	214	484	0.5	2.3	18	C
2011	7.0	230	457	0.5	2.9	21	C
2012	6.5	246	433	0.6	3.7	24	C
2013	6.5	262	409	0.7	4.6	29	D
2014	6.5	279	386	0.8	6.0	38	E
2015	6.0	297	362	0.9	8.0	52	F
2016	6.0	315	340	1.0	10.5	77	F
2017	6.0	334	318	1.1	13.7	117	F
2018	6.0	354	296	1.3	17.6	177	F
2019	6.0	375	275	1.4	22.1	255	F
2020	5.5	398	254	1.7	27.1	352	F
2021	5.5	420	235	1.9	32.1	462	F
2022	5.5	443	216	2.2	37.5	594	F
2023	5.5	467	198	2.6	43.1	754	F
2024	5.5	493	181	3.0	49.1	948	F
2025	5.0	520	164	3.5	55.3	1186	F

Note: The new ramps at IC-3 are taken into consideration
Source: PTPS

Table 7.5.6 Intersection Analysis at IC-2

Year	Annual Growth Rate %	IC-2-[A] Peak Flow Rate	Capacity	v/c	Q95	d	LOS	IC-2-[B] Peak Flow Rate	Capacity	v/c	Q95	d	LOS
2006	12.0	12	569	0.0	0.1	11	B	68	1,294	0.1	0.2	8	A
2007	10.0	14	486	0.0	0.1	12	B	75	1,276	0.1	0.2	8	A
2008	9.0	15	455	0.0	0.1	13	B	81	1,258	0.1	0.2	8	A
2009	8.0	16	426	0.0	0.1	13	B	88	1,241	0.1	0.2	8	A
2010	7.5	17	398	0.0	0.1	14	B	94	1,224	0.1	0.2	8	A
2011	7.0	18	372	0.0	0.2	14	B	101	1,207	0.1	0.3	8	A
2012	6.5	20	348	0.1	0.2	15	B	107	1,191	0.1	0.3	8	A
2013	6.5	21	324	0.1	0.2	16	C	114	1,174	0.1	0.3	8	A
2014	6.5	22	300	0.1	0.2	17	C	122	1,155	0.1	0.4	8	A
2015	6.0	24	278	0.1	0.3	18	C	129	1,138	0.1	0.4	9	A
2016	6.0	25	256	0.1	0.3	19	C	137	1,120	0.1	0.4	9	A
2017	6.0	26	235	0.1	0.4	20	C	145	1,100	0.1	0.5	9	A
2018	6.0	28	214	0.1	0.4	22	C	154	1,080	0.1	0.5	9	A
2019	6.0	30	194	0.2	0.5	24	C	163	1,060	0.2	0.5	9	A
2020	5.5	31	176	0.2	0.6	26	D	172	1,040	0.2	0.6	9	A
2021	5.5	33	159	0.2	0.8	29	D	182	1,019	0.2	0.6	9	A
2022	5.5	35	142	0.2	0.9	32	D	191	998	0.2	0.7	9	A
2023	5.5	37	126	0.3	1.1	37	E	202	976	0.2	0.8	10	A
2024	5.5	39	111	0.3	1.4	43	E	213	954	0.2	0.9	10	A
2025	5.0	41	99	0.4	1.8	51	F	224	932	0.2	0.9	10	B

Year	Annual Growth Rate %	IC-2-[C] Peak Flow Rate	Capacity	v/c	Q95	d	LOS	IC-2-[D] Peak Flow Rate	Capacity	v/c	Q95	d	LOS
2006	12.0	13	488	0.0	0.1	12	B	74	1,373	0.1	0.2	8	A
2007	10.0	15	409	0.0	0.1	14	B	83	1,353	0.1	0.2	8	A
2008	9.0	16	377	0.0	0.1	14	B	91	1,335	0.1	0.2	8	A
2009	8.0	18	348	0.1	0.2	15	C	100	1,317	0.1	0.2	8	A
2010	7.5	19	322	0.1	0.2	16	C	108	1,300	0.1	0.3	8	A
2011	7.0	20	297	0.1	0.2	17	C	116	1,283	0.1	0.3	8	A
2012	6.5	22	274	0.1	0.3	18	C	124	1,266	0.1	0.3	8	A
2013	6.5	23	253	0.1	0.3	19	C	132	1,250	0.1	0.4	8	A
2014	6.5	25	232	0.1	0.4	20	C	140	1,232	0.1	0.4	8	A
2015	6.0	26	212	0.1	0.4	22	C	150	1,214	0.1	0.4	8	A
2016	6.0	28	193	0.1	0.5	24	C	159	1,196	0.1	0.5	8	A
2017	6.0	30	175	0.2	0.6	26	D	168	1,178	0.1	0.5	9	A
2018	6.0	31	158	0.2	0.7	29	D	178	1,158	0.2	0.5	9	A
2019	6.0	33	141	0.2	0.9	33	D	189	1,138	0.2	0.6	9	A
2020	5.5	35	125	0.3	1.1	38	E	200	1,117	0.2	0.7	9	A
2021	5.5	37	112	0.3	1.3	44	E	211	1,097	0.2	0.7	9	A
2022	5.5	39	98	0.4	1.7	52	F	223	1,076	0.2	0.8	9	A
2023	5.5	41	86	0.5	2.1	64	F	235	1,055	0.2	0.9	9	A
2024	5.5	44	75	0.6	2.7	83	F	248	1,033	0.2	0.9	10	A
2025	5.0	46	64	0.7	3.5	115	F	262	1,010	0.3	1.0	10	A

Note: The new ramps at IC-3 are taken into consideration
Source: PTPS

Table 7.3.7 Intersection Analysis at IC-3 and IC-4

Year	Annual Growth Rate %	IC-3-[A] Peak Flow Rate	Capacity	v/c	Q95	d	LOS	IC-4-[A] Peak Flow Rate	Capacity	v/c	Q95	d	LOS
2006	12.0	102	906	0.1	0.4	9	A	142	385	0.4	1.7	20	C
2007	10.0	114	890	0.1	0.4	10	A	159	342	0.5	2.4	24	C
2008	9.0	125	877	0.1	0.5	10	A	174	310	0.6	3.2	30	D
2009	8.0	135	864	0.2	0.6	10	A	187	281	0.7	4.4	40	E
2010	7.5	145	851	0.2	0.6	10	B	202	255	0.8	6.0	56	F
2011	7.0	155	839	0.2	0.7	10	B	216	231	0.9	8.1	87	F
2012	6.5	165	826	0.2	0.7	10	B	230	209	1.1	10.7	137	F
2013	6.5	176	814	0.2	0.8	11	B	245	189	1.3	13.9	215	F
2014	6.5	187	800	0.2	0.9	11	B	260	168	1.5	17.4	321	F
2015	6.0	198	787	0.3	1.0	11	B	276	151	1.8	21.0	448	F
2016	6.0	210	773	0.3	1.1	11	B	293	134	2.2	24.8	609	F
2017	6.0	223	759	0.3	1.2	12	B	310	118	2.6	28.8	812	F
2018	6.0	236	744	0.3	1.4	12	B	329	103	3.2	32.9	1069	F
2019	6.0	250	729	0.3	1.5	13	B	349	90	3.9	37.1	1396	F
2020	5.5	264	714	0.4	1.7	13	B	368	78	4.7	41.0	1779	F
2021	5.5	279	699	0.4	1.9	14	B	388	67	5.8	45.0	2266	F
2022	5.5	294	683	0.4	2.2	14	B	409	57	7.1	49.1	2890	F
2023	5.5	310	667	0.5	2.5	15	B	432	49	8.9	53.3	3698	F
2024	5.5	327	651	0.5	2.8	16	C	456	41	11.2	57.6	4757	F
2025	5.0	344	635	0.5	3.3	17	C	478	34	13.9	61.6	6017	F

Year	Annual Growth Rate %	IC-4-[B] Peak Flow Rate	Capacity	v/c	Q95	d	LOS	IC-4-[C] Peak Flow Rate	Capacity	v/c	Q95	d	LOS
2006	12.0	12	1,312	0.0	0.0	8	A	14	696	0.0	0.1	10	B
2007	10.0	13	1,277	0.0	0.0	8	A	16	671	0.0	0.1	10	B
2008	9.0	15	1,249	0.0	0.0	8	A	18	647	0.0	0.1	11	B
2009	8.0	16	1,222	0.0	0.0	8	A	19	624	0.0	0.1	11	B
2010	7.5	17	1,196	0.0	0.0	8	A	21	602	0.0	0.1	11	B
2011	7.0	18	1,169	0.0	0.0	8	A	22	580	0.0	0.1	11	B
2012	6.5	19	1,144	0.0	0.1	8	A	24	560	0.0	0.1	12	B
2013	6.5	21	1,117	0.0	0.1	8	A	25	538	0.0	0.1	12	B
2014	6.5	22	1,090	0.0	0.1	8	A	27	517	0.1	0.2	12	B
2015	6.0	23	1,063	0.0	0.1	8	A	29	496	0.1	0.2	13	B
2016	6.0	25	1,036	0.0	0.1	9	A	31	475	0.1	0.2	13	B
2017	6.0	26	1,008	0.0	0.1	9	A	32	454	0.1	0.2	14	B
2018	6.0	28	978	0.0	0.1	9	A	34	433	0.1	0.3	14	B
2019	6.0	30	948	0.0	0.1	9	A	36	411	0.1	0.3	15	B
2020	5.5	31	920	0.0	0.1	9	A	39	391	0.1	0.3	15	C
2021	5.5	33	891	0.0	0.1	9	A	41	371	0.1	0.4	16	C
2022	5.5	35	861	0.0	0.1	9	A	43	351	0.1	0.4	17	C
2023	5.5	37	831	0.0	0.1	10	A	45	330	0.1	0.5	18	C
2024	5.5	39	800	0.0	0.2	10	A	48	310	0.2	0.5	19	C
2025	5.0	41	771	0.1	0.2	10	A	50	292	0.2	0.6	20	C

Source: PTPS

Chapter 8. DESIGN STANDARDS

8.1 General

According to the "Standards for Road in Pakistan" by NHA, roads shall be designed to meet the following basic criteria:

- Provide road users with a comfortable and stress free driving environment
- Accommodate existing and future traffic needs
- Provide the highest practical and feasible level of safety to highway users
- Match the surrounding weather, terrain and soil conditions
- Meet international highway design standards
- Minimize future maintenance requirements
- Minimize adverse community and environmental impacts.

The structural, drainage and pavement design standards shall follow the American Association of State Highway and Transport Design Guides with required modifications where necessary to accommodate local conditions.

The Project aims at providing a dual carriageway by construction of two additional lanes on the east side (right-hand side towards Peshawar) of land in parallel to the existing road. The design standards applied for the Project road are as follows:

- Roadway:
  - Standards for Roads in Pakistan, NHA, February 1992
  - Typical and General Drawings (Highways), NHA, April 2004
  - Policy on Geometric Design of Highways and Streets, AASHTO, 2001
  - Highway Drainage Guidelines, AASHTO, 1992
- Pavement:
  - AASHTO Guide for Design of Pavement Structures, 1993
- Bridges:
  - Standardization of Bridge Superstructures, NHA, March 2005
  - Standard Specifications for Highway Bridges, AASHTO, 17th Edition
  - Draft Seismic Design Standard, NHA, August 2006 (Note: New PGA established after the earthquake in October 2005)
- Tunnel:
  - Technical Standards for Road Tunnels, Japan Road Association, 2001 and 2003
  - Design Manual Volume III (Tunnel), Japan Highway Public Corporation, 1997
  - Standards of Tunnels in Mountainous Terrain, Japan Society of Civil Engineers, 1996
- Materials:
  - Standard Construction Specifications, NHA, 1998

In addition to the above, the design standards used for the 1st Kohat Tunnel and Access Roads were referred to since the 2nd Tunnel and Access Roads are planned to be constructed in parallel to the 1st Kohat and Access Roads.

8.2 Classification of the Project Road

The Kohat Tunnel and Access Roads are a part of the National Highway N-55 (Indus Highway) administrated by NHA. The Project road (length 30 km) starts at Kohat Toi Intersection (south of Kohat Town), crosses over the Kohat Pindi (N-80) IC at Sta.9+646, the Kohat Link Road IC at Sta.15+575, the Sanda Basta (N.W.F. Road) IC at Sta.19+088 and ends at Dara Adam Khel Intersection, 30km south of Peshawar.

8.3 Highway Design Standards

8.3.1 Design Speed and Design Vehicles

The geometric design standards applied for the Project road are NHA Standards and AASHTO Geometric Design Guide (2001) where the design speed and design vehicle govern the major elements of road geometry. The geometric design standards of the Project road are also governed by the existing 1st Kohat Tunnel and Access Roads as it is constructed at 13.3 m and 10.8 m away and in parallel to the existing road.

The design vehicle applicable for the Project road is truck—trailers, Vehicle Type WB-12 (H:4.1m, W:2.4m, L:13.9m), WB-15 (H:4.1m, W:2.6m, L:16.8m) and WB-19 (H:4.1m, W:2.6m, L:20.9m), referring to AASHTO specifications.

The design speeds applied for the geometric design are as shown in Table 8.3.1. The same design speeds (90 km/h for the tunnel south section and 80 km/h for the tunnel north section) were used for the 2nd Kohat Tunnel and Access Roads as it constitutes a widened part of the existing road.

Table 8.3.1 Design Speed of Throughway

Road Section	Terrain	Area	Design Speed (km/h)*		Remarks
			1st Kohat Road	2nd Kohat Road	NHA 1992**
Kohat Toi - Changai Algada (Sta.18+000)	Flat to Rolling	Sub-urban to Rural	90	90	100
Changai Algada (Sta.18+000) - N.W.F.Road IC. (Sta.19+000)	Mountain	Rural	80	80	80
N.W.F.Road IC. - Dara Adam Khel (End of Project)	Flat to Rolling	Rural	80	80	100
Kohat Tunnel			60	60	-

Notes: * The design speed is based on A Policy on Geometric Design of Highways and and Streets, 2001, AASHTO
** Standards for Roads in Pakistan, NHA, 1992

8.3.2 Geometric Design Standards

The geometric design standards applied for the Project road are as summarised in Table 8.3.2.

(1) Cross Section Elements

Figures 8.3.1 and 8.3.2 show the typical cross sections for the north and south sections respectively. The two new lanes of the tunnel south section are located at 13.3 m away from the existing road centreline providing a 6m-wide median as originally planned in the 1st Kohat Tunnel and Access Road Project, and those of the north section s are located at 10.8 m away from the existing road, providing a 3.5m-wide median. The original median was 3.0 m wide for the north section but it was reviewed in this FS to provide a minimum median width of 3.2 m at four bridges (see the following illustration) and to avoid the centreline deviation in a short distance.

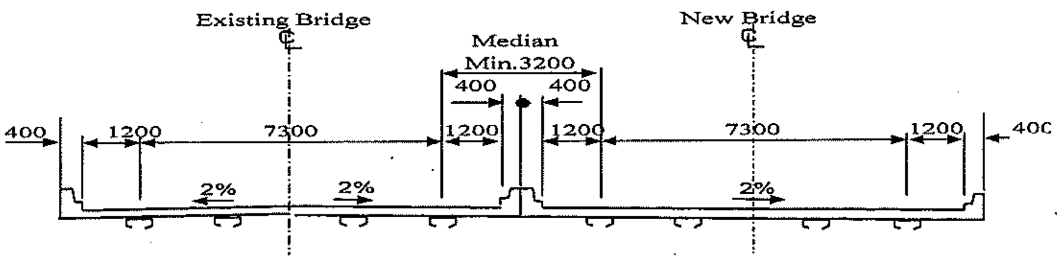


Table 8.3.2 Geometric Design Standards

Item	Unit	Design Standards			
		1st Kohat Acesss Road		**2nd Kohat Acesss Road**	
Section		South	North	South	North
Design Section	Km/h	90	80	90	80
Cross Section Elements:					
- Lane width	m	3.65	3.65	3.65	3.65
- Outer Shoulder Width	m	3.00	3.00	3.00	3.00
- Outer Shoulder Width for climbing lane	m	1.00	1.00	-	-
- Inner Shoulder Width	m	1.00	1.00	1.00	1.00
		(Future 4-lanes)			
- Median Width	m	6.00	3.00	6.00	3.50
		(Future 4-lanes)			
- Climbing Lane Width	m	3.00	-	-	-
- Crossfall of Travelled Way	%	2	2	2	2
- Crossfall of Shoulder	%	4	4	4	4
- Vertical Clearance	m	5.03	5.03	5.03	5.03
- Railway Vertical Clearance	m	6.71	6.71	6.71	6.71
- Stopping Sight Distance	m	137	120	160	130
- Passing Sight Distance	m	600	550	615	540
Horizontal Alignment:					
Circular Curve:					
- Min. Radius	m	270	220	275	210
- Min. Superelevation Runoff	m	50	46	115	108
		(one lane rotated)		(two lane rotated)	
- Max. Superelevation Rate	%	10	10	10	10
- Tangent Runout	m	16	15	23	22
Transition Curve:					
- Type of transition curve		-	-	Spiral Curve (Clothoid)	-
- Min. Transition Curve Length	m	-	-	50	-
- Max. Radius for Use of	m	-	-	480	-
a Spiral Curve Transition *				(1200)	-
Vertical Alignment:					
- Max. Grade	%	7	7	4	5
Crest Curve					
- Stopping Sight Distance	m	-	-	160	130
- Passing Sight Distance	m	600	550	615	540
Sag Curve					
- Stopping Sight Distance	m	-	-	160	130

Note: * recommended max. radius for use of a transition curve if site condition allows

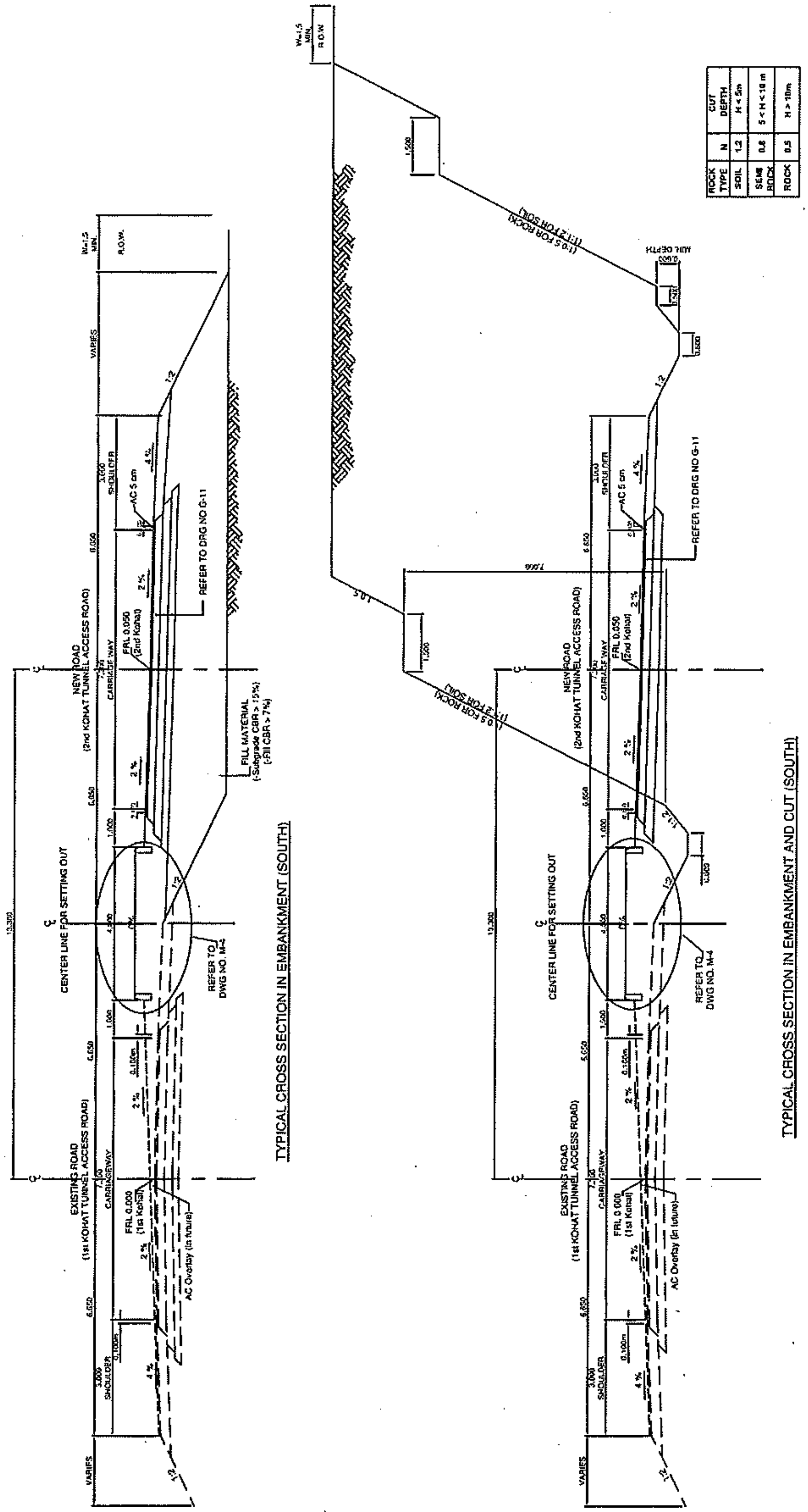


Figure 8.3.1 Typical Cross Sections for South Section

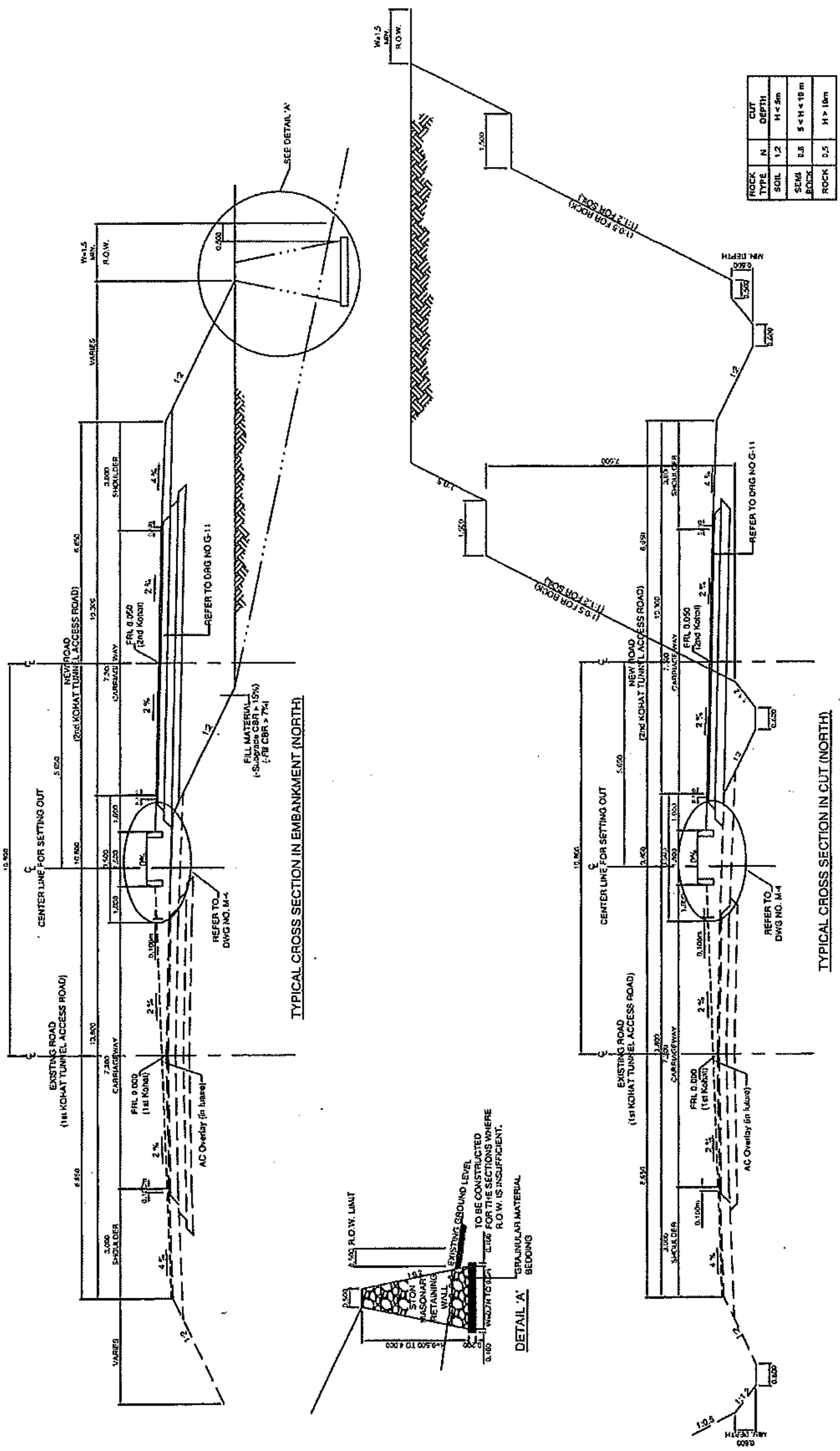


Figure 8.3.2 Typical Cross Sections for North Section

The carriageway width is 7.3 m (3.65 m x 2 lanes), the outer shoulder width is 3.0 m and inner shoulder width is 1.0 m. The standard cross fall of the travel way is 2.0% and that for shoulders is 4.0%.

Slopes for cuts are 1 (V) : 1.2 (H) for common soil, 1 (V) : 0.7 (H) for semi-rock and 1 (V) : 0.5 (H) for rock. Intermediate 1.5m-wide berms will be provided for the cuts higher than 7m. Embankment slopes are 1 (V): 2 (H) without intermediate berms irrespective of heights. Retaining walls will be constructed at the fill and cut sections where the existing Right of Way (ROW) is insufficient in the tunnel north section to avoid additional land acquisition.

The maximum superelevation of 10%, which is same as the 1st Kohat Tunnel and Access Roads Design, is used for the Project road. The superelevation (SE) and SE run-off are as shown in Table 8.3.3 (AASHTO Geometric Design Standards).

Table 8.3.3 Superelevation and Minimum Length of SE Runoff for $e_{max} = 10\%$

R	V = 80 Km/h			V = 90 Km/h		
	e	L (m)		e	L (m)	
(m)	(%)	2-lanes	4-lanes	(%)	2-lanes	4-lanes
7000	NC	0	0	NC	0	0
5000	NC	0	0	NC	0	0
3000	NC	0	0	NC	0	0
2500	NC	0	0	RC	15	23
2000	RC	14	22	2.2	17	25
1500	2.4	17	26	2.9	22	33
1400	2.6	19	28	3.1	24	36
1300	2.8	20	30	3.3	25	38
1200	3.0	22	32	3.6	28	41
1000	3.5	25	38	4.2	32	48
900	3.9	28	42	4.6	35	53
800	4.3	31	46	5.1	39	59
700	4.8	35	52	5.8	44	67
600	5.5	40	59	6.5	50	75
500	6.4	48	69	7.6	58	87
400	7.5	54	81	8.8	67	101
300	9.0	65	97	9.9	76	114
250	9.7	70	105	R_{min} = 275 m		
	R_{min} = 210 m					

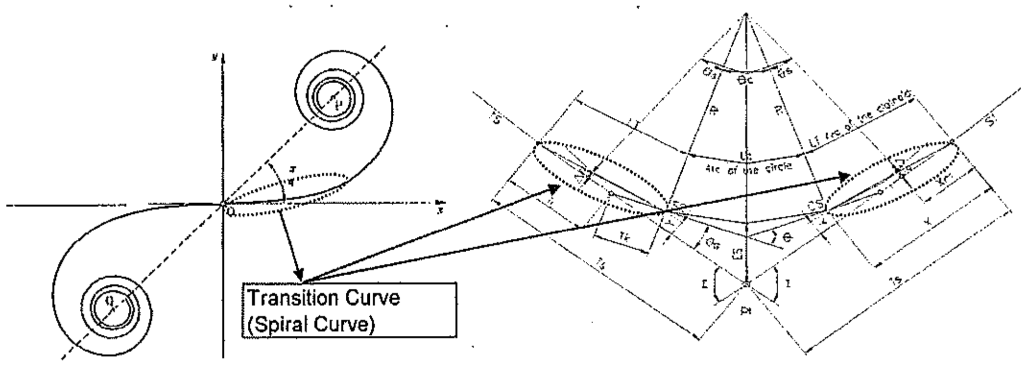
Source: A Policy on Geometric Design of Highways and Streets, AASHTO, 2001

where,

	R:	Radius of Curve
	Vd:	Assumed Design Speed
	e:	Rate of Superelevation
	L:	Minimum Length of Runoff (not including tangent run out)
	NC:	Normal Crown Section
	RC:	Remove adverse crown, superelevation at normal crown slope

(2) Horizontal Alignment

The NHA design standards do not specify the necessity of transition curves. The road geometry used for the 1st Kohat Tunnel and Access Roads was a combination of straight lines and simple curves. However, it is common to insert a transition curve between the straight section and the circular curve taking safety and convenience of driving into consideration. Clothoid or spiral curves (see the following illustration), which show a similar trail of vehicle movement after turning handle, are used as transition curves by most of the world road agencies.



Calculation and site set out of spiral curve were very complicated before personal computers are available at an acceptable price. However, it is easy now as computer programs give all necessary data for drawings preparation and site set out.

Providing safe and user friendly road facilities is the mission statement of road administrators and agencies, not only in Pakistan but also throughout the world. The Study Team designed the 2nd Kohat Tunnel by both methods: one without transition curves and the other with transition curves and compared them for application.

The minimum curve radius applied for the tunnel south section is 300m and that for the north section is 260m and both meet the geometric design standards shown in Table 8.3.2 except at the junctions. The radius of curves in the tunnel south section is relatively larger because this section is located in a flat/rolling terrain. However, the curves in the tunnel north section have a smaller radius with short straight sections due to the mountainous terrain at this site.

Travelway widening is needed for certain horizontal curves because the design vehicles occupy a greater width on curves or drivers may not run on the lane centre. The design widening values are shown in Table 8.3.4.

Table 8.3.4 Travelway Widening for Two-Lane Highways (One-way or Two-way)

R (m)	Design Vehicle WB-12 (Semi-trailer)					Design Vehicle WB-15 (Semi-trailer)					Design Vehicle WB-19 (Semi-trailer)				
	Design Speed (Km/h)					Design Speed (Km/h)					Design Speed (Km/h)				
	50	60	70	80	90	50	60	70	80	90	50	60	70	80	90
2000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1000	-	-	-	-	-	-	-	-	0.1	0.1	0.1	0.1	0.1	0.2	0.2
900	-	-	-	-	-	-	-	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2
800	-	-	-	-	-	-	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
700	-	-	-	-	-	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3
600	-	-	-	-	-	0.1	0.2	0.2	0.2	0.3	0.2	0.3	0.3	0.3	0.4
500	-	-	-	-	-	0.2	0.2	0.3	0.3	0.4	0.3	0.3	0.4	0.4	0.5
400	-	-	-	-	-	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.7
300	-	-	-	0.1	0.2	0.4	0.5	0.5	0.6	0.7	0.6	0.7	0.7	0.8	0.9
250	0.1	0.1	0.2	0.2	0.3	0.5	0.6	0.7	0.7	0.8	0.7	0.8	0.9	0.9	1.0
200	0.1	0.2	0.3	0.3		0.7	0.8	0.9	0.9		0.8	1.1	1.2	1.2	

Notes: 1. The above are adjusted values for the roadway width from 7.20 m in USA to 7.30 m in Pakistan.
2. Values less than 0.6m may be disregarded.

Source: A Policy on Geometric Design of Highways and Streets, AASHTO, 2001

However, as not so many truck-trailers of Type WB-15 (or WB-12 and WB-19) use the Project road and they run at a speed lower than the design speed, and as the widening cost is high, travelway widening should be considered carefully. As travelway widening was not applied for the 1st Kohat Tunnel and Access Roads, the same policy of design without widening should be adopted for the 2nd Kohat Tunnel and Access Roads.

(3) Vertical Alignment

Two new lanes will be provided for the south-bound traffic from Peshawar to Kohat/Bannu. The road climbs up from Dara Adam Khel to the tunnel north portal and then descends to Kohat Toi. The maximum grade is limited to less than 4.8% for the access roads. The grade of the new tunnel, which is to be used for the down-grade traffic, is 2.4% compared to 2.2% of the existing tunnel. Vertical curve alignment is designed to meet the stopping site distance and taking visual comfort of driving into consideration.

The 1st Kohat Tunnel and Access Roads have a climbing lane at Sta.17+800 – Sta.19+700 (L=2.3 km) where the grade of vertical alignment is 3.9%. The 2nd Kohat Tunnel and Access Road will not be provided a climbing lane as this section will be used for the down-grade traffic only.

8.3.3 Drainage Facilities

Drainage structures for the Project road consist of river bridges/box culverts, roadway cross drainages (pipe culverts), road side drainages and tunnel drainages. The flood return period of 50 years is used for bridge design and 25 years for culvert design.

Cross drainage structures (bridges and culverts) are at the same location and have the same capacity as those of the 1st Kohat Tunnel and Access Roads, in principle, because those structures are positioned either down-stream or up-stream of the existing structures. As the Project road is to provide a dual carriageway system, median drainage is necessary for the in-curve sections.

8.3.4 Pavement Design Standards

Pavement of the Project road is designed according to the standards set forth in the AASHTO Guide for Design of Pavement Structures 1993. Asphalt concrete pavement will be used for the Project road except for the toll plaza and tunnel sections where Portland cement concrete pavement (PCC) is used. Flexible pavement (AC pavement) is adopted for the design period of 10 years and rigid pavement (PCC pavement) for 20 years.

Pavement structures are designed taking into account high ambient temperature in the dry season, relatively low temperatures in the cold season, and high axle loads. Structural design of pavements is performed based on the following surveys and analysis:

- Soil condition along the road alignment
- Subgrade bearing capacity analysis
- Traffic counts, future traffic and CESA estimate
- Drainage characteristics of the subgrade soils
- Materials availability analysis.

Work experience and performance of the pavement during and after the 1st Kohat Tunnel and Access Roads construction was also incorporated in the design. Appropriate materials (see Tables 8.3.5 and 8.3.6) conforming to the Standard Construction Specifications of NHA are used for the pavement design. AC pavement is composed of 3 layers: AC Base Class A, AC Base Class B and AC wearing course Class B.

Table 8.3.5 Asphalt Concrete Materials

Item	AC Wearing Course		AC Base Course	
	Class A	Class B	Class A	Class B
Asphalt Concrete				
Asphalt Penetration Grade	40-50, 60- 70 or 80-100		40-50, 60- 70 or 80-100	
AC Content	3.5% (Min.)		3.0% (Min.)	
Stability	1000 kg (Min)		1000 kg (Min)	
Flow, 0.25 mm	8-14		8-14	
Air Void	4% - 7%		4% - 8%	
Loss in Stability	20% (Max.)		25% (Max.)	
Aggregates				
Max. Particle Size	25 mm	20 mm	50 mm	38 mm
LA Abrasion	30% (Max.)		40% (Max.)	
Loss by SS Soundness	12% (Max.)		12% (Max.)	
Flat particles	10% (Max)		15% (Max)	
Course Aggregate (>4.75 mm)	Crushed rock or crushed gravel (crushed particle =100%)		Crushed rock, crushed gravel or crushed boulder (crushed particle > 95%)	
Fine Aggregate	100% crushed rock or crushed boulder		100% crushed rock or crushed boulder	

Source: Data extracted from Standard Construction Specifications of NHA, 1998

Table 8.3.6 Base and Subbase Materials

Item	Granular Subbase		Aggregate Base	
	Grading A	Grading B	Grading A	Grading B
Max. Particles	60 mm	50 mm	50 mm	50 mm
Uniformity (D60/D10)	3 (Min.)		4 (Min.)	
CBR	50% (min) at 98% max. density		80% (min) at max. density	
LA Abrasion	50% (Max.)		40% (Max.)	
Loss by SS Soundness	-		12% (Max.)	
Fraction < 0.075 mm	LL< 25%, PI < 6		LL< 25%, PI < 6	
Materials	Natural or processed aggregate		Crushed aggregate (crushed particle > 90%)	

Source: Data extracted from Standard Construction Specifications of NHA, 1998

8.3.5 Other Road Facilities

Other road facilities including toll plaza, intersections, right/left turn lanes, road safety facilities, traffic control facilities, etc. are designed in accordance with the NHA standards and those used for the 1st Kohat Tunnel and Access Road Project.

8.4 Bridge and Culvert Design Standards

8.4.1 Design Standards and Loading

(1) Design Standards

The "Standardization of Bridge Superstructures, NHA, 2005", "West Pakistan Code of Practice for Highway Bridges (WPCHB)" and the bridge design for the 1st Kohat Tunnel and Access Road are referred for bridge design.

(2) Loads

a) Dead Load

The material densities to be sued for defining dead loads for the design are chosen in accordance with the WPCHB standards (Table 8.4.1).

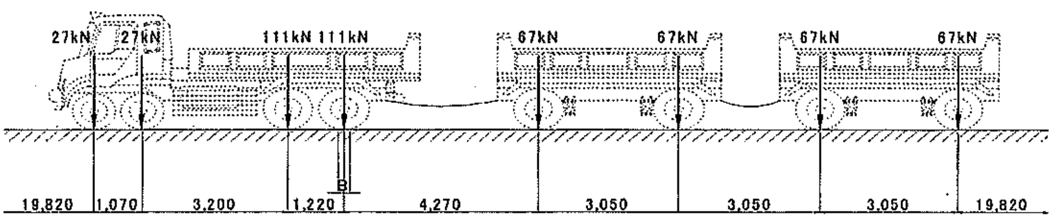
Table 8.4.1 Material Densities

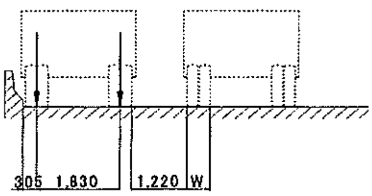
Material	Density (lbs/cu-foot)	Density (kN/cu-m)
Steel	490.0	77.0
Reinforcement Concrete	150.0	24.0
Normal Concrete	140.0	22.0
Asphalt Concrete	140.0	22.0
Macadam	140.0	22.0
Compacted Sand	120.0	19.0
Loose Sand	90.0	15.0
Water	62.5	10.0

Source: WPCHB

b) Live Load

The live load of "Class A loading (Figure 8.4.1)" specified in WPCHB, Article 2.4 is used for the design. WPCHB specifies the highway live loads on roadway bridges and incidental structures. A standard truck-trailer consists of a four-axle truck and two two-axle trailers. For the bridge deck slab, punching shear strength shall be checked in design, where the wheel load is 95 kN, and the contact area is 0.25 x 0.50 m² of tire.





Class of Loading	Axle Load	Ground Contact Area	
		B	W
	kN	mm	mm
A	111	254	508
	67	203	381
	27	152	203

Source: WPCHB

Figure 8.4.1 Class A Loading

c) Other Loads

As per WPCHB and AASHTO, other loads to be considered for the bride design are the following:

- Impact effect of live loads
- Wind force
- Earth pressure
- Overall temperature
- Water flow
- Seismic force

d) Seismic Force

NHA has reviewed the Peak Ground Acceleration (seismic force) and seismic zone after the earthquake of October 8, 2005 and the review is currently at the final draft stage. The new PGA value will be used for the bridge design for the 2nd Kohat Tunnel and Access Roads.

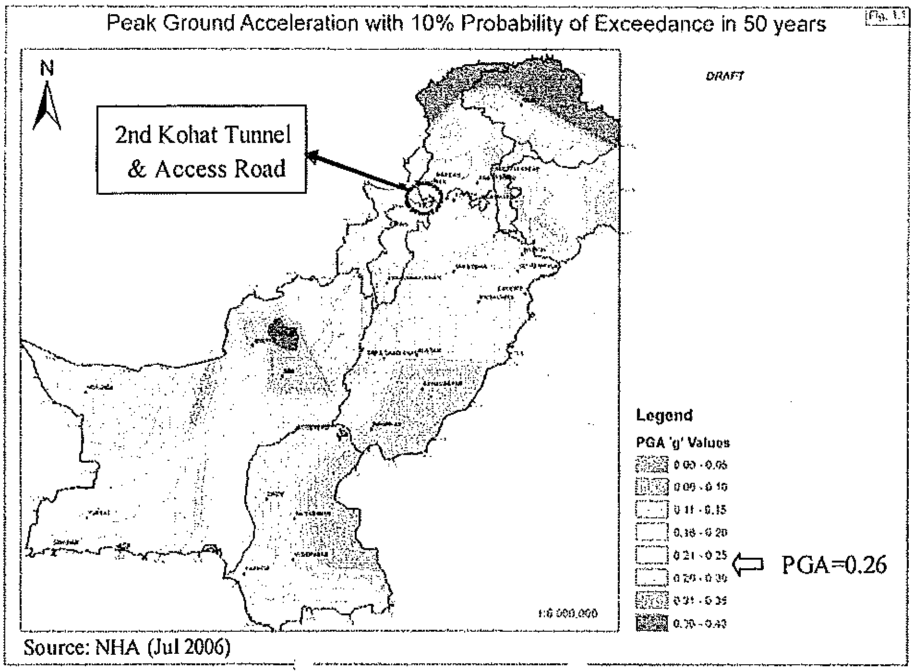


Figure 8.4.2 New Seismic Force (PGA) for Project Area

8.4.2 Bridge Planning

There are 11 bridges on the existing Kohat Tunnel and Access Roads: Seven in the south section and four in the north section. Of those, Bridge No.4 at Sta.19+200 was already constructed with a dual carriageway (4 lanes). As others bridges are 2-lane structures, therefore 10 new bridges are to be constructed in parallel to the existing bridges. The length, type and spans of the new bridges are same as those of the existing bridges, except Bridge No.5 located after the north portal. A special consideration has been made for Bridge No.5 to ensure smooth river flow. The superstructure of short span bridges consists of RC girders and that for longer span bridges consist of PC girders. The PGA value applied in the Project area is 0.05-0.07g (Zone III) and the new PGA is 0.26g. Therefore, more foundation piles, larger foundation and piers are required for the 2nd Kohat Tunnel and Access Roads as compared to the 1st Kohat Tunnel and Access Roads.

8.4.3 Culvert Planning

Over 80 box culverts were constructed under the 1st Kohat Tunnel and Access Road Project. Most of them require extension for the dual carriageway construction under the 2nd Kohat Tunnel and Access Road Project. Standard structures of NHA will be used.

8.5 Tunnel Design Standards

8.5.1 Design Standards

(1) Rock Classification for Support System

There are five representative design standards for mountainous tunnel linings (support system) in the world. Those standards are almost the same. Standards of rock classification, which is a basis for tunnel design, specified in these standards are summarized in Table 8.5.1

Table 8.5.1 Standards of Rock Classification

Country	Austria,	Austria,	Switzerlan	France	South Africa	Norway	Japan
Name of Standard	ONORM B2203	Rabcewicz-Pacher	SIA 198	AFTES	Rock Mass Rating (RMR)	Norwegian Tunneling Method (NTM)	Standards for Road Tunnels
Number of Rock	7	6	6	10	5	9	7
Method of Rock Classification	Qualitative Observation of Rock Mass Behavior			Rating of Rock Mass by Protojakonof coefficient f value	Rating of Rock Mass by RMR	Rating of Rock Mass by Q-Value	Rock Mass Classfication by Parameters
Characteristics of Analysis	Qualitative			Quantitative			
Parameters/Items of Rating/Classification	None			f=tanϕ+c/σc (Soil) c: Cohesion ϕ: Angle of internal friction σc: Unconfined Compression Strength f=σk/100 (Rock) σk: Unconfined Compression Strength	-Strength (Point load or Unconfined Compression) -RQD -Spacing of Discontinuities -Condition of Discontinuities -Ground Water Condition -Strike and Dip Orientations	Q=(RQD/Jn)x(Jr/Ja)x(Jw/SRF) RQD Jn:Joint Set Number Jr:Joint Roughness Number Ja:Joint Alterration Number Jw:Joint Water Reduction SRF:Stress Reduction Factor	Seismic Wave Velocity RQD Distance between Cracks GN=qu/γh qu:Uncofined Compression strength γ:Unit Weight of Rock Mass h:Overburden Depth
Application	Medium to hard rock	Medium to hard rock	Medium to hard rock	Soil to hard rock	Medium to hard rock	Medium to hard rock	Highly weathered rock to hard rock
Remarks	The definition of the rock classification depends on the behavior of rock mass during construction stage. Therefore, it is very difficult to apply at planning and design stage. During construction stage, the suitability of applied rock classification and its support system is checked and confirmed by convergence measurement, etc.			This method is widely applied from soil to hard rock. However, the parameter for hard rock is only unconfined compression strength. Therefore, conditons related cracks in rock mass is not considered well.	RMR is rated by many parameters related to rock mass strength, condition of cracks and water, etc. Therefore, the actual rock mass condition could be defined. In order to use at planning and design stage, many boring data will be required. This method is most widely used in the world.	Q-value is rated by many parameters related to rock mass strength, condition of cracks and water, etc. Therefore, the actual rock mass condition could be defined. However, definition of the parameter is very complicated and experienced geologist is required for evaluation. In order to use at planning and design stage, many boring data will be required.	Seismic wave velocity test is carried out to compensate the geological boring data. Usually this standard is used at planning and design stage. During construction, the evaluation of rock mass is supplemented by face observation which is similar to RMR. Measurement such as convergence, stress,etc is also used to confirm the suitability of installed support system.

The standards of Germany/Austria and Switzerland classify tunnel support type according to rock classification encountered during tunnel excavation. Tunnel support type in other standards is determined by rock classified in geological investigation prior to the construction. "f–value" and "Q-value" are used for rock classification in French and Norwegian standards respectively. Seismic velocity is used in the Japanese Standard.

(2) Design Standard

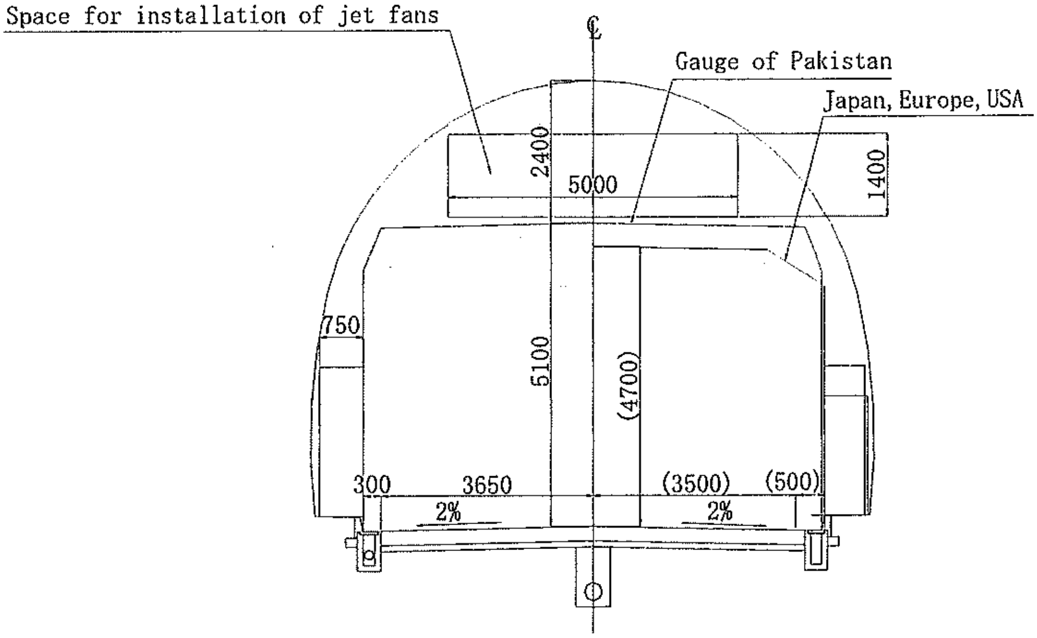
The 2nd Kohat Tunnel becomes the third road tunnel in Pakistan following the 1st Kohat tunnel designed and constructed based on the Japanese standards and the Lowari Tunnel (railway/road tunnel) currently under construction.

As the 2nd Kohat Tunnel is planned to provide an additional dual carriageway facility, the Japanese standards used for the 1st Kohat Tunnel will be applied for the design. The main standards are the following.

- Technical Standards for Road Tunnels (Structures), Japan Road Association, 2003
- Technical Standards for Road Tunnels (Ventilation Facilities), Japan Road Association, 2001
- Design Guide for Lighting System of Tunnel, Express Highway Research Foundation of Japan, 1990
- Standards of Tunnel in Mountainous Terrain, Japan Society of Civil Engineer, 1996, Japan Society of Civil Engineers, 1996
- Design Manual Volume III (Tunnel), Japan Highway Public Corporation, 1997
- Design Manual Volume III (Electricity/Machinery Facilities), Japan Highway Public Corporation, 1990

8.5.2 Standard Cross Section of Tunnel

The standard clearance limit is based on the gauge of the 1st Kohat Tunnel. The road width is 7.9 m: two 3.65 m lanes and 0.3 m shoulder on each side. Clearance height limit is 5.1 m, which is higher than the Japanese, USA and European standards, to meet vehicles used in Pakistan. Figure 8.5.1 shows the standard cross section for the 1st/2nd Kohat Tunnel and comparison with the world standards.



Note: Dimensions in parenthesis are the Japanese Standard

Figure 8.5.1 Standard Cross Section for the 1st/2nd Kohat Tunnel and Comparison with Japanese, European and USA

The cross slope of roadway (camber) is 2%. The inspection gallery width is 0.75 m. A space of 1.4 m x 5 m on tunnel ceiling is used for installation of jet fans for ventilation. Emergency parking bays (a space of 3 m x 30 m) are provided at every 750 m.

Standard Support Patterns are shown in Table 8.5.2.

Table 8.5.2 Standard Support Patterns

Grade of Ground	Excavation method	Standard round length (Upper half) (m)	Rock bolt			Steel arch supporting			Shotcrete thickness (cm)	Lining Thickness (cm)		Over cut designed to allow ground deformation (cm)		
			Length (m)	Installation pitch		Upper half	Lower Half	Standard pitch (m)		Arch and side wall	Invert	Upper half	Lower half	Invert
				Circumferential (m)	Longitudinal (m)									
B	Full face method with auxiliary bench and upper half method	2.0	3.0	1.5 (upper half only)	2.0	None	None	-	5	30	0	0	0	0
CI	Full face method with auxiliary bench and upper half method	1.5	3.0	1.5	1.5	None	None	-	10	30	0	0	0	0
CII	Full face method with auxiliary bench	1.2	3.0	1.5	1.2	H-125 or U-21	None in Principle	1.2	10	30	0	0	0	0
	Upper half method						None							
DI	Full face method with auxiliary bench and upper half method	1.0	4.0	1.2	1.0	H-125 or U-21	H-125 or U-21	1.0	15	30	45	0	0	0
DII	Full face method with auxiliary bench	1.0 or less	4.0	1.2	1.0 or less	H-125 or U-29	H-125 or U-21	1.0 or less	20	30	50	10	10	0
	Upper half method											10	0	0

8.5.3 Ventilation system

The air inside a tunnel is polluted by exhaust gas from the traffic since fresh air can not be supplied naturally. The natural wind in tunnel is developed merely by the pressure difference between the two portals and also because of movement of traffic. This kind of phenomena to provide natural ventilation is possible only in short tunnels. But in long tunnels, a mechanical ventilation system producing continuous air supply is required for proper ventilation.

The report of PIARC (Permanent International Association of Road Congress, XIV-XVII) recommends that carbon monoxide (CO) should be less than 150 ppm and smoke measured for 100m visibility is 50%. However, the above figures are applicable where engines of vehicles are well maintained.

Table 8.5.3 Limit for Exhaust Gas from PIARC (for V = 60 km/h)

Trucks, buses with diesel motors (m>3.5t)									
Emission law	Control	q^{OT} (V=60km/h) (m2/h,veh) Truck weight (t)				$q^{O\ NOX}$ (V=60km/h)			
		5	10	20	40	5	20	40	
No Low	No	80-130	160-250	300-400	400-600	500	1400	1900	
EEC R49+24	No	80	160	240	280	500	1400	1900	
EEC R49+24	Yes	65	130	240	240	470	1300	1800	
EEC 88/77	Yes	50	100	160	200	360	1000	1400	
US Transient 88	Yes	50	100	160	200	330	900	1200	
US Transient 91	Yes	30	60	100	140	270	750	1000	
US Transient 94	Yes	20	40	70	110	220	600	800	

Emission law	Control	$q^{O\ CO}$ (m^3/h,pc)
No Low	No	1-1.5
EEC R 15/04	No	0.70
EEC R 15/04	Yes	0.50
EEC 89/458	Yes	0.16
FTP75	Yes	0.12
diesel engine		0.08

Considering the old and poorly maintained vehicles and the design speed 60km/hr in the tunnel and following the Japanese Standard, the parameters for revision are given below:

- Permissible CO: 100ppm
- Smoke transmittance measured for 100m visibility: 40%

Since at this moment no Detail Standard for Road Tunnel in Pakistan and the Existing 1st Kohat tunnel was designed based on Japanese Road Tunnel standards and Guidelines, the same standards used for the 1st Kohat Tunnel will be applied for the design.

8.5.4 Lighting system

Sunlight is always blocked inside the tunnel. It can enter into the tunnel only up to about 10 m from the portal. The tunnels with a total length of about 50 m may not require lighting system from this consideration. However, a proper lighting system is required for tunnels longer than 50 m. Besides, to adapt car driver for the difference in brightness between inside and outside of tunnel, a part of portal should be arranged with adaptation lighting zone with a gradual change in brightness of light.

The standards for lighting system used in Europe require bigger scale of lighting system than that in Japan. In this context, the design standards of Japanese may be more practical to be used in this Study and are proposed to be applied. Figure 8.5.2 shows the Japanese Standard and above facts.

	unite	CIE	CEN	BS	Japan
L1	cd/m^2	200	120	200	58
L2	cd/m^2	80	48	-	35
L3	cd/m^2	2	2	3	2.3
D1	m	-	-	70	25
D2	m	60	70	-	65
D3	m	418	285	265	135
ΣD	m	478	355	335	225

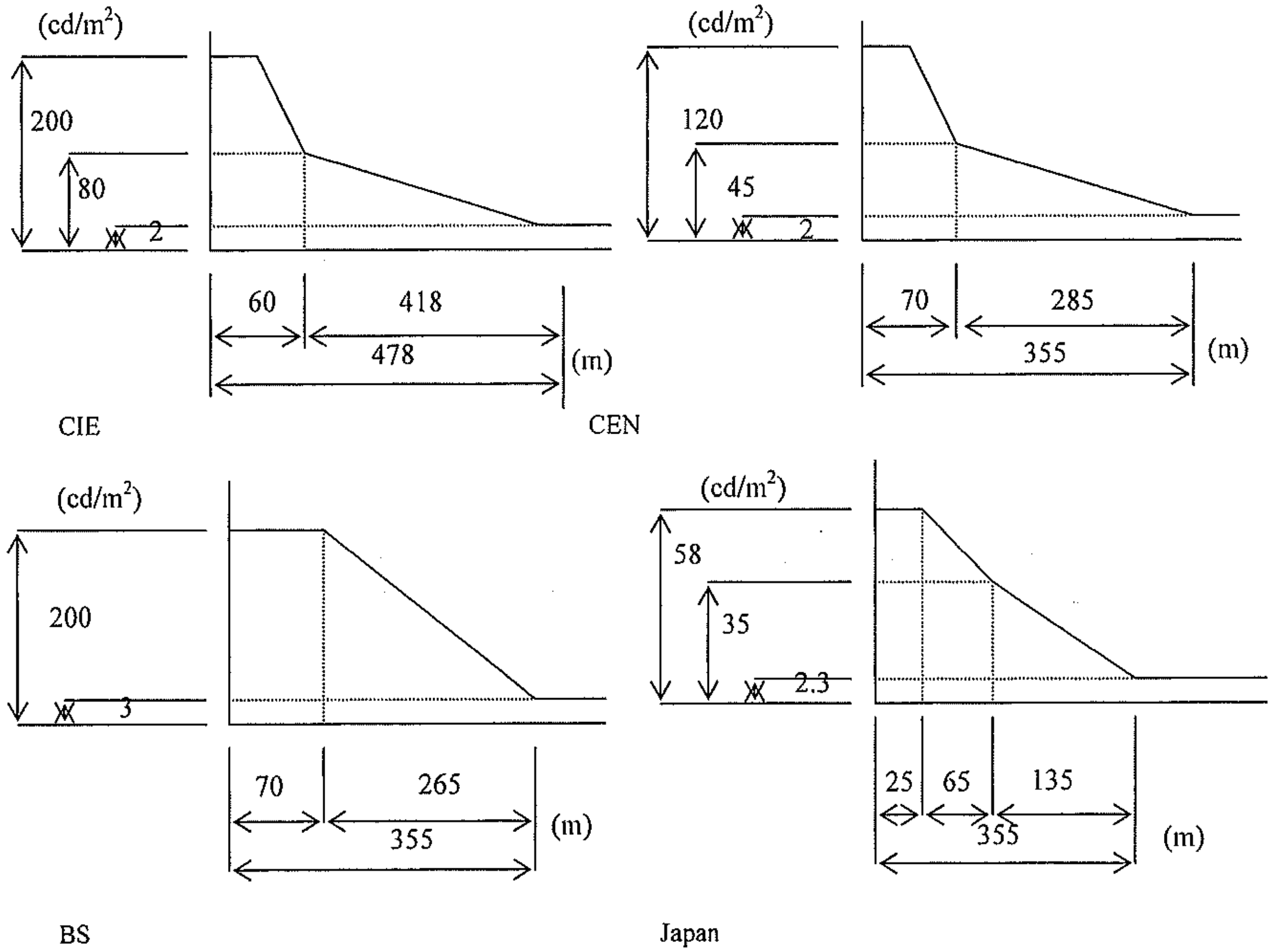


Figure 8.5.2 Comparison of Intensity of Lighting (Field luminance 400cd/m^2)

8.5.5 Power Supply System

The supply electric power and protection of those cable at the high voltage, and low voltage part, the entrance and the exit, the dynamotor and other equipments shall be completed in Power supply system. Power lines for field equipment in tunnel shall be introduced from tunnel substations. Power distribution box shall be arranged at where field equipment is dense.

(1) Incoming Power from WAPDA

Power Supply System: 3-Phase 3-wire 50 Hz 11KV

(2) The facilities to be supplied are as follows:

Ventilation Fans, Tunnel Lighting, Tunnel Measurements Devices, Traffic Signal, Facilities in the substation and Control Room at the portal, Facilities in the Tunnel substations and etc.

(3) Wiring System for Facilities

Mainly 3 ϕ 3w 400V are used

(4) Maximum Permissible Volt Drop

Total voltage drop between the consumer's terminals and any other point in the installation must not exceed 2.5 percent of the normal voltage.

UPS shall be used for tunnel field equipment, which shall be responsible by monitoring system.

8.5.6 Emergency facilities

Tunnel emergency facilities are provided to mitigate damage in the event that fire or any other accidents occur inside of the tunnel. In case accidents occur inside tunnels, evacuation and rescue operations are very difficult because of space constraint. In this regard, proper emergency facilities must be installed. The extent of the requirements of facilities is based on the length of the tunnel and the traffic volume. Japanese standard was used for the design of emergency facilities in this Study, since the standard covers wider and more detail than other standards.

Table 8.5.4 shows the Standards for installation of emergency facilities by tunnel classification.

Emergency facilities are categorized as information and alarm equipment, fire extinguishing equipment, escape and guidance equipment, and others. Requirements of parking bays and their spaces will be studied.

Table 8.5.4 Standards for installation of Emergency Facilities by Tunnel Classification

Emergency Facilities	Tunnel Classification	AA	A	B	C	D
Communication and Alarm Equipment	Emergency Telephone	O	O	O	O	O
	Alarm Button	O	O	O	O	O
	Fire Detector	O	Δ			
	Signal and Alarm	O	O	O	O	O
Fire Fighting Equipment	Extinguisher	O	O	O		
	Fire Hydrant	O	O			
Escape and Guidance Equipment	Exit Guide Board	O	O	O		
	Smoke Discharge Equipment or Refuge Passage	O	Δ			
Other Equipment	Hydrant (Water Supply)	O	Δ			
	Radio Communication Ancillary	O	Δ			
	Radio Rebroadcast Equipment Or Loudspeaker	O	Δ			
	Sprinkler	O	Δ			
	Television	O	Δ			

Notes: O Denotes "Should be installed as the Rule" Δ Denotes "To be installed as Required "

CIE: Commission Internationale de l'Eclairage (French: International Commission on

Illumination - standardization body)

CEN: Comité Européen de Normalisation (French: European Committee for Standardization)

BS: British Standards

Chapter 9. ALTERNATIVE ROUTE STUDY FOR HIGH CUT AND FILL SECTIONS

9.1 Objective of Alternative Route Study

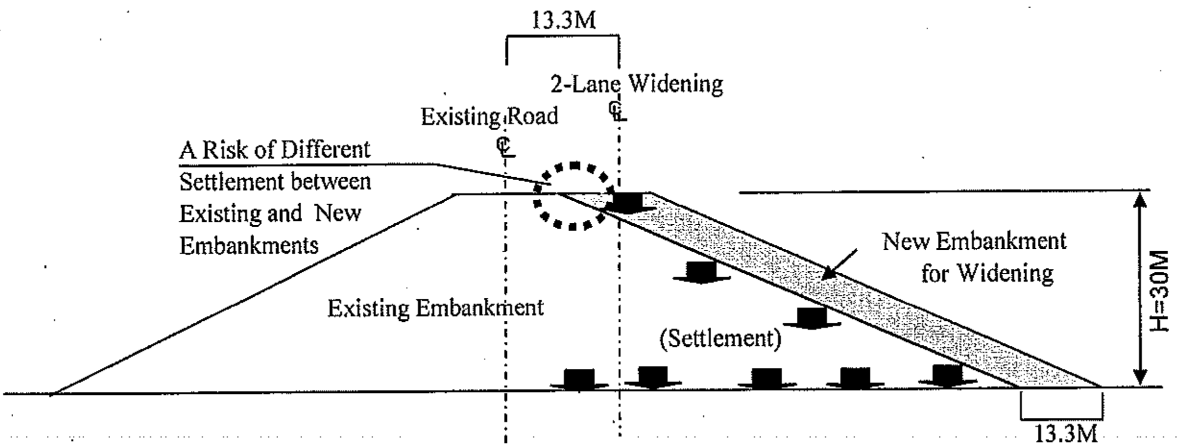
According to the original plan proposed by the design consultant for the 1st Kohat Tunnel and Access Roads Project, there are several high cuts for the 2nd Kohat Tunnel and Access Roads construction as listed in Table 9.1.1.

Table 9.1.1 List of High Cuts for the 2nd Kohat Tunnel and Access Roads Construction

No.	Station		Estimated Quantity	Classification of Materials				Max. Cut Height
				Common		Rock		
	From	To	(m^3)	%	(m^3)	%	(m^3)	(m)
South Section: Kohat Toi (Start Point) - Kohat Tunnel (South Portal)								
S-1	7+325.000	7+475.000	23,800	5	1,190	95	22,610	28
S-2	14+425.000	14+625.000	4,200	60	2,520	40	1,680	10
S-3	15+250.000	15+425.000	32,100	5	1,610	95	30,490	32
S-4	**18+000.000**	**18+700.000**	**165,600**	**60**	**99,360**	**40**	**66,240**	**30**
Sub-Total:			225,700	46	104,680	54	121,020	
North Section: Kohat Tunnel (North Portal) - Dara Adam Khel (End Point)								
N-1	18+132.000	18+825.000	33,000	5	1,650	95	31,350	15
N-2	21+575.000	21+725.000	26,600	0	0	100	26,600	32
N-3	22+300.000	22+400.000	2,000	0	0	100	2,000	6
N-4	23+850.000	23+975.000	15,500	0	0	100	15,500	24
N-5	24+300.000	24+400.000	7,200	0	0	100	7,200	14
Sub-Total:			84,300	2	1,650	98	82,650	
Total:			310,000	34	106,330	66	203,670	

Except for S-4 (Sta.18+000-Sta.18+700) in the above list, there are no alternative routes advantageous in both traffic control and cost saving aspects. Therefore, only S-4 is subjected to a study under this Chapter.

The roadway excavation quantity at Sta.18+000-Sta.18+700 for the 2nd Kohat Tunnel and Access Roads construction was estimated at 165,600 m3, of which 40% is rock excavation. Because of this large volume, disturbance to the traffic (7,500 veh/day) during excavation is unavoidable. The fill volume required for widening at Sta.18+700-Sta.20+182 in the north section of the above cut section is also large, estimated at 280,000 m3, with a height of 30m. Since it is widening construction, different settlement between the existing and new embankments is a matter of concern (as illustrated bellow).



Under such background, a study was carried out to examine whether an economical alternative route can be set out for the section of Sta.18+000-Sta.20+182 to avoid deep cut and high embankment from the view points of reducing:

- Effects of earthworks construction onto the existing traffic
- A risk of settlement between the existing and new embankments.

9.2 Alternative Route Selection

The original road alignment planned for the Sta.18+000-Sta.20+182 section in the 1st Kohat Tunnel and Access Roads Project was widening of the existing road on the east side for the 2nd access road.. The road alignment in this section was changed during construction in order to modify a grade from 6% to 4% (referred to as the modified original plan). The south portal was still kept at the 70m-offset position from the 1st tunnel.

Alternative routes and alignments were selected based on site reconnaissance, birds eye view photographs (see Figure 9.2.1) from the mountain top over the Kohat Tunnel and satellite images of 1m-resolution. Alternative A is almost same as the modified original plan except the south portal approach. Alternative B is a new route of approximately 600 m to the east of the existing road.

Table 9.1.2 summarizes the concept of the alternative route study.

Table 9.1.2 Concept of Alternative Route Study for the Sta.17+500-Sta.20+182 Section

Route/Alignment	Design Concept	Conditions / Key Issues
Original Plan / Modified Original Plan	• South portal of the 2nd tunnel was planned at the 70m-offset position from the 1st tunnel centre. • The road alignment was connected to Bridge No.4 at Sta.19+200.	• Technically not applicable unless modifying the tunnel south portal location as studied in Chapter 10.
Alternative A	• Change of the modified original plan for south portal approach section (South portal of the 2nd tunnel is planned at the 30m-offset position from the 1st tunnel centre) • Construction of the two new lanes beside the existing road	• High-cut and traffic management during construction • Different settlement between the existing and new high embankments • Bridge No.4 at Sta.19+200 already constructed with a dual carriageway • ROW already acquired for the additional two lanes
Alternative B	• New Plan • Two new lanes about 600 m to the east of the existing access road	• Longer roadway and pavement construction • Extent of reduction of cut and fill volumes • New ROW acquisition

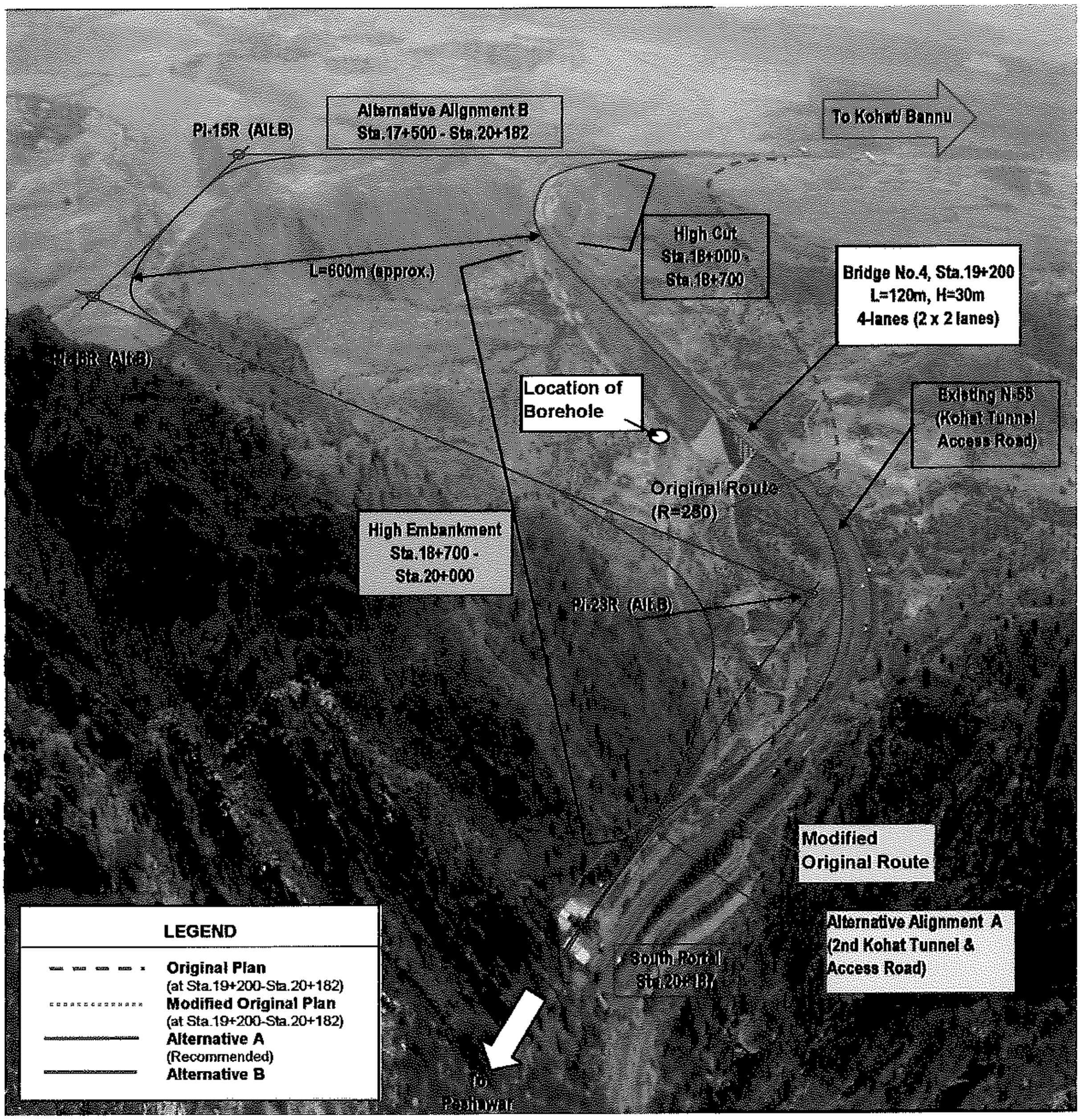


Figure 9.2.1 Alternative Routes at Sta.17+500-Sta.20+000

A borehole was drilled near Bridge No.4 to evaluate settlement of the new high embankment at Sta.18+700-Sta.20+000 (refer to Sub-section 6.4 of this Report).

9.3 Preliminary Design and Cost Estimate

Topographic survey was conducted along the preliminary alternative road centreline from Sta.17+500 to Sta.20+182 (tunnel south portal) with a 100 m band and topographic maps were produced. The horizontal alignment was drawn on topographic maps (see Figure 9.3.1). Ground elevations were taken along the centreline for vertical alignment design.

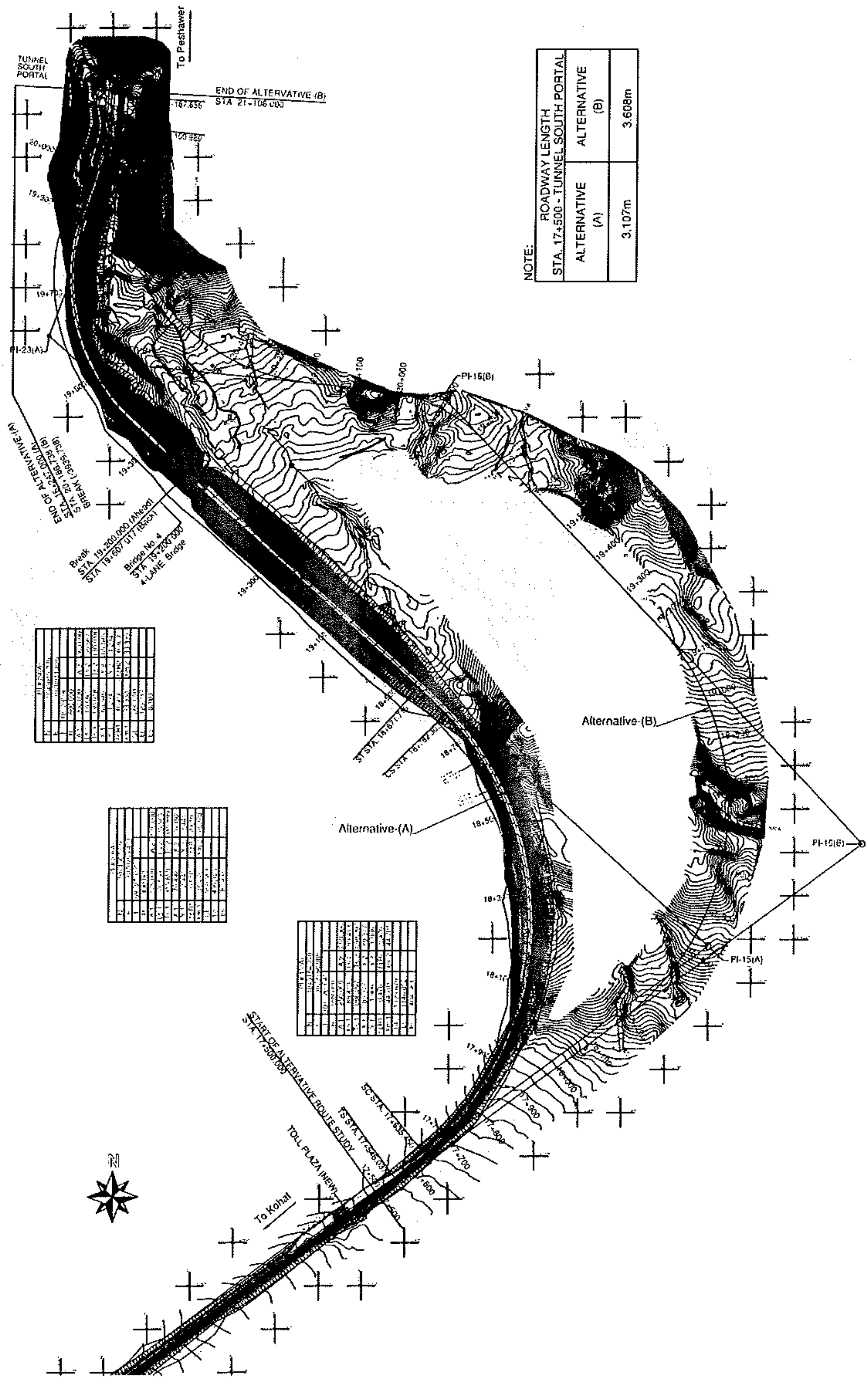


Figure 9.3.1 Alternative Alignments at Sta.17+500–Sta.20+182

Approximate quantities and cost, including earthworks, pavement and other works were estimated for Alternatives A and B. The construction cost for Alternatives A and B was estimated at Rs.255.8 and Rs.628.1 million respectively (refer to Table 9.3.1). The construction cost of Alternative B is about 2.3 times higher than that of Alternative B.

Table 9.3.1 Construction Cost Estimate of Alternative Routes

Item / Description	Unit	Unit Price (Rs.)	Alternative A		Alternative B	
			Quantity	Amount (Rs.)	Quantity	Amount (Rs.)
Road Length from Sta.17+500 to Tunnel South Portal:			3,100 m		3,600 m	
● Earthworks						
- Roadway Embankment						
Common Materials	m^3	340	99,360	33,782,400	490,240	166,681,600
Rock	m^3	870	66,240	57,628,800	122,560	106,627,200
Traffic Safety Measure	sum	(10 of the above)		9,141,120		-
- Borrow Embankment	m^3	370	180,640	66,836,800	453,200	167,684,000
● Pavement						
- AC Wearing /AC Base	m^3	9,500	4,800	45,600,000	6,200	58,900,000
- Aggregate base / subbase	m^3	1,500	12,200	18,300,000	15,700	23,550,000
● Other Items (20% of the above)	sum			46,257,824		104,688,560
Total				277,546,944		628,131,360

Note: Approximate estimation only

The roadway length of Alternative B is approximately 500m longer than Alternative A. The largest construction quantity/cost difference between two alternatives exists in the earthworks because Alternative A is construction of fill or cut for the widening while Alternative B is a new construction as illustrated in Figure 9.3.2.

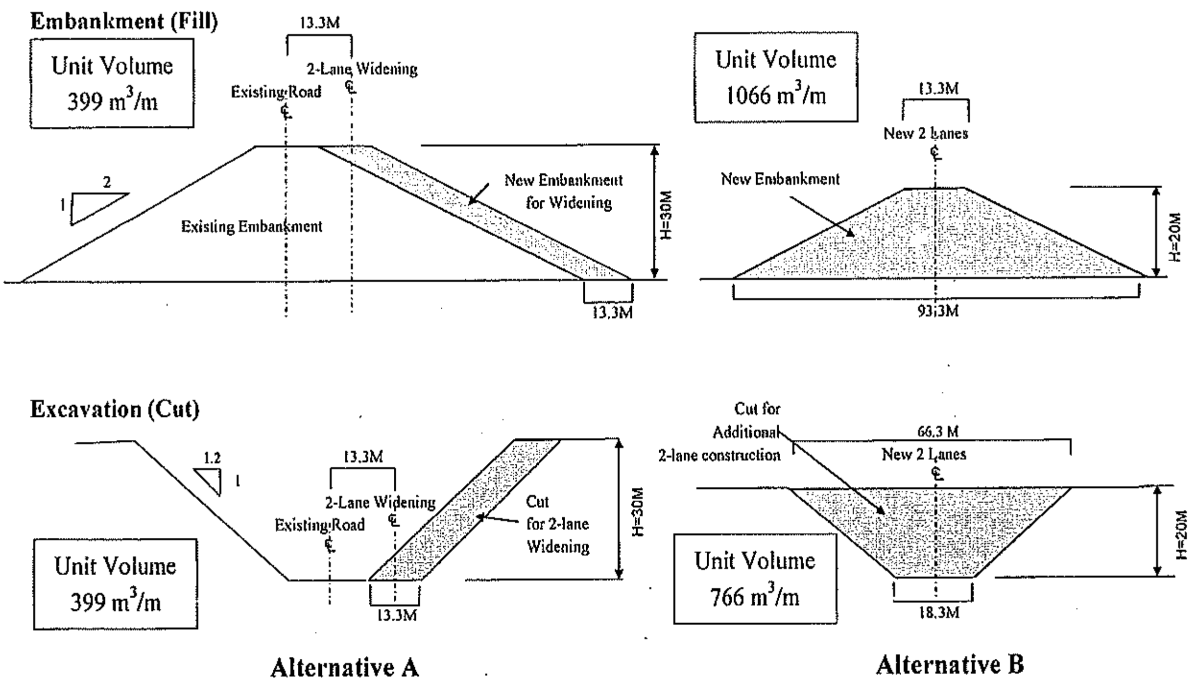


Figure 9.3.2 Comparison of Unit Earthworks Volume

9.4 Comparison and Evaluation of Alternative Route

Comparison and evaluation of the alternative routes were made taking consideration technical, economic and ROW and other aspects as summarized in Table 9.4.1.

Table 9.4.1 Evaluation of Alternative Route Plans

Item	Alternative A	Alternative B
● Technical Aspects	△	○
- Roadway Length	3,100 m	3,600 m
- High Cut	H=30 m, L=700 m	H= 20 m, L=800 m
(Volume)	(165,600 m^3)	(612,800 m^3)
- Adverse Effects to Traffic	* Medium	Low
- High Embankment	H= 30 m, L=1300 m	H= 20 m, L=1000 m
(Volume)	(280,000 m^3)	(1,066,000 m^3)
● Economical Aspects	○	△
- Construction Cost	Rs.256 million	Rs.628 million
- Additional ROW Acquisition Cost	None (ROW was already acquired)	Required
● ROW	○	X
- New ROW Acquisition	None	Required
- Relocation of Building, etc.	None	None
● Others	○	X
- Bridge No.4	Use of Bridge No.4 constructed with 4 lanes	Not using Bridge No.4
- Other Projects	-	An on-going development project at Sta.19+500 (R)
Overall Evaluation	○ (Recommended)	X

Notes 1: ○ Good, △ Fair, X Bad

2: Construction methods which minimize disturbance to the existing traffic should be applied.

Bridge No.4 (L=120 m, H=30 m) which has been constructed with a dual carriageway should be utilized. For Alternative A, the required ROW for the two new lanes was already acquired during the 1st Kohat Tunnel and Access Roads Project. For Alternative B, new ROW acquisition is required. Therefore, Alternative A (Modified Original Plan) is advantageous and is recommended from the economic, ROW acquisition and other view points.

As approximately 30 cm settlement (1% of fill height) of the high embankment occurred during the 1st Kohat Tunnel and Access Roads construction, embankment settlement and its influence on the existing roadway were evaluated for Alternative A based on the geological investigation results. As the underneath soil is composed of granular materials and soft/hard rock, settlement will be minor and no serious adverse effects to the existing road are expected (refer to Subsection 6.4).

The estimated quantity of cuts at Sta.18+000–Sta.18+700 is 165,000 m3 and 40% of which is classified as rock material. As the existing cut slopes are not steep (1 : 1.2), most of them could be excavated by bulldozer with ripper. Hard rock could be excavated with a combination of hydraulic breaker and control blasting (refer to Subsection 15.2) without much disturbance to the existing traffic.

The excavation will be executed to minimize materials falling down to the existing roadway. Installation of temporary concrete barriers will be required along the roadway to prevent falling rocks from hitting the traffic (refer to Subsection 15.2).

Chapter 10. LOCATION OF TUNNEL PORTALS

10.1 South Portal

10.1.1 Alternative Plans

The road alignment of the 2nd Kohat Tunnel was examined in the design stage of the 1st tunnel, where the south portal was located at 70 m east of the 1st tunnel (referred to as the "original plan").

The approach road alignment for the tunnel south portal was changed during construction in order to reduce a grade (vertical alignment) from 6% to 4% without paying much attention to the creek (nullah) on the right hand side (referred to as the "modified original plan"). The south portal was still kept at 70 m. The location of Bridge No. 4 was changed accordingly, and on the condition that the tunnel approach will be connected to Bridge No. 4 (L=120m) at Sta. 19+200, constructed with a dual carriageway (4 lanes).

However, the Study Team noticed that the location of south portal in the original and modified original plans is inappropriate because of the following reasons.

- The portal is located at the position of difficult topography and geology, right on the steep and deep creek from the northeast of the tunnel, involving a risk of flush water (estimated at 55 m^3/sec for 50 years return period) and debris flow, and unstable slope standing on its back.
- High embankment is required in the north of Bridge No. 4 (Sta. 19+300 - Sta. 19+800), with an estimated volume of over 1 million m^3 for the original plan. It is preferred to avoid such big embankment. The problem associated with the high embankment is a need of costly construction of a large culvert or a bridge to drain water and debris flow from the creek. The possible radius of curvature in the northern approach to the bridge is only 250 m and it is inappropriate.
- A bridge or box culvert is required for the original and modified original plans to pass over the creek on the right of south portal by structures.
- No sufficient construction yard (space) for the tunnel construction is available at the south portal because of the exiting control room.

The following two alternative locations for the south portal were examined together with the above original and modified original plans.

Alternative-A: A plan to locate the portal closer to the existing portal to avoid debris flow from the steep creek. A normally required minimum distance of 30 m center-to-center (about three times of tunnel width) for safe construction of parallel tunnels is secured.

Alternative-B: A plan passing under the creek by extending tunnel length by 420 m. Taking into account the topographic and geological condition, the tunnel location was selected at 100 m distant from the existing portal.

The location of south portal and the alignment for the tunnel approach road by alternative are illustrated in Figures 10.1.1 and 10.1.2, together with the original and modified original plans.

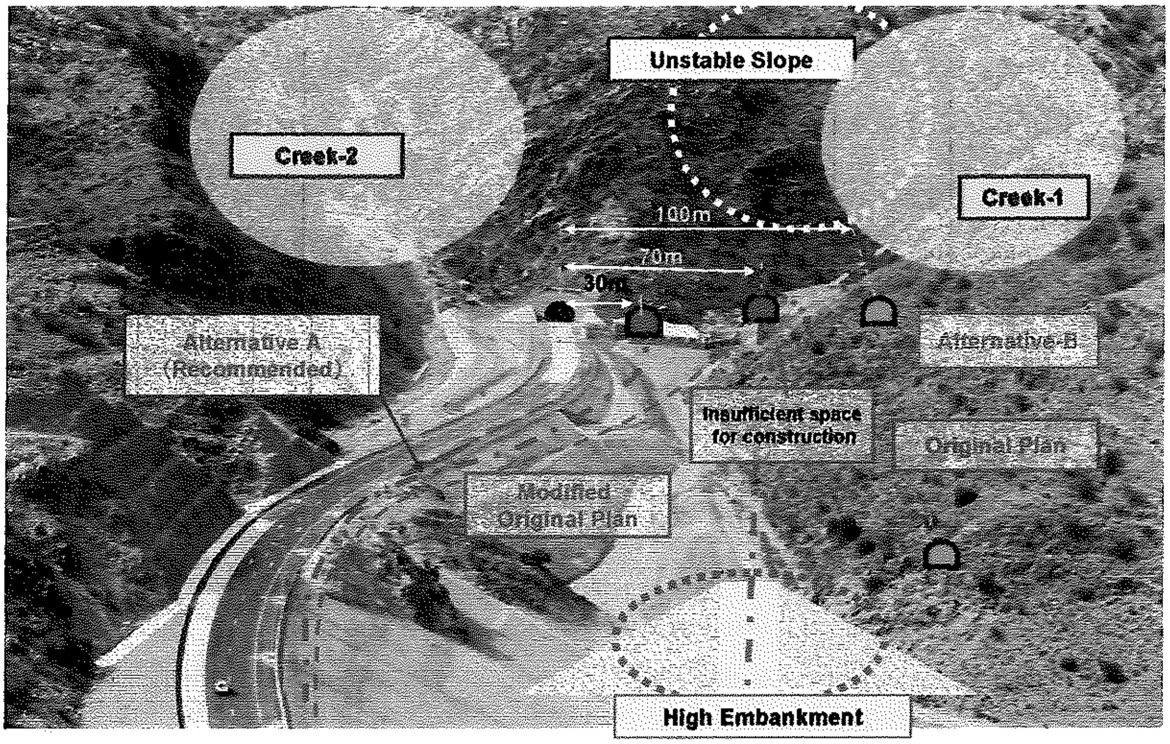


Figure 10.1.1 Location of the South Portal

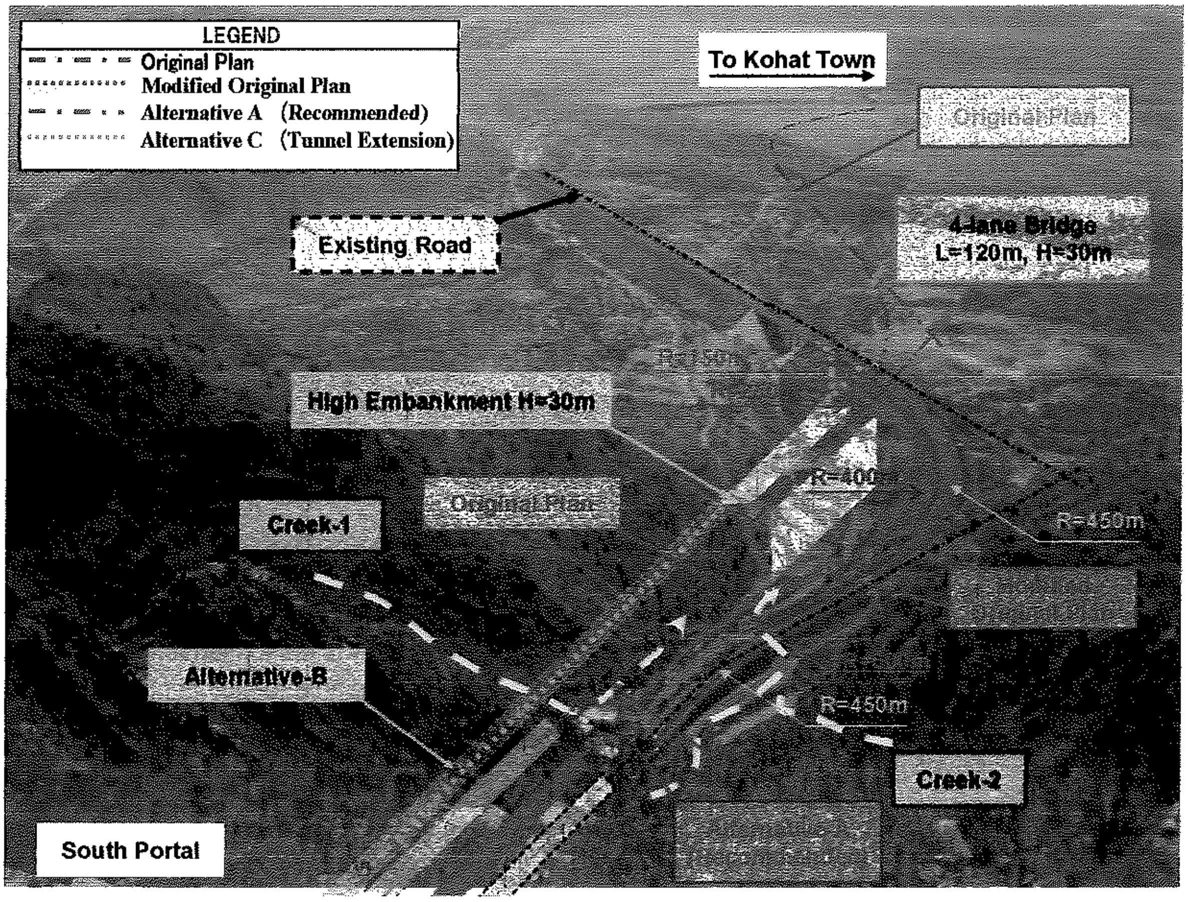


Figure 10.1.2 Road Alignment for the South Portal Approach Road

10.1.2 Evaluation of Alternative Plans

The two alternatives and the original/modified original plans were compared and evaluated as summarised in Figure 10.1.3 on the following technical and economical aspects.

- Risk against flush water (estimated at 55 tones/sec) and debris flow from the steep creek located at the east of portal.
- Radius of curvature for approach road connecting to the existing 4-lane bridge.
- Availability of a space for the tunnel construction at the south portal.
- Earthworks quantities for the approach road construction from Sta.19+200 to Sta.20+186 (south portal).
- Requirements of additional structures for approach road or tunnel extension.
- Necessity of relocation of the existing tunnel control room at the south portal.
- Overall cost including earthworks, additional structures and relocation of the control room.

The original plan is not possible because of technical defects and high cost. The radius of curvature for the bridge approach is only 250 m and this is too small concerning safety. This plan needs a high-fill just after Bridge No.4 and a high-cut before the south portal

In the case of the modified original plan, a curve alignment starts inside the tunnel and it goes along with the existing road about 200 m after the south portal. This alignment will provide safe approach for Bridge No.4. However, this plan requires a bridge or box culvert construction to provide an opening for debris flow from the creek. As this plan intends to maintain the existing control room, securing of a space for the tunnel construction between the control room and the creek is difficult as it is quite narrow.

Alternative-B has a critical defect. Apparently, an alignment which satisfies the minimum radius of curvature cannot be set at the northern approach to Bridge No.4, meaning that the already constructed 4-lane bridge cannot be utilized. In addition, this alternative needs to extend the tunnel length by 420 m, as well as high embankment construction and additional ROW acquisition.

Alternative-A is recommended, which is superior technically and economically, avoiding problems in the original and modified original plans. A 400m-radius of curvature is secured for the approach to Bridge No.4 satisfying the design standard. At tunnel portal, a 600m-radius of curvature is secured, which is sufficient for tunnel approach alignment. This plan can also secure a sufficient space for open channel (drainage) construction for debris flow.

For Alternative-A, it is required to relocate the existing tunnel control room. A space can be secured in the west of the existing portal or at the north portal left hand. The relocation should be completed in the initial stage of construction, but no difficulty is foreseen. As the current tunnel monitoring facilities (computers, CCTV, etc.) will be required replacement at every 8-10 years, the next timing of replacement will match with the time of 2nd tunnel construction.

Alternative-A is the most economical and safe plan compared with other plans. Alternative-B is the most expensive plan because of addition tunnel length requirement. The original plan is also expensive as high-fill, high-cut and structures are required. The modified original plan is not much expensive compared with the original plan and Alternative-B but this plan is not safe.

Items / Description		Original & Alternative Plans			
		Alternative-A (Realignment)	**Original Plan**	**Modified Original Plan** [1]	**Alternative-B (Tunnel Extension)**
Position of South Portal	**Distance from the existing tunnel**	**30m**	**70m**	**70m**	**100m**
Basic Concept of Plan	Alignment between the south portal and Bridge No.4.	The alignment of the new two lanes just beside the existing road from the south portal.	Connect the bridge No.4 and South portal by straight line.	The alignment of the new two lanes just beside the existing road from the south portal.	Passing under the deep creek by tunnel and connect to Bridge No.4
	Treatment of a deep creek on the right hand of the south portal	Provide a space for open channel [3]	No plans were shown how to treat the creek	No plans were shown how to treat the creek	No influence by creek
Technical Aspects	Risk of Debris Flow from Creek on East (55 ton/sec)	O A little	× Large A bridge or box culvert is required	× Large A bridge or box culvert is required	O None
	Radius of curve (m) for Bridge No.4 Approach	400m O Good	250m Δ Poor	400m O Good	150m × Bad
	Space for the tunnel construction at South Portal	Sufficient O	Insufficient ×	Insufficient ×	Sufficient O
Economical Aspects	Embankment Quantity (m^3)	120,000 O Small	1,010,000 × Very Large	130,000 O Small	660,000 Δ Large
	Roadway Excavation Quanity(m^3)	500 (rock) O Small	24,500 (rock) × Large	6,000 (rock) Δ Medium	1000 (rock) O Small
	Requirements of Additional Structures at the south portal	O No	Δ Yes Bridge or Culvert: L=100m	Δ Yes Bridge or Culvert: L=100m	× Yes Tunnel Extension: L=420m
	Necessity of relocation of Control Room	× Yes	O No	O No	O No
	Overall Cost	O Low	Δ High	Δ Medium	× Very High
Evaluation		**O Good (Recommended)**	**× Bad**	**Δ Fair**	**× Bad**

Notes: 1. The original road alignment was modified during the construction of the 1st tunnel access road to reduce a grade from 6% to 4% at Sta.17+500 - Tunnel South Portal.

2. O Advantageous Δ Fair or possible with some measures × Disadvantageous

3. Measures against risk pf debris flows from the right hand creek

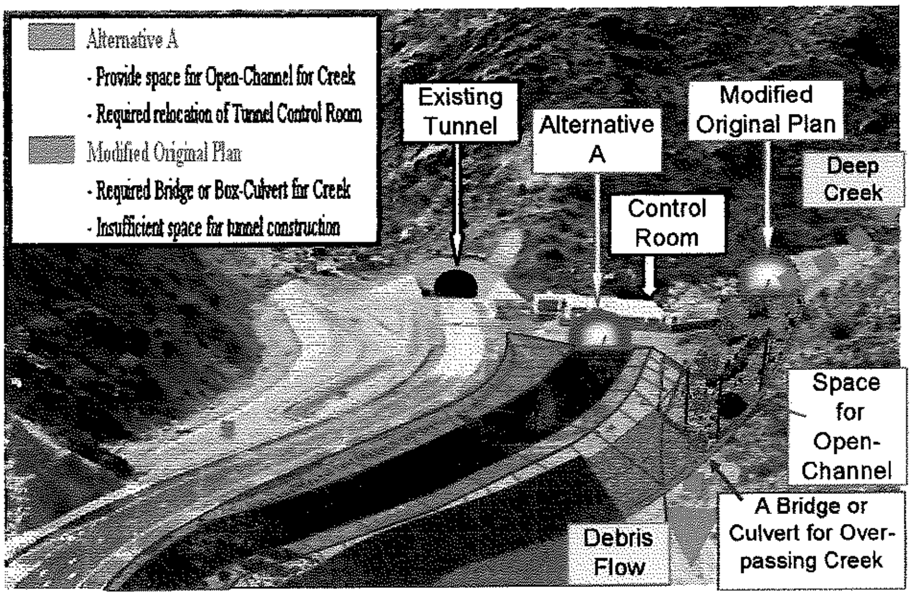


Figure 10.1.3 Evaluation of Alternative Plans

10.1.3 Elevation of South Portal

It is recommended to lower the elevation of the south portal of the 2nd tunnel by 4m from that of the 1st tunnel, because of the following purposes.

- To secure enough opening for water and debris flow from the creek from the northeast of the tunnel (Creek-1 in Figures 10.1.1 and 10.1.2).
- To reduce the embankment height of the tunnel approach, thus reduce the construction cost.
- To avoid headlight beams of the northbound vehicles disturbing the vehicles coming out from the tunnel

Keeping the same elevation for the north portal, the grade of the 2nd tunnel will be 2.4%. 0.2 % steeper than the 1st tunnel. Since the 2nd tunnel will be used for southbound traffic in down grade, this grade will not affect traffic flow and safety.

10.2 North Portal

In the original design, the north portal of the 2nd tunnel is located 30m center-to-center from the 1st tunnel, and at the same elevation. There is no problem in the original design and it will be maintained.

Chapter 11. PRELIMINARY DESIGN

11.1 General

The scope of the 2nd Kohat Tunnel and Access Roads construction is to provide two additional lanes to the existing road to create a dual carriageway road. NHA already acquired the Right-of-Way (ROW) on the east side (right hand side) for the 2nd Kohat Access Road during the 1st Kohat Tunnel and Access Road construction. As there are no advantageous alternative routes, the preliminary design was carried out based the road and tunnel alignments recommended in Chapters 9 and 10 and in accordance with the design standards established in Chapter 8.

The design results are reflected in Volume II (Preliminary Design Drawings) of the Feasibility Study Report.

11.2 Highway Design

11.2.1 Alignment Design (Plan and Profile)

(1) Position of the 2nd Kohat Tunnel Access Road

The roadway centreline of the 2nd tunnel access roads was set out as the centreline of the 4-lane dual carriageway, except for the tunnel and approach sections as illustrated in Figure 11.2.1.

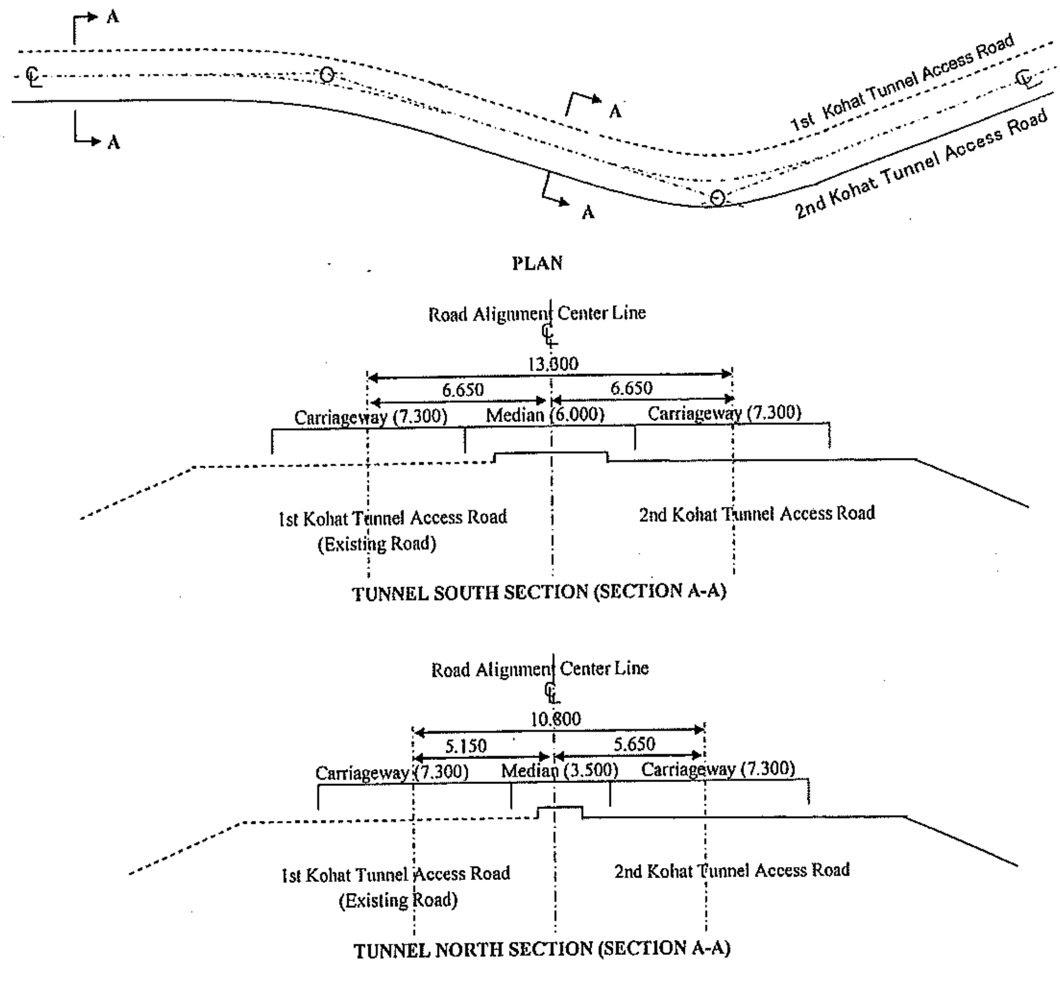


Figure 11.2.1 Position of the 2nd Kohat Tunnel Access Roads

The distance from the 4-lane dual carriageway centreline to the centreline of the existing road centreline (to the left) and to the centreline of the new 2-lane (to the right) is 6.65 m for the south section up to Sta.18+700. The section from Sta.18+700 to Sta.19+200 is a transition section to Bridge No.4 (dual carriageway bridge). Separate centrelines are set out for the tunnel approach section from Sta.19+200 to Sta.20+186.738 (tunnel south portal). The centreline off-set distance between the 1st and 2nd Kohat tunnels is 30m. In the north section, the distance from the 4-lane dual carriageway centreline to the left 2-lane carriageway centreline (1st road) is 5.15 m and that to the right 2-lane carriageway centreline (2nd road) is 5.65 m.

(2) Horizontal Alignment

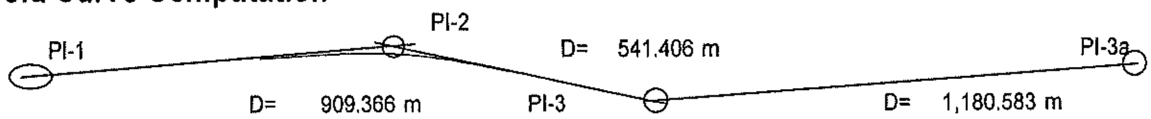
The Study Team designed alternative horizontal alignments for the tunnel south sections; one without transition curves (as same as the 1st Kohat Tunnel and Access Roads) and the other with a transition curve as described in Sub-section 8.3.2(2). Excel basis Clothoid curve elements computation program (Figure 11.2.2) was used for the alignment design. The maximum deviation of the horizontal alignment with and without transition curve is limited to about 0.50 m to absorb the alignment deviation within the median. However, the introduction of transition curves is difficult for the north section as the existing alignment is a combination of short straight lines and sharp curves. The vertical alignment changes also in a short distance. Moreover, as the median width of the north section is 3.5m and it is difficult to absorb the centreline deviation within this median not like the 6.0m-wide median in the south section, transition curves are not introduced for the north section.

The total Project length is 30.271 km from Sta.0+000 to Sta.25+906.255. Several breaks were inserted in the carriageway centreline of the 1st Kohat Tunnel Access and Roads. These breaks were retained as they are considering the needs to use the same types of cross drainages, bridges, tunnel and other structures of the 1st road in the design of the 2nd road to ensure consistency between the tow roads. The beaks are introduced at the same locations, in principle, for the 1st Kohat Tunnel and Access Roads as summarized in Table 11.2.1.

Table 11.2.1 Breaks and Project Road Length

	Break Length (m)	Station	Length (m)
● **South Section:**			
- **Project Start Point Sta.**		0+000.000	
Break	-12.895	6+318.981 (B)	
		6+306.086 (A)	
Break	-407.017	19+607.017 (B)	
		19+200.000 (A)	
Total Break (S)	-419.912 m		
- **South Section Length:**			**20,606.650 m**
Break	-3,939.738	20+186.738 (B)	
(Tunnel South Portal Sta.)		16+247.000 (A)	
● **Tunnel Section Length:**			**1,885.000 m**
(Tunnel North Portal Sta.)		18+132.000	
● **North Section:**			
Break	19.932	18+874.472 (B)	
		18+894.404 (A)	
Break	4.257	21+792.502 (B)	
		21+796.759 (A)	
Break	-29.691	24+908.443 (B)	
		24+878.752 (A)	
Total Break (N)	-5.502 m		
- **North Section Length:**			**7,779.757 m**
- **Project End Point Sta.**		25+906.255	
Total Break	-4,365.153 m		
● **Total Project Length:**			**30,271.408 m**

Clothoid Curve Computation



PI-2

Input (replace red figures)

R= 590 m

I =	deg.	min.	sec.		
	29	10	5	29.1681 degrees =	0.5091 radian

A1 =	250.000			A2 =	250.000		
Note:	R/3	=< A <=	R	R/3	=< A <=	R	
	197	=< A1 <=	590	197	=< A2 <=	590	

Ls1 = A^2 / R = 105.932 Ls2 = A^2 / R = 105.932

Note: Design Speed	Min. Transition Curve Length
90 km/h	50 m
80 km/h	44 m

Straight Section Length			
From / To	PI-1	PI-2	424.062 m
From / To	PI-2	PI-3	181.698 m

(Note: ST to TS Distance)

CL = Ls1 + Ls2 + Lc = 406.289

Ts1 = Xm1+W2-z1 = 206.666 Ts2 = Xm2+W2+z2 = 206.666

$\theta_s 1$ = Ls / 2R = 0.0898 radian

	degree	deg.	min.	sec.
=	5.1436	5	8	37

$\theta_s 2$ = Ls / 2R = 0.0898 radian

	degree	deg.	min.	sec.
=	5.1436	5	8	37

X1= $Ls (1 - Ls^2 / 40 R^2 + Ls^4 / 3456 R^4 - Ls^6 / 599040 R^6)$ = 105.847

X2= $Ls (1 - Ls^2 / 40 R^2 + Ls^4 / 3456 R^4 - Ls^6 / 599040 R^6)$ = 105.847

Y1 = $Ls^2 / 6R (1 - Ls^2/(56*R^2) + Ls^4/(7040*R^4) - Ls^6(1612800*R^6))$ = 3.168

Y2 = $Ls^2 / 6R (1 - Ls^2/(56*R^2) + Ls^4/(7040*R^4) - Ls^6(1612800*R^6))$ = 3.168

ΔR1 =	Y1 + Rcos θs1 - R =	0.792	ΔR2 =	Y1 + Rcos θs1 - R =	0.792
Xm1 =	X1 - Rsin θs =	52.952	Xm2 =	X1 - Rsin θs1 =	52.952
W1 =	TAN (I/2) x (R+ΔR1) =	153.714	W2 =	TAN (I/2) x (R+ΔR1) =	153.714
TL1 =	X1 - Y1 cot (θs1) =	70.651	TL2 =	X1 - Y1 cot (θs1) =	70.651
Tk1 =	Y1 / sin θs1 =	35.338	Tk2 =	Y1 / sin θs1 =	35.338

σ1 = cot (Y1/X1) = 0.030 radian

	degree	deg.	min.	sec.
=	1.7144	1	42	52

σ2 = cot (Y2/X2) 0.030 radian

	degree	deg.	min.	sec.
=	1.7144	1	42	52

$\theta_s 1 - \sigma 1$ = 0.0599 (radian)

	degree	deg.	min.	sec.
=	3.4292	3	25	45

$\theta_s 2 - \sigma 2$ = 0.0599 (radian)

	degree	deg.	min.	sec.
=	3.4292	3	25	45

θc = I-(θs1+θs2)= 0.32953 radian =

degree	deg.	min.	sec.
18.8808	18	52	51

Lc =	R * θc =	194.424			
LT1 =	$(X1^2 + Y1^2)^{1/2}$ =	105.894	LT2 =	$(X2^2 + Y2^2)^{1/2}$ =	105.894
U1 =	$(Tk1^2 - Y1^2)^{1/2}$ =	35.196	U2 =	$(Tk^2 - Y^2)^{1/2}$ =	35.196
z1 =	(ΔR1 - ΔR2) / tan (I) =	0.000	z2 =	(ΔR1 - ΔR2) / sin(I) =	0.000
Es =	(R+(ΔR1+ΔR2)/2) / cos I/2 - R =	20.462			

Figure 11.2.2 Clothoid (Spiral) Curve Elements Computation Program

(3) Vertical Alignment

The vertical alignment follows the existing 1st Kohat Tunnel and Access Roads in principle. As the 1st road was constructed with two lanes (single carriageway), there are two representative methods to provide carriageway cross slopes and the finished road level (FRL) of the 2nd Kohat Tunnel and Access Road as shown in Figure 11.2.2.

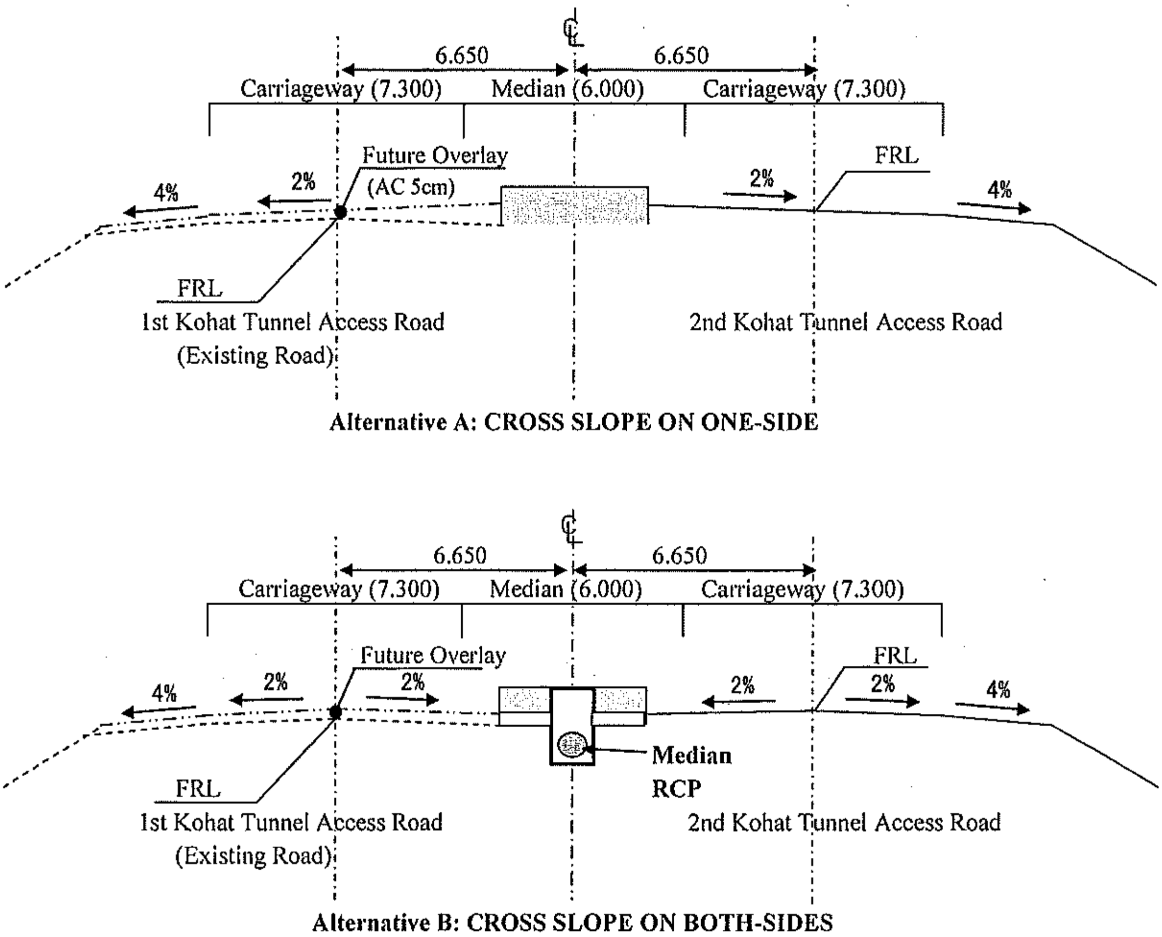


Figure 11.2.3 Carriageway Cross Slope Alternatives

Alternative A is to provide carriageway cross slopes on one side (outside) and Alternative B is to provide cross slopes at both sides. The Study Team adopted Alternative A considering the fact that Alternative B requires a median drainage system through the Project road.

Asphalt concrete overlay will be required in year 2012-2013 for the 1st Kohat Tunnel Access Roads, as the design period of the existing AC pavement is 10 years. The Finished Road Level (FRL) of the 2nd road is designed to be 5 cm higher than that of the 1st road taking the future AC overlay thickness into consideration.

The average grade is -1.07% (down-grade) for the south section and 1.03% (up-grade) for the north section. The maximum grade is 4.76% for the down-grade section and 4.34% for the up-grade section as listed in Table 11.2.2.

Table 11.2.2 Vertical Grade of the 2nd Kohat Tunnel and Access Roads

South Section

No.	From Sta.	To Sta.	Distance (m)	Grade
S.1	0+000.000	0+200.000	200.000	0.7200%
S.2	0+200.000	0+700.000	500.000	0.6500%
S.3	0+700.000	1+100.000	400.000	0.2500%
S.4	1+100.000	1+500.000	400.000	0.2000%
S.5	1+500.000	1+900.000	400.000	0.8000%
S.6	1+900.000	2+400.000	500.000	-0.6238%
S.7	2+400.000	2+850.000	450.000	0.0000%
S.8	2+850.000	3+000.000	150.000	0.6000%
S.9	3+000.000	3+700.000	700.000	-0.7500%
S.10	3+700.000	3+900.000	200.000	-1.0000%
S.11	3+900.000	4+300.000	400.000	-0.1380%
S.12	4+300.000	4+500.000	200.000	0.9510%
S.13	4+500.000	4+900.000	400.000	-1.4608%
S.14	4+900.000	5+100.000	200.000	-0.7285%
S.15	5+100.000	5+400.000	300.000	1.7667%
S.16	5+400.000	6+200.000	800.000	0.6250%
S.17	6+200.000	6+800.000	612.895	0.6853%
S.18	6+800.000	7+200.000	400.000	0.3250%
S.19	7+200.000	7+500.000	300.000	0.0667%
S.20	7+500.000	7+900.000	400.000	1.2500%
S.21	7+900.000	8+400.000	500.000	-0.1800%
S.22	8+400.000	8+900.000	500.000	-0.5820%
S.23	8+900.000	9+391.212	491.212	2.0633%
S.24	9+391.212	9+767.240	376.028	0.0056%
S.25	9+767.240	9+950.000	182.760	-1.6667%
S.26	9+950.000	10+350.000	400.000	1.2500%
S.27	10+350.000	11+000.000	650.000	0.7692%
S.28	11+000.000	11+300.000	300.000	0.5667%
S.29	11+300.000	11+700.000	400.000	-0.3750%
S.30	11+700.000	12+100.000	400.000	0.9600%
S.31	12+100.000	12+700.000	600.000	0.5000%
S.32	12+700.000	13+000.000	300.000	1.0000%
S.33	13+000.000	13+300.000	300.000	1.9533%
S.34	13+300.000	13+900.000	600.000	0.3833%
S.35	13+900.000	14+200.000	300.000	1.5000%
S.36	14+200.000	14+700.000	500.000	4.7600%
S.37	14+700.000	15+350.000	650.000	1.3138%
S.38	15+350.000	15+700.000	350.000	-0.4400%
S.39	15+700.000	16+100.000	400.000	1.2000%
S.40	16+100.000	16+500.000	400.000	2.8750%
S.41	16+500.000	16+700.000	200.000	0.0000%
S.42	16+700.000	17+100.000	400.000	0.9000%
S.43	17+100.000	17+800.000	700.000	2.4174%
S.44	17+800.000	19+600.000	2,207.017	3.9000%
S.45	19+600.000	20+100.000	500.000	2.6303%
S.46 [a]	20+100.000	20+186.738	86.738	2.4000%
			Average Grade:	1.0686%

Note: a. Tunnel South Portal

Tunnel Section

No.	From Sta.	To Sta.	Distance (m)	Grade
T.1 [b]	20+187.637 ← 16+247.000	18+132.000	1,885.000	2.4000%

Note: b. A break at Sta.20+187.637 / Sta.16+247.000 (3,939.

North Section

No.	From Sta.	To Sta.	Distance (m)	Grade
N.1 [c]	18+132.000	18+250.000	118.000	2.4000%
N.2	18+250.000	18+797.200	547.200	-2.8560%
N.3	18+797.200	19+250.000	432.868	-0.0069%
N.4	19+250.000	19+550.000	300.000	-3.8600%
N.5	19+550.000	20+050.000	500.000	-0.9000%
N.6	20+050.000	20+600.000	550.000	0.3509%
N.7	20+600.000	20+750.000	150.000	-1.6780%
N.7	20+750.000	21+500.000	750.000	-0.3077%
N.8	21+500.000	21+950.000	445.743	-3.0679%
N.9	21+950.000	22+350.000	400.000	-0.7375%
N.10	22+350.000	22+600.000	250.000	0.3800%
N.11	22+600.000	23+025.000	425.000	-1.0965%
N.12	23+025.000	23+250.000	225.000	-1.5769%
N.13	23+250.000	23+500.000	250.000	-1.1768%
N.14	23+500.000	24+076.000	576.000	1.8920%
N.15	24+076.000	24+300.000	224.000	-2.4607%
N.16	24+300.000	24+850.000	550.000	-1.7520%
N.17	24+850.000	25+050.000	229.691	0.0000%
N.18	25+050.000	25+298.400	248.400	-4.3402%
N.19	25+298.400	25+700.000	401.600	-1.1121%
N.20	25+700.000	25+850.000	150.000	-0.9627%
N.21	25+850.000	25+906.255	56.255	-0.9980%
			Average Grade:	-1.0300%

Note: c. Tunnel North Portal

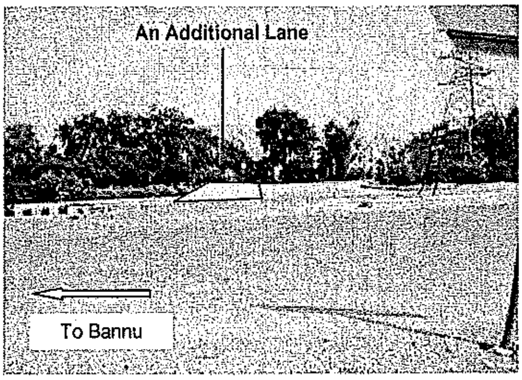
11.2.2 Intersections/Interchanges

(1) Major Intersections/Intersections

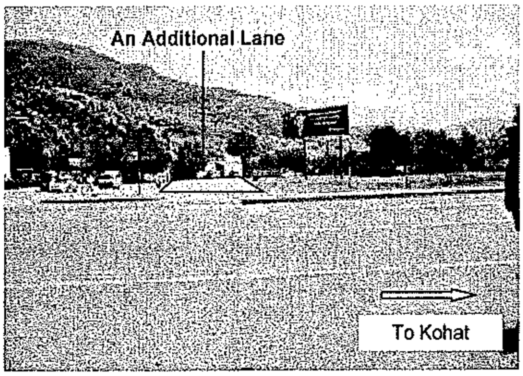
Following are the major intersections and interchanges on the Project road:

- Kohat Toi Intersection at the Project road start point
- Kohat Pindi Interchange Interchange with N-80 (Off-Ramps and On-Ramps)
- Kohat Link Road Interchange (Off Ramp and On-Ramp)
- Sanda Basta Interchange with N.W.F. Road (Off Ramp and On-Ramp)
- Dara Adam Khel Intersection at the Project road end point.

The Kohat Toi and Dara Adam Khel Intersections were already constructed with a 4-lane carriageway under the 1st Kohat Tunnel and Access Roads Project. However, as the traffic capacity of the right turn traffic from Kohat Town to Bannu will become insufficient in future, one lane should be added for the Kohat Toi Intersection. One additional lane is also required for the Dara Adam Khel Intersection to solve the similar under-capacity problem. No additional ROW acquisition is required as the new lanes can be accommodated within the existing ROW (following photos).



ROW for An Additional Lane
Provision for Kohat Toi Intersection



ROW for An Additional Lane
Provision for Dara Adam Khel Intersection

Introduction of a traffic control signal system will be a better alternative to increase the capacity of those junctions if a systematic operation and maintenance system is secured.

The traffic capacity of the current N-80 Rawalpindi – Kohat Town Road Intersection is sufficient and no improvement is required.

Approximately 40% of the traffic on the Kohat Tunnel and Access Roads diverts from/to Kohat Town through the Kohat Link Road IC. Besides, the Kohat Link Road IC will work as a bypass/ ring road for Kohat Town in future as illustrated in Figure 11.2.4. Part of the traffic currently passing through the Kohat Town centre will use the Kohat Link Road/N-55 as its passage becomes free after the relocation of the main toll gate at Sta.10+600 to a new site at Sta.17+400.

Therefore, a proper IC traffic flow system is planned, providing an On-Ramp for the traffic from Kohat Town to the south/Rawalpindi (N-80) and an Off-Ramp for the traffic from the south/Rawalpindi (N-80) to Kohat Town through the Kohat Link Road (see Figure 11.2.5).

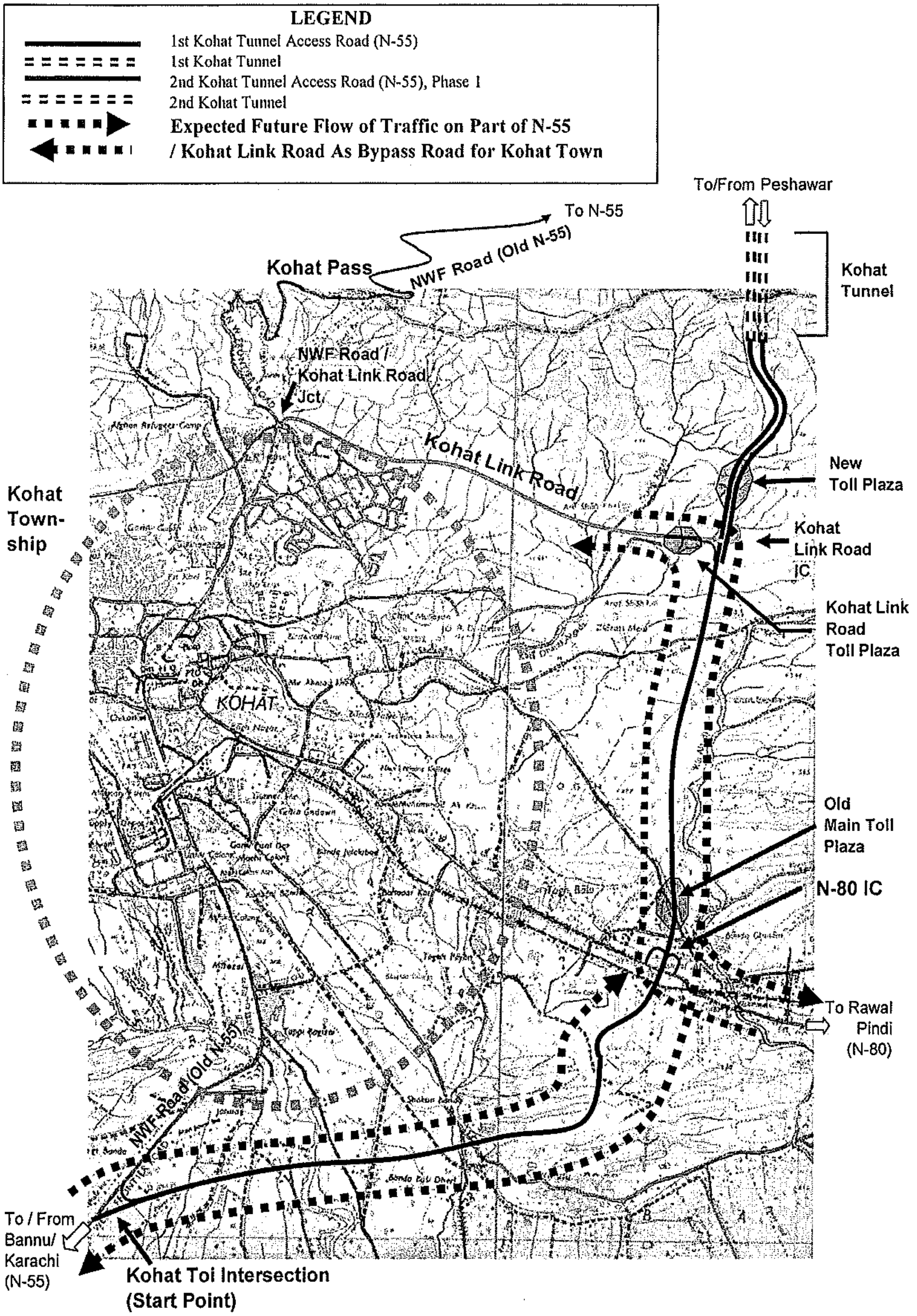


Figure 11.2.4 Future Bypass Road System for Kohat Town

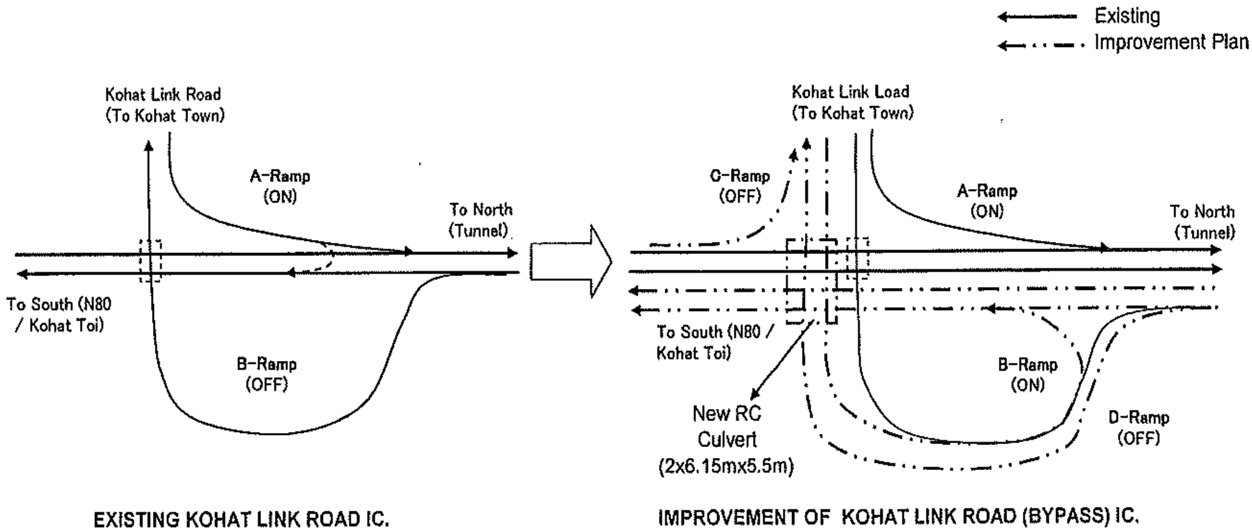
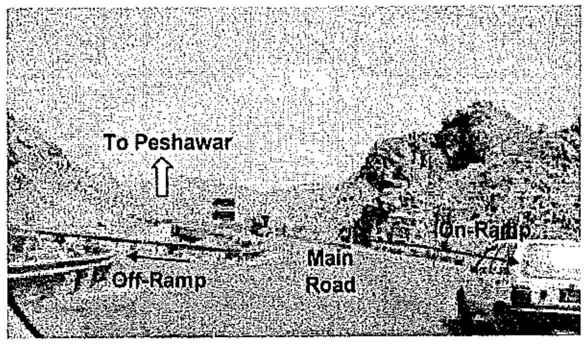


Figure 11.2.5 Kohat Link Road IC Improvement Plan

There is almost no traffic on On/Off Ramps (see the right photo) of the N.W.F. Road IC as the traffic uses the Dara Adam Khel Intersection for tunnel access. However, these On/Off Ramps have an important role after the construction of the 2nd Kohat Tunnel and Access Roads as they will be used by the tunnel maintenance vehicles. The end part of the On-Ramp requires reconstruction to connect to the new 2 lanes.



N.W.F.Road IC (Sta.19+088)

(2) Minor Intersections

There are several minor intersections between Kohat Toi and the N-80 IC at Sta.1+300, Sta.2+200, Sta.2+900, Sta.3+500, Sta.3+900, Sta.4+810, Sta.4+900 and Sta.5+400. To ensure safety of high speed traffic on the through lanes, right and left turn lanes are provided though this traffic is not much.

11.2.3 Slope Protection

No major slope failures have occurred during and after the opening of the 1st Kohat Tunnel Access Road. As the slope protection works adopted for the 1st road are effective, the following same slope stabilisation methods are adopted for the 2nd Kohat Tunnel and Access Roads.

Slope Protection Works for Cut Slopes:

- Grouted riprap
- Shotcrete
- Rock net

Slope Protection Works for Fill Slopes:

- Grouted riprap
- Rock fill

11.2.4 Drainage Structures

The drainage structures for the Project road consist of roadway cross drainages (box and pipe culverts), median drainages, road side drains and tunnel drainages (refer to Sub-section 11.4 for box culverts and Subsection 11.5 for tunnel drainage). Table 11.2.3 is a list of RCC pipe culverts to be extended from/to the existing RC pipes constructed under the 1st Kohat Tunnel and Access Roads Project.

Table 11.2.3 List of RC Pipe Culverts

No.	Pipe Culvert No.	Station	RCCP Dia.910 mm (m)	RCCP Dia.1070 mm (m)
South Section				
1	1	00 + 423.65	30	
2	3	00 + 692.20	32	
3	7	01 + 270.22	11	
4	7A	01 + 427.28	11	
5	8	01 + 432.48		12
6	9A	01 + 450.73	12	
7	9B	01 + 512.86	12	
8	10	01 + 575.29	11	
9	11	01 + 678.68	10	
10	12	01 + 809.50	11	
11	13A	01 + 827.02	11	
12	13B	01 + 856.00	14	
13	16	02 + 218.25	12	
14	17	02 + 284.16	11	
15	18	02 + 302.79	11	
16	20	02 + 940.89		12
17	21	03 + 033.00		11
18	21A	03 + 035.50	12	
19	22	03 + 120.26		12
20	23	03 + 170.00	13	
21	24	32 + 360.30		12
22	26	03 + 390.31		13
23	28	03 + 635.00	12	
24	29B	04 + 034.48	17	
25	30	04 + 096.45	17	
26	30A	04 + 178.95	27	
27	32	04 + 360.93	17	
28	37B	07 + 532.00	11	
29	46	10 + 946.60	46	
30	50A	11 + 038.00	26	
31	59	11 + 038.00		24
Sub-Total for South Section			**397**	**96**
North Section				
1	74	18 + 558.00		16
2	76	19 +323.00		21
3	78	19 + 600.00		11
4	79	19 + 800.00		10
5	87a	22 + 246.00		15
6	91	23 + 247.00		15
7	95a	25 + 075.00		20
8	96b	24 +792.00		18
Sub-Total for North Section			**0**	**126**
Grand Total			**397**	**222**

Median drainages are provided where run-off from the carriageway flows to the roadway centre as illustrated in Figure 11.2.3. Their dimensions and length depend on the road geometry and topography. Roadside drainages (lined ditches) are providing along the roadside for cut sections or part of the embankment sections where run-off from the cut-slopes and the carriageway is to be drained out.

11.2.5 Other Incidentals

Other road facilities including bus stops, traffic signs, pavement marking, guardrail, traffic guides posts, median barriers, Km posts, ROW fence and ROW markers are also provided to ensure safety and convenience of road users. PCC curve stones are constructed along the median. Appropriate shrubs, flower trees and grasses are planted in the median.

The existing guardrails on the right shoulders of the existing road will be removed and reinstalled for the 2nd Kohat Tunnel and Access Roads.

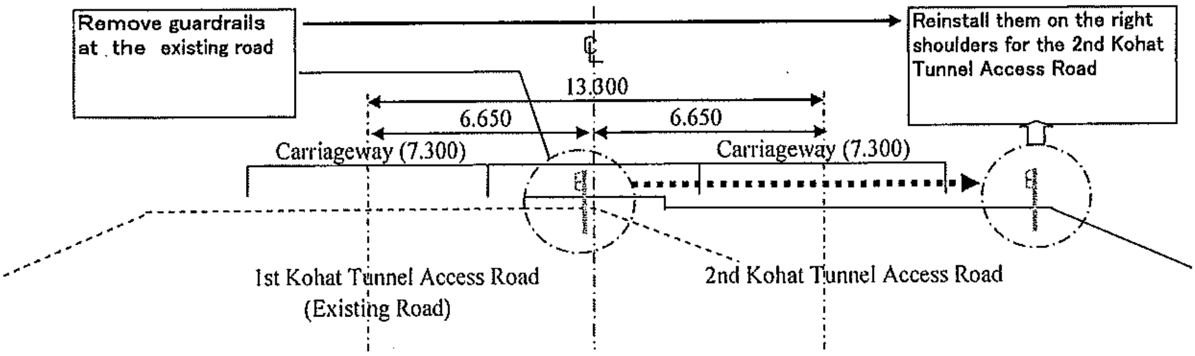


Figure 11.2.6 Removal and Reinstallation of Guardrails

Installation of RC concrete barriers (New Jersey Barrier) will be one of the best alternatives to prevent crush accidents at smaller curves with a radius less of than 300m in the north section (see Figure 11.2.7).

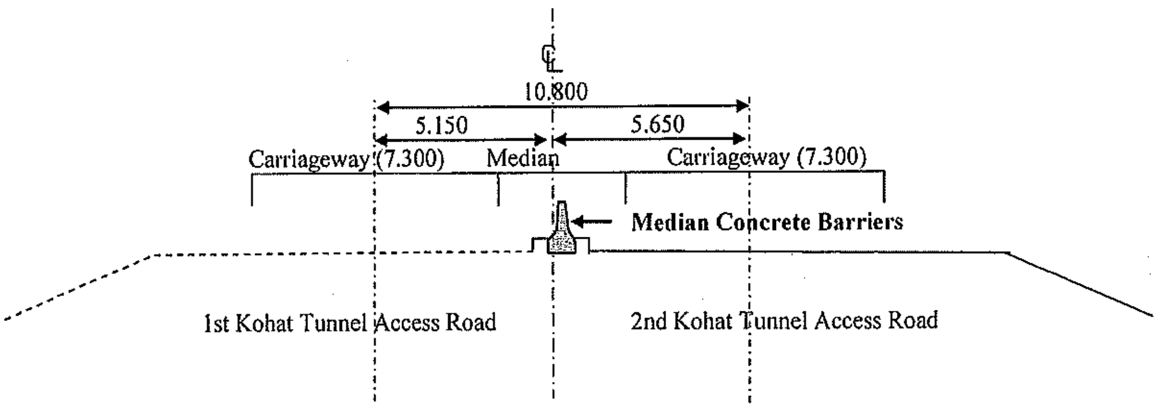


Figure 11.2.7 Median Concrete Barriers for North Section at Small Curves (R < 300 m)

11.3 Pavement Design

11.3.1 Design Conditions

(1) Design Traffic and CESA (Cumulative Equivalent Single Axle Load)

The design traffic, traffic growth rate and directional distribution used for the pavement design are as analyzed in the section on Traffic Analysis in Chapter 7.

NTRC conducted a comprehensive axle load survey on national highways in 1995 and the results of this survey are used for estimating the axle load since there is no comprehensive up-date study since that. There were two survey stations on N-55 near Kohat. One is between Kohat and Peshawar and the other between Bannu and D.I. Khan. The Equivalent Single Axle (ESA) of the latter is higher than that of the former as vehicles are less loaded when running on the steep Kohat Pass. The ESA used for the pavement design (see Table 11.3.1) is based in principle on the axle load study at the Bannu station as it is considered that the current traffic characteristics at this station are similar to those of N-55 near Kohat after the opening the Kohat Tunnel in 2003. NTRC provided two different axle loads: one is based on AASHTO and the other on the Road Note 31. The former is applied for the Project because the Road Note 31 is not applicable as its Cumulative Equivalent Single Axle Load (CESA) limit is 30 x 10^6.

Table 11.3.1 Average ESA for Pavement Design

Vehicle Type	ESA/Veh.			
	Road Note 31 Method		AASHTO Method	
	Empty	Loaded	Empty	Loaded
Bus	-	0.50	-	0.50
Truck (2-Axles)	0.04	7.33	0.04	5.47
Truck (3-Axles)	0.08	16.26	0.08	8.28
Tractor/ Trailer	0.43	19.14	0.43	11.50

Source: Data processed by the Study Team based on the Axle Load Study
NTRC, July 1996

CESA was computed from several relevant factors including ESA, AADT, traffic growth rate, loading/empty ratio, directional distribution and lane distribution (see Figures 11.3.1 and 11.3.2). Only buses, trucks and truck trailers are accounted for determining the pavement design load as effects of lighter vehicles are little. The design period for flexible pavement is 10 years and that for rigid pavement is 20 years. Flexible pavement (asphalt concrete pavement) is used for the access roads. Rigid pavement (cement concrete pavement) is adopted only for the toll plaza and tunnel pavement.

The CESA value estimated for flexible pavement design is 28.0 million for Section 1-1 (Sta.0+000-Sta.10+000), 30.0 million for Section 1-2 (Sta.10+000-Sta.15+000) and 32.0 million for Section 2 (Sta.15+000-Sta.25+906). The CESA applied for rigid pavement design is 86.2 million as summarized in Table 11.3.2.

Table 11.3.2 Cumulative Equivalent Single Axle Load (CESA) for Pavement Design

Unit: 10^6

Section	CESA for Flexible Pavement Design Period (10 years)		CESA for Rigid Pavement Design Period (20 years)		Remarks (CESA for 1st Kohat)	
	AASHTO	RN 31	AASHTO	RN 31	Flexible	Rigid
Section 1-1 (Sta.0 - Sta.10+000) Kohat Toi to N-80 IC	**28.0**	45.6	75.5	122.8	17.0	40.0
					(Sta.0 -Sta.9+000)	
Section 1-2 (Sta.10+000 - Sta.15+000) N-80 IC to Kohat Link Road	**30.0**	48.7	80.6	131.1	17.0	40.0
					(Sta.0 -Sta.9+000)	
Section 2 (Sta.15+000 - Sta.25+906) Kohat Link Road to Dara Adam Khel	**32.0**	51.6	**86.2**	138.7	40.0	40.0
					(Sta.9+000 - End Point)	

Note: Rigid Pavement is only for Toll Gate and Tunnel in the case of the 2nd Kohat Access Road

Road Section: Section 1 (Kohat Toi - Kohat Link Road) **Project Start Point - Sta.10+000 (N-80 IC)**

Traffic Survey Station : At Kohat Link Road IC (Bypass IC)
Base Year: 2006 DD/ Pre-construction: 2008 - 2009 Construction: 2009 - 2011
Opening Year : 2012

Project's Lifespan : 10 years for ACP and 20 years for PCCP

TGR : (Traffic Growth Rate)

Vehicle Type	2006 to 2010	2011 to 2014	2015 to 2019	2020 to 2024	After 2025
Bus	12% - 7%/ann.	6.50 %/ann.	6.00 %/ann.	5.50 %/ann.	5.00 %/ann.
Truck (2 & 3-Axles)	12% - 7%/ann.	6.50 %/ann.	6.00 %/ann.	5.50 %/ann.	5.00 %/ann.
Tractor/ Trailer	12% - 7%/ann.	6.50 %/ann.	6.00 %/ann.	5.50 %/ann.	5.00 %/ann.

AADT (Base Year): (Survey May.2006)
Empty rate from OD Survey by PTPS in Aug.2005

Vehicle Type	Empty (Veh.)	Empty (%)	Loaded (Veh.)	Loaded (%)	Total (Veh.)	Total (%)
Bus	-	0%	129	100%	129	7.2%
Truck (2-Axles)	232	27.5%	610	72.5%	842	46.7%
Truck (3-Axles)	146	30.8%	329	69.2%	475	26.4%
Tractor/ Trailer	89	25.0%	267	75.0%	356	19.8%
Total:	467		1,335		1,802	100.0%

Truck Factors : (ESA from NTRC 1995 Axle Load Survey)

Vehicle Type	Empty ESA/Veh.	Empty ESA/day	Loaded ESA/Veh.	Loaded ESA/day	Average ESA/day
Bus	-	-	0.50	65	0.50
Truck (2-Axles)	0.04	9.3	5.47	3,337	3.97
Truck (3-Axles)	0.08	11.7	8.26	2,724	5.76
Tractor/ Trailer	0.43	38.3	11.50	3,071	8.73

Summary of Design ESA Estimate

Estimated CESA:

Vehicle Type	Flexible Pavement Design 10-years ESA (2012 - 2021)		Rigid Pavement Design 20-years ESA (2012 - 2031)	
Bus	519,809	0.7%	1,398,678	0.7%
Truck (2-Axles)	26,965,421	36.2%	72,557,342	36.2%
Truck (3-Axles)	22,047,950	29.6%	59,325,631	29.6%
Tractor/ Trailer	25,053,734	33.6%	67,413,459	33.6%
Total:	74,586,914	100.0%	200,695,110	100.0%

Direction Distribution Factor:

	North Bound	South Bound	North Bound	South Bound
From Survey:	53%	47%	53%	47%
	39,531,064	35,055,850	106,368,408	94,326,702

Lane Distribution Factor: (Between 80% and 100%)

	Flexible	Rigid
	80%	80%
	28,044,680	75,461,361

Design CESA for Pavement Design of the 2nd Kohat Tunnel & Access Road (South Bound)

Flexible Pavement Design (Asphalt Concrete Pavement) From Year 2012 to 2021 (10 years): 28.0 x 10^6

Rigid Pavement Design (Reinforced Concrete Pavement) From Year 2012 to 2031 (20 years): 75.5 x 10^6

ESA Estimation Table (for both directions/lanes)

Stage	Year	Bus TGR	Bus AADT	Bus T.FACTOR	Bus ESA/Year	Truck (2-Axles) TGR	Truck (2-Axles) AADT	Truck (2-Axles) T.FACTOR	Truck (2-Axles) ESA
FS	2006	12.0%	129	0.50	23,543	12.0%	842	3.97	1,221,283
FA	2007	10.0%	142		25,897	10.0%	926		1,343,411
DD	2008	9.0%	155		28,227	9.0%	1,010		1,464,318
Tender	2009	8.0%	167		30,486	8.0%	1,090		1,581,463
C1	2010	7.0%	179		32,620	7.0%	1,167		1,692,166
C2	2011	6.5%	190		34,740	6.5%	1,242		1,802,157
C3	2012	6.5%	203		36,998	6.5%	1,323		1,919,297
OM1	2013	6.5%	216		39,403	6.5%	1,409		2,044,051
OM2	2014	6.5%	230		41,964	6.5%	1,501		2,176,914
OM3	2015	6.0%	244		44,482	6.0%	1,591		2,307,529
OM4	2016	6.0%	258		47,151	6.0%	1,686		2,445,981
OM5	2017	6.0%	274		49,980	6.0%	1,788		2,592,740
OM6	2018	6.0%	290		52,979	6.0%	1,895		2,748,304
OM7	2019	6.0%	308		56,157	6.0%	2,008		2,913,203
OM8	2020	5.5%	325		59,246	5.5%	2,119		3,073,429
OM9	2021	5.5%	342		62,505	5.5%	2,235		3,242,467
OM10	2022	5.5%	361		65,942	5.5%	2,358		3,420,803
OM11	2023	5.5%	381		69,569	5.5%	2,488		3,608,947
OM12	2024	5.5%	402		73,395	5.5%	2,625		3,807,439
OM13	2025	5.0%	422		77,065	5.0%	2,756		3,997,811
OM14	2026	5.0%	443		80,919	5.0%	2,894		4,197,702
OM15	2027	5.0%	466		84,964	5.0%	3,039		4,407,587
OM16	2028	5.0%	489		89,213	5.0%	3,191		4,627,966
OM17	2029	5.0%	513		93,673	5.0%	3,350		4,859,364
OM18	2030	5.0%	539		98,357	5.0%	3,518		5,102,333
OM19	2031	5.0%	566		103,275	5.0%	3,694		5,357,449
OM20	2032	5.0%	594		108,439	5.0%	3,878		5,625,322
Total CESA for Flexible Pavement Design (2013-2022):				0.7%	519,809			36.2%	26,965,421
Total CESA for Rigid Design (2013-2032):				0.7%	1,398,678			36.2%	72,557,342

Stage	Year	Truck (3-Axles) TGR	Truck (3-Axles) AADT	Truck (3-Axles) T.FACTOR	Truck (3-Axles) ESA	Tractor / Trailer TGR	Tractor / Trailer AADT	Tractor / Trailer T.FACTOR	Tractor / Trailer ESA	Yearly Total AADT	Yearly Total ESA	CESA for Design
FS	2006	12.0%	475	5.76	998,567	12.0%	356	8.73	1,134,701	1,802	3,378,093	
FA	2007	10.0%	523		1,098,424	10.0%	392		1,248,171	1,982	3,715,903	
DD	2008	9.0%	570		1,197,282	9.0%	427		1,360,507	2,161	4,050,334	CESA for
Tender	2009	8.0%	615		1,293,064	8.0%	461		1,469,347	2,333	4,374,361	Pre-Opening
C1	2010	7.0%	658		1,383,579	7.0%	493		1,572,201	2,497	4,680,566	Period
C2	2011	6.5%	701		1,473,512	6.5%	525		1,674,394	2,659	4,984,803	
C3	2012	6.5%	746		1,569,290	6.5%	559		1,783,230	2,832	5,308,815	30,492,873
OM1	2013	6.5%	795		1,671,294	6.5%	596		1,899,140	3,016	5,653,888	Opening
OM2	2014	6.5%	847		1,779,928	6.5%	635		2,022,584	3,212	6,021,390	
OM3	2015	6.0%	897		1,886,723	6.0%	673		2,143,939	3,405	6,382,674	
OM4	2016	6.0%	951		1,999,927	6.0%	713		2,272,576	3,609	6,765,634	
OM5	2017	6.0%	1,008		2,119,922	6.0%	756		2,408,930	3,826	7,171,572	
OM6	2018	6.0%	1,069		2,247,118	6.0%	801		2,553,466	4,055	7,601,867	For Flexible
OM7	2019	6.0%	1,133		2,381,945	6.0%	849		2,706,674	4,298	8,057,979	Pavement
OM8	2020	5.5%	1,195		2,512,952	5.5%	896		2,855,541	4,535	8,501,167	Design
OM9	2021	5.5%	1,261		2,651,164	5.5%	945		3,012,596	4,784	8,968,732	(2013 - 2022)
OM10	2022	5.5%	1,330		2,796,978	5.5%	997		3,178,288	5,047	9,462,012	74,586,914
OM11	2023	5.5%	1,404		2,950,812	5.5%	1,052		3,353,094	5,325	9,982,422	
OM12	2024	5.5%	1,481		3,113,107	5.5%	1,110		3,537,514	5,618	10,531,456	
OM13	2025	5.0%	1,555		3,268,762	5.0%	1,165		3,714,390	5,899	11,058,028	
OM14	2026	5.0%	1,633		3,432,200	5.0%	1,224		3,900,110	6,194	11,610,930	
OM15	2027	5.0%	1,714		3,603,810	5.0%	1,285		4,095,115	6,503	12,191,476	
OM16	2028	5.0%	1,800		3,784,000	5.0%	1,349		4,299,871	6,829	12,801,050	For Rigid
OM17	2029	5.0%	1,890		3,973,200	5.0%	1,416		4,514,865	7,170	13,441,103	Pavement
OM18	2030	5.0%	1,984		4,171,860	5.0%	1,487		4,740,608	7,528	14,113,158	Design
OM19	2031	5.0%	2,084		4,380,454	5.0%	1,562		4,977,638	7,905	14,818,816	(2013 - 2032)
OM20	2032	5.0%	2,188		4,599,476	5.0%	1,640		5,226,520	8,300	15,559,757	200,695,110
Total CESA for Flexible Pavement Design (2013-2022):				29.6%	22,047,950			33.6%	25,053,734	100.0%	74,586,914	
Total CESA for Rigid Design (2013-2032):				29.6%	59,325,631			33.6%	67,413,459	100.0%	200,695,110	

Notes: 1. CESA estimation by an Excel-basis program developed by the JICA Study Team. The same conditions were used for the CESA estimation of Section 1 except the AADT.
2. FS; Feasibility Study, DD; Detailed Engineering Design, C; Construction, OM; Operation and Maintenance

Figure 11.3.1 Cumulative Equivalent Single Axle (CESA) Estimation for Pavement Design

Road Section: Section 2 (Kohat Link Road - Dara Adam Khel) **Sta.15+000 - Project End Point**

Traffic Survey Station :	At Kohat Link Road IC (Bypass IC)			
Base Year:	2006	DD/ Pre-construction: 2008 - 2009	Construction:	2009 - 2011
Opening Year :	2012			
Project's Lifespan :	10 years for ACP	and	20 years for PCCP	

TGR : (Traffic Growth Rate)

Vehicle Type	2006 to 2010	2011 to 2014	2015 to 2019	2020 to 2024	After 2025
Bus	12% - 7%/ann.	6.50 %/ann.	6.00 %/ann.	5.50 %/ann.	5.00 %/ann.
Truck (2 & 3-Axles)	12% - 7%/ann.	6.50 %/ann.	6.00 %/ann.	5.50 %/ann.	5.00 %/ann.
Tractor/ Trailer	12% - 7%/ann.	6.50 %/ann.	6.00 %/ann.	5.50 %/ann.	5.00 %/ann.

AADT (Base Year): (Survey May,2006)
Empty rate from OD Survey by PTPS in Aug,2005

Vehicle Type	Empty (Veh.)	Empty (%)	Loaded (Veh.)	Loaded (%)	Total (Veh.)	Total (%)
Bus	-	0%	147	100%	147	7.0%
Truck (2-Axles)	290	27.5%	765	72.5%	1,055	50.3%
Truck (3-Axles)	158	30.8%	354	69.2%	512	24.4%
Tractor/ Trailer	96	25.0%	288	75.0%	384	18.3%
Total:	544		1,554		2,098	100.0%

Truck Factors : (ESA from NTRC 1995 Axle Load Survey)

Vehicle Type	Empty ESA/Veh.	Empty ESA/day	Loaded ESA/Veh.	Loaded ESA/day	Average ESA/day
Bus	-	-	0.50	74	0.50
Truck (2-Axles)	0.04	11.6	5.47	4,185	3.98
Truck (3-Axles)	0.08	12.6	8.28	2,931	5.75
Tractor/ Trailer	0.43	41.3	11.50	3,312	8.73

Summary of Design ESA Estimate

Estimated CESA:

Vehicle Type	Flexible Pavement Design 10-years ESA (2012 - 2021)		Rigid Pavement Design 20-years ESA (2012 - 2031)	
Bus	592,340	0.7%	1,593,842	0.7%
Truck (2-Axles)	33,816,984	39.7%	90,993,219	39.7%
Truck (3-Axles)	23,723,910	27.9%	63,835,229	27.9%
Tractor/ Trailer	27,024,252	31.7%	72,715,642	31.7%
Total:	85,157,487	100.0%	229,137,932	100.0%

Direction Distribution Factor:

	North Bound	South Bound	North Bound	South Bound
From Survey:	53%	47%	53%	47%
	45,133,468	40,024,019	121,443,104	107,694,828

Lane Distribution Factor: (Between 80% and 100%)

	Flexible	Rigid
	80%	80%
	32,019,215	86,155,862

Design CESA for Pavement Design of the 2nd Kohat Tunnel & Access Road (South Bound)

Flexible Pavement Design		Rigid Pavement Design	
(Asphalt Concrete Pavement) From Year 2013 to 2022 (10 years)	32.0 x 10^6	(Reinforced Concrete Pavement) From Year 2013 to 2032 (20 years)	86.2 x 10^6

ESA Estimation Table (for both directions/lanes)

Stage*	Year	Bus TGR	Bus AADT	Bus T.FACTOR	Bus ESA/Year	Truck (2-Axles) TGR	Truck (2-Axles) AADT	Truck (2-Axles) T.FACTOR	Truck (2-Axles) ESA	Truck (3-Axles) TGR	Truck (3-Axles) AADT	Truck (3-Axles) T.FACTOR	Truck (3-Axles) ESA	Tractor / Trailer TGR	Tractor / Trailer AADT	Tractor / Trailer T.FACTOR	Tractor / Trailer ESA	Yearly Total AADT	Yearly Total ESA	CESA for Design
FS	2006	12.0%	147	0.50	26,828	12.0%	1,055	3.98	1,531,595	12.0%	512	5.75	1,074,472	12.0%	384	8.73	1,223,947	2,098	3,856,842	
FA	2007	10.0%	162		29,510	10.0%	1,161		1,684,754	10.0%	563		1,181,920	10.0%	422		1,346,342	2,308	4,242,526	
DD	2008	9.0%	176		32,166	9.0%	1,265		1,836,382	9.0%	614		1,288,292	9.0%	460		1,467,513	2,516	4,624,353	CESA for
Tender	2009	8.0%	190		34,739	8.0%	1,366		1,983,293	8.0%	663		1,391,356	8.0%	497		1,584,914	2,717	4,994,302	Pre-Opening
C1	2010	7.0%	204		37,171	7.0%	1,462		2,122,123	7.0%	709		1,488,751	7.0%	532		1,695,858	2,907	5,343,903	Period
C2	2011	6.5%	217		39,587	6.5%	1,557		2,260,061	6.5%	756		1,585,520	6.5%	567		1,806,088	3,096	5,691,256	
C3	2012	6.5%	231		42,161	6.5%	1,658		2,406,965	6.5%	805		1,688,578	6.5%	603		1,923,484	3,297	6,061,188	34,814,370
OM1	2013	6.5%	246		44,901	6.5%	1,766		2,563,418	6.5%	857		1,798,336	6.5%	643		2,048,511	3,511	6,455,165	Opening
OM2	2014	6.5%	262		47,820	6.5%	1,881		2,730,040	6.5%	913		1,915,228	6.5%	684		2,181,664	3,740	6,874,751	
OM3	2015	6.0%	278		50,689	6.0%	1,993		2,893,842	6.0%	967		2,030,141	6.0%	726		2,312,564	3,964	7,287,236	
OM4	2016	6.0%	294		53,730	6.0%	2,113		3,067,473	6.0%	1,025		2,151,950	6.0%	769		2,451,317	4,202	7,724,470	
OM5	2017	6.0%	312		56,954	6.0%	2,240		3,251,521	6.0%	1,087		2,281,067	6.0%	815		2,598,397	4,454	8,187,939	
OM6	2018	6.0%	331		60,371	6.0%	2,374		3,446,613	6.0%	1,152		2,417,931	6.0%	864		2,754,300	4,721	8,679,215	For Flexible
OM7	2019	6.0%	351		63,993	6.0%	2,517		3,653,409	6.0%	1,221		2,563,007	6.0%	916		2,919,558	5,004	9,199,968	Pavement
OM8	2020	5.5%	370		67,513	5.5%	2,655		3,854,347	5.5%	1,288		2,703,972	5.5%	966		3,080,134	5,280	9,705,966	Design
OM9	2021	5.5%	390		71,226	5.5%	2,801		4,066,336	5.5%	1,359		2,852,691	5.5%	1,020		3,249,541	5,570	10,239,794	(2013 - 2022)
OM10	2022	5.5%	412		75,144	5.5%	2,955		4,289,984	5.5%	1,434		3,009,588	5.5%	1,076		3,428,266	5,876	10,802,983	85,157,487
OM11	2023	5.5%	434		79,277	5.5%	3,118		4,525,934	5.5%	1,513		3,175,116	5.5%	1,135		3,616,821	6,200	11,397,147	
OM12	2024	5.5%	458		83,637	5.5%	3,289		4,774,860	5.5%	1,596		3,349,747	5.5%	1,197		3,815,746	6,541	12,023,990	
OM13	2025	5.0%	481		87,819	5.0%	3,453		5,013,603	5.0%	1,676		3,517,235	5.0%	1,257		4,006,533	6,868	12,625,189	
OM14	2026	5.0%	505		92,209	5.0%	3,626		5,264,283	5.0%	1,760		3,693,096	5.0%	1,320		4,206,860	7,211	13,256,449	
OM15	2027	5.0%	531		96,820	5.0%	3,807		5,527,497	5.0%	1,848		3,877,751	5.0%	1,386		4,417,203	7,572	13,919,271	
OM16	2028	5.0%	557		101,661	5.0%	3,998		5,803,872	5.0%	1,940		4,071,639	5.0%	1,455		4,638,063	7,950	14,615,235	For Rigid
OM17	2029	5.0%	585		106,744	5.0%	4,198		6,094,066	5.0%	2,037		4,275,221	5.0%	1,528		4,869,966	8,348	15,345,997	Pavement
OM18	2030	5.0%	614		112,081	5.0%	4,408		6,398,769	5.0%	2,139		4,488,982	5.0%	1,604		5,113,465	8,765	16,113,296	Design
OM19	2031	5.0%	645		117,685	5.0%	4,628		6,718,707	5.0%	2,246		4,713,431	5.0%	1,685		5,369,138	9,203	16,918,961	(2013 - 2032)
OM20	2032	5.0%	677		123,570	5.0%	4,859		7,054,643	5.0%	2,358		4,949,102	5.0%	1,769		5,637,595	9,664	17,764,909	229,137,932
Total CESA for Flexible Pavement Design (2013-2022):				0.7%	592,340			39.7%	33,816,984			27.9%	23,723,910			31.7%	27,024,252	100.0%	85,157,487	
Total CESA for Rigid Design (2013-2032):				0.7%	1,593,842			39.7%	90,993,219			27.9%	63,835,229			31.7%	72,715,642	100.0%	229,137,932	

Notes: 1. CESA estimation by an Excel-basis program developed by the JICA Study Team. The same conditions were used for the CESA estimation of Section 1 except the AADT.
2. FS; Feasibility Study, DD; Detailed Engineering Design, C; Construction, OM; Operation and Maintenance

Figure 11.3.2 Cumulative Equivalent Single Axle (CESA) Estimation for Pavement Design

The CESA valued used for the 1st Kohat Tunnel and Access Roads are not consistent between flexible and the rigid pavements as shown in the right column of Table 11.3.2.

(2) Design CBR and Resilient Modules (M_R)

The CBR values of soil along the road alignment vary form 5% to 60%. The design CBR for subgrade used for flexible pavement is 15% throughout the Project road as most of the sections are fill sections where the borrow material with CBR of more than 15% are introduced (refer to Material Survey in Section 6.5). Most of the cut sections are composed of soft/hard rock. Subgrade improvement will be made where CBR is less than 15%. The design CBR used for rigid pavement is 30% (a mixture of borrow and crushed aggregates) for subgrade. There are several methods to define Subgrade Resilient Modules (M_R) as shown in Figure 11.3.3 and the Study Team applied the conservative values. The M_R used for flexible pavement is 12,000 psi and that for rigid pavement is 16,500 psi.

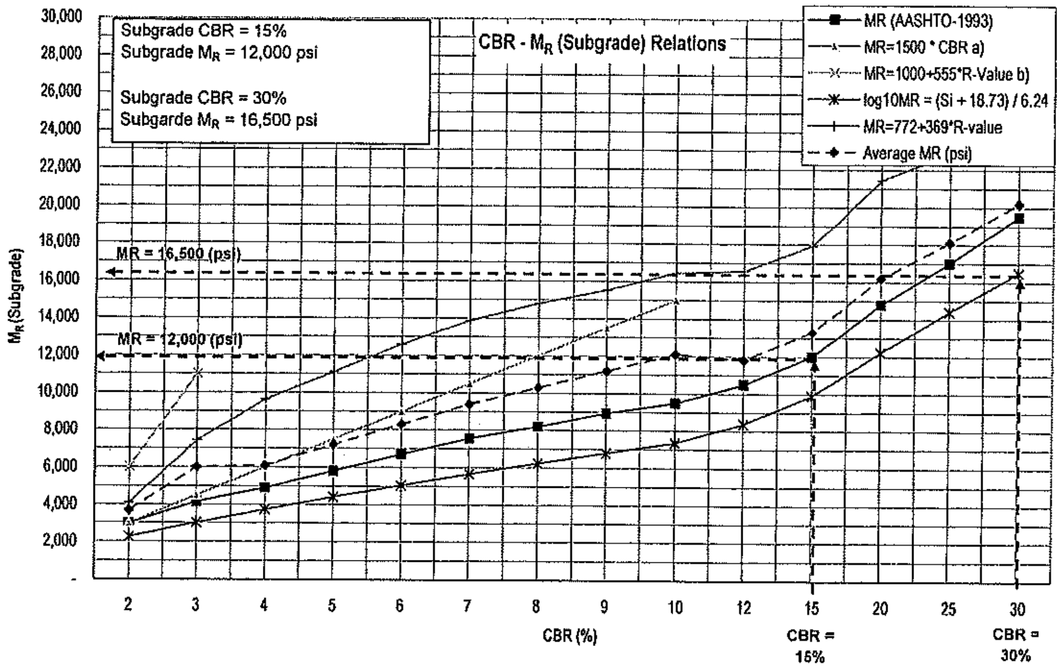


Figure 11.3.3 Subgrade CBR and Modules for Pavement Design

(3) Design Equations and Parameters

The design equations, design parameters, layer coefficients, drainage coefficients, pavement material modules are based on "AASHTO Pavement Design Guide of 1993". The pavement materials are those specified in the NHA's Standard Construction Specifications.

11.3.2 Pavement Thickness Design

The pavement design was carried out using Excel-basis design programs developed by the Study Team as shown in Figures 11.3.4 and 11.3.5 for flexible pavement design and in Figure 11.3.6 for rigid pavement design. Table 11.3.3 summarises the flexible pavement structures for both the 1st and the 2nd Kohat Tunnel and Access Roads. The AC wearing/base thickness (22 cm-23 cm) of the 2nd Kohat Tunnel and Access Roads is thinner than that of the 1st Kohat Tunnel and Access Roads, while the aggregate base/subbase thickness (30 cm) of the former is thicker than the latter.

2ND KOHAT TUNNEL & ACCESS ROADS PROJECT
Section 1-1: N-80 IC- Kohat Link Road (Sta.0+000 - Sta.10+000)
Flexible Pavement Design (AASHTO 1993 Design Guide)

FLEXIBLE PAVEMENT DESIGN
(Load based on AASHTO)

Design Conditions:
- Design Period: 10 years
- Loading: NHA Standard
- Design ESAL: 28.00 x 10^6

Note:

SN Design Equation:

$$\log_{10} W_{18} = Z_R \cdot So + 9.36 \cdot \log_{10}(SN+1) - 0.20 + \{\log_{10}[\Delta PSI/(4.2-1.5)] / [0.40 + 1094/(SN+1)^{5.19}]\} + 2.32 \cdot \log_{10} M_R - 8.07$$

Design Inputs:

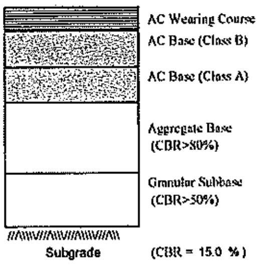
- R = 95 %
- Z_R = -1.645
- So = 0.45
- W_{18} = 28.00 x 10^6 *(18KIP ESAL)*
- MR = 12,000 *psi*
- DPSI = 1.70 *(4.2-2.5)*

(For try&error computation)
7.447 = 7.447

Output:
SN = 5.185 o.k. !!!

Note: Input approx.SN and repeat as suggested

PAVEMENT STRUCTURE



M_R = 1500*CBR(%) if a CBR value < 10% is entered.
Otherwise, M_R = value in from other sources
Input M_R or CBR

M_R psi	CBR (%)
12,000	

	Layer Coefficient per cm (Input)	per inch	Thickness Product mm (Input)	in inch	Drainage Coefficient
a_1=	0.173	0.44	50	0.87	
a_2=	0.173	0.44	80	1.39	
a_2=	0.173	0.44	90	1.56	
$a_{2'}$=	0.053	0.135	150	0.88	1.10
a_3=	0.049	0.124	93 (150)	0.50	1.10
		Total:	463	5.19	
			Total Design SN =	5.187	o.k. !!!
			Required SN =	5.185	

Drainage Coefficients (Input)

m_2	Aggregate Base	1.10
m_3	Granular Subbase	1.10

Module of Pavement Materials

Surface	Wearing Course	440,000 psi, MS =	1,000 kg
	Binder Course	440,000 psi, MS =	1,000 kg
Base	AC Base	440,000 psi, MS =	1,000 kg
	Asphalt Treated Base (ATB)		
	Aggregate Base	28,500 psi, CBR>	80%
Subbase	Granular Subbase	17,200 psi, CBR>	50%

Note:

Layer Thickness Design
FLEXIBLE PAVEMENT DESIGN
(Load based on AASHTO)

Required SN = 5.185

Layer SN Design Equation:

$$\log_{10} W_{18} = Q_R \cdot So + 9.36 \cdot \log_{10}(SN+1) - 0.20 + \{\log_{10}[\Delta PSI/(4.2-1.5)] / [0.40 + 1094/(SN+1)^{5.19}]\} + 2.32 \cdot \log_{10} M_R - 8.07$$

Required SN_1 for Surface Course

Design Inputs:
- R = 95 %
- Z_R = -1.645
- So = 0.45
- W_{18} = 28.000 x 10^6 *(18KIP ESAL)*
- MR = 440,000 *psi* *AC Base (ATB)*
- DPSI = 1.70 *(4.2-2.5)*

(For try&error computation)
7.447 = 7.448

Output:
SN_1 = 1.296 o.k. !!!

Note: Input approx.SN and repeat it as suggested

Required SN_2 for Base Course (AC Base/ATB)

Design Inputs:
- R = 95 %
- Z_R = -1.645
- So = 0.45
- W_{18} = 28.000 x 10^6 *(18KIP ESAL)*
- MR = 28,500 *psi (CBR 80%)*
- DPSI = 1.70 *(4.2-2.5)*

(For try&error computation)
7.447 = 7.447

Output:
SN_2 = 3.835 o.k. !!!

Note: Input approx.SN and repeat it as suggested

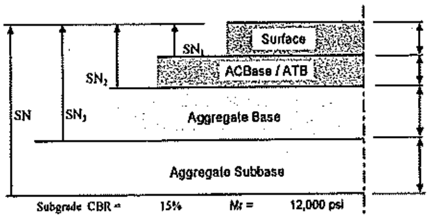
Required SN_3 for Base Course (Aggregate)

Design Inputs:
- R = 95 %
- Z_R = -1.645
- So = 0.45
- W_{18} = 28.000 x 10^6 *(18KIP ESAL)*
- MR = 17,200 *psi (CBR 50%)*
- DPSI = 1.70 *(4.2-2.5)*

(For try&error computation)
7.447 = 7.446

Output:
SN_3 = 4.595 o.k. !!!

Note: Input approx.SN and repeat it as suggested



D1 =	13 cm (Min.10cm)	SN_1^* =	2.252	OK	>=	1.296
D2 =	9 cm	SN_2^* =	1.559	OK	<	1.583
D3 =	15 cm (Min.15cm)	SN_3^* =	0.877	OK	>=	0.784
D4 =	9 cm	SN_4^* =	0.499	OK		

Total Design SN = 5.187 o.k. !!!
(Required SN = 5.185)

$D1 >= \frac{SN_1}{a_1}$ = 2.95 inches = 7.48 cm

$D2 >= \frac{SN_2 - SN_1^*}{a_2}$ = 3.60 inches = 9.14 cm

$D3 >= \frac{SN_3 - (SN_1^* + SN_2^*)}{a_{2'} \times m_2}$ = 5.28 inches = 13.41 cm

$D4 >= \frac{SN - (SN_1^* + SN_2^* + SN_3^*)}{a_3 \times m_3}$ = 3.64 inches = 9.26 cm

Layer Coefficients

a_1	Surface Course (Wearing & Binder)	0.44
a_2	AC Base	0.44
$a_{2'}$	Aggregate Base (CBR>80%)	0.135
a_3	Granular Subbase (CBR>50%)	0.124

Drainage Coefficients

m_2	Aggregate Base	1.10
m_3	Granular Subbase	1.10

Notes: 1. The required SN and the layer thickness estimation by an Excel-basis program developed by the Study Team.
2. The same design conditions were applied for Section 1 except the CESA.

Figure 11.3.4 Flexible Pavement Design for Section 1 (Kohat Toi - Kohat Link Road)

THE 2ND KOHAT TUNNEL & ACCESS ROAD PROJECT
Section 2: Kohat Link Road - Dara Adam Khel (Sta.15+000 - Sta.25+906)
Flexible Pavement Design (AASHTO 1993 Design Guide)

FLEXIBLE PAVEMENT DESIGN
(Load based on AASHTO)

Design Conditions:
- Design Period: 10 years
- Loading: NHA Standard
- Design CESA: 32.00 x 10^6

Note:

SN Design Equation:

$\log_{10} W_{18} = Z_R{*}So + 9.36{*}\log_{10}(SN+1) - 0.20 + \{\log_{10}[\Delta PSI/(4.2-1.5)] / [0.40 + 1094/(SN+1)^{5.19}]\} + 2.32{*}\log_{10}M_R - 8.07$

Design Inputs:

- R = 95 %
- Z_R = -1.645
- So = 0.45
- W_{18} = 32.00 x 10^6 *(18KIP ESAL)*
- MR = 12,000 *psi*
- DPSI = 1.70 *(4.2-2.5)*

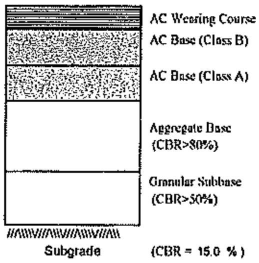
(For try&error computation) 7.505 = 7.506

Output:

SN = 5.285 o.k. !!!

Note: Input approx.SN and repeat as suggested

PAVEMENT STRUCTURE



	Layer Coefficient per cm (Input)	Layer Coefficient per inch	Thickness mm (Input)	Product in inch	Drainage Coefficient
a_1=	0.173	0.44	50	0.87	
a_2=	0.173	0.44	80	1.39	
a_3=	0.173	0.44	100	1.73	
$a_{2'}$=	0.053	0.135	150	0.88	1.10
a_3=	0.049	0.124	79 (150)	0.42	1.10
		Total:	459	5.29	
		Total Design SN =		5.285	o.k. !!!
		Required SN =		5.285	

M_R = 1500*CBR(%) if a CBR value < 10% is entered.
Otherwise, M_R = value in from other sources
Input M_R or CBR

M_R *psi*	CBR (%)
12,000	

Drainage Coefficients (Input)
- m_2 Aggregate Base 1.10
- m_3 Granular Subbase 1.10

Module of Pavement Materials

Surface	Wearing Course	440,000 psi, MS =	1,000 kg
	Binder Course	440,000 psi, MS =	1,000 kg
Base	AC Base	440,000 psi, MS =	1,000 kg
	Asphalt Treated Base (ATB)		
	Aggregate Base	28,500 psi, CBR>	80%
Subbase	Granular Subbase	17,200 psi, CBR>	50%

Note:
The same pavement thickness can be obtained for Section 1-2 for Design ESA 30 x 10^6.

Layer Thickness Design

Required SN = 5.285

FLEXIBLE PAVEMENT DESIGN
(Load based on AASHTO)

Layer SN Design Equation:

$\log_{10} W_{18} = Z_R{*}So + 9.36{*}\log_{10}(SN+1) - 0.20 + \{\log_{10}[\Delta PSI/(4.2-1.5)] / [0.40 + 1094/(SN+1)^{5.19}]\} + 2.32{*}\log_{10}M_R - 8.07$

Required SN_1 for Surface Course

Design Inputs:
- R = 95 %
- Z_R = -1.645
- So = 0.45
- W_{18} = 32.000 x 10^6 *(18KIP ESAL)*
- MR = 440,000 *psi* *AC Base (ATB)*
- DPSI = 1.70 *(4.2-2.5)*

(For try&error computation) 7.505 = 7.505

Output: SN_1 = 1.329 o.k. !!!

Note: Input approx.SN and repeat it as suggested

Required SN_2 for Base Course (AC Base/ATB)

Design Inputs:
- R = 95 %
- Z_R = -1.645
- So = 0.45
- W_{18} = 32.000 x 10^6 *(18KIP ESAL)*
- MR = 28,500 *psi (CBR 80%)*
- DPSI = 1.70 *(4.2-2.5)*

(For try&error computation) 7.505 = 7.505

Output: SN_2 = 3.918 o.k. !!!

Note: Input approx.SN and repeat it as suggested

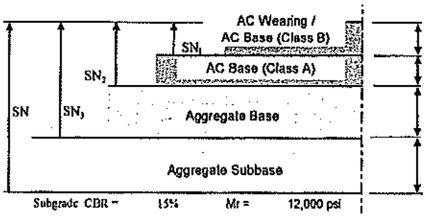
Required SN_3 for Base Course (Aggregate)

Design Inputs:
- R = 95 %
- Z_R = -1.645
- So = 0.45
- W_{18} = 32.000 x 10^6 *(18KIP ESAL)*
- MR = 17,200 *psi (CBR 50%)*
- DPSI = 1.70 *(4.2-2.5)*

(For try&error computation) 7.505 = 7.505

Output: SN_3 = 4.688 o.k. !!!

Note: Input approx.SN and repeat it as suggested



D1 =	13 cm (Min.10cm)	$SN_1{*}$ =	2.252	OK	>=	1.329
D2 =	10 cm	$SN_2{*}$ =	1.732	OK	>=	1.666
D3 =	15 cm (Min.15cm)	$SN_3{*}$ =	0.877	OK	>=	0.704
D4 =	8 cm (15cm)	$SN_4{*}$ =	0.424	OK		
		Total Design SN =	5.285 o.k. !!!			
		(Required SN =	5.285)			

$D1 >= \frac{SN_1}{a_1}$ = 3.02 inches = 7.67 cm

$D2 >= \frac{SN_2 - SN_1{*}}{a_2}$ = 3.79 inches = 9.62 cm

$D3 >= \frac{SN_3 - (SN_1{*} + SN_2{*})}{a_{2'} \times m_2}$ = 4.74 inches = 12.04 cm

$D4 >= \frac{SN - (SN_1{*} + SN_2{*} + SN_3{*})}{a_3 \times m_3}$ = 3.11 inches = 7.89 cm

Layer Coefficients
- a_1 Surface Course (Wearing & Binder) 0.44
- a_2 AC Base 0.44
- $a_{2'}$ Aggregate Base (CBR>80%) 0.135
- a_3 Granular Subbase (CBR>50%) 0.124

Drainage Coefficients
- m_2 Aggregate Base 1.10
- m_3 Granular Subbase 1.10

Notes: 1. The required SN and the layer thickness estimation by an Excel-basis program developed by the Study Team.
2. The same design conditions were applied for Section 1 except the CESA.

Figure 11.3.5 Flexible Pavement Design for Section 2 (Kohat Link Road – Dara Adam Khel)

THE 2ND KOHAT TUNNEL & ACCESS ROAD PROJECT

Section-2 (Toll Gate / Tunnel)

Rigid Pavement Design (AASHTO 1993 Design Guide)

RIGID PAVEMENTDESIGN
(Load based on AASHTO)

Design Equation:

$\log_{10}W_{18}$ = Z_R*So + 7.35*$\log_{10}$(D+1) - 0.06 + {$\log_{10}$[APSI/(4.5 - 1.5)]} / {1 + [(1.624*10^7)/$(D+1)^{8.46}$]} + (4.22 - 0.32pt)*log10{[Sc' * Cd(D0.75 - 1.132)] / [215.63*J(D0.75-(18.42/(Ec/k)0.25))]}

Design Inputs:

R = 90 %
Z_R = -1.282
So = 0.35
W_{18} = 86.20 x 10^6 *(18 KIP ESAL)*
pt = 2.50
APSI = 2.00 (4.5-2.5)
S'c = 722 *psi*
Cd = 1.10
J = 3.20 with Dowel Bars
Ec = 3.40 x 10^6 *psi*
k = 630 pci
(For try&error computation)
7.936 7.935

Ec = 57,000 $(f'c)^{0.5}$ = 3.40 x 10^6psi
where, fc (28 days) = 3,560 psi
(250 kg/cm²)

S'c = Sc + z (SDs) = 722 psi
where, Sc (28 days) = 640 psi
(45 kg/cm²)
z =standard normal variate
1.037 for PS =15 %
1.282 for PS = 10%
SDs = Sc x 10% = 64 psi

Output:

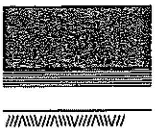
D = 11.58 inches o.k. !!! 29.41 cm,
Say 30.0 cm (= 11.8 in.)

Note: Input approx.D and repeat as suggested

Design Conditions (input):
- Design Period: 20 years
- Loading: NHA Standard
- Design CESA: 86.20 x 10^6
- Concrete Strength at 28 days:
  - Compression: 250 kg/cm²
  - Flexural: 45 kg/cm²

Note:

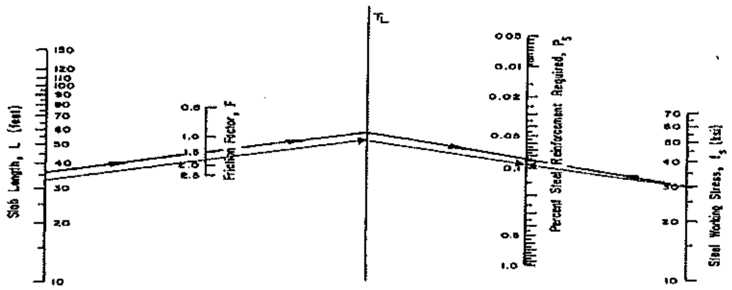
PAVEMENT STRUCTURE



PCC Thickness T= 30.0 cm
Lean Concrete T= 7 - 10 cm
Aggregate Base (CBR 80%) T= 10.0 cm
Subgrade CBR = 30.0%
(M_R = 16,500.0 psi)

(input)
Drainage Coefficient (Cd): 1.10
Load Transfer Coefficient (J): 3.20

Note 1: Design of steel-mesh spacing (transverse steel spacing)



Y = $\frac{A_s}{P_t D}$ x 100 = 4.80 inches = 122 mm, Say 120 mm

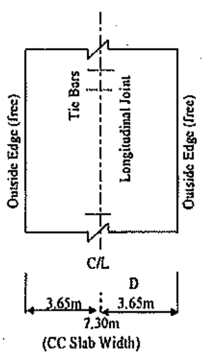
where,
Y = transverse steel spacing (inches)
A_s = cross sectional area of transverse reinforcing steel for dia. 6.0 mm
= 0.056 in.²
P_t = percent transverse steel = 0.10 %
D = slab thickness (inches) = 30.00 cm = 11.81 in.
P_s = $\frac{LF}{2f_s}$ x 100 = 0.10 %

where,
L= Slab Length = 32.8 ft = 10.00 m
F= Friction Factor = 1.8 for Cement stabilization base
f_s (allowable working stress) = 30,000 psi for Grade 40

Note 2: Design of Tie Bar spacing

Friction Factor between CC Slab and Base: 1.8 for Cement Stabilized Base
Tie Bar (Deformed Steel Bars): Grade 40, Dia.5/8 inches (16mm)
CC Slab Thickness: 30 cm = 11.8 inches
Distance to Free Edge (D): 3.65 m = 12.0 feet
Maximum Tie Bar Spacing for 5/8 inch bars: 89 cm = 35 inches
(From a Monograph on the right)

Hence, Maximum Tie Bar Spacing for 12mm = 89cm x As_{12mm}/As_{16mm}
(conversion from 16mm to 12mm) = 51 cm
Say; 50 cm



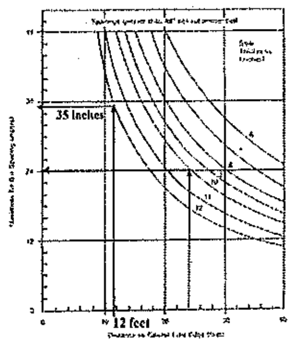


Figure 11.3.6 Rigid Pavement Design for Section 2 (Toll Gate and Tunnel)

Table 11.3.3 Summary of Flexible Pavement Structures

The 1st Kohat Tunnel Access Road

Pavement Structures From / To	Section 1 Kohat Toi / Sta.9+000	Section 2 Sta.9+000 / Sta.25+450
AC Wearing	5 cm	5 cm
AC Base	18 cm	21 cm
Aggregate Base	20 cm	22 cm
Granular Subbase	-	-
Subgrade (Borrow Material)	30%	15%
Note: Design SN	4.370 (inch)	4.889 (inch)

The 2nd Kohat Tunnel Access Road

Pavement Structures From / To	Section 1-1 Kohat Toi / Sta.15+000	Section 1-2 Sta.10+000 / Sta.15+000	Section 2 Sta.15+000 / Dara Adam Khel
AC Wearing	5 cm	5 cm	5 cm
AC Base (Class B)	8 cm	8 cm	8 cm
AC Base (Class A)	9 cm	10 cm	10 cm
Aggregate Base	15 cm	15 cm	15 cm
Granular Subbase	15 cm	15 cm	15 cm
Subgrade (Borrow Material)	15%	15%	15%
Note: Design SN	5.153 (inch)	5.235 (inch)	5.291 (inch)

As the design period of flexible pavement is 10 years, AC overlay will be required after 10 years to secure performance of the pavement further for the next 10 years. The estimated minimum overlay thickness is 5-10 cm after repair of spot failures and rutting as analyzed in Figure 11.3.7.

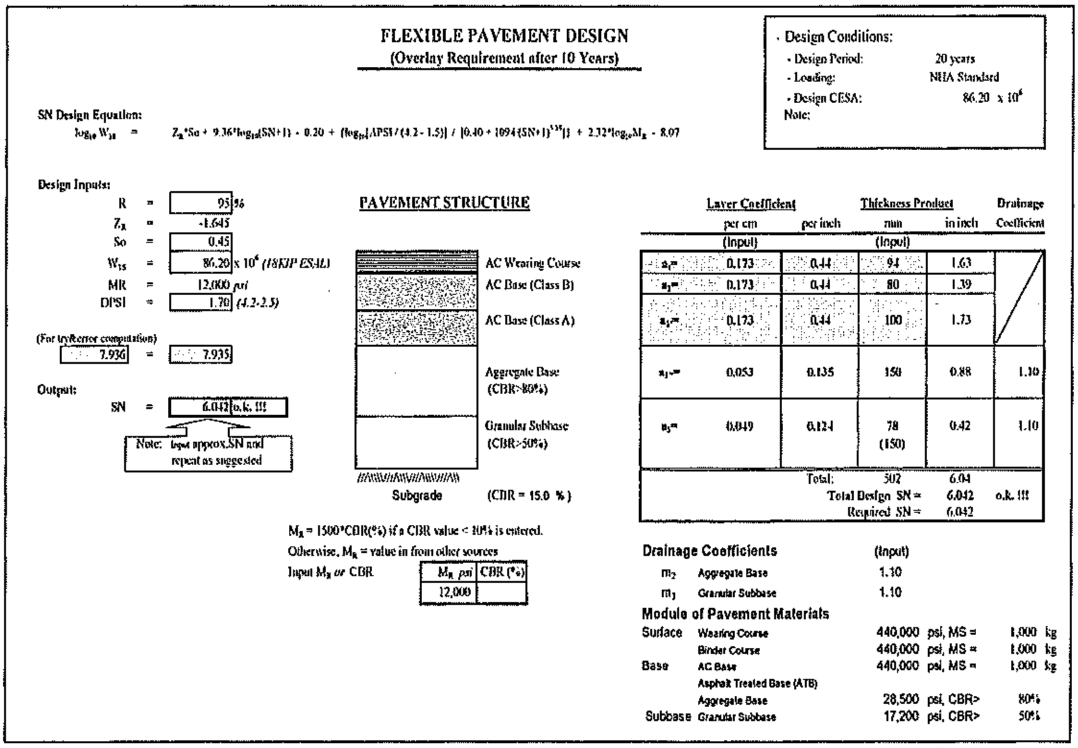


Figure 11.3.7 AC Overlay Thickness Estimate after 10 Years

The design concrete pavement slab thickness is 30 cm which is same as the 1st Kohat Tunnel pavement. Concrete slabs are reinforced with ϕ 6 mm steel mesh (120 mm x 120 mm). Transverse contraction joints are dowel bar joints (ϕ 32 mm x 600 mm) provided at 10 m intervals. Tie bars (ϕ 12 mm x 600 mm) are provided at every 50 cm as illustrated in Figure 11.3.5.

11.4 Bridge and Culvert Design

11.4.1 Bridge Design

(1) List of Bridges

Ten new bridges are planned to be constructed for the dual carriageway system of the 2nd Kohat Tunnel and Access Roads as listed in Table 11.4.1.

Table 11.4.1 List of Bridges

No.	Station (at center)	Type	Length (m)	Span	Pile Length (m)	Remarks (Crossing)
1 R	2+736.245	PC Girder	120	4 - 30m Span	16	Over Jerma Minor River
2 R	4+735.415	PC Girder	50	2 - 25m Span	14	Over Chargai Algada
3A R	9+454.363	PC Girder	20	1 - 20m Span	20	Over railways
3B R	9+645.760	PC Girder	30	1-30m Span	21.5	Over N-80 (Rawalpindi Road)
9 R	14+800.000	RC Girder	12	1-12m Span	20	Over Bazi Khel Road
10 R	16+585.000	RC Girder	12	1-12m Span	20	Over a track
Kohat Tunnel*						
5 R	18+935.415	PC Girder	80	25m+30m+25m	20	Over Osti Khel Algad
8 R	19+088.355	PC Girder	20	1 - 20m Span	Spread Fd.	Over NWF Road
6A R	21+260.525	PC Girder	180	6-30m Span	12	Over Osti Khel Algad & Panderi Algada
7 R	25+388.915	PC Girder	40	2-20m Span	20	Over Mullah Khel Algad
Total:			564	m		

Notes: * Break at Sta. 20+186.738 /Sta.16+247.000 (-3,939.738)

The Bridges 1R, 2R, 5R, 6AR and 7R cross over rivers, Bridge 3AR over a railway, Bridge 3BR over the National Highway N-80 IC and Bridge No.8R over the NWF road. The river crossing bridges satisfy discharge, HFL clearance and scouring depth as analyzed in Sub-section 6.3 of this report.

(2) Cross Section

The typical cross section of bridge is illustrated in Figure 11.4.1. Their total width is 10.500m. The width of the carriageway and shoulder is the same as the 1st Kohat Tunnel and Access Roads. The outer distance between the bridges on the 1st and 2nd Kohat Tunnel and Access Roads is 2.80 m in the south section and 0.30 m in the north section.

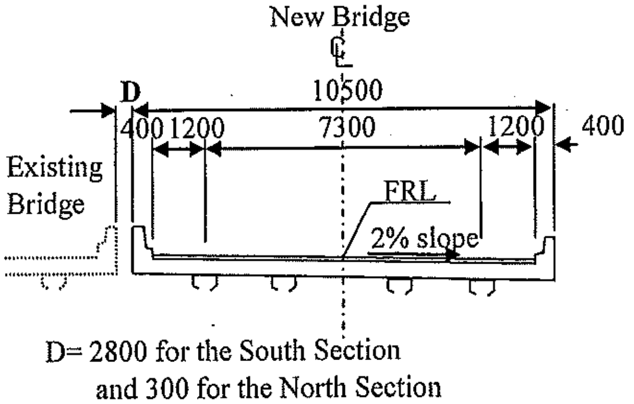


Figure 11.4.1 Typical Section of Bridge Structures

(3) Bridge Structures

The bridge superstructure consists of RC deck on standard PCC girders, except for Bridges 9R and 10R for which RCC girders are used. The abutments are of the reverse T-type on pile foundations (dia.900 mm or 750 mm), except for Bridge No.5R for which spread foundation is used. Piers are the circular column type with larger dimensions than these used in the 1st Kohat and Access Roads to provide sufficient resistance to the new seismic force. The diameter of foundation piles for some bridges was increased form 750 mm to 900 mm to meet the new seismic load.

(4) Wing Walls and Protection Works

Wing walls are provided for embankment protection. Grouted ripraps are provided for protection of abutments.

A part of the wing walls and the grouted ripraps should be demolished for construction of the new bridges for the 2nd Kohat Tunnel and Access Roads Project. These shall be reconstructed later.

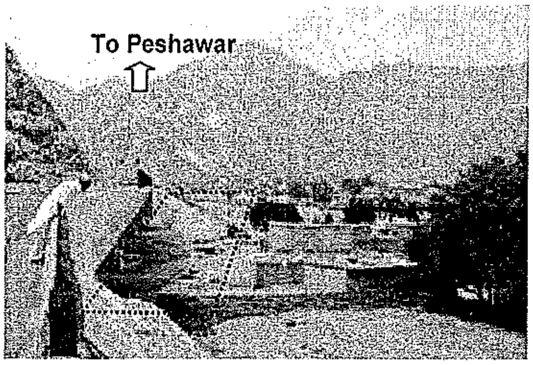
(5) Scouring Protection Works

Scouring protection works are provided for the river crossing bridges (Bridges No.1R, No.2R, No.9R, No.5R, No.6A R and No.7R). The protection works are either one of the following types or a combination of there of:

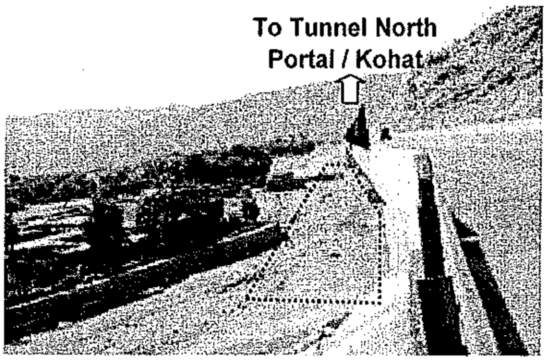
- Gabions
- Rock Fill (dia.300-600 mm)
- Grouted Riprap.

(6) ROW for New Bridges

The ROW necessary for construction of the new bridges was already secured together with the Roadway ROW acquisition during the 1st Kohat Tunnel and Access Road construction. However, there is still a private land at the site where Bridge No.6AR is constructed (see following photos).



A Piece of Private Land located at No.6AR Bridge Construction Site (River Bed) at Sta.21+260



A Piece of Private Land located at No.6AR Bridge Construction Site (River Bed) at Sta.21+260

11.4.2 Box Culvert Design

Eighty six box culverts are planned for the 2nd Kohat Tunnel and Access Roads as listed in Table 11.4.2. Standard box-culverts of NHA are used. The total length of box culverts is 1,388m. Most of them are for roadways cross drainage and some are underpasses of the 2nd Kohat Tunnel and Access Roads. The box-culverts (2 cells x 6.15 m x 5.5 m) at Sta.15+575 are for the Kohat Link Road underpass.

Table 11.4.2 List of Box Culverts

No.	Culvert No.	Station	Dimension (Cell No.xWxH)	Length m
South Section				
1	2	00 + 532.74	1-1.0x1.0	15.0
2	4	00 + 819.44	1-1.0x1.0	11.4
3	9	01 + 445.19	1-1.0x1.0	11.8
4	13	01 + 819.97	2-1.5x1.5	10.5
5	14	02 + 039.89	1-1.0x1.0	13.1
6	15	02 + 125.58	1-1.0x1.0	12.2
7	27	03 + 627.00	1-2.0x1.5	9.9
8	29	03 + 895.15	1-1.0x1.0	10.7
9	31	04 + 207.85	1-1.0x1.0	11.3
10	33	04 + 459.09	1-1.0x1.0	19.3
11	34	04 + 511.00	1-4.5x4.8	13.4
12	35	04 + 523.08	2-2.5x2.5	25.8
13	36	05 + 041.25	1-1.0x1.0	10.5
14	37A	05 + 296.00	1-1.5x1.0	17.6
15	38	08 + 286.00	1-2.0x2.0	9.8
16	39	08 + 615.00	1-1.0x1.0	12.8
17	40	08 + 866.00	1-1.0x1.0	14.8
18	41	09 + 062.00	1-1.0x1.0	19.2
19	41A	09 + 822.00	1-1.0x1.0	31.9
20	41B	10 + 017.50	1-1.0x1.0	29.0
21	47	10 + 954.00	1-1.5x1.5	38.9
22	48	10 + 962.00	1-4.5x4.8	16.2
23	50	11 + 021.00	1-2.5x2.5	17.6
24	51	11 + 109.00	1-1.0x1.0	24.3
25	52	11 + 260.00	1-4.5x4.8	9.4
26	53	11 + 312.45	2-1.5x1.5	40.0
27	53A	11 + 338.00	1-1.0x1.0	41.1
28	54	11 + 674.00	2-1.5x1.5	11.9
29	55	12 + 040.00	1-1.0x1.0	11.5
30	56	12 + 171.00	1-1.5x1.5	13.5
31	57	12 + 340.00	1-1.0x1.0	13.1
32	58	13 + 366.00	1-3.5x4.0	11.9
33	60	13 + 872.60	1-2.0x2.0	9.5
34	61	14 + 361.00	1-2.0x2.0	15.9
35	62	14 +. 734.00	1-2.0x2.0	21.4
36	63	14 + 900.00	1-1.0x1.0	23.5
37	64	15 + 050.00	1-1.0x1.0	16.7
38	65	15 + 244.00	1-2.0x2.0	12.1
39	66	15 + 480.00	2-3.0x3.0	36.7
40	66A	15 + 789.00	1-1.5x1.5	34.6
41	66B	15 + 575.00	2-6.15x5.5	34.9
42	67	18 + 562.60	1-2.0x2.0	70.6
43	68	18 + 636.30	1-2.0x2.0	81.2
44	69	19 + 642.00	1-2.0x2.0	32.4
45	69A	19 + 838.00	1-2.0x2.0	11.6
46	69B	19 + 975.00	3-2.5x2.5	17.5
47	72	20 + 002.46	1-4.0x4.0	11.1
Sub-Total for South Section				**989.1**
North Section				
1	73	18 + 380	3-3.0x3.0	21.2
2	75A	18 + 829	1-1.5x1.5	20.1
3	75b	19 + 290	1-5.0x5.0	16.1
4	77	19 + 491	1-2.5x2.5	15.2
5	80	20 + 123	1-2.0x2.0	16.1
6	80A	20 + 355	3-3.5x3.5	13.7
7	80b	20 + 400	1-2.5x2.5	22.3
8	81	20 + 567	1-4.5x4.8	17.2
9	81A	20 + 753	2-3.0x3.0	14.8
10	82	20 + 818	4-3.0x3.0	18.3
11	88A	22 + 645	1-3.5x3.5	11.1
12	89	22 + 833	1-3.0x3.0	14.4
13	90	23 + 023	1-3.5x3.5	13.4
14	92	23 + 415	1-2.5x2.5	11.1
15	93	23 + 520	1-2.5x2.5	14.4
16	94	23 + 675	1-1.0x1.0	27.5
17	95	23 + 897	1-2.75x2.75	10.3
18	95b	24 + 296	1-2.0x2.0	12.5
19	96	24 + 531	1-3.0x3.0	15.2
20	96a	24 + 703	1-2.5x2.5	10.8
21	96c	24 + 862.800	1-1.5x2.0	16.3
22	97	24 + 900	1-3.0x3.0	15.6
23	97a	24 + 995	1-2.0x2.0	13.2
24	97b	25 + 070	1-2.0x2.5	10.5
25	98	25 + 121	1-2.5x2.5	11.9
26	98A	25 + 317	1-1.5x2.0	9.6
29	SBC-3	00 + 277	1-1.0x1.0	6.1
Sub-Total for North Section				**398.9**
Total				**1,388.1**

Notes: * Break at Sta. 20+186.738 /Sta.16+247.000 (-3,939.738)

11.5 Tunnel

11.5.1 Design Conditions

(1) Design Conditions

The new tunnel is a two-lane road tunnel and will be constructed paralleled to the existing Kohat Tunnel at 30 m away. The design conditions of 2nd Kohat Tunnel are listed in Table 11.5.1. Tunnel length is 1,885 m, and the longitudinal slope is 2.4%. The support method is NATM (New Austrian Tunnelling Method). The tunnel is excavated from both portals. The excavation method is top-heading and bench cut method. Excavated materials are hauled by trucks.

Table 11.5.1 Tunnel Design Conditions

Items		2nd Kohat Tunnel
1. Tunnel Length		1,885m
2. Portal Locations		Sta.16+247 ~ Sta.18+132
3. Tunnel Slope (grade)		i =2.4% (upgrade from south to north)
4. Support and Excavation Method	CI, CII	- NATM
	DI	- Top heading and bench cut method
5. Geological Condition		CI, C-II and DI (almost same as the 1st Kohat Tunnel)
6. Excavation Method		Blasting
7. Mucking Method		Loading by a loader and hauling by trucks
8. Direction of Excavation		From both south and north portals
9. Design Standards		Technical Standards for Road Tunnel in Japan

(2) Geological Conditions

Geological condition is based on Section 6.4, Geological Survey, of this report. 59.7% of rock is classified as CI, 13.5% as CII and 26.8% as DI (Table 11.5.2). Geological profile is shown in Figure 11.5.1.

Table 11.5.2 Classified Rocks in Tunnel

Soil Classification	Section Length (m)	Proportion (%)
CI	1124.5	59.7
CII	255.5	13.5
DI	505.0	26.8
Total	1885.0	100

Note: DI includes the tunnel entrance sections.

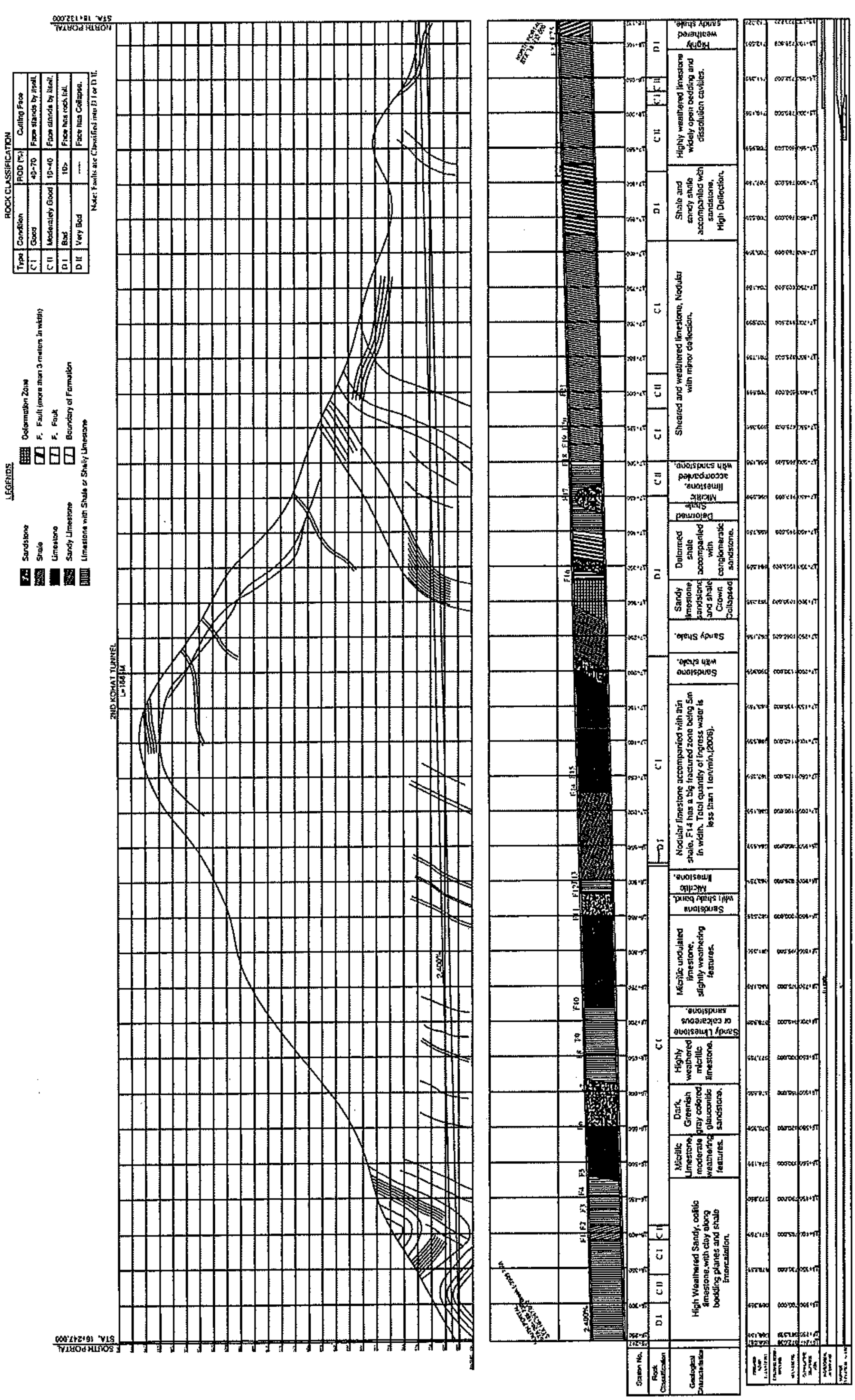


Figure 11.5.1 Geological Profile

a) Study and Analysis of Geological Report of the 1st Kohat Tunnel Construction

The following geological report was prepared for the construction of the 1st Kohat Tunnel and Access Road:

"Kohat Tunnel and Access Road Project, Technical Report of Geological Supervision - Pacific Consultant International J/V Mouchel Consulting Limited in association with Engineering Associates and National Engineering Services Pakistan (PVT) LTD. (September, 2003)"

The main contents of this report are as follows:

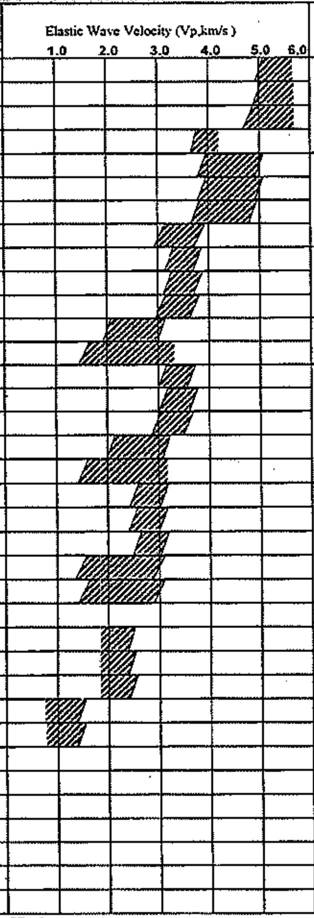
1) Tunnel peripheral mapping
2) Geological profile of the tunnel
3) Rock classification for support pattern
4) Measurement of groundwater
5) Laboratory test for rock
6) Analysis of supporting pattern
7) Analysis of rock bolt
8) Analysis of inner space deflection
9) Daily tunnel observation record
10) Suggestion for second tunnel

Table 11.5.3 Result of Rock Test for the 1st Kohat Tunnel

location (Sta.No)		17+178	17+208	17+317		17+357	17+378	17+590	17+870
Rock Type		Lime stone	Sandstone	Lime stone	Shale	Shale	Shaley Limestone	Lime stone	Shaley sand stone
Supporting Pattern		CI	CI	DI	DI	MDI	MDI	CII	DI
Specific Gravity		2.71	2.75	2.77	-	-	2.77	2.73	2.77
Water Absorption (%)		0.30	2.10	0.10	-	-	2.20	0.61	0.53
Compressive Strength (Mpa)		82	-	86	-	-	42	-	-
Statistic Modulus of Elasticity (Mpa)		8.86 E+04	-	2.90 E+04	-	-	-	-	-
Static Poision's Ratio		0.767	-	0.555	-	-	-	-	-
Cohesion	(Mpa)	12.5	-	25.0	-	-	25.0	-	-
	(tf/m²)	12.8	-	25.5	-	-	25.5	-	-
Angle of Internal Friction(°)		38	-	35	-	-	31	-	-
Slaking Index		-	-	0	1	2	0	-	3

Technical Report of Geological Supervision,
Pacific Consultant International, Tokoyo Japan ,2003
Note : Cohesion Values were corrected by re-calculation

Table 11.4.5.1 Rock Classification for Tunnel



GRADE		TYPE OF ROCK	2- Strength - Earth Pressure Rate	(3) Boring Core: State of Core	(3) Boring Core: RQD(%)	(4) Geological Features (result of geological test or the state of the face)	Observation: When Hammered	Observation: Pitch of Opening	(6) State after excavation: Face Stability	(6) State after excavation: Convergence (mm)
A		a, b, c, d1	-	Generally has more than 90% core recovery and shows a perfect columnar shape. Rarely contains fragments.	90 or More	- Very hard and fresh rock forming large mass which is continuous and stable with few cracks. - No deterioration caused by water.	Hammer springs back. Strong hammering barely breaks to expose fresh planes.	100 to 50 Minimum	- In very good self-standing state and no loosening for a long time. - Loosening height is 1.6m.	Slight
B		a, b, c, d1	-	Generally has more than 70% core recovery and shows a shape of rather large fragmental rock, a short columnar shape, or a rod-like shape. Most cores are 10 to 20 cm in length but there are some with lengths of about 5cm.	90 ~ 70	- Fresh and hard relatively few cracks. - Despite considerable hardness, rock appears to have been depenerated by weathering. - Rock is hard but in strata; stratification or schistosity is found and rock easily breakable along the plane. No deterioration caused by water.	Broken when Hammered strongly but break mostly run along cracks, or joints& broken pieces are relatively large.	70 ~ 10	- Face stands by itself. Unsupported excavated face shows local fall of rocks but remains generally stable. - If there are locally loosened portions, the ground seeds partial supporting. - Loosing height is 1.5-3.0 m	Slight
C	I	a, b, c	-	Core recovery rates range from 40 to 70%. A large number of cracks are found. Decreases in size as it is crushed easily. Pieces which are 5 cm or less are recovered in abundance. Difficult to restore to original shape.	70 ~ 40	- Altered by weathering and rock is somewhat softened. - Though rock is relatively hard, fine cracks are formed and clay is sandwiched thinly between them. - Rock shows clear stratification. Very thin and easily broken. - Narrow and small faults are sandwiched.	Easily broken by a hammer into cracked planes. Breaking is rather difficult on planes other than cracks.	About 50 minimum	- Face stands by itself, the ground requires shotcrete on the crown immediately after blasting. - Loosening height is 2.04.0 m. - Face stands by itself. Unsupported excavated face has fall of rocks near the crown and the ground requires un supporting. - Loosening height is 2.0–4.0m.	50 or Less
		d1, d2	4 or More							
	II	a, b, c, d1, d2	4 or More	Core recovery rates range from 40% or less Core become small piece or sometimes mixed with brecidated pebbles, or clay.	40~10		Rapidly crushed by a hammer. Rock is brittle and easily broken by hand.		- Both face and unsupported excavated face has either large-scale fall of rocks or slight squeezing. The ground needs immediate presupporting and early support. - Plasticity range or loosening height is 3.0-6.0 m.	
D	I	a, b, c, d1, d2	4~2		No more than about 10	- Subjected to severe weathering, rock is partially transformed to soil. Soft and brittle with slightly hard portions remaining inside. - Joints are so numerous that scraping in places other than cracks is possible. - Crush zone which still has time to be changed completely to clay; cohesive soil is mixed with rock fragments, containing some hard portions. - Soil, talus cone, etc. - If face is softened by water, the ground is classified under DII				60 or Less
		c	2 or more	-						
	II	a, b, c, d1, d2	2~1				Crushed when hit slightly with a hammer. The end of the hammer runs into the ground.		- Face has large -scale fall of rocks. Unsupported excavated face has squeezing pressure. - Plasticity range or loosening heights is 3.0-6 m	200 or Less
E		a, b, c, d1, d2, c	1 or Less	-	-	- Faults conspicuously changed to clay, under high unsymmetrical earth pressure or circumferential earth pressure, and considerably large in width. - Easily deteriorated by water to be softened.			- Squeezing is caused on face. Faces May be thrusted out by earth pressure. - Unsupported excavated face has circumferential squeezing pressure. - Plasticity range >7.0 m	400 or Less

(Notes) 1. Type of Rocks
a : Metamorphic rock (phyllite, graphite schist, siliceous graphite schist, quartz schist, green schist, gneiss, serpentinite, hornfels, etc.), plutonic rock (gabbro, peridotite, etc.)
b: Palaeozoic strata and Mesozoic strata (state, sandstone and conglomerate, hard sandstone, limestone, quartzite, diabasic tuff, etc.)
c: Volcanic rock (quartz trachyte, andesite, basalt, etc.), Dike rock (granite porphyry, quartz porphyry, porphyrite, diabase, etc.), Plutonic rock (granite, diorite)
d: Tertiary Strata and lower diluvium strata (mud stone, shale, siliceous shale, sandstone and conglomerate, tuff, tuff breccia, agglomerate, etc.) However, by using the uniaxial compressive strength (qu) 200 kgf/cm2 of fresh rock samples as a reference, this rock type is subdivided into dl and d2.
d1: qu more than and equal to 200kgf/cm2
d2: qu less than 200kgf/cm2
c: Upper diluvium strata (loam and clay, volcanic pyroclastic matter), alluvial strata (talus, surface soil, etc.)

National Expressway Practice in Japan (Tunnel), Expressway Technology Center (ETC), Japan, in 1995

Table 11.5.4 Rock Classification for Tunnel

The results of rock test are shown in Table 11.5.3 and the standard of rock classification is shown in Table 11.5.4. The geological condition of tunnel described in this report is as follows:

1) Rock types found in the tunnel are as follows:

   Limestone = 70%, Sandstone = 15%, Shale = 15%

2) Ratio of rock classification in the tunnel is as follows:

   C I = 59.7%, C II = 13.5%, D I = 26.8%

3) Relation between rock type and rock classification is mainly as follows:

   Limestone and sandstone : C I and C II, Shale and fractured zone : D I

4) In the tunnel, there are 25 faults. Their main strikes are E-W and dips are between 70° and 90° .Among these faults, there are 3 main big faults and the width of fractured zones is between 1.5 m and 5.0 m.

5) Main ingress water was found between Sta. 17+000 and Sta. 17+150. A maximum water ingress rate of about 5,000 litres/min was recorded at this site.

6) According to the result of rock test, the compressive strength of limestone ranges between 42 MPa (428.3 kgf/cm2) and 86 MPa (876.9 kgf/cm2).

b) Evaluation of Geological Condition

i) Slope Condition at the Portal

North Portal

As shown in Figure 6.4.2 Geological Cross Section, the 2nd Kohat Tunnel and Access Road is aligned on a gentle monoclinal slope covered with thin talus deposit with a 3.5 m thickness.

The basement rock consists of weathered shale. The gradient of slope is between 20° and 25° westward, and the dip of shale is also 20° westward. Therefore there is a possibility of slope collapse due to tunnel excavation. Therefore, appropriate measures should be taken to dig the north portal composed of talus deposit and weathered shale.

South Portal

As shown in Figure 6.4.3 Geological Cross Section, the 2nd Kohat Tunnel and Access Road is aligned at the end of a small ridge between the east valley and the west valley. The bottom of both valleys is buried by debris flow deposits. The basement rock consists of weathered fine limestone. On the slope, there is no talus deposit and limestone on the portal is hard enough. For that reason therefore, the excavation at this site would cause no problem. But it is possible that debris flow from the east valley directly hits the projected road in the section downstream of the portal. Under this Project, the control office is planned to be relocated from the east valley side to the west valley side. If large scale debris flow happens in the west valley, the new control office may be damaged. Therefore some protection facilities like sabo dam are required to be provided on the east and west valleys.

ii) Geological Condition of the 2nd Kohat Tunnel

The geological profile of the 2nd Kohat Tunnel is shown in Figure 11.5.1. According to the underground geological map of the 1st Kohat Tunnel, there are 25 faults in the tunnel. These faults and formations extend mainly in the E-W direction, and dip southward or vertically. Therefore the geological profile of the 2nd Kohat Tunnel is prepared by extending the strikes and dips from the 1st Kohat Tunnel to 30 m eastward.

According to the rock classification of the 1st Kohat Tunnel, limestone and sandstone are classified into C I and C II, and shale, fractured zone and deformation zone are classified into D II. The ratio of C I and C II to the total length is 73.2%. Therefore, for that reason, it is considered that there are few geo-technical problems for excavation of the tunnel, except for faults and groundwater. The locations and widths of main fractured zones by faults are as follows.

- . F4: Sta.No.16+460, w = 1.0m
- . F8: Sta.No.16+650, w = 2.0m
- . F12: Sta.No.16+880, w = 2.0m
- . F14: Sta.No.17+060, w = 5.0m
- . F15: Sta.No.17+090, w = 1.5m
- . F20: Sta.No.17+560, w = 1.0m
- . F21: Sta.No.17+570, w = 1.0m
- . F22: Sta.No.17+933, w = 2.0m
- . F23: Sta.No.17+940, w = 1.0m

At the section with the above faults, rock fall and collapse happened during construction works. Between Sta. 17+250 and Sta. 17+340, a deformation zone accompanied by complex folded sandstone, shale, conglomerate and limestone was found. Rock fall and collapse also occurred in this zone.

The sections with ingress water in the tunnel are the following:

- Sta. 16+940 ~ Sta. 17+100 Limestone
- Sta. 17+190 ~ Sta. 17+240 Sandstone and Shale
- Sta. 17+290 ~ Sta. 17+400 Sandstone and Shale
- Sta. 17+660 ~ Sta. 17+665 Limestone
- Sta. 17+720 ~ Sta. 17+740 Limestone
- Sta. 17+820 ~ Sta. 17+830 Shale
- Sta. 17+890 ~ Sta. 17+900 Sandstone and Shale

Among these sections, the section between Sta. 17+000 and Sta. 17+100 including F14 and F15 are the most remarkable ingress water zones. The variation of the total volume of water is as follows.

2003 : 5,000 litres/min.

2005 : 2,000 litres/min.

2006 : 500 ~ 1,000 litres/min.

The volume of ingress water varies with annual rainfall. It increases during the monsoon season between July and August, and decreases during the dry season. At present, ingress water from the tunnel runs through a channel and is led into a measure beside the control office at the south portal.

In conclusion, it can be said that the 2nd Kohat Tunnel has no geo-technical problem for excavation. But proper measures are to be taken to cope with the fractured zones, deformation zones, and ingress water in the tunnel.

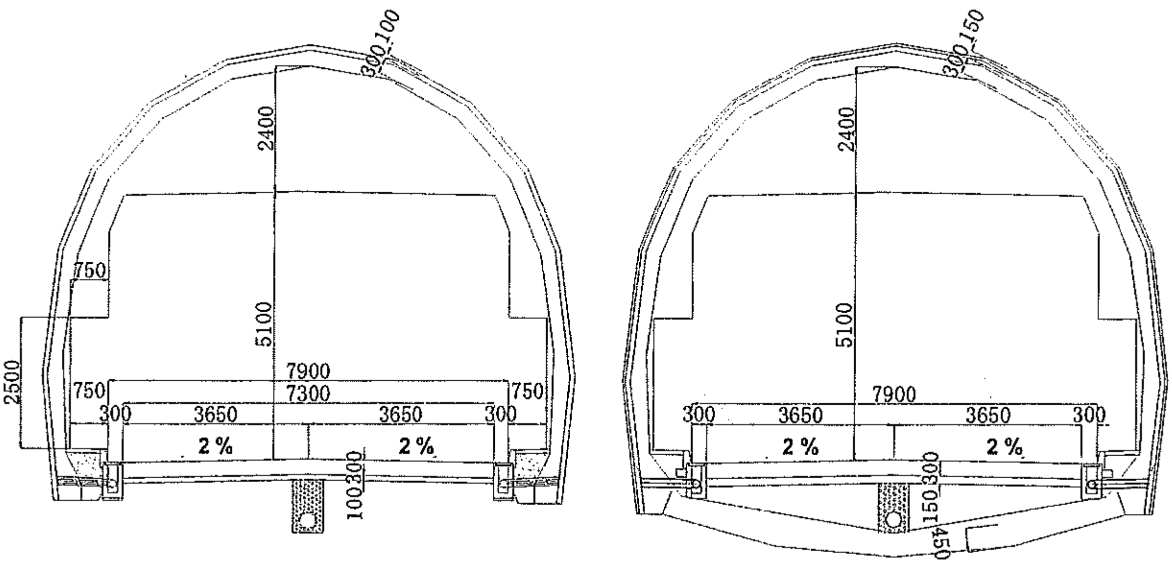
11.5.2 Cross Sections of Tunnel

The tunnel cross sections were designed referring to the design of 1st Kohat Tunnel. The standard road width is 7.9 m; two 3.65 m-wide lanes and 0.3 m-shoulder on each side. Vertical clearance limit is 5.1 m high.

Thickness of shotcrete, support work pattern and lining thickness are determined by rock classification. Five patterns are provided by rock classification; two types for portal section and emergency parking bay and three patterns for CI, CII and DI.

Figure 11.5.2 shows typical cross sections for CI, C-II and DI. The same cross section is applied for CI and CII. Invert is constructed for DI considering the ground condition. Invert is also constructed at portals since it is difficult to form grand arch.

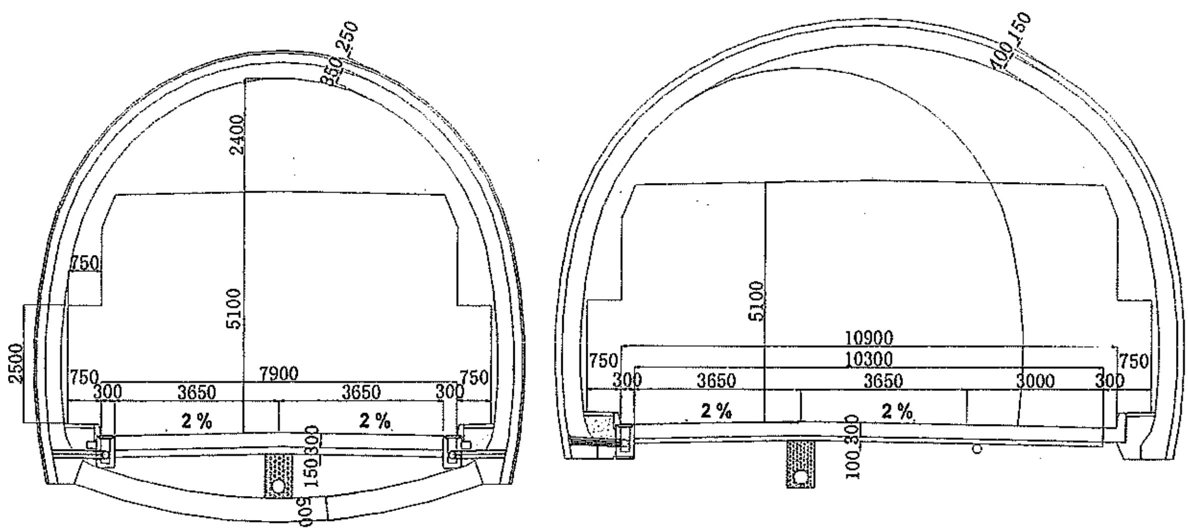
Figure 11.5.3 shows typical cross sections for portals and emergency parking bays. Invert is necessary for the portals but it is not necessary for the emergency parking bays as they are located at CI and CII rock sections.



Type: CI and CII

Type: DI

Figure 11.5.2 Typical Cross Sections for CI, CII and DI



Type: Tunnel Portals

Type: Emergency Parking Area

Figure 11.5.3 Typical Cross Sections of Portal and Emergency Parking Bay

11.5.3 Support System Design

The support system of the tunnel was designed by rock classification.

(1) Type CI

Sixteen (16) rock bolts of 3 m in length are fixed at 1.5m.

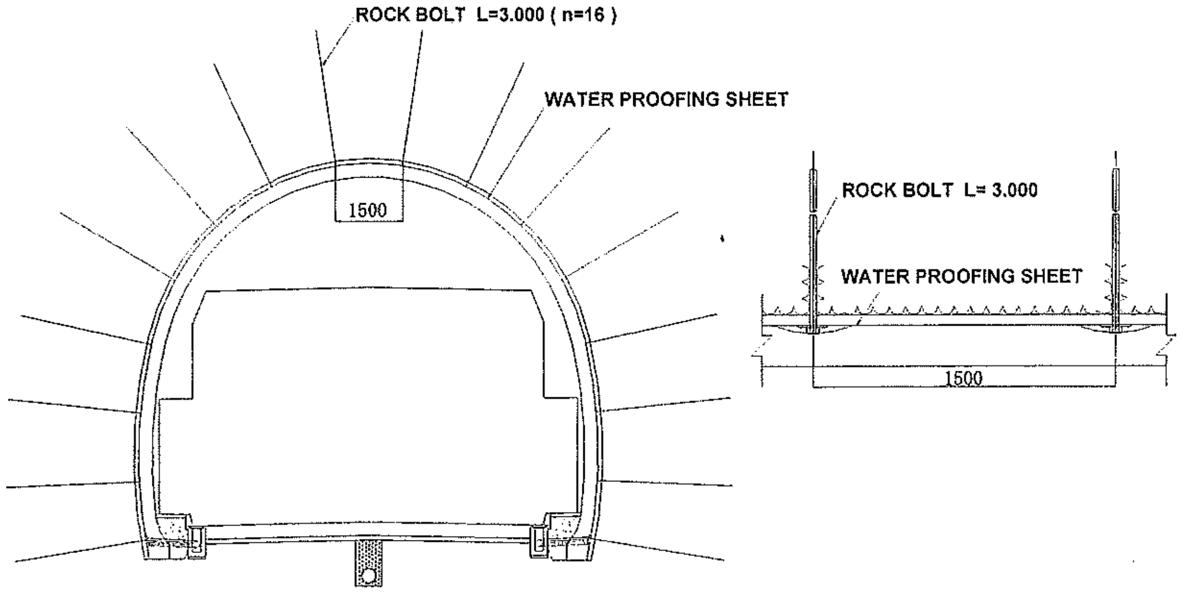


Figure 11.5.4 Support System for Type CI Sections

(2) Type CII

Sixteen (16) rock bolts of 3 m are fixed at 1.5m. H-beams (125x125x6.5x9) are installed around the upper arch section.

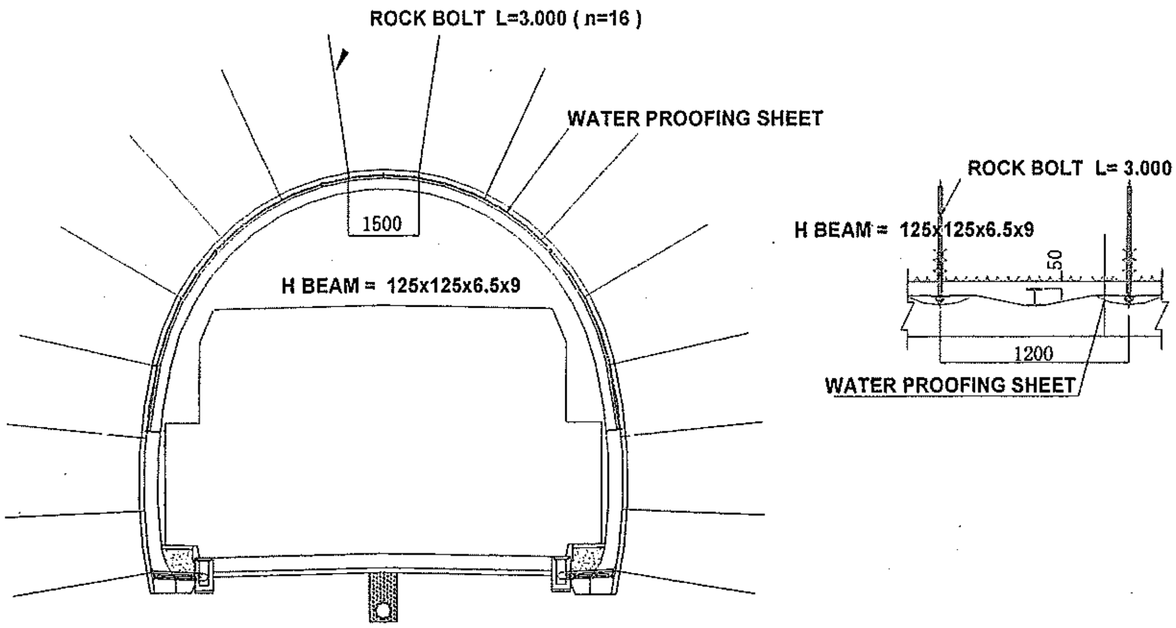


Figure 11.5.5 Support System for Type CII Sections

(3) Type DI

DI geology for the Kohat tunnel section is comprised of weathered limestone, sandstone and sandy shell. Figure 11.5.5 shows basic support pattern for DI. Twenty (20) number of 4 m rock bolts are fixed against the tunnel arch.

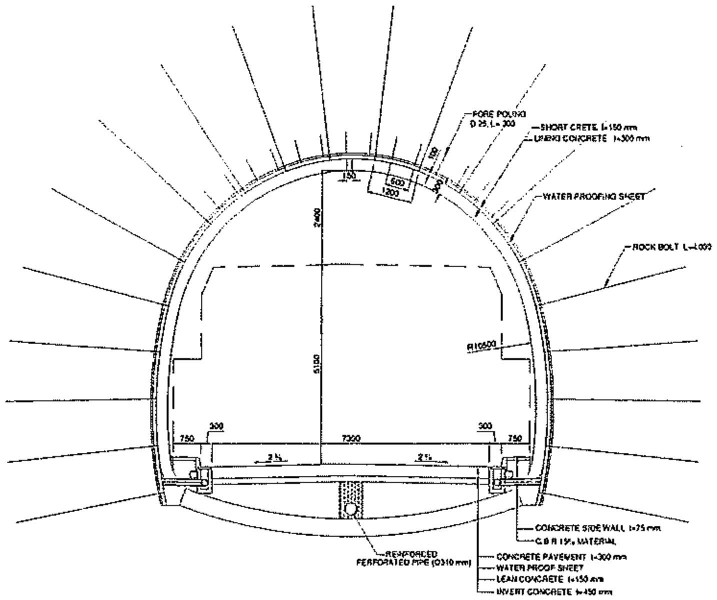


Figure 11.5.6 Support System for DI Sections with Fore-Poling

Fore-poling (pre-support) was used together with rock bolts for DI sections for stabilizing highly weathered rock during the 1st Kohat Tunnel construction as it was the 1st road tunnel in Pakistan. The fore-poling section was approximately 30% of the total tunnel length. As well as in the 1st tunnel, the fore-poling method is applied for the 2nd tunnel design on safety aspects as the tunnel construction experience is still premature in Pakistan.

(4) Portal

Fourteen (14) fore-poles are fixed before excavation and then 10 rock bolts and H-beams are installed along the arch at one meter interval after 1st or 2nd shotcrete (Figure 11.5.7).

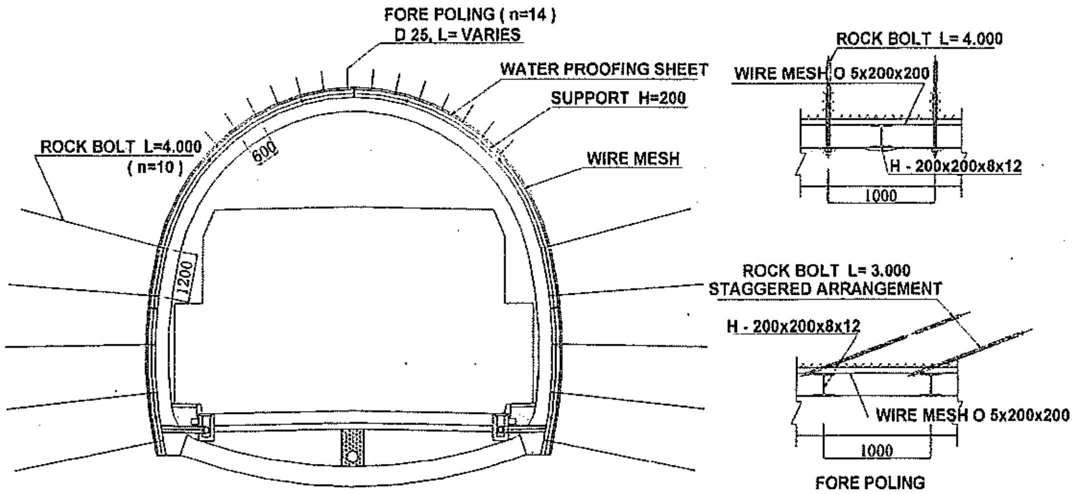


Figure 11.5.7 Support System for Tunnel Portals

(5) Emergency Parking Bay

At emergency parking bay, 22 rock bolts of 4m in length and H-beams are installed at every 1.2 m (Figure 11.5.8).

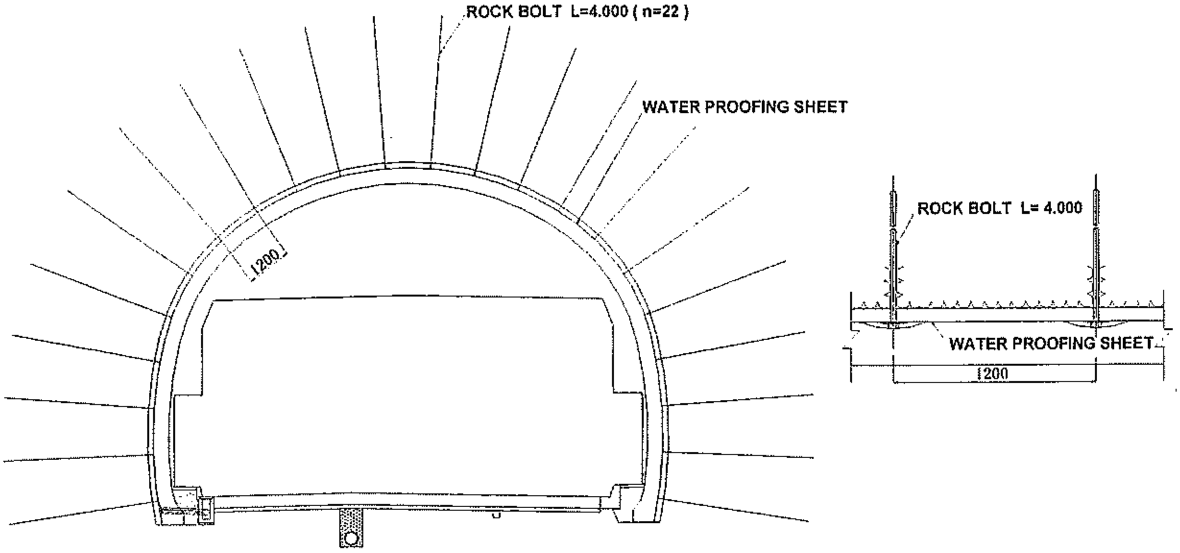


Figure 11.5.8 Cross Section of Emergency Parking Bay

11.5.4 Cross Passage (Evacuation Tunnel)

A part of the two cross passages (evacuation tunnels) was already constructed during the 1st tunnel construction. These cross passages are required to connect to the 2nd Kohat Tunnel. As there is some elevation difference between the 1st and 2nd tunnels, these two tunnels need to be connected by stairs as shown in Figure 11.5.9.

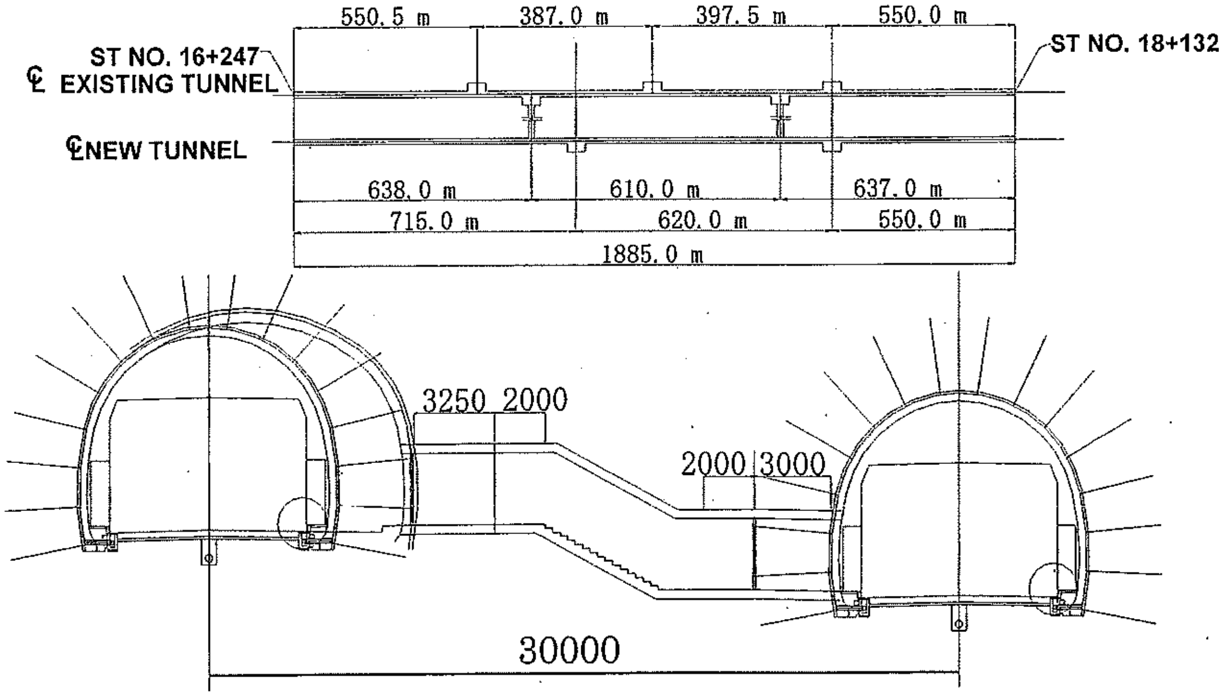


Figure 11.5.9 Cross Passage (Evacuation Tunnel) between the 1st and 2nd Kohat Tunnels

11.5.5 Portal Design

The tunnel portal consists of a portal and tunnel adjacent section (portal section). The starting point of portal section is determined considering necessary covering (3-4 m) for tunnel construction by NATM. The wing type portal is deigned for both south and north portals.

The portals are designed as follows:

- Portal section is extended up to the covering depth becomes at least 3.0 m.
- Fore-poling is used for the tunnel crown to prevent rock fall.
- Ring cut excavation method is adopted to stabilize the tunnel face.
- Cut slope is protected by shotcrete.
- Temporary supports are installed until completion of the portal construction.

The current tunnel control room located at the right hand side of south portal is required to move to either the opposite site or the north portal prior to the tunnel excavation from the south.

11.5.6 Drainage Design

(1) Relief of Seepage

Seepage water is required to drain out from the tunnel as soon as possible. Retention of water causes problems including excess loading on the lining, cracking in the lining, reducing the life of lighting/safety facilities and adverse affects on pavement. In order to protect the tunnel lining from seepage, waterproof sheets (1.5 mm-thick) are placed on surface of shotcrete. The sheet is also effective for crack protection in lining concrete.

(2) Drainage

Seepage water behind the lining collected at the tunnel knee is guided to catch basins at approximately 50 m intervals. It is drained out through PVC pipes of ϕ 150mm along the roadside to the tunnel south portal. The road surface water from rainfall and surface cleaning is directly collected by catch basins and drained to the outside of tunnel through PVC pipes under the gutters. Any ground water to the tunnel underneath is drained by perforated pipes (ϕ 300) installed under the pavement at the centre of tunnel. Though the capacity of centre drain is large, it was not used effectively under the existing system.

(3) Capacity of Drainage Facilities of the 1st Kohat Tunnel

The heavy rainfall on 1st March 2005 induced overflow in catch basins in the tunnel. The recorded run-off was 2.1 m^3/min (0.035 L/sec) and this was over the discharge capacity of catch basin and PVC pipes.

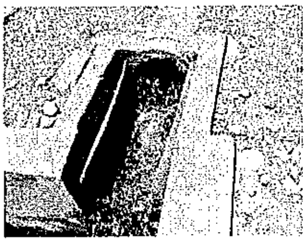
Table 11.5.3 shows a discharge capacity computation for the centre and side drains.

Table 11.5.5 Capacity of Drainage Pipes

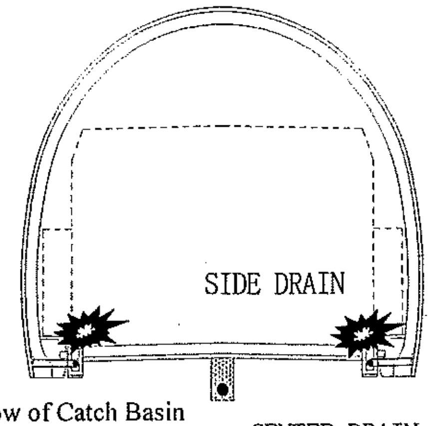
Type of Drains	Diameter (mm)	Roughness Coefficient	Discharge (m³／sec)	
			slope of waterway: 2.2%*	slope of waterway: 2.4%*
CENTER DRIN (Perforated Pipe)	φ300	0.025	0.025	0.026
SIDE DRIN (P.V.C)	φ150**	0.01	0.010×2=0.020	0.010×2=0.020
	φ200		0.021×2=0.042	0.022×2=0.044
	φ250		0.038×2=0.076	0.040×2=0.080

Notes:*2.2% for the 1st Kohat Tunnel and 2.4% for the 2nd Kohat Tunnel.

** φ 150 for the 1st Kohat Tunnel.



Drainage Outlet at South Portal



Overflow of Catch Basin

Figure 11.5.10 Tunnel Drainage System

The left figure in Figure 11.5.10 shows the current drainage system. A flow through the road side drain and spring water from mountain met at small basins (30 cm x 30 cm) and induced overflow.

A recommended improvement plan for the 2nd Kohat Tunnel is shown in the right figure of Figure 11.5.11. The drain for spring water from mountain is connected to the centre drain and separated from surface drain to avoid overflow in the tunnel. This will also contribute to the improvement of the 1st tunnel drainage.

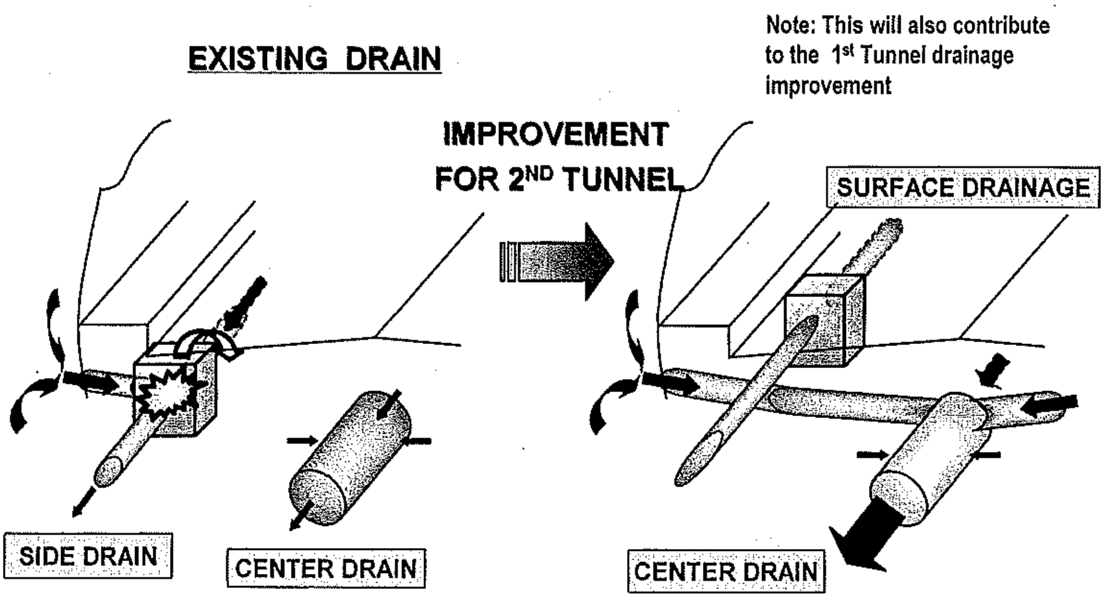


Figure 11.4.11 Drainage Plan for 2nd Kohat Tunnel

11.5.7 Pavement Design

The pavement in the tunnel and the tunnel approach sections (L=150m each) is concrete pavement as it is almost maintenance free compared with the AC pavement. The design thickness of concrete pavement is 30cm (refer to Subsection 11.3.2 of this report as to the detailed of design). The concrete pavement is constructed on the lean concrete base (10-15cm thick). Concrete slabs are reinforced with ϕ 6 mm steel mesh (120mm x 120mm). The transverse contraction joints are dowel bar joints (ϕ 32mm x 600mm) provided at 10m. Tie bars (length= 600mm) are ϕ 12 mm at 50 cm.

11.6 Tunnel Facility Works

11.6.1 General

For the safety of driving through tunnel, following systems should be provided in the tunnel.

1) Ventilation System
2) Lighting System
3) Power Supply System
4) Emergency Facilities
5) Other Facilities

According to the Section 10.1.1 Location of the South Portal and Approach Road Alignments, the exiting control room yard is necessary to move. So, the relocation of the existing Control room yards is also described last part of this section.

The image of Mechanical and Electrical facilities in tunnel is shown in figure 11.6.1.

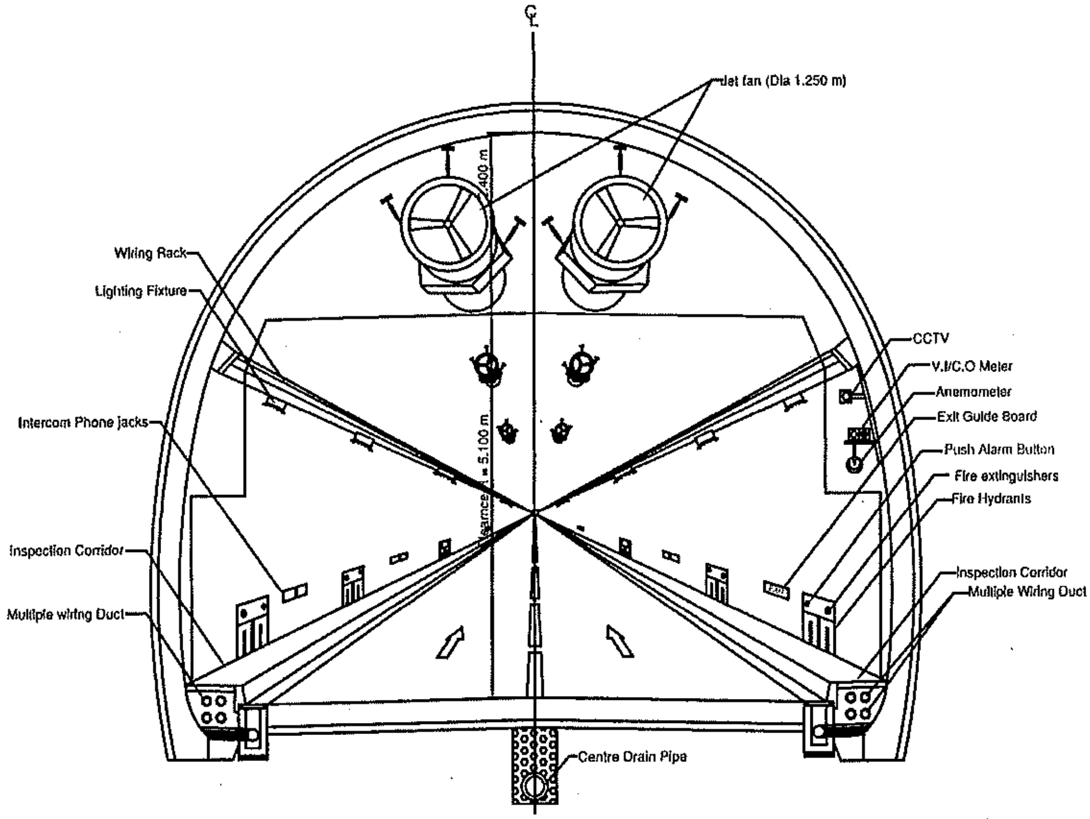


Figure 11.6.1 Image of Mechanical & Electrical Facilities in tunnel

11.6.2 Design Conditions and Data

From the Tunnel civil part design, following design conditions and data are applied for the tunnel facility systems.

1) Tunnel geometric conditions

- Tunnel length: 1885m (length is same as No1 Kohat tunnel)
- Tunnel profile: 2.2% continuous grade, rising from south to north (Existing Kohat tunnel change from both way to one way North ward traffic), and 2.4% continuous grade, descend from north to south (Planed No2 Kohat tunnel is used one way South ward traffic)

- Tunnel inner sectional area: 61.8 Sq.m (Cross section is same as No1 Kohat tunnel)

2) Traffic Direction: two-ways traffic with 2 lanes becomes one-way traffic with 2 lanes each after construction.

3) Traffic Characteristics

- Design traffic volume: 11,685 veh./day (2012) and 33,760 veh./day (2032)
- Traffic speed: 60km/hour
- Traffic composition: 40% (with diesel engine), 60% (with gasoline engine)

4) Tunnel Finishing:

Surface of Ceiling/Wall/Road: Same as No.1 Kohat Tunnel: Concrete

5) Reference Data

- Kohat Tunnel and Access Road Project
- Design review report, August 1998

11.6.3 Ventilation System

(1) General

In a tunnel it is necessary to minimize the presence of contaminated air, which is caused by the emission from internal combustion engines of vehicles. The polluted air in a long tunnel with heavy traffic volume is minimized by a mechanised ventilation system that is a key factor in deciding the tunnel structure plans and cross sections of the tunnel.

Provision for power supply and facilities to be used in emergency should be determined together with that of ventilation. Thus the ventilation system is integrated in to whole tunnel system.

(2) Tunnel Ventilation System

The road tunnel needs ventilation system because the vehicles driven by internal combustion engines exhaust gas which is harmful for people in the vehicles and produced smoke and dust that interfere with a driver's visual field.

a) Ventilation System

A short length tunnel will not need any mechanical ventilation system as long as the natural draft in the specific tunnel is effective enough to blow out these exhausted gases; smoke and dust. In the case of Kohat tunnel, the tunnel length is too long for only natural draft system especially for during the two-way traffic with 2 lanes (In a situation No.1 Kohat tunnel only).

b) Adopted Ventilation System

It is apparently clear that longitudinal system is most economic for the Kohat Tunnels.

Looking from the economical point of view the following advantages are there for longitudinal ventilation system:

- Less pressure losses.
- No extra ventilation duct required in the tunnel.
- No building required for ventilation fans installation.

Jet fans have been selected for longitudinal flow system.

Those advantages are as follows:

- Adjustable to add fans to match with the increasing volume of traffic.
- Less initial cost
- Cross-sectional area in the tunnel to be smaller than other systems.

c) Design Criteria

The report of PIARC (Permanent International Association of Road Congress, XIV-XVII) recommends that carbon monoxide (CO) should be less than 150 ppm and smoke measured for 100m visibility is 50%. However, the above figures are applicable where engines of vehicles are well maintained. Where the majority of engines are old and poorly maintained the above criteria should be revised and adapted.

Considering the old and poorly maintained vehicles and the design speed 60km/hr in the tunnel and following the Japanese Standard, the parameters for revision are given below:

- Permissible CO: 100ppm
- Smoke transmittance measured for 100m visibility: 40%

d) Design Conditions

Table 11.6.1 presents design conditions and factors to determine the ventilation system of Kohat tunnel.

Table 11.6.1 Design Condition and Factors

Item		Contents
Traffic Direction		One-way Two lane traffic
Traffic Characteris	Design Traffic Volume	In 2013 : 11,685 veh./day (760 veh./hr) In 2032 : 33,760 veh./day (2,195 veh./hr)
	Traffic Travel Speed	60 km/hour
	Traffic Composition	With Diesel Engine : 40% With Gasoline Engine : 60% Heavy Vehicle ratio : 26.5% Other Vehicles ratio : 73.5%
Tunnel Geometric Conditions		Plan- Straight For Kohat #1: Straight 2.2% gradient rising from South to North For Kohat #2: Straight 2.4% gradient descending from North to South
Tunnel Inner Section area		Ar = 62.2 Sq.m Dr = 8.24m

Note:
i) Ar : Calculated effective tunnel area for ventilation.
ii) Dr: Calculated hydraulic diameter of tunnel.

e) Required Air Volume for Ventilation

CO is mainly generated by petrol drive vehicles, while smoke is produced by diesel driven vehicles.

The required air volume is determined by taking the volumes calculated against diluting CO and smoke whichever is greater.

In this project, however, the required air volume is calculated against the criterion for smoke, which is greater than CO, as almost all the vehicles involved would be truck with diesel engine.

The calculation normally follows the method by which the "basic" air volume is first calculated, followed by the adjustments in the volume against altitude and gradient.

The results of calculations based upon the criteria to maintain 100m visibility and 40% smoke transmittance are summarized and shown in Table 11.6.2

Table 11.6.2 Required Air Volume in Tunnel

Tunnel	Existing #1 K.	#1 Kohat (Northbound One way)		#2 Kohat (Southbound One way)	
Tunnel length	1,885m	1,885m		1,885m	
Vertical Gradient	2.2%	2.2%		2.4%	
Year	In 2013	In 2013	In 2032	In 2013	In 2032
	(before construction)	Initial stage	Final stage	Initial stage	Final stage
Vehicle per hour	760	360	1,039	400	1,156
Unit Air Volume	0.1054	0.1110	0.1110	0.0674	0.0674
Gradient Factor	1.70	1.98	1.98	0.55	0.55
	0.57				
Altitude Correct coefficient	1.09	1.09	1.09	1.09	1.09
Required air volume	221 m3/s	161.2 m3/s	469.6 m3/s	30.7 m3/s	88 m3/s

Note: Gradient Factor (G.F)
G.F = Traffic Volume Ratio to Northbound / Traffic Volume Ratio to Southbound
= 0.4734/ 0.5266 = 0.899

f) Number of Jet Fans

Number of Jet Fans is calculated as in Table 11.6.3

Table 11.6.3 Number of Jet Fans calculated

Tunnel Name		No.1 Kohat		No.2 Kohat		Remarks
Year	In:	2013	2032	2013	2032	
	stage	Initial	Final	Initial	Final	
Tunnel length		1885	1885	1885	1885	
	Vt=	60	60	60	60	
Traffic Direction		Northbound		Southbound		
Traffic Volume		360	1039	400	1156	
Air Requi.	Qm3/s	161.2	469.6	30.7	88.0	
						Ar=61.8m2
Air Speed		2.61	7.60	0.50	1.42	Dr=8.24m
Pressure	ΔPr (mmAg)	29.88	253.56	1.08	8.90	
Losses	Δpmte	27.45	27.45	27.45	27.45	
in	ΔPt	65.90	70.53	101.26	254.95	
Tunnel	ΔP Total	-8.58	210.48	-72.73	-218.59	
	ΔPj	19.626	16.051	21.139	20.475	
Number of Jet Fans		-0.4	13.1	-3.4	-10.7	Ptoal/PJ
		(2)	14	(2)	(2)	

ΔPr : Frictional losses at the Inlet and exit portals
ΔPmte : Atmospheric back-pressure
ΔPt : Piston effect force
ΔP total : Total of the ΔPr + ΔPmte + ΔPt
ΔPj : Jet fan ascend-pressures

g) Location of Jet Fans

Two sets of jet fan are fitted on the tunnel ceiling by supporting materials at each centre of lane, upper part of tunnel vertical clearance in tunnel section.

h) Detector for Air Control

The following detectors are installed in the tunnel for Air Control.

- Carbon monoxide (CO) meter 2 sets
- Visibility (VI) meter 2 sets
- Air Speed meter (Anemometer) 1 set

i) Calculation Sheets

The design calculation sheets for jet fun number determination are attached in Annexure.

11.6.4 Lighting System

(1) General

The objective of tunnel lighting is to secure safe and smooth passage of traffic in a tunnel.

The tunnel lighting system is designed mainly based on Japanese Standard referring PIARC recommendation.

(2) Lighting Inside the Tunnel (Interior zone)

The following road luminance and illuminance for the interior zone lighting were adopted:

- Luminance: 3 cd/m2 (Based on PIARC recommendation)

- Illuminance: 40 lux (Based on PIARC recommendation)

(3) Tunnel Entrance Lighting

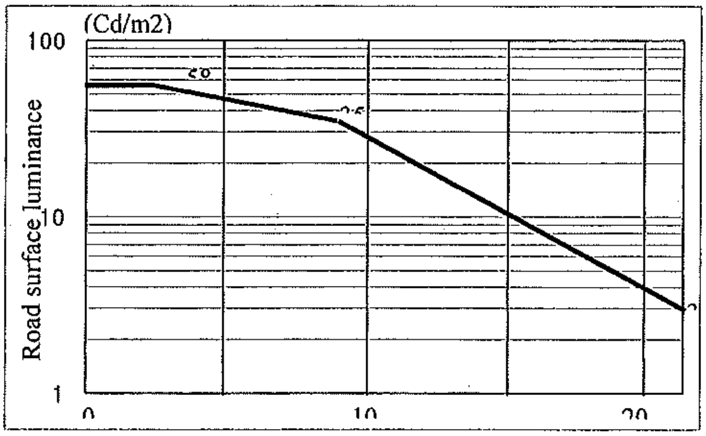
In order to design the entrance lighting, the following factors are required and adopted the factor as follows;

- Outside luminance (Portal): 4,000 cd/m2
- Entrance luminance curve involving the adopted design speed.

A tunnel entrance luminance curve is selected for the lighting design involving the adopted travel speed.

Table 11.6.4 Adopted Entrance Luminance

10 Speed	Threshold Zone			Threshold Zone			Adaptation Zone			Interior Zone	
Km/hr	Lumin-ance	Illumi-nance	Required distance	Lumin -ance	Illumi-nance	Required distance	Lumin -ance	Illumi-nance	Required distance	Lumin -ance	Illumi-nance
	cd/m2	lux	m	cd/m2	lux	m	cd/m2	lux	m	cd/m2	lux
60	58	760	25	58 to 35	760 to 460	65	35 to 3	460 to 40	125	3	40



Note: 1 cd/m2 = 13 lux (Concrete Pavement)

Figure 11.6.2 Adopted Entrance Luminance Curve

(4) Design Conditions

The following design conditions and data are used for the lighting design.

- Outdoor Luminance: 4000 cd/m2
- Travel Speed: 60km/hr
- Tunnel Geometric Conditions: See 11.4.1
- Reflection factor: 0.25 (Value for Concrete of Ceiling, Wall Surface and Road Surface)
- Maintenance Factor: 0.45 (Typical value of the MOC-J Design Standard, recognized by PIARC)

(5) Tunnel Lighting Requirements

The tunnel lighting requirements are based on the following factors.

a) Installation of Lighting luminaries

The tunnel lighting luminaries are to be installed at 5.2 m or more above the road level, outside the carriageway limits. Higher, the better luminance distribution to the road surface is obtained, but at the same time poorer maintenance of fittings results.

From the design point of view the mounting height of lighting luminaries is adopted as 5.5m.

b) Fitting arrangement

There are three type of fitting arrangement; Centre Lined, Opposed and Staggered arrangements.

Centre lined one has big disadvantage for maintenance because of its height. The opposite fitting arrangement is adopted. Since there are following advantage compared with the staggered one.

- Better luminance distribution,
- Less glare of fittings and
- Less flickering

Therefore, the opposed fitting arrangement is adopted.

c) Spacing of Lighting Luminaries

Proper spacing between light luminaries should be provided to satisfy the following conditions:

i) Space between luminaries (S) in related to the installing height (H):

$S \leqq 2.5H$

ii) The spacing (S) shall be limited as shown by the following formula to avoid the flickering phenomenon, in relation to travel speed:

$S \geqq V/18$ and $S \leqq V/36$

V= travel speed (km/hr)

d) Formula for spacing of Lighting Luminaries

The determination of the luminaries spacing is computed by the lumen method formula generally in use.

The formula is:

$$S = F \times U \times M \times N / E \times W$$

Where,

S : Spacing between lighting luminaries. (m)
F : Luminous flux of light source: (1m)
U : Utilization factor
M : Maintenance factor
N : Number of light source: (Opposite = 2)
E : Average horizontal-plane illuminance of the road surface: (lux)
W : Width of road surface: (m) Carriageway

e) Emergency lighting during power failure

i) Emergency Lighting by battery power

- The emergency lamp should be lit inside the tunnel by the non-failure type battery power source during power failure.
- The lamp should be turned on automatically and should be capable of providing light for more than 3 minutes continuously, immediately after the power failure.
- Every tenth luminaire inside the tunnel will be battery powered fro safety point of view.

ii) Emergency lighting by stand by power source

Fifty percent of the total (full) illuminance inside the tunnel (Interior zone), should be provided with stand by power source within 2 minutes after the main power failure.

Stand by power source will be provided by diesel-engine generator.

(6) The tunnel Lighting System:

a) Interior Tunnel Lighting

The 70 watts high-pressure sodium lamp (HPS) installed at a height of 5.5 m on both side-walls will light the interior length of the tunnel carriageway maintaining the lux level at 40.

The lighting fittings on each sidewall will be fed by 2 main circuits, connected alternately, so that one circuit can be kept off at night to provide only 20 lux throughout the tunnel.

Table 11.6.5 Circuit Control Schedule

		Day Time	Night Time	Stand by Power
One Side				
Circuit	A	O	O	O
Circuit	C	O	X	X
Opposite Side				
Circuit	D	O	X	X
Circuit	B	O	O	O

Notes:
i) O Denotes circuit "On:" Position
X Denotes circuit "OFF" Position
ii) Daytime : 7am to 6 pm
Night time : 6pm to 7 am
Emergency : Ditto
iii) Any time setting is adjustable by hand

During main power failure the illuminance in the tunnel will be kept at 20 lux throughout, the power being fed, by the standby Diesel Generating Set.

Automatic switch devices will control the circuits.

b) Tunnel Entrance Lighting

250 watt HPS lamp and 70 watt HPS lamps will light the tunnel entrance zone ilel, the threshold, the transition and the adaptation in addition to the lights mentioned in Interior zone. Sets of fitting with HPS-250 lamps and HPS-70 lamps will serve to light each entrance.

The lighting luminaries on the one sidewall will be fed by 2main circuits.

A circuit control schedule is as shown in Table 11.6.6

Table 11.6.6 Circuit Control Schedule for Entrance

		8 am – 2 pm		2 pm – 6 pm	
	Cd/Sq.m	Over 1000	Over 3000	Under 3000	Under 1000
One Side					
Circuit	E	O	O	O	X
Circuit	G	X	O	X	X
Opposite Side					
Circuit	H	X	O	X	X
Circuit	F	O	O	O	X

Notes:
i) O denotes circuit "On:" Position
X denotes circuit "OFF" Position
ii) Based on the outside luminance level, a set of automatic switch device will control the circuits shown in the table for the economical utilization of lighting.

c) Outside of tunnel entrance lighting

A 150 W HPS lamp and highway type fitting mounted at 9 m tapered pole will be installed for adjusting the drivers' eyes to outside darkness from higher illuminance inside the tunnel at night-time.

(7) Selection of Light Sources

High pressure sodium lamps have been chosen for the interior and entrance zones of the tunnel rather than low pressure sodium lamps for the following reasons:

- High luminous efficiency,
- Large capacity of lumens,
- Good colour rendering and
- Common light source for road lighting in Pakistan

The Consultants considered and selected the light source as follows:

- For the interior zone: HPS-70W 6,500 lm
- For the entrance zone: HPS-250W 30,000 lm

Selection of one type of lamp involves less initial cost and easier maintenance compared with the adoption of several types.

(8) Calculation Data

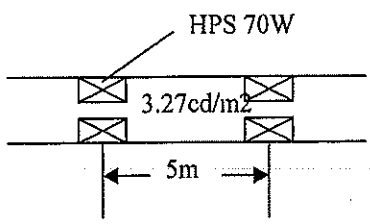
a) Determination of lantern spacing at the Interior zone

i) Calculation based on the Required Average Intensity of Illuminance/luminance.

S = F x U x M x N/E x B

Where;

S = Required spacing of lantern in metre, S = 5.0 m
F = 6500 lm
U = 0.266
M = 0.45
N = 2
E = 40 lx (approx 3 cd/sq.m x 13 lx/cd/sq.m)
W = 7.3 m



Luminance
= F x U x M x N/S x W x 13 cd/sq.m
= 3.27 cd/sq.m

ii) Spacing selection based on the Favourable Distribution of Brightness.

S< 2.5H = 2.5x 5.5	= 13.75m	S <13.75m
S> V/18 = 60/18	= 3.3m	S > 3.3m
S< V/36 = 60/36	= 1.6m	S < 1.6m

iii) Adopted lantern spacing

5.0m lantern spacing is adopted in the design.

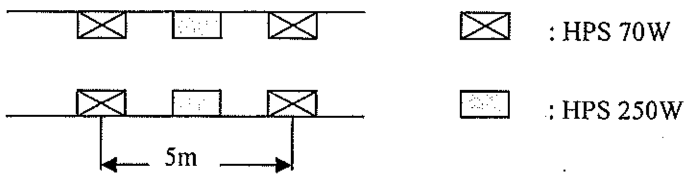
b) Determination of lantern spacing at Entrance and Transition Zones

Luminance = F x U x M x N/S x W x 13 cd/sq.m

Where;

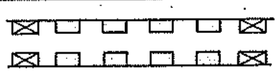
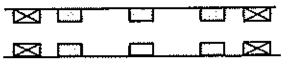
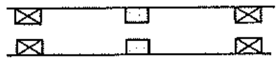
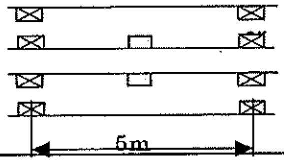
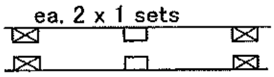
F = 30,000 lm
U = 0.266
M = 0.45
N = 2
Luminance = 15.13 cd./m2

W = 7.3 m
S = 5.0 m
Luminance = E/13 (cd/m2)



Selected lanterns layout together with numbers of lamps are shown in Table 11.6.7

Table 11.6.7 Arrangement of Lanterns

Discription / Block (Length)	Required Average Intensity of Luminance (cd/m2)	Luminance in Interior Zone (cd/m2)	Additional Luminance in Entrance Zone: Nos. of HPS 250 Lanterns	Additional Luminance in Entrance Zone: Caluculated Luminance (cd/m2)	Total Luminance in Entrance Zone (cd/m2)	Arrangement of Lanternes
A (40m)	58	3.27	2 x 4sets	60.52	63.79	
B (45m)	46	3.27	2 x 3sets	45.39	48.66	
C (35m)	28	3.27	2 x 2sets	30.26	33.53	
D (60m)	16	3.27	2 x 1sets	15.13	18.40	
E (35m)	5.3	3.27	2 x 0.5 sets	7.57	10.84	 or
Note	ea. 2 x 1 sets 		 HPS 70  HPS 250			

11.6.5 Power Supply System

(1) General

The power supply system will feed electrical power to the Kohat tunnel facilities as well as the facilities in the Substation and the Control Room, at the South portal.

Power supply system may be named as,

- Power Supply System
- Stand-by Generators

(2) Design Codes and Standards

Design Codes and Standards will be applied for the design of the system determination. They will be:

- The regulations for the installation of electrical equipment in buildings 15th edition issued by the institute of Electrical engineers, London, England.
- Publications issued by the International Electro-Technical Commission (I.E.C).
- Service requirements and climatic conditions.
- Local rules and requirements for electrical installations.

(3) Design Conditions

a) Incoming Power from WAPDA

- Power Supply System: 3 Phase 3-wire 50 Hz 11KV
- Applied tariff for the Project: Tariff B-3 (for Industrial Supply at 11KV and 33KV)

b) The facilities to be supplied are as follows:

- Tunnel Ventilation Fans

- Tunnel Lighting
- Tunnel Measurements Devices [Carbon Monoxide meter (CO), Visibility meter (VI) and Air speed metre (AS)]
- Traffic Signal
- Facilities in the substation and Control Room at the portal
- Facilities in the Tunnel substations
- Lighting (Inside and outside building)
- Motor Power
- Communication devices (Telephone, Radio equipment)

c) Wiring System for Facilities

	Tunnel Facility	Wiring System
i)	Tunnel Ventilation Fan	3 ϕ 3w 400V
ii)	Tunnel Safety	3 ϕ 4w 400V
iii)	Tunnel Lighting	3 ϕ 3w 400V
		1 ϕ 2w 230V
iv)	Tunnel measurement Devices	3 ϕ 4w 400V
v)	Facilities in the Control Room	3 ϕ 4w 400V

d) Maximum Permissible Volt Drop

Total voltage drop between the consumer's terminals and any other point in the installation must not exceed 2.5 percent of the normal voltage.

(4) Requirements of Power Supply System

- The sub-station (S/S) for the Kohat Tunnel will be installed at the tunnel entrance of the South portal. An incoming line from WAPDA to the S/S will be 3-phase 3-wire 11KV 50Hz. Tunnel substations (TN S/S) will be provided at two emergency areas located within the tunnel
- The tunnel facilities will be fed from the tunnel substations. Approx-30 sq. meter tunnel substation will be provided.
- The S/S substation, including WAPDA room, High-tension room, Generator room, Generator panel room, Transformer room, (step-up and step-down) and UPS room will be approx. 270sq.meter and approx. 100sq.meter is provided for Generator room.

Un-interrupt able power supply (UPS) system room will be planned and installed. The UPS is approx. 10KV, of which 8KVA is for the control room and 2KVA for tunnel substation, roughly estimated.

Approx. 100sq. mm 3-core main cable will run between the UPS and the power terminal set in the Central Processing Unit Panel. From the terminal set, power supply cables to the relevant SVC system will be fed.

The UPS will feed to:

In Control room:	SVC System, Processing Computer Panel, Ventilation Control Panel and Safety Panel.
In Tunnel substation:	SVC System

(5) Summary of Power Supply System

Table 11.6.8 shows the summary of power consumption, and Table 11.6.9 shows the required load for diesel engine generator.

Selected Transformers and generator sets are shown in the same Tables.

Table 11.6.8 Summary of power Consumption

Item	Control Room	Substation S/S	1st TN TN S/S	2nd TN S/S	Total	Description
1st TN Ventilation	-	-	310.6 KW (6 sets) (264KVA)		310.6 KW (264 KVA)	Pf=0.85
1st TN Safety	25	-			25	
1st TN Lights	-	-	93	93	186	Includes TN Outside Lights
1st TN Facilities	25	50	3.5	3.5	82	
1st TN Total Load (KVA)	50	50	360.5	96.5	557	
1st TN Selected Transformers	100 KVA*		630 KVA*	100 KVA**		*Existing **New one
2nd TN Ventilation	-	-		310.6KW (6 sets) (264KVA)	310.6KW (264 KVA)	Pf=0.85
2nd TN Safety	25	-				
2nd TN Lights	-	-	93	93	186	Includes TN Outside Lights
2nd TN Facilities	25	50	3.5	3.5	82	
2nd TN Total Load (KVA)	50	50	96.5	360.5	557	
2nd TN Selected Transformers	100 KVA**		100 KVA**	630 KVA*		*Move from #1 ** New ones

Table 11.6.9 Required Load for Diesel Generators

Item	Max. Power Demand (KVA)	Max. Demand For D.G (%)	Required Loads For D.G (KVA)	Description
TN Ventilation	528	37.9 (6 No.)	198	First stage 4 sets 259KW pf=0,85 Final stage 12 sets 333 KW
TN. Safety	25 x 2	100	50	
TN. Lights	186 x 2	50	186	
Facilities	82 x 2	100	164	
Total (KVA)	1,114	-	598	<300KVA x 3 sets* * 2 sets are existing 1 set is new

Note: D.G: Diesel Engine Generator
3 sets work: 598/900 x 100% = 66%

11.6.6 Emergency Facilities and Safety Systems

(1) General

Tunnel emergency facilities are designed for mitigating damage in the event that fire or any other accident arises in the tunnel.

Emergency facilities are categorized as information and alarm equipment, fire extinguishing equipment, escape and guidance equipment others.

(2) Design Standards for Emergency Facilities

Emergency facilities requirements within the tunnel are shown by Table 11.6.10 and Figure 11.6.3 where Figure 11.6.3 presents a classification of tunnel into five groups with respect to the tunnel traffic volume and the length and Table 11.6.10 shows a list of facilities which should be installed in response to the grouping in the tunnel category. These were recommended in PIARC XVII world congress (October 1983).

The same design conditions are used for the safety system study as described in ventilation system.

Table 11.6.10 Standards for Installation of Emergency Facilities by Tunnel Classification

Emergency Facilities \ Tunnel Classification		AA	A	B	C	D
Communication and Alarm Equipment	Emergency Telephone	O	O	O	O	O
	Alarm Button	O	O	O	O	O
	Fire Detector	O	Δ			
	Signal and Alarm	O	O	O	O	O
Fire Fighting Equipment	Extinguisher	O	O	O		
	Fire Hydrant	O	O			
Escape and Guidance Equipment	Exit Guide Board	O	O	O		
	Smoke Discharge Equipment or Refuge Passage	O	Δ			
Other Equipment	Hydrant (Water Supply)	O	Δ			
	Radio Communication Ancillary	O	Δ			
	Radio Rebroadcast Equipment Or Loudspeaker	O	Δ			
	Sprinkler	O	Δ			
	Television	O	Δ			

Notes: O Denotes "Should be Installed as the Rule"
Δ Denotes "To be installed as Required "

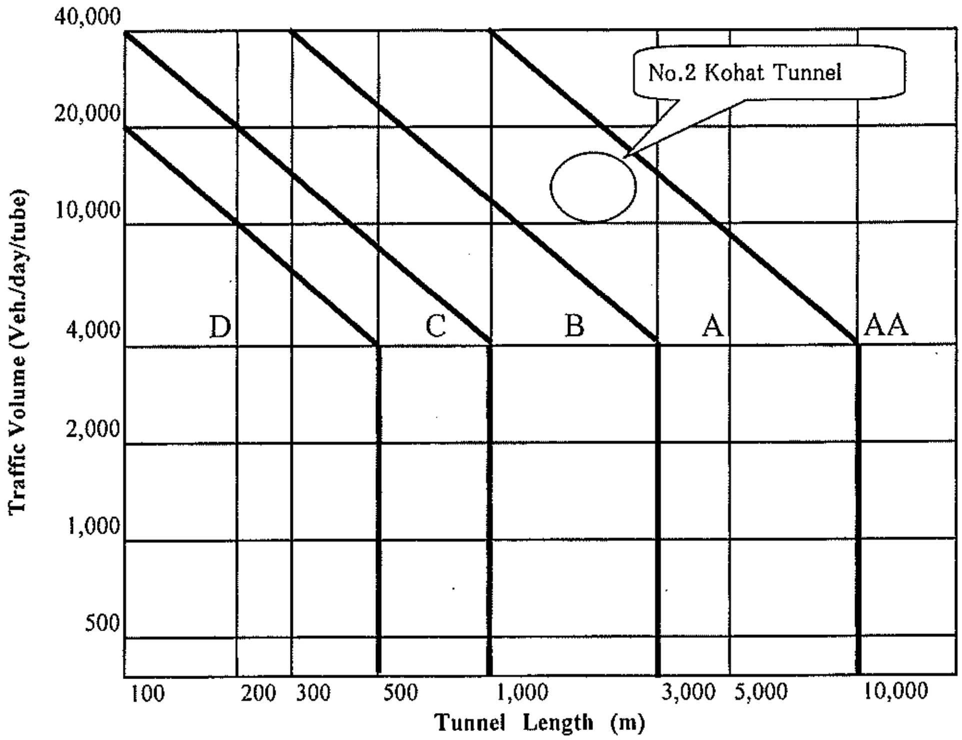


Figure 11.6.3 Classification of Tunnels

(3) Tunnel Emergency Areas and Escape corridor

After completion of No2 Kohat Tunnel, the Existing No.1 Tunnel tube became a one-way carriageway from South to North with two lanes and No.2 will be also two lanes for opposite direction. Not to disturb the traffic flow, a disabled car in the tunnel should be moved to a safety and suitable area in the tunnel.

Therefore, in the 2nd Kohat tunnel with a distance of 1885m emergency area or rescue yards will be provided two places at the left side of the tunnel along the vehicle flow.

The emergency area location plan is shown in Figure 11.6.4. The length of the area will be enough to accommodate a trailer truck.

Escape corridor for evacuation of road users in case of accident in the tunnel to a safety place, which connects the No.1 Kohat tunnel (Northbound) and the parallel tunnel No.2 Kohat (South bound). Position of these passages is decided by the existing tunnel's preparation, which was excavated before hand. The both ends of these corridors are closed by fire resistant door, which should be opened by hand at an emergency occasion.

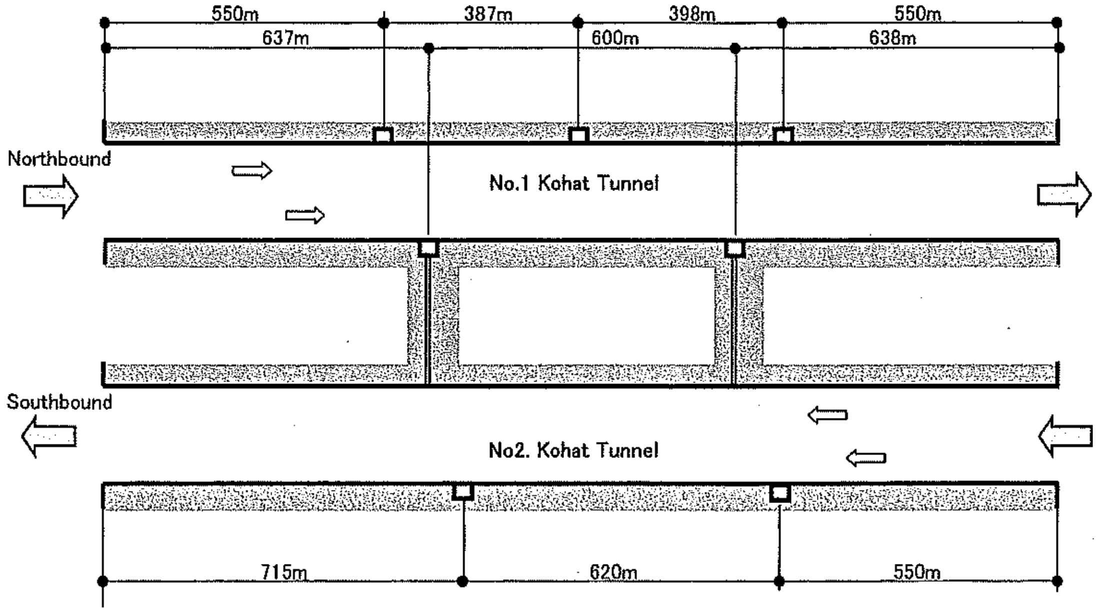


Figure 11.6.4 Location Plan of Emergency Area

(4) Safety System

The Kohat tunnel is belonging to the classification "A" as in Figure 11.6.3 based on the tunnel length and traffic volume. The classification "A" should have a safety system as outlined below:-

- Emergency Telephone
- Alarm Button
- Signal (Red and Amber) and Alarm
- Fire Extinguisher
- Fire Extinguisher in place of fire hydrant
- Exit guide board

The facilities include in tunnel safety system are as listed and their locations are shown in Table 11.6.11.

Table 11.6.11 Tunnel Safety System

Item	Location	Description
Emergency Telephone	Every Emergency Area (2) and Escape corridor (2)	Public telephone type
Alarm Button	Every 50m. Eastside wall mounted	Pushbutton - type
Traffic Signal	North side tunnel entrance, Mounted on the Guard Bar	Red and Amber, Automatic type
Extinguisher	Every 50m East side of wall mounted	Of Chemical type
Big Extinguishers	Every Emergency Area (2 Areas)	Of Chemical type
Exit Guide Board	Every 100m	Of plate type
Guard Bar	North side Tunnel Entrance	Continuous-type over-height protector

11.6.7 Supervision and Control System

(1) Introduction

The work of tunnel supervision and control is planned to systematize various facilities for safety of drivers running through the tunnel.

(2) Location of Substation and Control Room Bldg. Yard

For Toll Plaza, and an Administration Building, existing ones are enough after the 2nd Tunnel opening. Since planed tunnel entrance will be a just behind the existing Control Room Yard, it is necessary to relocate the existing control room and substation to another place.

As a potential site for the Yard, we selected two locations near the South Portal and near the North Portal, and through comparison of both site, the location at the South portal is selected for the yard. See Table 11.6.12 Comparison of the location of Control & Substation Building Yards.

(3) Tunnel Facilities to be Supervised and Controlled

a) Facilities to be supervised and controlled are as follows;

- Facilities in Tunnel
- Facilities in Substation
- Facilities in Control Room

Other building facilities provided in the Toll Plaza and Administration Building are managed separately.

The Control Room will be provided at the South side tunnel portal, Control Room supervisors in shifts will be available in the centre for 24 hours, for the purpose of control and supervision of the various facilities in the tunnel such as ventilation, safety, lighting and power supply.

Tunnel facilities are supervised and controlled as follows:

b) Ventilation

As described in the section on ventilation system, there would be 2 sets of CO meter, 2 sets of visibility meter and 1 set of Air-speed meter to guide and control the operation of Jet fans in the tunnel.

The limiting factors of CO content, smoke transmittance and Air-Speed which will determine the actual number of Jet fans to be run at any one time as follows;

- CO content 100ppm.
- Smoke transmittance 40%
- Maximum Air-Speed 12m/sec

The Supervisors in the control room will monitor the meters and operate the Jet fans accordingly.

Major facilities of Ventilation System for each tunnel are:

- 2 sets of Axial type dia 1250 x 37 Kw Jet Fans (Initial stage)
- 2 sets of CO meters
- 2 sets of visibility meters
- 1 sets of Air-Speed meter

After construction of 2nd Kohat tunnel, both tunnel become one way traffic so, load for ventilation will be improved very much compare to the existing ones.

c) Safety

For safety facilities against any accident or fire hazard in the tunnel, emergency telephones, extinguishers with alarm button and traffic signals will be provided. These will be interlinked with the control centre and monitored by the control room supervisor. For any accident or fire in the tunnel the emergency telephone can be used or the alarm button can be pressed by the tunnel user, informing the control room supervisor about the accident. The control room supervisor will in turn alert the rescuer staff or fire-fighting personnel, located at the portal for 24 hours, for immediate necessary action by dispatching the relief van and the ambulance in case of accident and by sending a fire-fighting person in case of fire. At the same time the traffic signal on both tunnel entrances will be turned red warning vehicles not to enter the tunnel.

Major facilities of the safety system are:

- Emergency telephone at every emergency area and entrance of escape corridor 4 Nos (Box-type)
- Alarm button, every 100m (Press-type)
- Red and Green Traffic Signal, Both tunnel entrance (Automatic-type)
- Extinguishers, every 100m (Chemical-type)
- Big Extinguishers at every emergency area, 2 Nos (Chemical-type)
- Exit guide board, every 100m (Continuous type)
- Guard Bar both tunnel entrances (for checking over-height vehicles)
- Telephone jack at every emergency area, 2 Nos in the tunnel and at both entrances of tunnel.

d) Lighting

One basic circuit for light would provide the illuminance throughout tunnel at 20 lux which is the requirement at night time, and also the requirement when the power is being fed by stand by Diesel Generating set. The other circuit, meant to provide another 20 lux making a total of 40 lux which is the requirement for interior zone during day time, will come into operation during the day.

The light illuminance in the entrance zone inside the tunnel would be determined by the luminance at the portal outside the tunnel. The light in the entrance zone would be automatically adjusted according to the external luminance by means of photoelectric sensors.

The light system is:

- 3cd/m2 of Interior tunnel lighting
- 58-5.3 cd/m2 of tunnel entrance lighting
- Outside of tunnel approach lighting (Pole mounted)

e) Power Supply

The main power supply will be fed by WAPDA. In case of power failure from WAPDA, power will be fed by stand-by diesel engine generators installed in the substaion building at the portal. Generator operators in shifts will be available for 24 hours in generator room for the operation of the generator whenever there is need.

The detail of power supply:

- 1 Line 3-phase 3-wire 50Hz 11KV WAPDA incoming
- 2 Line of 11KV, outgoing
- 3-phase 3-wire 50Hz 400V wiring system
- 3-phase 4-wire 50Hz 400V
- Single phase 2-wire 50Hz 230V wiring system
- 3sets of 300KV sand-by generator (including existing ones)

f) Substation Building and Facilities

i) Substation Building Location

The substation building is provided at approx. 40m from the tunnel south portal on the West side of the No.1 Kohat tunnel.

For minimizing voltage drop, the location of the substation building is selected near the tunnel entrance.

ii) Substation Building

The Building (Approx. 15m x 18m) will contain the following rooms:

- Stand-by operator room
- Generator panel Room
- Generator Room
- High Tension Room
- Transformer Room
- UPS Room
- WAPDA Room

iii) Facilities

The facilities for the building are:

- Lighting with switches in every room
- Interphone in every room
- Exterior lighting

The building facilities design is included in the Architectural design.

g) Control Room and Facilities

i) Control Room Location

The building of the control room is located beside the substation, approx. 10m apart, East side facing the road way.

ii) Control Room Building

The building (Approx. 12m x 11m) will contain the following rooms:

a) Control room

b) Staff room and corridor

c) Maintenance room

d) Store

e) Toilet

h) Tunnel Substation and Facilities

i) Tunnel Substation Location

Two tunnel substations are provided in the tunnel emergency area, for the same reason on the outside substation of the tunnel.

ii) Tunnel Substation

A minimum inner space 2.8m wide by 8 m long, is at right angles to the tunnel wall in the centre of east side emergency areas, with 2.8m wide entrance.

The substation is used for the installation of H.V and Transformer Panel, and L.V panels for Jet Fans and Tunnel Lighting, Tunnel Safety, polluted air detectors for ventilation system.

i) Water Reservoir

An approx. 200m3 water tank is provided for fire fighting as found necessary from safety point of view.

The location of the water reservoir is beside the Control Room Building.

(4) Tunnel Supervision and Control

a) General

The work of tunnel supervision and control is planned to systemize various facilities for safety of drivers running through the tunnel.

The work is considered in two categories as follows:

i) Category-1 Normal Condition

ii) Category-2 Accident Condition

Supervision and control is manned by the control room supervisors and is available for 24 hours in shifts.

b) Location of Control Room

The control room is located near substation for the following reasons:

i) easy and quick response available against any accident of fire hazard in the tunnel

ii) length and cost of control cables reduced

c) Tunnel Supervision and Control

The works of tunnel operation and control is categorized as following:

A) Category 1: The Works in Normal condition

At the works in Normal Condition, the control room supervisor monitors the meters and watches on the controlled facilities conditions.

But all facilities will be supervised and controlled automatically.

B) Category 2: The Works in Accident Conditions.

At the works in accident condition, the supervisor in to operate the following:

i) Traffic Accident in the Tunnel:

- The supervisor is to be informed by the Tunnel Patrol or tunnel users by wireless radio or emergency telephones or alarm buttons.
- To alert the rescue staff, patrol staff for immediate necessary action by dispatching the appropriate vehicles.
- To ensure that traffic signals on both tunnel entrances turn red, warning vehicles not to enter the tunnel.
- To rescue patient(s) for first aid, or to request help for the patient(s) to the Local Government Hospital if more medical action is judged necessary by the rescuer officer.

The supervisor should select the full levels of tunnel lighting and the full-notch of ventilation.

ii) Fire in the tunnel

- The supervisor is to be informed in the same way as traffic accident.
- To alert the fire fighting personnel, rescuer staff and patrol staff into actions by dispatching appropriate vehicles.
- To put into operation the available means such as powder type extinguisher and cart type extinguisher to fight the initial stage of fire.

- To ascertain the need of requesting the Local Government agencies, Police, Fire Fighting and Medical, to help fire or accident.
- To turn signals as "Red Warning" same as traffic accident.
- To act putting out fire by tunnel users with powder type extinguisher or fire fighting personnel with cart type extinguisher as initial arrangement until the local agencies arrive.
- To rescue the patient(s).

The supervisor should select the full levels of tunnel lighting and "OFF" notch of ventilation until receiving the authorized personnel's further instructions.

d) The System of Tunnel Supervision and Control

The system outline of Tunnel Supervision and Control (TN. SVC) is shown in Figure 11.6.5.

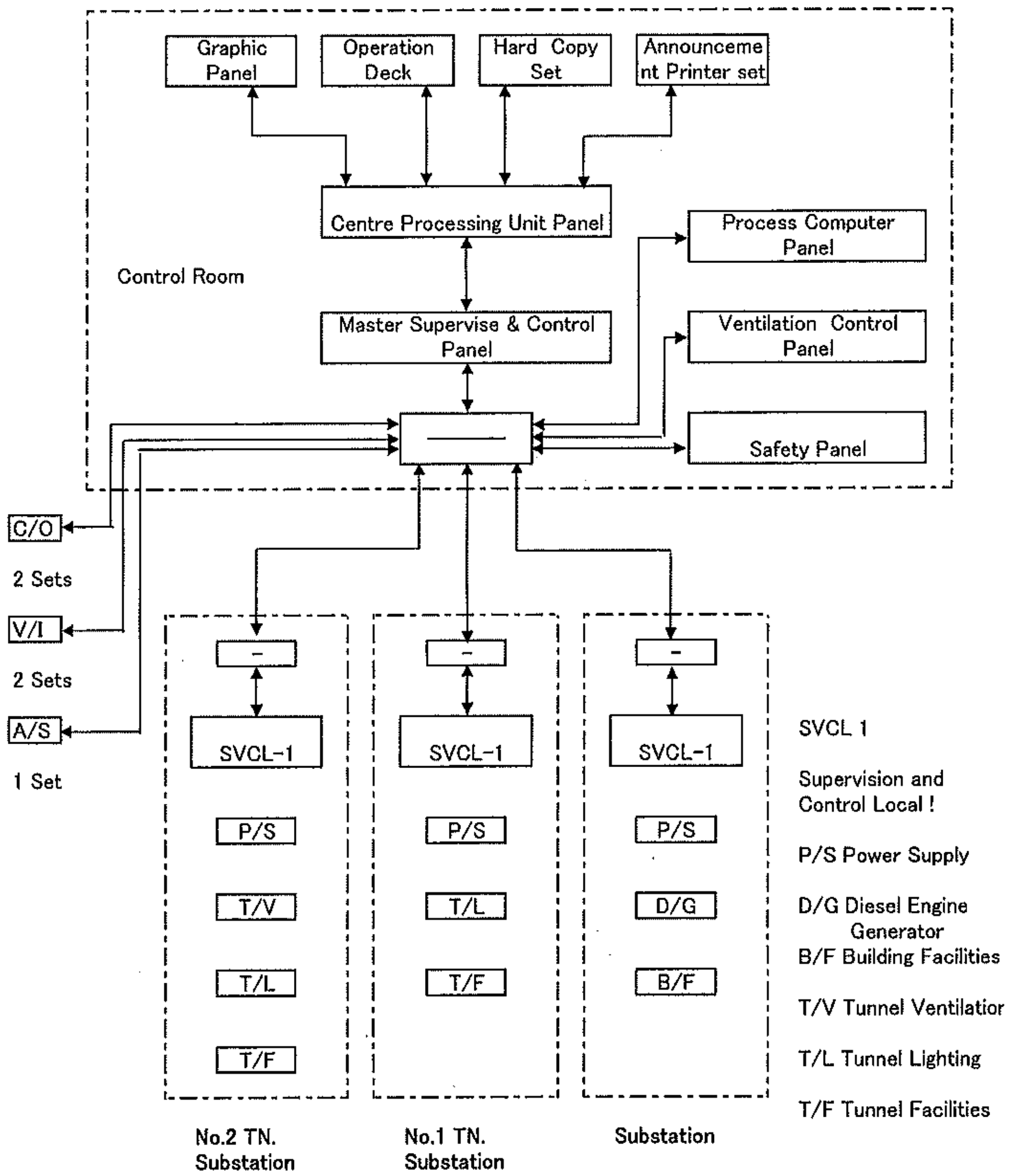


Figure 11.6.5 System Outline of Tunnel supervision and Control

e) Telephone System

For No2 Kohat Tunnel Project to maintain a smooth and effective operational system, same as the No.1 Kohat tunnel, a telephone exchange with multiple-line capacity is proposed for tunnel, substation, control room and administrative areas.

The tunnel controller will be connected to the emergency telephones and patrolmen's telephone jacks directory within the tunnel system. The controller can contact the rescue services direct as it is standing by in the same building and the police, fire brigade, administration building, toll office or other points connected to the T&T system by outside line.

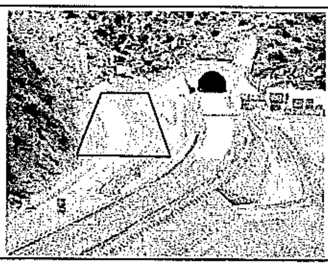
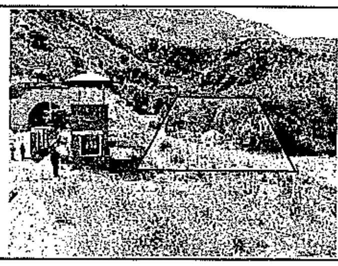
A system with the potential for 8 external and 40 interval connections has been included in the design.

11.6.8 Relocation of the Exiting Control Room and Substation Building

According to the Section 10.1.1 Location of the South Portal and Approach Road Alignments, Existing Control Building and Substation building yard is necessary to relocate to some other place, since it will be just in front of a new tunnels portal.

The necessary area would be 1,200m2 and preferable near the existing control building that means near South Portal. As a comparison of the re-location area, select potential two locations, In front of South Portal and In front of North Portal and made a comparison in the following Table 11.6.12.

West of South portal area is recommended. Though it is necessary to take care of the existing valley, the merit of near the existing control yard is prevailing for every other thing.

	Location	In front of South Portal West side	In front of North Portal West side
	Explanation of the location	Before the South portal of the Tunnel West side Elevation of the yard will be same as the elevation of the tunnel Entrance	Before the North Portal of the Tunnel West side. Elevation of the yard will be same as the elevation of the tunnel Entrance
	Photo of the location		
Characteristic of the location and evaluation for that point	* Distance from the existing Yard	Nearest to the existing Yard **O**	Opposite side of the tunnel entrance and far from the existing Yard **X**
	* Necessity of special consider for water flow and others	Need to reclaim an existing valley, so need to prepare not only water flow but also for debris flow. **Δ**	No special consideration is necessary **O**
	* Construction Procedure	Relocation of cable in side the existing tunnel is few and mostly out side of it. **Δ**	Relocation of cable in side the existing tunnel is essential and very difficult without long stoppage of traffic. **X**
	* Rough estimated Cost	Yard Preparation 49Mill Rp. Cable & Removal 12Mill Rp. Total 61Mill Rp. **O**	Yard Preparation 5Mill Rp. Cable & Removal 85Mill Rp. Total 90Mill Rp. **X**
	Total Evaluation	(Recommended) **O**	**X**

Note: O Good, Δ Fair, X Bad

Table 11.6.12 Comparison of the Location of Control & Substation Building Yard

11.7 Other Facilities and Buildings

11.7.1 Administration Offices and Control Room

The following buildings and associated facilities are provided for administration, operation and maintenance of the tunnel and access roads:

- South Administration Building at Sta.13+700 (L)
- Tunnel Control Room at South Portal (R)
- North Emergency Building at Sta.18+650 (L)
- Toll Plazas and Custom Office Buildings.

The existing South Administration Office and the North Emergency Building have sufficient area and facilities and no extension required for the 2nd Kohat Tunnel and Access Road. The existing Tunnel Control Room and associated facilities shall be relocated either on the left side of the south portal or at the north portal.

The Main Toll Plaza was constructed at Sta.10+600 for collection of toll fees for both the south-bound and north-bound traffic. The Kohat Link Road Toll Plaza was constructed at the Off/On Ramp at Sta.15+575 when the Kohat Link Road was constructed later for collection of toll fees and control of vehicles entering the main road. A New Toll Plaza was constructed at Sta.17+400 and started operation in July 2006. This New Toll Plaza will absorb the other two toll plazas and, therefore, additional toll booths are to be constructed for the 2nd Kohat Tunnel and Access Roads.

11.7.2 U-turn Facility for Tunnel Maintenance Vehicles

The tunnel maintenance vehicles are currently able to u-turn outside the tunnel as the existing lanes are not separated. However, as a median will be constructed on the whole Project road, a U-turn facility (median opening) is required to be constructed near the south portal at around Sta.19+700 for movement of the tunnel maintenance vehicles from the south-bound lane to the northbound lane as illustrated in Figure 11.7.1.

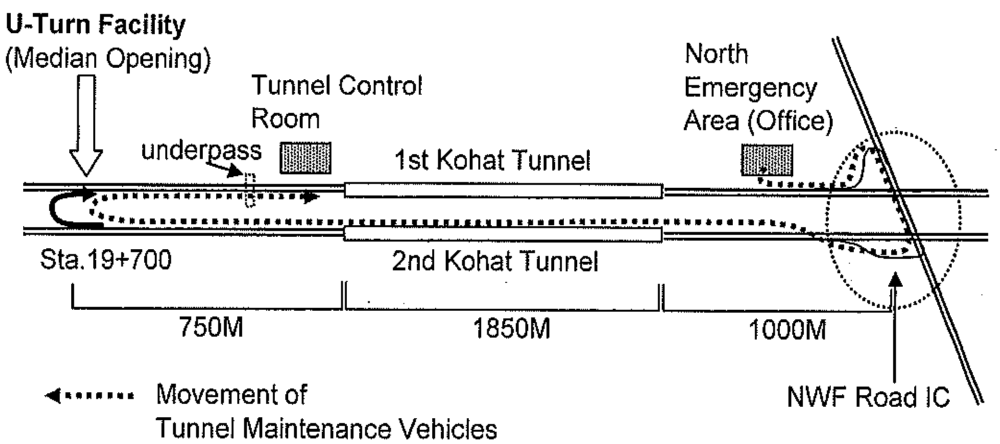


Figure 11.7.1 U-Facility (Median Opening) for Tunnel Maintenance Vehicles

Chapter 12. OPERATION AND MAITENANCE

12.1 General

NHA is responsible for the management of valuable road assets (national highways and motorways) under its administration. NHA needs to provide maintenance funding in a way that returns maximum benefits to road users, communities and the government. Maintenance is one of the important elements in the highway system management. It is a program to preserve and repair the road facilities in their designed or accepted configuration.

Maintenance programs include road surfaces, shoulders, drainage facilities, slopes, bridges, tunnels, traffic markings and signs, lighting fixtures, etc. The maintenance operations involve monitoring and assessment of the conditions of road facilities, diagnosis of the problems and adopting the most appropriate measures. Annual and periodic maintenance programs should be established based on the maintenance techniques, personnel, materials and equipment available in economical and effective ways. It includes defining activities (maintenance criteria and standards), planning works and schedule, allocating resources, organizing personnel or contractors, controlling fiscal aspects, monitoring and evaluating performance and feeding back results to seek further improvement.

12.2 Maintenance of Road Facilities

NHA is responsible for the physical maintenance of the road facilities including pavement, bridges, slopes and other road facilities. The budget of these maintenance works is allocated by the NHA head office.

Road maintenance for the Project road is defined as a process to optimize the overall performance of the roadway over time. The process comprises of a number of activities (or measures) that will have impacts on the road facilities. Classification of the maintenance activities to be applied for the Project road is as summarized in Table 12.2.1.

Table 12.2.1 Maintenance Activities for the Project Road Facilities

Category	Classification	Routine	Periodic	Emergency
Roadway	Road surface	Crack sealing Patching	Rutting Repair Overlay	
	Shoulders and approaches	Vegetation control		Damage by heavy vehicles
		Spot failure repair		
Drainage	Culverts	Cleaning		Cleaning debris
	Roadside Drains	Cleaning		Cleaning debris
Roadside	Embankments			Slope failure
	Cut slopes	Removal of fallen		Slope failure repair (grouted riprap, rock net)
Bridges	Superstructure	Drainage		
	Foundation			Scouring protection / repair
	Others	Approach road settlement		
Traffic control device	Information and regulation signs, markings,		Repainting of markings	Replacement of crushed signs, etc.
Safety devise	Guard rails, barriers, etc.			Replacement of crushed guard rails, signs, barriers, etc.

Routine maintenance is the activity that needs to be undertaken each year. It consists of cyclic works whose needs depend on environmental effects rather than traffic like vegetation control, clearing of side drains and culverts, and necessary works to remedy minor defects caused by a combination of traffic and environmental effects such as crack sealing, patching and depression repair.

Periodic maintenance is the activity to be undertaken at the interval of several years. As the design period of asphalt pavement for the 2nd Kohat Tunnel and Access Roads is 10 years, an overlay of 5-10cm thick is required in future.

Special (or emergency) maintenance is the activity that cannot be foreseen with certainty. The relevant works undertaken by the Kohat Administration Office so far include repair of shoulders damaged by passage and parking of heavy traffic on them, repair of bridge foundations scoured by floods, slopes damaged by rain water runoff, guard rails crushed by vehicles and removal of the crushed or broken vehicles. The daily patrols currently practised are very effective for identifying the emergency works necessary to address safety issues and this should be continued.

The maintenance policies and procedures for roadways should be well established and a yearly budget be allocated based on the maintenance plan.

Maintenance of the safety devices includes maintenance and repair of guardrails, guide posts, barriers, curbs, etc. Maintenance of traffic control devices includes traffic signs, pavement markings and other information and regulation system. Traffic markings should be periodically repainted for safe traffic operations.

The damage of shoulders by passage of heavy vehicles on them for overtaking was one of the major problems in terms of traffic safety and maintenance costs for the 1st Kohat Tunnel and Access Roads. This kind of incidents will be reduced substantially after the construction of the additional two lanes. However, education of drivers to respect the yellow lines at the boundary of the carriageway and shoulder is also important to eliminate these bad practices even after the improvement of the road to the dual carriageway system.

Periodic inspection should be carried out for approximately 120 numbers of RC box and RC pipe culverts crossing the Project road. As roadway cross drainages account for 90% of these structures, their emergency inspection is necessary during and after heavy rains. It is recommended to establish the data base for these culverts and keep inspection records so that it is possible to identify the culverts for which intensive care or improvement is necessary.

The major problems of the existing cut slopes are erosion, rock fall and blockage of roadside drains by debris. The current daily patrol should include slopes inspection in order to take appropriate actions for maintaining safety of the traffic and the road facilities. As weathering of cut surface will continue, periodic inspection should be conducted to plan the permanent measures of slope stability works, wherever necessary, like rock net installation or construction of grouted riprap.

12.3 Overload Control of Heavy Vehicles

Overloading control is one of the important operations for safety of the tunnel and minimizing pavement failures. The Kohat Operation and Maintenance Office started overloading control operation utilizing weigh bridges at the Main Toll Plaza (Sta.10+600) in July 2006 in compliance with the National Highways Safety Ordinance 2000. This operation should be continued.

When heavy vehicles pass on a weigh bridge, their gross weight is transmitted to a computer and the magnitude of overloading and corresponding imposed fines are identified and indicated on an electrical board automatically. This system is expected to contribute to substantial reduction of overloaded vehicles as many drivers and transport operators are using this route customarily.

Another weigh bridge exists at the on-ramp of the Kohat Link Road. This facility should be also utilized for overload control.

However, it may be better to combine the overloading control stations at the New Toll Plaza (Sta.17+400) in future so that all heavy vehicles are subjected to inspection and measurement in an efficient way.

Another important measure for minimizing overloading is education of transport operators and drivers by providing information on the overloading control and fine system periodically. The data of overload control practice should also be distributed to these operators as a part of public information system.

12.4 Maintenance of Bridges

Routine inspection and minor maintenance such as cleaning of drainages should be carried out as a part of the road inspection and maintenance operation. Periodic inspection should be carried out using a standard inspection form. Special inspections should be carried out after floods to check the condition of the foundations.

The current problem of bridge maintenance is scouring of foundations (Bridge No.1) by floods and settlement of the bridge approaches as no approach slabs were provided. Inspection and repair are necessary for bridge approaches against depression for the traffic safety and minimizing adverse effects on the bridge structures. As approach slabs are designed for all new bridges of the 2nd Kohat Tunnel and Access Roads, bridge approach settlement will be reduced.

12.5 Operation and Maintenances of Tunnel

12.5.1 Tunnel Operation

NHA contracted the operation and maintenance of the 1st Kohat Tunnel to a private company named AXS Pakistan (Pvt) Ltd. who works as Management Contractor & Operator (MC&O). Under the control and supervision of the Chief Operating Officer of NHA, who stays in the Administration building, MC&O is providing the tunnel operation and maintenance services.

The scope of works of MC&O includes:

- Tunnel operation including operation of supervisory and control (SV&C) system, ventilation system, lighting system, radio communication system, electronic toll and traffic management (ETTM) system, etc.;
- Toll collection;
- Maintenance and cleaning of buildings, tunnel maintenance vehicles, facilities of various system facilities, cleaning of tunnel floor and walls, approach roads, toll plaza and weigh bridges.

About facility maintenance, MC&O is responsible for routine inspection and preventive maintenance, and preparation of preventive maintenance plans. Repair and maintenance of civil works of tunnel and approach roads is out of scope of MC&O, which is managed directly by NHA.

The document of the standard operating procedures (SOP) of management and organization, tunnel operation, audit and accounting, facility maintenance and SV&C system operation was firstly developed with assistance of the Japanese Tunnel O&M Experts who carried out training of the MC&O. The SOP is to be revised and updated from time to time, and Revision No.3 is currently used.

There are four main operational sites and at weigh bridges and sizing barriers for tunnel operation and maintenance:

- Control Room and South Emergency Response Building at the south tunnel portal (Sta. 20+190);

- North Emergency Building at the north tunnel portal (Sta. 18+650);
- Main Toll Plaza (Sta. 10+600); and
- Kohat Link Road Toll Plaza.

NHA is installing a single toll plaza at Sta. 17+350 while cancelling the Main Toll Plaza and the Kohat Link Toll Plaza.

There will be no substantial modification of the tunnel operation and maintenance system, even after completion of the 2nd Kohat Tunnel.

12.5.2 Maintenance of Tunnel Civil Structures

(1) Inspection

The inspection of tunnels is broadly divided into two categories. One is the inspection of civil structures such as lining, portals and drainage facilities and the other is checking and maintenance of facilities including ventilation system, machines and equipment, and the communication system.

The inspection for the civil structures is categorized to daily inspection (routine inspection and periodic inspection). The daily inspection covers soundness inspection of concrete, exfoliation and detachment of concrete and water leakage visually from car or by foot.

Periodical inspection is more detailed inspections and conducted to check cracks, tunnel lining, etc. in an inspection gallery.

Special inspection is conducted when unusual phenomena occur as a supplementary to the daily and periodical inspections.

(2) Maintenance and Improvement

Since tunnels are closed structures, maintenance is necessary particularly in view of disaster or accidents prevention. The maintenance includes cleaning surface, remarking, cleaning drainage facilities and repair and replacement of traffic signs. Annual programs should be provided and required budget should be secured.

Database for maintenance should be established such as inspection results, repair and improvement records.

12.6 Organization for Operation and Maintenance

NHA has a well-established organization for operation and maintenance of the tunnel (refer to Subsection 5.3 of this Report). The Standard Operating Procedures Manual (SOP) for operation and maintenance of the 1st Kohat Tunnel is introduced in Subsection 5.3 of this Report. NHA has contracted the operation and management of the 1st Kohat Tunnel and Access Roads to a private company (AXS Pakistan Ltd.) since its opening in May 2003 under overall supervision of the Chief Operating Officer of NHA at the Kohat Administration Office. NHA has sufficient fund for the operation and maintenance (O&M Cost) of the tunnel. NHA collects approximately Rs. 130 million of toll fees per year from the Kohat Tunnel and spends approximately 70% of the toll revenues for that outsourcing. As the current operation and maintenance system has worked well, the same methodology will be applicable for the 2nd Kohat Tunnel and Access Roads. However, NHA should make efforts to for reduce the O&M costs of tunnel while keeping the current safety and service level. Introduction of competition and collaboration with local authorities will be one of the future issues.

NHA has carried out the physical road maintenance and repair of road facilities by contract to private firms. This is a common practice and an effective way. However, NHA should establish a system for timely emergency repair of safety facilities, like guardrails, damaged by vehicles.A National Highway Safety Ordinance has been enacted to provide the legal basis for establishing the Highway and Motorway Police (NH&MP) Force under the federal Ministry of Communications. This measure expands the role of the motorway police to the National Highway System, in a phased manner.

The Motorway Police and NHA are under the same ministry and work together for the safety and efficiency of Motorway traffics.

For example overload control of trucks mentioned in 12.3, the fines collected at weigh bridges are transferred the Road maintenance Fund of NHA. At this moment, Ministry of Communication expanding these checking system and operating fine collection from the exceeding the limits of restricted value, under the Motorway Police so that the road users have gradually understand and agree the overload control system.

Chapter 13. ENVIRONMENTAL STUDY

13.1 Environmental Legislations and EIA Procedure in Pakistan

13.1.1 EIA Regulations

In 1997, the National Assembly passed the 1997 Pakistan EP Act (PEPA), which subsumed the 1983 ordinance. This Act requires IEEs and EIAs for all development projects.

Environmental impact assessment of all development projects, whether public or private, is a legal requirement under section 12 of PEPA of 1997, which became operational in 2001. Project categories requiring an IEE are listed in Schedule A (See Figure 13.1.1). Projects for which an EIA is required appear in Schedule B.

The Pakistan EPA Review of IEE and EIA Regulations 2000 ("The 2000 Regulations") prepared under PEPA 1997 define the procedures for IEEs and EIAs, and give legal status to the Pakistan Environmental Assessment Procedures prepared by the Federal EPA in 1997.

The number of EIA reports submitted to EPAs has increased from 6 in 2000 to 29 in 2004, and the number of IEE's has passed from 31 in 2000 to 189 in 2004.

A mandatory list for EIA or IEE regarding the transportation sector may be stated as follows:

According to following table, the project proponent of the 2nd Kohat Tunnel and access road project may be required to submit an EIA but this decision will be based on the judgment of NWFP EPA.

Table 13.1.1 Mandatory List for EIA / IEE

List of Projects Requiring an EIA (Schedule 2)	List of Projects Requiring an IEE (Schedule 1)
■ Mining & Mineral Processing · Major mineral development activities including those related with mining and processing of coal, gold, copper, iron, and precious stones · Major smelting plants · Major non-ferrous metals, iron and steel rolling ■ Transport · Major ports and harbors development · Major airports · Federal or provincial highways or major roads with a value superior to 5 crore rupees, and their required maintenance works (rebuilding or reconstruction of existing roads is excepted from EIA implementation). · Major railway works ■ Environmentally Sensitive Areas · Any project located in an environmentally sensitive or critical area should be carefully analyzed. Results of the said study shall be communicated to the authority in charge deciding whether an EIA is to be carried out (See "Guidelines for Sensitive and Critical Areas.") ■ Any other project that the EPA may require	■ Mining & Mineral Processing · Commercial extraction of sand, gravel, limestone, clay and other minerals not included in Schedule A. · Crushing, grinding and separating processes · Minor smelting plants ■ Transport · Port and harbor development projects for ships less than 500 gross tons · Federal or provincial highways (except maintenance, rebuilding or reconstruction of existing metalled roads) with a value inferior to 5 crore rupees. ■ Any other project that the EPA may require.

13.1.2 EIA Procedure

No proponent of a project can proceed unless having filed an Initial Environmental Examination (IEE) with the Federal EPA, and received the corresponding approval. No particular project may be preceded, if it is likely to cause adverse environmental effects, unless the pertinent EIA has been approved by the Federal Agency.

After the filing of the IEE, the Federal EPA must respond within 10 working days and state if the submission is acceptable or not, or if an EIA is required. If acceptable, the Federal EPA is required to review the IEE and approve it within 45 days. If an EIA is required, the EPA must review the EIA, after which, the agency has three possible courses of action: (1) The EPA can give its approval subject to certain conditions within 90 days; (2) require that the EIA be re-submitted after any stipulated modifications, or (3) reject the project itself.

Every review of an EIA must be carried out with public participation. No commercially confidential information shall be disclosed during the said public participation though, unless such disclosure is in the public interest. The Federal Agency must communicate its approval, or any other conclusion, within four months from the date the IEE or EIA are first filed. If the submission is complete and complies with the required procedure, but no response is given, then the IEE or EIA shall be deemed approved. The Federal Government can, at its discretion, extend the four months period, if justified by the nature of the project.

The Federal Agency must maintain separate registers for IEE and EIA projects containing brief particulars of each project, as well as a summary of decisions taken. These registers are to be open to the public. The procedure pertaining to IEE and EIA submissions and approvals is shown in Figure 13.1.1.

13.1.3 Environmental Management Plan

The project proponent will be responsible for ensuring implementation of those environmental mitigation measures recommended in the IEE or EIA. The corresponding Environmental Management Plan (EMP) should be prepared during the planning phase of the respective IEE/EIA. The said EMP should include specific mitigation measures, environmental monitoring requirements, institutional arrangements and its corresponding budget.

The EMP is a crucial document and should be prepared during the IEE / EIA planning phase. Approved by the EPA, the EMP is to be taken into consideration when defining the contractual obligations to be imposed on the contractor.

Implementation of the EMP while performing the corresponding construction works is the responsibility of the contractor. The contractor is responsible for environmental monitoring and reporting activities. The project proponent must ensure that the performance of the contractor is in accordance with EMP. The contractor should submit annually a report on EMP implementation. The monitoring and approval procedure is shown in Figure 13.1.2. The Federal EPA has delegated power to approve IEEs / EIAs to the provincial level EPAs.

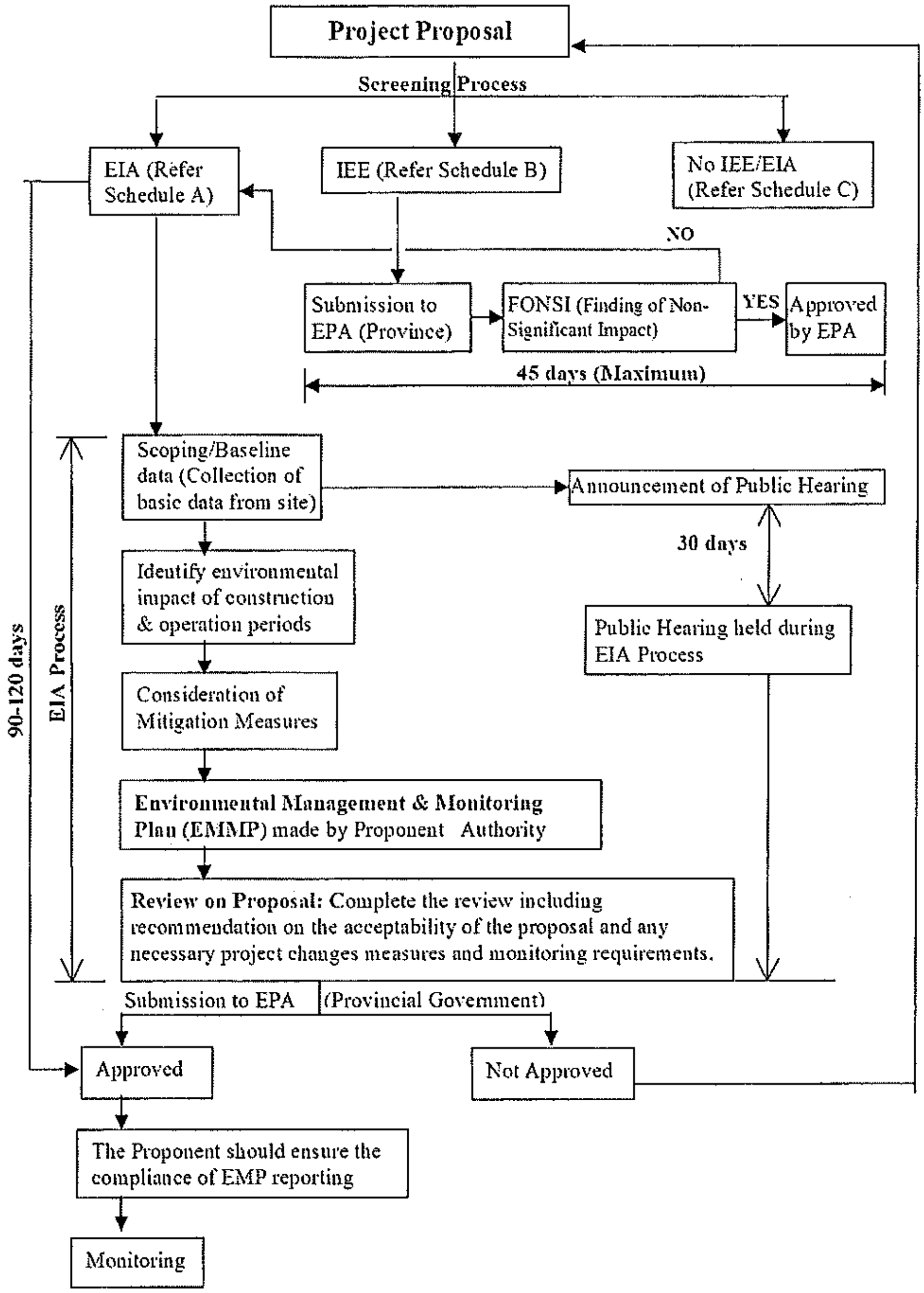


Figure 13.1.1 EIA Approval Procedures

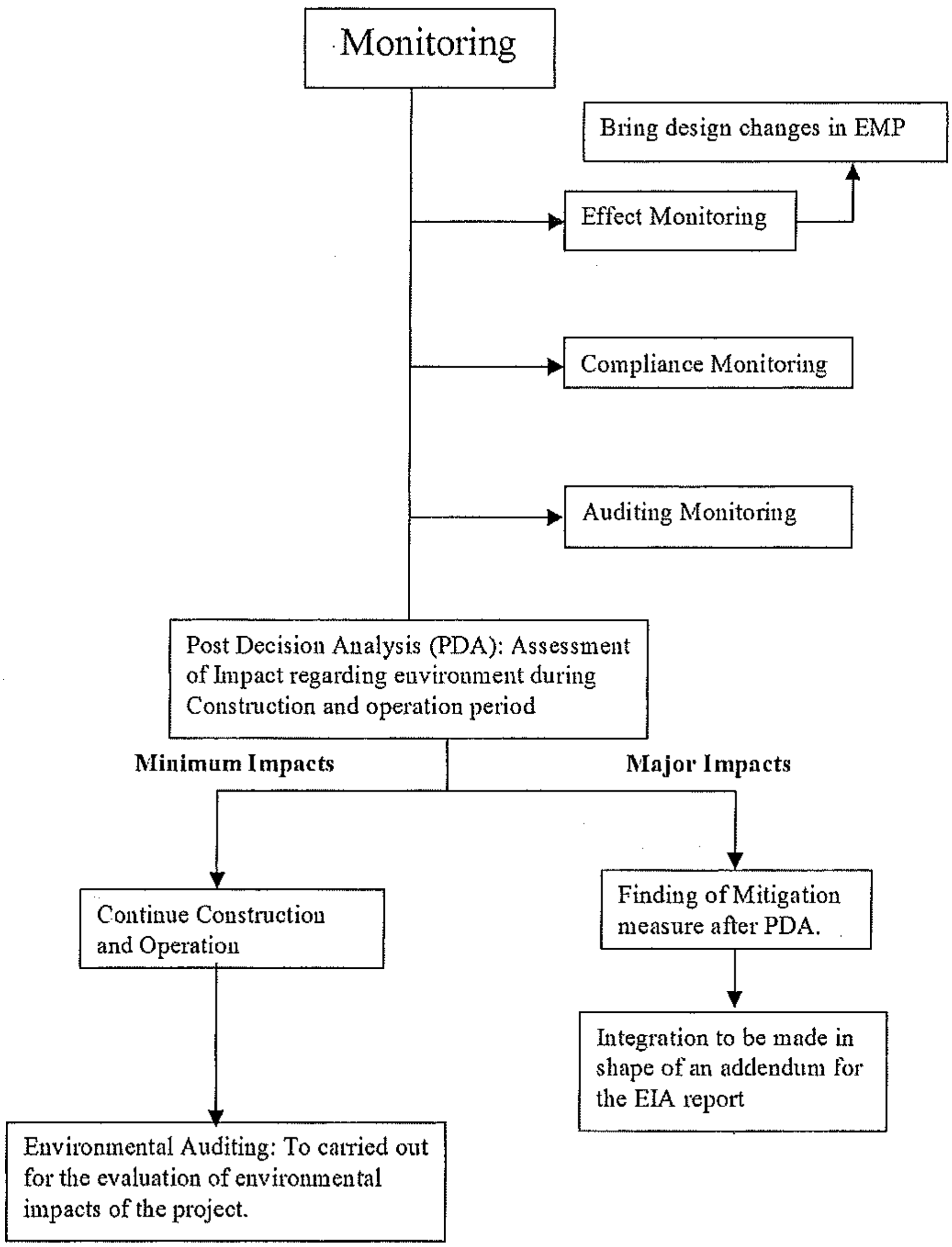


Figure 13.1.2 Post-EIA Monitoring Procedure

13.1.4 JICA and Pakistan EPA Guidelines

Upon comparing JICA guidelines and the requirements of the Federal EPA, no significant differences have been found.

JICA guidelines make reference to a Strategic Environmental Assessment (SEA), which the Pak-EPA does not mention. However, MOE would like to see this included at a policy level. Resettlement is taken into consideration in both guidelines. Nevertheless, MOE admits not to count on enough capacity to assess such an issue.

In relation to technical considerations, no relevant differences have been found. A comparison is provided below in Table 13.1.2:

Table 13.1.2 JICA and Pak-EPA Environmental Guidelines:
A Comparison of Requirements

Scope of Impacts for Evaluation in Environmental Assessments	
JICA	**Pak – EPA**
Direct and immediate impact of projects	Site selection
Derivative, secondary and cumulative impact	Indirect impact on natural resources
Environmental impact of a trans-boundary or global scale, e.g. global warming	Project-related impact
Impacts on natural environment:	Impacts on natural environment:
Air	Air quality
Water and water usage	Water quality, water supply, storm water management, ground water and flooding
Soils, ground subsidence, sedimentation and geographical features	Soil stability, soil erosion and sedimentation
Waste	Safe storage of materials on construction site
Accidents	Construction hazards, traffic accidents and disaster response plan
Ecosystems and biota	Flora and fauna (biota), destruction of habitats (ecosystems) and loss of species
Noise and vibration	Noise and vibration
Social considerations:	Social considerations:
Migration of people, social institutions and infrastructure local decision-making institutions, and existing social infrastructures and services	Displacement of existing uses, breakdown of community cohesion, and provision of replacement community facilities
Involuntary resettlement	Adequate resettlement and compensation to allow viable lifestyle to continue
Local economy, employment and livelihood distribution of benefits and losses, and equality in the development process	Economic issues and loss of livelihood
Land use and utilization of local resources	Landscape, visual amenity and induced land change
Cultural heritage	Cultural heritage
Infectious diseases such as HIV/AIDS.	Health and spread of diseases
Local conflict of interests among vulnerable social groups: poor and indigenous peoples, and gender and children's right issues	

13.2 Evaluation of Environmental Impacts by the First Kohat Tunnel and Access Roads Construction

13.2.1 Environmental Aspects of the First Kohat Tunnel and Access Roads

(1) Background

The National Highway 55, called the "Indus Highway," connects Karachi with Peshawar, and passes through the North-West Frontier Province near the Afghanistan border. This area is mountainous and has long been considered dangerous because of narrow roads, sharp curves and steep slopes. The 9.2 km-long mountainous Kohat Pass must be crossed to reach Peshawar. This represented a hot spot where frequent traffic accidents occurred, resulting in nearly 30 deaths every year, as large vehicles could not drive over this pass, and were required to make major detours. In order to ease traffic congestion and improve safety, the "Kohat Tunnel and Access Roads Construction Project" was initiated to provide an alternative route. The construction of a 1,885m long 2-lane tunnel began in 1999, and once it was completed, it enabled an easier passage for large vehicles, alleviated traffic congestion, improved traffic safety, and reduced mileage and travel time. The tunnel was inaugurated and opened to the public in June 2003. The tunnel increased the role of the Indus Highway (N-55) as a trunk road, stimulating social and economic development of the region, particularly in the North-West Frontier Province.

(2) Operations

The tunnel has an operational centre at its southern portal, as well as an emergency response centre at its northern portal. The operational centre maintains a close circuit television (CCTV) monitoring of the tunnel interior and access roads. It also controls the ventilation system and lighting. The longitudinal ventilation system is employed. There are five paired fans with provision for installation of three more pairs. The fans are capable of reverse flow, and this is determined by the wind direction at the north and south portals. The fans are designed to give a maximum ventilation speed of 5.6 m/second. In case of power failure, the fans may also run with an 11kv WAPDA (Water and Power Development Authority) supply including an UPS and a backup diesel generator.

The access roads connected to the tunnel have a design speed of 80kms/hr. The tunnel itself has a design speed of 60kms/hr. In fact, the speed limit in the tunnel is 40kms/hr, which means that the design transit time is around two or three minutes.

The tunnel ventilation system is designed to control two main parameters: Carbon monoxide (CO) and visibility. The tunnel sensor system has two carbon monoxide sensors, two visibility meters and a wind velocity meter near the portals. The design standard for CO requires concentrations to be maintained at less than 100 ppm, which is a level based on international practice. The design standard for visibility requires it to be kept below 40% obscuration at 100 metres. The ventilation system is based on a computer-controlled threshold activation system. A fan pair starts operating if the CO level rises above 30 ppm. If the said level persists, extra fans switch on. In case the visibility falls below 85%, the fans commence operation. The threshold system can also be controlled by manual override.

(3) Emergency Response and Safety

The emergency response centre provides facilities for on-site safety. It has a relief van for towing disabled vehicles movement, an ambulance, a fire engine and a water tanker truck. The fire fighting water tank next to the control room holds 200m^3 of water, of which 250 gallons per minute during two hours can be supplied. Emergency stopping lay-bys are provided in the tunnel. Fire extinguishers are provided every 100 meters, and five big extinguishers are located in the emergency areas. Traffic lights at both portals can be turned red in order to prevent traffic entering into the tunnel during an emergency. All staff working in the tunnel wear masks and carry personal CO exposure meters. There is a "Committee for Safety Action for Kohat Tunnel" called COMSAK.

(4) Environmental Impact Assessment and Issuance of NOC

In 2001, NHA requested NWFP EPA to issue a "Certificate of No Objection" for the tunnel construction and the corresponding operation. EPA pointed out that 36% of the tunnel had already been completed, and the application should have been made at the PC-1 planning stage. However, EPA stated that there were no overriding environmental reasons why the project should not proceed. Some conditions relating to construction drainage, ventilation, and safety reporting during construction were imposed, and NHA was requested to give an undertaking in order to comply with such conditions.

13.2.2 Current and Future Environmental Issues

(1) Vehicle Speed

Commercial vehicles in Pakistan are generally old and overloaded beyond their design load. They move slowly on gradients, and when climbing up even modest gradients of 2.2% in the tunnel, they usually limit their maximum speed to 10-20 km/hour. This reduces drastically the overall traffic speed, and vehicles require around 6-12 minutes to traverse the tunnel. For the Heavy Goods Vehicles (HGVs), this still compares favourably with the two to three hours previously needed to climb over the Kohat pass. As the Kohat tunnel is a single carriageway with dual lanes, private cars' drivers feel frustrated at having to follow those slow moving vehicles with no chance of overtaking them.

(2) Fire Hazard

The access roads to the tunnel are steep, and vehicles can overheat before they reach the tunnel. Despite this there has never been so far a major fire in the tunnel. Nevertheless, three fires in vehicles outside the tunnel, and a minor fire inside a bus in the tunnel have been reported. Apparently, this was due to a relief driver dropping a cigarette in his sleeping area. The bus exited the tunnel north portal, and the fire response team put out the fire after being alerted by the CCTV monitors.

Some vehicles are not permitted in the tunnel. Vehicles classed as HAZCHEM (carrying hazardous materials) are sent over the pass. Buses are not allowed to enter if passengers are sitting on the roof or have their arms outside the windows. Pedestrians are not allowed to pass through the tunnel either.

(3) Control of Overheating and Slow Vehicles

The tunnel operators have implemented a "convoy" system for slow smoking vehicles. Vehicles reaching the entrance to the south portal are ordered to stop and rest their engines. This gives their brakes and engines time to cool down. They are given free water for their radiators. Without having to wait more than ten minutes, they are then sent through in a group. Drivers accept this system and do not object as it allows their vehicles to cool off. This cooling is not needed in winter, only in summer.

(4) Fuel Quality

A major concern is the use of low-quality fuel in poorly maintained engines. Although certain allowances have been made in the design of the ventilation system for Pakistani vehicles, it is still suspected that petrol engines emit excessive CO, while diesel engines produce excessive smoke. In addition to this, the fuel used is high in sulphur, which can lead to considerable SOx emissions, and badly tuned diesel engines can emit high NOx emissions. These issues are not currently being monitored. Although vehicle emissions are excessive, the tunnel has removed traffic from the Kohat town centre, thus relieving urban congestion.

(5) Fiscal Control Measures

The tunnel management considered offering cheaper fares for slow and heavy vehicles to use the tunnel at night, and not during the day, in order to allow faster traffic speed for passenger cars. A proposal was submitted to NHA from Kohat chief operating officer, based on differing toll rates at different times. At present, HGVs pay an Rs150 toll. It was suggested to increase this up to the level of Rs200 during the day, and reduce it to Rs100 at night. This proposal has not met with general support, as it may encourage falsifying timings. Further, transporters complained that it would cause adverse effects on the timing of departures from certain points of origin such as Karachi. At the present moment, this initiative seems unlikely to be adopted.

(6) Interior Lighting

It has been indicated by NWFP EPA that the interior roof of the tunnel is dark. It was originally dark grey, this being the colour of cement. It has become darker due to soot from vehicles. The internal wall tiles and roof light panels are cleaned regularly, but the roof is not. This is because the electrical wiring is not waterproof, and use of high-pressure hoses would cause damage to the circuitry. In order to compensate for this, more lights are switched on, particularly in the transition zone from daylight to darkness at the portal entrances.

13.2.3 Issues Regarding the Second Kohat Tunnel

(1) Spoil Disposal

The construction of the aperture will be by rock tunnelling, with the rock spoil being removed in both, north and south directions. The access roads will require cutting of existing rock faces for widening. Each access road will also require fill material for new embankments. The mass balance is shown in Table 13.2.1 below. The extracted tunnel rock will be used as fill with 60% for the north approach road, and 40% for the south approach road. There will be a shortfall of approximately 594,000 m3 of material that will be needed for embankment formation. This will probably be taken from a borrow area to the south and east of the existing south access road.

Table 13.2.1 Cut and Fill Balance

	Cut Material	Fill Material
Tunnel	181,477 m^3	None
North access road	100,833 m^3	260,168 m^3
South access road	229,879 m^3	846,181 m^3
Total	512,190 m^3	1,106,349 m^3
Balance	None	- 594,159 m^3
N.B. The tunnel rock spoil will be used as fill: 60% for north road, and 40% for south road.	All figures estimated and accurate to ± 20%	Extra fill material will be prepared from existing borrow pit

(2) Air Quality Monitoring

It is not normal to monitor NOx and SOx in tunnels as they are pollutants which have long-term chronic effects. Conversely, CO has a direct short-term toxic effect, can be lethal at high concentrations, and is normally measured in real time. However, due to the large amount of adulterated fuel leading to high NOx and SOX emissions it may be useful to install NOx and SOx monitors in the second tunnel.

(3) Positive Benefits of Second Tunnel

The second tunnel will create several positive benefits:

- The operation of a second tunnel will provide two lanes of traffic per tunnel. This will allow overtaking in each tunnel so HGVs can use a slow lane and passenger cars can use a fast lane. The transit time through the tunnel should be restored to the design value of 3-4 minutes for cars.
- The ventilation system will be improved as all vehicles will be moving in the same direction. This will create a piston effect. Also the longitudinal fans will be more effective.
- The second tunnel will be close to the first tunnel, as their centrelines will be 30m apart. Two cross passages to connect two tunnels will be constructed and this is an added safety feature as it provides evacuations routes in the event of an emergency in either tunnel.

13.3 Initial Environmental Examination Based on the JICA's Environmental and Social Consideration Guidelines

13.3.1 Objectives and Methodology for the IEE

(1) Objectives

Initial Environmental Examination (IEE) means a study including analysis of alternative plans, prediction and assessment of environmental impacts, and preparation of mitigation measures and monitoring plans on the basis of secondary data and simple field surveys.

Objectives for the IEE are as follows:

- Before conducting environmental and social consideration activities based on the Pakistan's EIA law, the proponent should grasp the current status of the project site, possible impacts, required approval procedures and other relevant issues.
- The proponent will illustrate required mitigation measures based on IEE results, or adopt alternatives including such as "without the project."
- The proponent will conduct an environmental and social baseline survey through a scoping report based on the IEE.

(2) Target Items for the IEE

IEE has been carried out by exploratory and literature surveys. Items for the IEE are as presented below in Figure 13.3.1, and are all inclusive, which are described also in the JICA's and Pakistan's EIA Guidelines.

Table 13.3.1 IEE Items

Items	
1) Social Environment	a. Involuntary resettlement b. Local economy, employment and livelihood c. Land use and local resources utilization d. Existing social infrastructures and services e. Local communities f. Benefit and damage misdistribution g. Gender h. Children's rights i. Cultural heritage j. Local conflicts of interests k. Public sanitation l. Infectious diseases such as HIV/AIDS m. Water usage and rights n. Traffic accidents
2) Natural Environment	o. Global warming p. Biota and ecosystems q. Geographical features r. Soil erosion s. Underground water t. Hydrological situation u. Coastal zone (mangroves, coral reefs, tidal flats, etc.) v. Climate w. Landscape
3) Pollution	x. Air pollution y. Water pollution z. Soil contamination aa. Waste ab. Noise and vibration ac. Ground subsidence ad. Offensive odors ae. Bottom sediment in sea and rivers

13.3.2 IEE Results

(1) Outline of the IEE

The IEE has been carried out by the PTPS JICA Study Team, Environmental Specialists in the NHA and the NTRC, which included the following activities.

Table 13.3.2 IEE Outline

	Items
Data and Time Table	[31st May, 2006] ・0900-1030) Site survey from existing road (From Darra Village to NHA Kohat Office) ・1030-1200) Interview with NHA Kohat Office ・1200-1300) Site survey in operation room ・1300-1600) Site survey from existing road (1st Kohat Tunnel - Kohat junction – Kohat Town – Starting point for the project [south part of Kohat Town]) [7th June, 2006] ・1000-1200) Interview with Wildlife Dept. NWFP ・1300-1400) Interview with Wildlife Dept. Kohat ・1400-1500) Site survey

(2) Current Status

Current Status of the IEE may be explained as follows:

a) Social Environment

i) Involuntary Resettlement

The planned access road will pass through Darra Village. However, there are no inhabitants in the right of way. (See Figure 13.3.1)

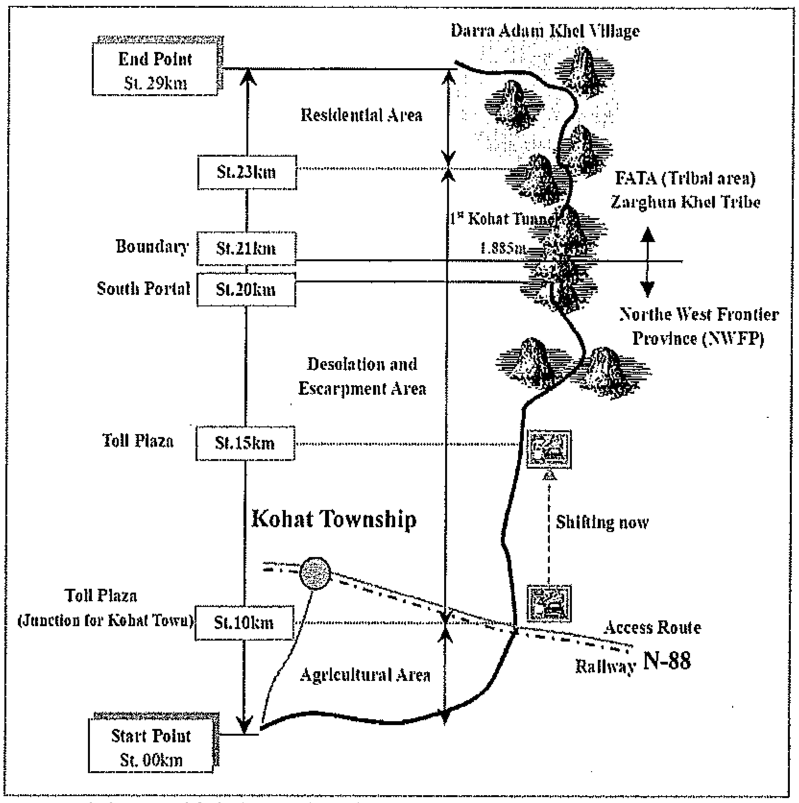


Figure 13.3.1 Project Image Map

ii) Local Economy, Employment and Livelihood

Darra Adam Khel village is one of the major residential areas through which the existing road passes. Darra Adam Khel is the nearest village to the project area that is located on the southwest side of Peshawar. The local economy in Darra Adam Khel is based largely on the gun-making cottage industry. Except agriculture, no other industries exist in the concession area. Scarcity of water does not support commercial agricultural activity. A large proportion of the population's livelihood is based on service industries such as the armed forces, police, militia and other services. The ratio of people having agriculture as means of livelihood is very small. The remainder of the population is engaged in various types of business either in Peshawar, Karachi, Rawalpindi and other cities of Pakistan.

iii) Land Use and Local Resources Utilization

Due to limited water supplies for irrigation, the level and management of agricultural practices in the project area is low. As a result, subsistence agriculture does not produce enough to meet the food and financial requirement of the farming population. Rainfall uncertainty is also one of the major reasons for low agriculture production. Major crops in the project area are rain fed, such as groundnuts and pulses in Kharif, and wheat, barley and oil seeds.

Roughly 50% of the total project area is not available for cultivation because of the existence of hills, mountains and houses. Due to the inaccessibility, between 25% and 30% of the total cultivable land is not cultivated at all. The cropped area in any season amounts to only about 20% of the total cultivable area. In the project area, the agricultural area starts from about 10 km from the Kohat Toi junction, the escarpment area from 10 to 22 km, and the residential / settlement area from 22 to end point.

iv) Social Infrastructure and Local Decision-making Institutions

The project area is located in the tribal area called Frontier Region (FR) Kohat, which is about 23 to 25 km away from the provincial capital of Peshawar. The jurisdiction of FR Kohat starts from the check post of Spina Thana and culminates towards Kohat Tunnel in its south. Thereafter, the jurisdiction of the provincial government starts (both ends of the tunnel). Here in the project area, the administration of two governments are thus involved.

In the southern part of the project area a small mosque, some shops and a restaurant are situated on the existing access road. No other relevant infrastructure is available.

v) Local Communities

In Darra Adam Khel, there are five tribes residing: the Zarghun Khel, the Akhurwal, the Shareki, the Tur Chapper and the Bazti Khel Tribes. Details are available in b) above.

vi) Benefits and Reduction of Damage

The construction of the Kohat Tunnel will not only reduce the traveling time between Peshawar and Kohat, but also reduce environmental pollution in the tunnel due to vehicular emissions. There will also be a great saving in fuel consumption.

vii) Gender

This implementation of this project will not affect the movement of women due to local customs.

viii) Children's Rights

No findings in the site survey were available.

ix) Cultural Heritage

The culture and traditions of this area are deeply motivated by, and related to Pushtuns customs. During the survey, neither sites of archaeological importance likely to be considered as a world cultural heritage or national heritage, nor historical cultural heritage findings have been identified in the project area. However, each village has a graveyard on its outskirts usually located on common property, which is called Shamilaat.

x) Local Conflicts of Interests

There is no conflict among local people and the government during the 1st Kohat Tunnel project because the public authorities have already provided and distributed displacement reimbursement fees to local village leaders.

However, certain disputes among local people and the village leaders still exist due to non-transparent distribution of government money on occasions.

xi) Public Sanitation

In the Darra Adam Khel area, no proper drainage or sanitation system exists. The people are mostly illiterate, and they are still using primitive types of toilet.

xii) Infectious Diseases such as HIV/AIDS

In the Darra Adam Khel tribal area, there are no reported signs of any infectious diseases like HIV, AIDS, etc.

xiii) Water Usage and Rights

In the Darra Adam Khel area, no river or canal exists. A tube well system is available, but a piped water distribution system is very limited. Ground water is available only after rainfall. Water wells and hand pumps are operational only sporadically, not throughout the year round. A majority of residents located in the project area rely on the water accumulated from rainwater, which they consider to be fit for human consumption.

b) Natural Environment

i) Traffic Accidents

In the project area, due to reckless and rough driving, minor traffic accidents are observed.

ii) Global Warming

No findings in the site survey have been observed.

iii) Biota and Ecosystems

The native vegetation of the project area is limited to shrubs and dry sub-tropical temperate vegetation. There is no major forest cover in the project area, and no exotic species or medicinal plants were found. Hence, there is quite limited fauna and flora in the escarpment area, with the exception of some birds of prey.

The DFO Wild Life Department NWFP Kohat City considers that the project site has few sensitive areas, forest reserves, product reserves, or endangered species, hence, have "no objection" regarding this project.

iv) Geographical Features

The region expanding from the start point to 15 km is a plain area; the one from 15 km to 19 km is hilly; and from 19 km to 29 km (end point) the site is an escarpment area. The escarpment area has a very steep rocky slope in which truck accidents occur from land sliding.

v) Soil Erosion

As it is explained in the "Geographical Features" section, landslide and soil erosion are confirmed in the escarpment and hilly areas. Annual rainfall is around 400 mm, but its hourly rainfall intensity is very high, which removes soil from the agricultural field to the seasonal river "wadi".

vi) Underground Water

According to the local people, the underground water is fresh water, found at about 300 to 400 ft depth. The water is located underneath rocks with low permeability and infiltration rates. During the site visit, ground water extraction was not observed. Because of its location at a considerable topographic depth, it is considered that no exploitable underground water resources exist in the project area.

vii) Hydrological Situation

Underground water may come out through excavation activities for tunnel construction. However such volume will be limited and will not impact the existing hydrological situation.

viii) Coastal Zone (mangroves, coral reefs, tidal flats, etc.)

There is no coastal zone or sensitive habitat in the river.

ix) Climate

As the project area is mountainous, variations in local temperature are obvious. The climate is marked by seasonal fluctuations in temperature and rainfall. The climatic conditions of the project area vary from extreme cold in the snow-clad mountains, to hot and sultry in the plains. The rainfall is scanty, varying from 150mm in the hills, to 40mm or less in the plains, per year.

x) Landscape

The landscape is categorized into two types: One is the desert plain and hilly area, and the other is the skyline of the escarpment area. The most representative element of these areas is a few acacia trees and rocks.

c) Pollution

i) Air Pollution

Ambient Air Quality Standards (AAQS) have not yet been introduced in any part of Pakistan, and there is no data available on the measured values of SPM (Suspended Particulate Matter), SOx, NOx, Lead, CO, and other traffic related pollutants.

According to the data obtained in the operation room in 1st Kohat Tunnel, the CO meter shows very low values of around 1-5 ppm at both portals, much less than the allowable max of 100ppm.

In dry weather, especially in sand storms, high dust levels may cause visibility problems for transportation. Visibility problems can also arise in cold or foggy winter seasons as well.

ii) Water Pollution

As there is no river or canal in the project area, there is no effect on water.

iii) Soil Contamination

No findings in the site survey are available.

iv) aa) Waste Solid

No findings in the site survey are available.

v) ab) Noise and Vibration

The residential area in Darra Village is set back by at least 50 meters from the existing road. So far, there are no complains regarding noise or vibration.

vi) ac) Ground Subsidence

No findings in the site survey are available.

vii) ad) Offensive Odors

No findings in the site survey are available.

13.4 Scoping for Environmental and Social Considerations through the IEE

13.4.1 General Information in the Project Site

(1) Natural Conditions

Much of Pakistan is a dry, sun-scorched region. To the west of the Indus are the rugged dry mountains of the Sulaiman Range, including the project area, and merging with the treeless Kirthar Range in the south. Farther west are the arid regions of the Baluchistan Plateau and the Kharan Basin. A series of mostly barren low mountains and hills predominate in the western border areas. Furthermore, there are no wetlands, major rivers with continuous flow or sensitive forests.

(2) Climate

The climate of Pakistan varies widely with sharp differences between the high mountains and low plains. The country experiences four seasons. In the mountainous regions of the north and west, including the project area, temperatures fall below freezing during the winter and are mild during the summer. Average temperature through the year in Peshawar is around 22 degrees Celsius. The minimum temperature is 11 degrees Celsius in January, while the maximum temperature is 33 degrees Celsius in June.

In relation to rainfall, most precipitations come with the summer monsoons during February, March, April, July and August. The summer monsoons are seasonal winds that bring torrential rainfall, breaking the hot, dry spell and providing much-needed relief.

The annual rainfall level is approximately 400 – 500 mm. The minimum rainfall level is 10 mm in June, while the maximum is around 70 mm in March or August.

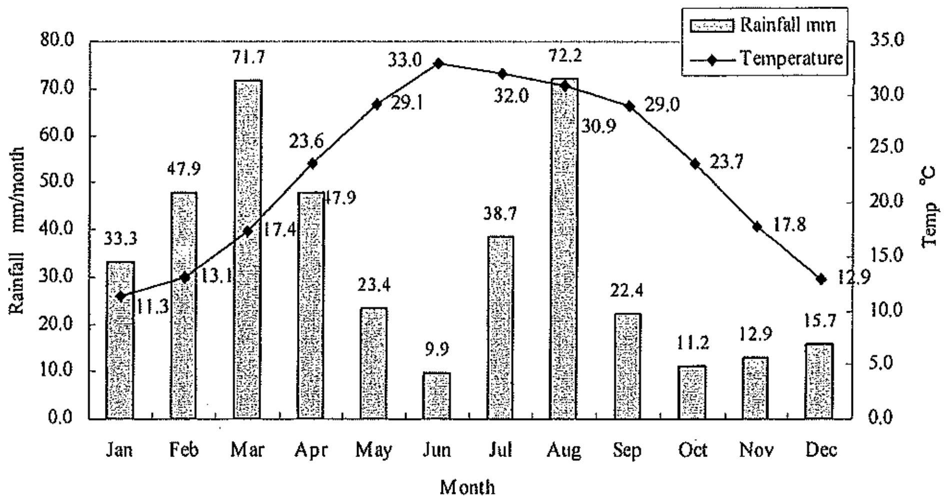


Figure 13.4.1 Annual Rainfalls and Temperature in Peshawar

(3) Public Administration

The ethnic groups of Pakistan are distributed according to their historical settlement in the region. The current political regions of Pakistan roughly correspond to the settlement patterns established long before the partition of British India in 1947, when Pakistan was created as a homeland for Indian Muslims. The four provinces are: Punjab, the Muslim portion of the historic Punjab region; Sind, the traditional homeland of the Sindhis; the North-West Frontier Province (NWFP), a small portion of the Pashtun tribal lands; and

Baluchistan, a portion of the Baluchi tribal lands. The traditional homelands of the Pashtuns and Baluchis extend beyond the political borders, both provincial and national.

The NWFP consists of a population of 17.7 million (2002), while the majority corresponds to Pashtuns. The province is a part of the historic Pashtun tribal lands, which extend throughout southern and southeastern Afghanistan well into western Pakistan, including the Federally Administered Tribal Areas and northern Baluchistan. The NWFP is Pakistan's smallest province in terms of size. In the 1980s, refugees from war-torn Afghanistan began to settle in the province. Refugee camps and rudimentary villages were set up in the border areas. A large number of refugees also established communities in cities such as Peshawar. Many became semi-permanent residents of Pakistan because Afghanistan remained in a state of war through the mid-1990s. The majority of refugees were Pashtuns, facilitating their assimilation into the province's population, in many cases through marriage.

In relation to the project area, from the start point near Kohat Town to Kohat Tunnel (21 km from start point) is located in NWFP, while from 21 km to the end point is in the Federally-Administered Tribal Areas (FATA), Zarghun Khel Tribe, and Orakuzai Agency.

(4) Industry

The major industry in the project area is agriculture, such as wheat. In Pakistan, about 28 % of the total land area is cultivated. Agriculture and related activities, including fishing, engage 48 % of the workforce and provide with 23 % of the GDP. Major cash crops are cotton (textile yarn and fabrics produce more than one-half of export earnings) and rice. Principal crops in 2004 (with output in metric tons) included the following: Sugarcane, 52 million; wheat, 19.8 million; rice, 7.6 million; cotton lint, 6 million; and corn, 1.8 million. Livestock included cattle, water buffalo, sheep, goats, and poultry.

However, it is said that firearms manufacture is the major industry in the Darra Adam Khel village, north of Kohat tunnel. Kohat Town is famous for being a military town with its own armaments industry located on the border. It also counts on restaurants and workshops.

13.4.2 Planned Project Design and Activities by Stages

(1) Project Outline

The project in question is represented by a series of construction works pertaining to the 2nd Kohat Tunnel and the expansion of the access road from two to four carriageways. (See Figure 13.4.2)

As described in the design, most of the additional part of the access road will be in the right of way, totaling 66.7 meters (200 yards), except from the bridge to the south portal of the 2nd Kohat Tunnel.

Both Kohat Tunnels are to permit one-way traffic, with the first one being for traffic towards Peshawar City, and the second being for traffic towards Kohat Town.

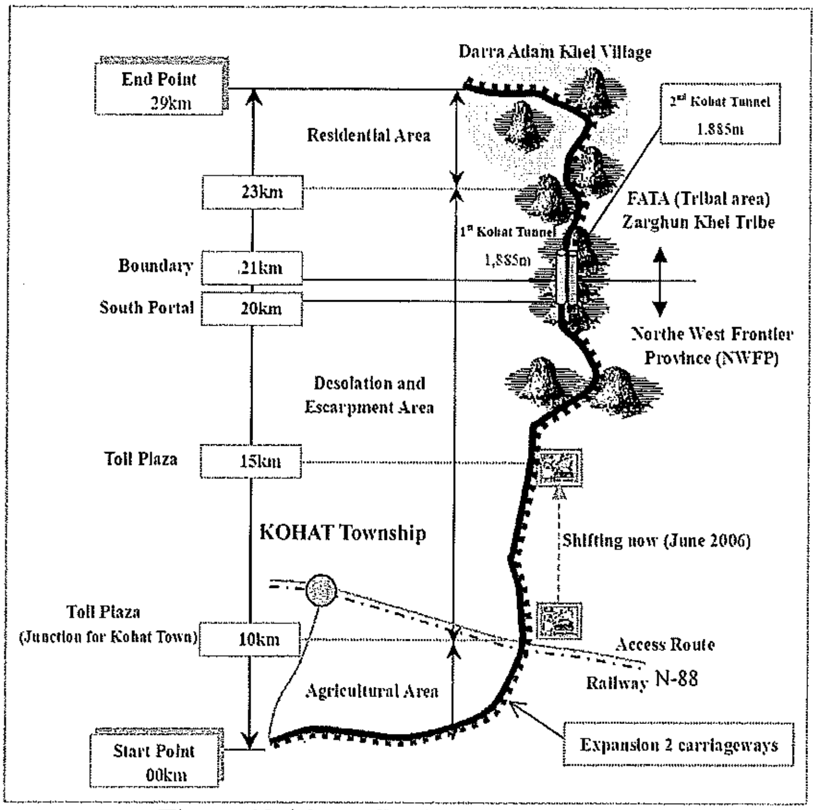


Figure 13.4.2 Project Image Map

(2) Project Activities by Stage

The project activities that may result in adverse impacts are those that, during construction, imply the drilling for the tunnel, cutting escarpment area and creating embankments along the existing access road.

On the other hand, major activities or changes to be obtained after implementation of construction works are vehicle transportation and existence of the tunnel and embankment.

Table 13.4.1 Project Activities (by Stage)

	ACTIVITIES	DEGREE OF PREDICTED IMPACTS
During Construction	1. Clearance (Right of way, yard and base camp)	D
	2. Cutting and drilling of the escarpment area	D
	3. Creation of embankment	D
	4. Operation of heavy vehicle	D
	5. Labor's occupation in the base camp and around villages	B
	6. Operation in borrow pit and quarry	D
Post Construction	1. Existence of the road, embankment and tunnel	D
	2. Traveling of vehicles	E
	3. Management of the tunnel (Monitoring for traffic safety and air quality)	D

A: Expected serious impact
B: Expected certain impact
C: Not clear, further detailed information required
D: Expected minor impact
E: Expected positive impact

13.4.3 Predicted Environmental and Social Impacts by Stages

An outline of the expected positive and negative impacts by stages and works may be presented as follows.

Regard to resettlement and land acquisition, it is considered that there is no impact in this project. Hence relevant law and guidelines are placed as reference data in the appendix.

Table 13.4.2 Predicted Impacts Outline

	Items	Comprehensive Rating	Predicted Impacts			
			Rating	During Construction	Rating	Post Construction
Social Environment	1. Involuntary resettlement	D	D	Resettlement will not occur due to nonexistence of inhabitant in the right of way. However road alignment may touch a part of house wall in the Darra Village.	D	Few activities that may provoke adverse impact are predicted.
Social Environment	2. Local economy, employment and livelihood	E	E	Most of workers for the project will be hired from nearest residential areas, such as the Darra Village or Kohat Town. Further, related consumption shall take place in the same residential area, with which this project is likely to have a positive impact in the zone.	D	In the Darra Village, the main industry is agriculture. Military industry is prevalent in the Kohat Town. Therefore, this project is likely to provoke no more than a minor adverse impact.
Social Environment	3. Land use and local resources utilization	D	C	Drilling for the tunnel may cut conductions for residents' drinking water in the Darra Village.	D	Few activities that may provoke adverse impact are predicted.
Social Environment	4. Existing social infrastructures and services	D	D	There is no social infrastructure on the designed route. A mosque is located at St. 19.5 km from start point, but it is out of right of way.	D	Few activities that may provoke adverse impact are predicted.
Social Environment	5. Local communities	D	D	Few activities that may provoke adverse impact are predicted.	D	As described in "Site Description," the project area is managed by two public administrations: One is FATA (Orakzai Agency), and the other is Kohat district NWFP. No conflict between them regarding this project has been found. No adverse impact is predicted so far. In the next stage, the proponent should collect stakeholders' feedbacks through meetings.
Social Environment	6. Benefit and damage misdistribution	E	E	Most of workers for the project will be hired from nearest residential areas, such as the Darra Village or Kohat Town. Further, related consumption shall take place in the same residential area, with which this project is likely to have a positive impact in the zone.	E	Traveling cost and time will be reduced, and such benefit will be distributed fairly.
Social Environment	7. Gender	D	D	Few activities that may provoke adverse impact are predicted.	D	Few activities that may provoke adverse impact are predicted.
Social Environment	8. Children's rights	D	D	Few activities that may provoke adverse impact are predicted.	D	No activities likely to give adverse impact have been predicted.
Social Environment	9. Cultural heritage	D	D	No world heritage, national monument or provincial monument may be found in the nearby.	D	No activities likely to give adverse impact have been predicted.

	Items	Comprehensive Rating	Predicted Impacts			
			Rating	During Construction	Rating	Post Construction
	10. Local conflicts of interests	D	D	Few activities that may provoke adverse impact are predicted.	D	As described in "Site Description," the project area is managed by two public administrations: One, FATA (Orakzai Agency); the other, Kohat district NWFP. No conflict between them has been observed regarding this project. No adverse impact so far has been predicted. In the next stage, the proponent should collect stakeholders' feedback from meetings.
	11. Public sanitation	E	E	Most of workers are likely to stay in the Darra Village or Kohat Town. Public sanitation systems including toilets or water supply conditions may improve as a result of the increase in their earnings.	E	Traveling cost and time will be reduced through implementation of this project, resulting in a considerable economic benefit to the project area. This project will also improve public sanitation systems.
	12. Infectious diseases such as HIV/AIDS	B	B	Some of workers or technicians are from foreign countries. In some cases, such labors may have relation with prostitution. Possibilities of spreading sexually transmitted disease (STD) and infectious diseases among workers and residents are real.	D	No activities likely to give adverse impact have been predicted.
	13. Water usage and rights	C	C	Drilling or cutting works may cut connections for drinking water in Darra Village.	D	No activities likely to give adverse impact have been predicted.
	14. Traffic accidents	E	D	Construction activities will be carried out separately to present access road and tunnel. Hence, few activities that may provoke adverse impact are predicted.	E	Present congestion in the first Kohat tunnel is to be solved
Natural Environment	15. Global warming	D	D	No activities likely to give adverse impact have been predicted.	E	Reduction of traveling cost and time will save greenhouse gases.
	16. Biota and ecosystems	D	D	Limited fauna and flora in the project area are found. Few rare and endangered species such as listed IUCN and CITES have been found in the area.	D	Limited fauna and flora in the project area are found. Few rare and endangered species such as listed IUCN and CITES have been found in the area.
	17. Geographical features	D	C	Project route is lying in valleys with steep escarpment with frequent landslide. Project works may also trigger landslide.	D	Landslide will be minimized by implementation of disaster protection in this project
	18. Soil erosion	C	C	Cutting steep slope without countermeasure design may provoke soil erosion.	C	Cutting steep slope and creation of embankment without countermeasure design may provoke soil erosion.
	19.Underground water	C	C	Drilling or cutting works may cut conductions for drinking water in Darra Village.	D	No activities likely to give adverse impact have been predicted.
	20. Hydrological situation	D	D	Few activities that may provoke adverse impact are predicted.	D	No activities likely to give adverse impact have been predicted.
	21. Coastal zone (mangroves, coral reefs, tidal flats, etc.)	D	D	There is no ecozone such as mangrove and swamp area	D	There is no ecozone such as mangrove and swamp area
	22. Climate	D	D	Few activities that may provoke adverse impact are predicted.	D	No activities likely to give adverse impact have been predicted.

	Items	Comprehensive Rating	Predicted Impacts			
			Rating	During Construction	Rating	Post Construction
	23. Landscape	D	D	Few activities that may provoke adverse impact are predicted.	D	No activities likely to give adverse impact have been predicted.
Pollution	24. Air pollution	E	D	Cutting escarpment and transportation of materials for creation of embankment will provoke dust pollution.	E	Ambient air quality is expected to be the same as present condition due to maintenance of similar traffic volume. Improvement inside of tunnel is expected as a result of increasing of lanes.
	25. Water pollution	D	D	Although water and mud discharge from drilling of tunnel is to be pumped out to the nearest river, no toxic substances are included.	D	No activities likely to give adverse impact have been predicted.
	26. Soil contamination	D	D	Although soil discharge from drilling of tunnel is to be expelled outside, such soil will be used for materials of embankment	D	No activities likely to give adverse impact have been predicted.
	27. Waste	D	B	Labor's occupation may result in waste solid and night soil in work base camp and surrounding areas.	D	No activities likely to give adverse impact have been predicted.
	28. Noise and vibration	D	D	Construction vehicles will drive through the old current road in the Darra village. Although traffic noise is not likely to exceed 75 dB (A) for 12 hours, the proponent may receive complains from residents living along the old road in Darra FATA.	D	Complaints from residents on current traffic noise and vibration have not been observed so far. Further, calculated traffic noise after construction is likely to be less than 85 dB (A), without exceeding WHO Guidelines.
	29. Ground subsidence	D	D	No activities likely to give adverse impact have been predicted.	D	No activities likely to give adverse impact have been predicted.
	30. Offensive odors	D	D	No activities likely to give adverse impact have been predicted.	D	No activities likely to give adverse impact have been predicted.
	31. Bottom sediment in sea and rivers	D	D	Although water and mud discharge from drilling of tunnel is to be pumped out to the nearest river, no toxic substances are included.	D	No activities likely to give adverse impact have been predicted.

13.4.4 Proposed Mitigation Measures and alternatives by Stages

(1) Alternatives

Some options for alignment of the access road and tunnel location have been considered. However, as such options are less attractive for economic reasons, it was decided that the present route and location represented a more practical alternative.

In the scenario that this project is not conducted, the present 1st Kohat Tunnel is to become a bottleneck to the Indus Highway that is time wasteful and fuel costly for vehicles passing the Kohat Pass.

(2) Mitigation Measures

Proposed mitigation measures are as follows in Table 13.4.3.

Table13.4.3 Proposed Mitigation Measures

	Items	Comprehensive Rating	Proposed Mitigation Measures			
			Rating	During Construction	Rating	Post Construction
Social Environment	1. Involuntary resettlement	D	D	a) Construction of access road in right of way b) Holding of stakeholders meeting in the Darra Adam Khel village FATA and Kohat Town c) Set up by relevant bodies of a service to handle complaints	D	Not required
Social Environment	2. Local economy, employment and livelihood	E	E	Not required	D	a) Discount of toll charge for residents in the Darra village and Kohat district
Social Environment	3. Land use and local resources utilization	D	C	In the case of cutting drinking water conduction, the proponent should set up a new well.	D	Not required
Social Environment	4. Existing social infrastructures and services	D	D	a) Construction of access road in right of way b) Holding of stakeholders meeting in the Darra Adam Khel village FATA and Kohat Town c) Reconstruction of such social infrastructure	D	Not required
Social Environment	5. Local communities	D	D	Not required	D	Not required
Social Environment	6. Benefit and damage misdistribution	E	E	Proponent should hire labors from nearest village	C	Discount toll charge for residents in the project area
Social Environment	7. Gender	D	D	Not required	D	Not required
Social Environment	8. Children's rights	D	D	Not required	D	Not required
Social Environment	9. Cultural heritage	D	D	Not required	D	Not required
Social Environment	10. Local conflicts of interests	D	D	Holding of stakeholders meeting in the Darra Adam Khel village FATA and Kohat Town	D	Not required
Social Environment	11. Public sanitation	E	E	Not required	E	Not required
Social Environment	12. Infectious diseases such as HIV/AIDS	B	B	Healthcare education of workers	D	Not required
Social Environment	13. Water usage and rights	C	C	In the case of cutting drinking water conduction, the proponent should set up a new well.	D	Underground water from tunnel should be lead to the Darra village by piping it.
Social Environment	14. Traffic accidents	E	D	a) Education on traffic rules to workers b) Staffing of traffic control c) Create diversion ways and no use of certain existing road by inhabitants	E	Not required
Natural Environment	15. Global warming	D	D	Not required	E	Not required
Natural Environment	16. Biota and ecosystems	D	D	Not required	D	Not required
Natural Environment	17. Geographical features	D	C	Setting up of slope protection	D	Periodical monitoring and maintenance
Natural Environment	18. Soil erosion	C	C	Setting up of slope protection	C	Periodical monitoring and maintenance
Natural Environment	19. Underground water	C	C	In the case of cutting drinking water conduction, the proponent should set up a new well.	D	Underground water from tunnel should be lead to the Darra village by piping it.
Natural Environment	20. Hydrological situation	D	D	Not required	D	Not required

	Items	Comprehensive Rating	Proposed Mitigation Measures			
			Rating	During Construction	Rating	Post Construction
	21. Coastal zone (mangroves, coral reefs, tidal flats, etc.)	D	D	Not required	D	Not required
	22. Climate	D	D	Not required	D	Not required
	23. Landscape	D	D	Not required	D	Not required
Pollution	24. Air pollution	E	B	Sprinkling water near residential area to reduce suspended particles	E	Monitoring of air quality such as CO in the tunnel
	25. Water pollution	D	D	Not required	D	Not required
	26. Soil contamination	D	D	Not required	D	Not required
	27. Waste solid	D	B	Education of waste separation and appropriate disposal	D	Setting up signboards for prohibition of littering
	28. Noise and vibration	D	D	a) Fixing of work time (limited work time in the daytime) b) Consideration of praying time	D	Not required
	29. Ground subsidence	D	D	Not required	D	Not required
	30. Offensive odors	D	D	Not required	D	Not required
	31. Bottom sediment in sea and rivers	D	D	Not required	D	Not required

13.5 Terms of References for Baseline Surveys

13.5.1 Items to be Surveyed and Monitored by Stages

As mentioned earlier, the project proponent of the 2nd Kohat Tunnel and access road project may be required to submit an EIA but this decision will be based on the judgment of NWFP EPA.

The project proponent should carry out following baseline survey in the case of full scale EIA.

Proposed baseline survey for the EIA and monitoring items are shown in following table:

Table 13.5.1 Baseline Survey Items and Monitoring Items

Items		Baseline Survey	Monitoring Survey	
			During Construction	Post Construction
Social Environment	1. Involuntary resettlement	a) Counting all houses on right of way and planned route b) Holding a stakeholders meeting in the Darra village and Kohat town	Interview with village leader	Interview with village leader
	2. Local economy, employment and livelihood	Social survey through interview with inhabitants	Not required	Not required
	3. Land use and local resources utilization	Making land use map by aerial photograph	Not required	Not required
	4. Existing social infrastructures and services	a) Counting social infrastructures such as schools, religious facilities, graveyards, water supply pipes and meeting places on right of way and planned route b) Holding a stakeholders meeting in the Darra village and Kohat town	Not required	Not required
	5. Local communities	Social survey through interviews with inhabitants	Not required	Interview with village leader
	6. Benefit and damage misdistribution	Social survey through interviews with inhabitants	Not required	Interview with village leader
	7. Gender	Not required	Not required	Not required
	8. Children's rights	Not required	Not required	Not required
	9. Cultural heritage	a) Social survey through interviews with inhabitants (Local cultural heritage, graveyard and sanctuary) b) Confirmation in relevant department in NWFP	Not required	Not required
	10. Local conflicts of interests	Social survey through interviews with inhabitants	Not required	Not required
	11. Public sanitation	Social survey through interviews with inhabitants	Not required	Not required
	12. Infectious diseases such as HIV/AIDS	Social survey through interviews with inhabitants and medical doctor	Social survey through interviews with inhabitants and medical doctor	Social survey through interviews with inhabitants and medical doctor
	13.Water usage and rights	Social survey through interviews with village leader (location of well, pump displacement and water quality)	Not required	Social survey through interviews with village leader
	14. Traffic accidents	Collection of statistical data from NHA and police department	Collection of statistical data from NHA and police department	Collection of statistical data from NHA and police department

Items		Baseline Survey	Monitoring Survey	
			During Construction	Post Construction
Natural Environment	15. Global warming	Not required	Not required	Not required
	16. Biota and ecosystems	a) Interview with Wildlife Dept. and Forest Dept. in Kohat Town b) Fauna and Flora survey by specialists on right of way and planned route	Interview with Wildlife Dept. and Forest Dept. in Kohat Town	Interview with Wildlife Dept. and Forest Dept. in Kohat Town
	17. Geographical features	Geological survey by drilling	Not required	Not required
	18. Soil erosion	Natural environment survey through interview with village leader	Not required	Not required
	19.Underground water	a) Natural environment survey through interview with village leader b) Measurement of underground water in well in the Darra Village	Measurement of underground water quality (every month / pH, COD, F)	Measurement of underground water quality (every month / pH, COD, F)
	20. Hydrological situation	a) Natural environment survey through interview with village leader b) Check of river condition in rainfall	Not required	Not required
	21. Coastal zone (mangroves, coral reefs, tidal flats, etc.)	Not required	Not required	Not required
	22. Climate	Collection of statistical data from Kohat Town and NHA Kohat operation center	Not required	Not required
	23. Landscape	Taking pictures on present condition from major residential area	Not required	Not required
Pollution	24. Air pollution	a) Measurement of ambient air quality in the Darra and Kohat Town (NO+NO2, SO2, CO and TPM) b) Data Collection of air quality inside tunnel from NHA Kohat operation room	Measurement of TPM (Total Particulate Material) in the Darra and Kohat town	a) Measurement of ambient air quality in the Darra and Kohat Town (NO+NO2, SO2, CO and TPM) b) Data Collection of air quality inside two tunnels from NHA Kohat operation room
	25. Water pollution	Not required	Not required	Not required
	26. Soil contamination	Pollution survey through interview with village leader (history of land use and factory)	Not required	Not required
	27. Waste Solid	Pollution survey through interview with village leader	a) Confirmation of disposal system through constructor b) Site inspection	Not required
	28. Noise and vibration	Measurement of ambient noise and traffic noise in the Darra and Kohat Town (Equivalent noise for 12 hours)	Measurement of construction noise on the boundary	Measurement of traffic noise
	29. Ground subsidence	Confirmation of consolidation settlement from road planner	Not required	Measurement of consolidation settlement once a year
	30. Offensive odors	Not required	Not required	Not required
	31. Bottom sediment in sea and rivers	Not required	Not required	Not required

13.5.2 Proposed Methodologies for Project Evaluation in the Future

(1) Objectives

It is anticipated that the 2nd Kohat tunnel and access roads project will bring significant benefits in many diverse areas, such as boosting the economy, an improved social environment and so on.

It is important to carry out an impact assessment of this project from the view of project evaluation. Hence the project proponent should conduct a survey for project evaluation before implementation of the project and post project completion. This survey must collect quantitative data, and these data will be used as an indicator for evaluation of the project.

(2) Approach & Methodology

a) Approach

It is important to know how road users feel the road situation has changed and what extra benefits have occurred before and after construction of the 2nd Kohat Tunnel. The following indicators should show the differences, especially saving time and fuel consumption as these indicators are directly convertible from quantitative data.

Questions on the following key subject areas would be included in the survey:

- Problems faced before the tunnel
- Any problems faced now
- Benefits of tunnel (See note: Travel Cost Method)

  Time saving:
  - i) Normal journey time
  - ii) Time saving as a result of fewer breakdowns (involving oneself)
  - iii) Time saving as a result of less traffic jams (accident provoked by others)

  Economic savings:
  - i) Increase in number of trips
  - ii) More load carried
  - iii) Fuel saving
- Safety element as perceived by users
- Environmental issues (smoke, etc.) as perceived by users

b) Methodology

A survey will be conducted with travelers picked at random from the following key tunnel traffic groups divided into three categories: vehicles carrying goods, public transportation and private vehicles:

Table 13.5.2 Numbers and Types for Interview

Categories	Type of Vehicle	Number of Persons to be Interviewed			Total
		Drivers	Passengers	Owners	
Vehicles Carrying Goods	Heavy Truck	10	--	5	15
	Light Truck	10	--	5	15
	Very Light Vehicle	10	--	5	15
Public Transport Carrying Passengers	Bus	10	10	5	25
	Van	10	10	5	25
	Taxi	10	10	5	25
Private Vehicles	Cars	--	--	15	15
	Motorcycles	--	--	15	15
Total		60	30	60	150

These target groups cover most of the users of the tunnel. Regular, long-time users of both, the Kohat Pass and Tunnel, will be targeted for the survey. This is because they would be able to provide a comparative analysis of certain issues pertaining to the tunnel before and after implementation of works.

Note: Travel Cost Method

The TCM is a means of determining value figures for things which are generally not bought or sold, and therefore fall outside of the market's pricing system. These are non-market assets that most often apply to 'recreational resources which necessitate significant expenditure for their enjoyment.' This means that the TCM is often used to assess the value of parks, lakes, and other similar public areas hosting recreational activities that are far enough away from many people and require users to drive or fly to those sites.

The basic premise of the TCM is that, although the actual value of the recreational experience does not have a price tag, the costs incurred by individuals in travelling to the site can be used as surrogate prices. The weak level of compensation for the goods required for travel to the site makes it possible to estimate a demand curve for the site, and from it, a measure of the sites' consumer surplus can be found. It is important to note that the consumer surplus figure is a measure of the user value of the site only, and does not necessarily measure the site's environmental or intrinsic value.

Chapter 14. CONSTRUCTION PLAN

14.1 General

The objectives of construction planning are:

- Establishing the most appropriate construction plan and construction period for implementation of the Project on economical and technical aspects.
- Providing a basis for cost estimate and construction schedule establishment.
- Addressing specific issues including construction methods to minimize disturbance to public traffic on the Project road during construction and environmental considerations.
- Addressing ROW problems, especially for the north section where the Project road passes through a tribal area.

The major elements to be considered for construction planning are:

- Site conditions (access roads, geology, climate, traffic, workable days, law and regulations, ROW, etc.).
- Work experience of the 1st Kohat Tunnel and Access Road Projects.
- Major work quantities.
- Contract and construction specifications.
- Availability of contractors, equipment and skilled workers.
- Materials sources.

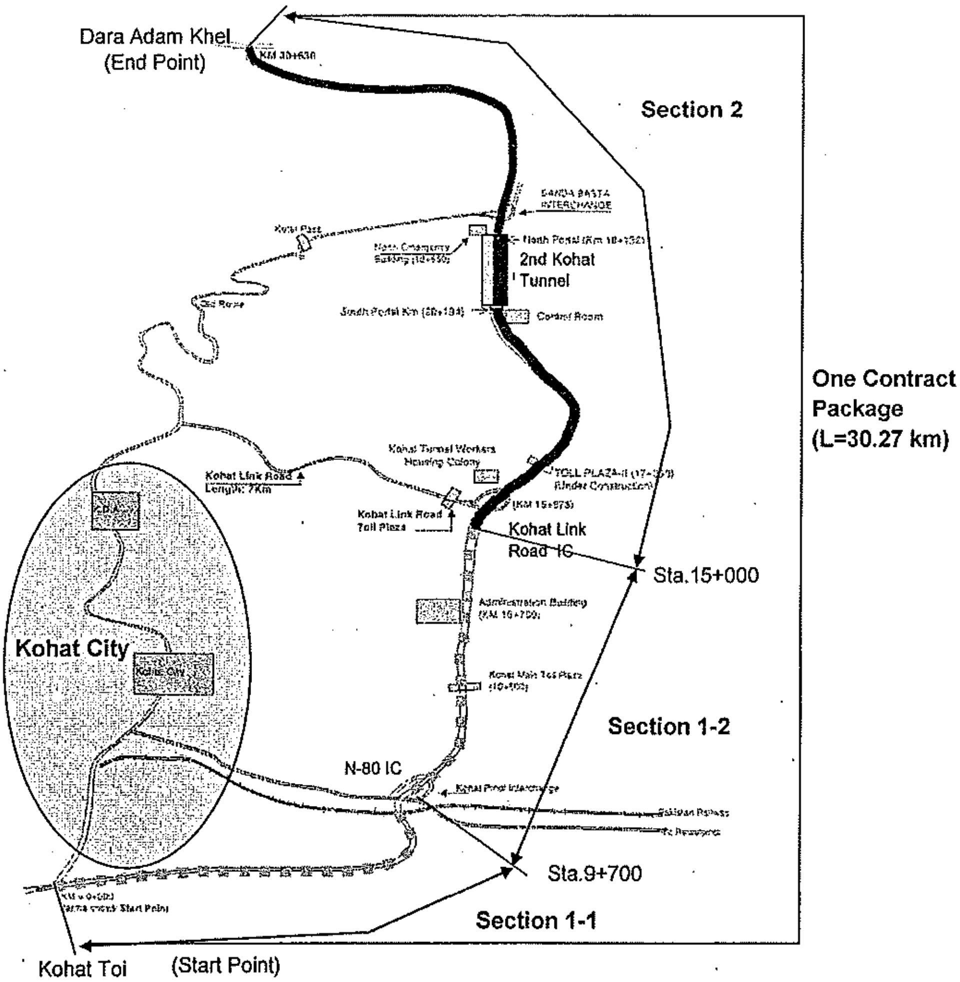


Figure 14.1.1 Contract Packaging for Project Implementation

The Project road is divided into two sections (Figure 14.1.1) according to the traffic capacity analysis in Chapter 7 and the economic evaluation in Chapter 17. Section 1 is from Kohat Toi (Sta.0+000) to the Kohat Link Road (Sta.15+000) and Section 2 from the Kohat Link Road (Sta.15+000) to Dara Adam Khel (the end of Project road). However, since simultaneous implementation is recommended for both sections in Chapter 17, construction planning was made for one contract package.

Construction works are assumed to be conducted by qualified international contractors who have sufficient capability to perform the work as no well-qualified local contractors are available for tunnel construction. Besides, locally available construction methods and materials should be used as much as possible to save the construction cost and to create job opportunity in and around the Project area.

14.2 Specific Issues to be addressed

14.2.1 Hard Rock Excavation along the Existing Road

Several high cut sections (4 locations in the tunnel south section and 5 locations in the tunnel north section) required for the construction of the 2nd Kohat Tunnel and Access Roads (Table 14.2.1). About 66% of the materials are hard rock and 34% is soil and semi-rock (soft rock). The cut slopes are 1 (V): 0.5 (H) for rock, 1 : 0.8 for semi-rock and 1 : 1.2 for soil. Hard rock excavation is also required for the north and south portals construction.

Table 14.2.1 List of High-cuts for Sections 1 and 2

No.	Station		Estimated Quantity	Classification of Materials				Max. Cut Height
	From	To		Common		Rock		
			(m^3)	%	(m^3)	%	(m^3)	(m)
South: KohatLink Road - Kohat Tunnel (South Portal)								
S-1	7+325.000	7+475.000	23,800	5	1,190	95	22,610	28
S-2	14+425.000	14+625.000	4,200	60	2,520	40	1,680	10
S-3	15+250.000	15+425.000	32,100	5	1,610	95	30,490	32
S-4	18+000.000	18+700.000	165,600	60	99,360	40	66,240	30
Sub-Total:			225,700	46	104,680	54	121,020	
North: Kohat Tunnel (North Portal) - Dara Adam Khel (End Point)								
N-1	18+132.000	18+825.000	33,000	5	1,650	95	31,350	15
N-2	21+575.000	21+725.000	26,600	0	0	100	26,600	32
N-3	22+300.000	22+400.000	2,000	0	0	100	2,000	6
N-4	23+850.000	23+975.000	15,500	0	0	100	15,500	24
N-5	24+300.000	24+400.000	7,200	0	0	100	7,200	14
Sub-Total:			84,300	2	1,650	98	82,650	
Total:			310,000	34	106,330	66	203,670	

Source: JICA Study Team

As the current ADT is approximately 7,500 vehicles, it is difficult to apply normal blasting operation. Construction methods that do not disturb or endanger the traffic should be used. The rock excavation for N-3, N-4 and N-5 in the north section is near houses/ buildings, therefore blasting operation should be also limited.

Following alternative excavation methods have been planned and compared.

- Soil (and semi-rock): Excavation of soil by hydraulic excavator and semi-rock by 45-ton class bulldozer with ripper.
- Rock (refer to Figure 14.2.1):
  - Common blasting.

- Excavation in association with controlled blasting (pre-blasting using 1/3 to 1/4 amount of explosive) and by hydraulic breaker.
- Excavation in association with non-explosive demolition agent and a hydraulic breaker.
- Excavation with special rock breaking equipment.

A comparison of rock excavation methods is summarized in Table 14.2.2.

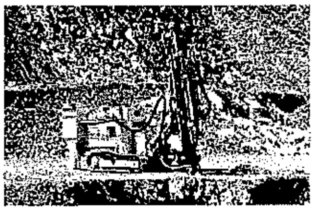
Table 14.2.2 Comparison of Rock Excavation Methods

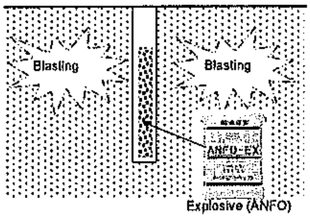
Excavation Method		Influence to Public Traffic	Productivity (cu.m./hour)	Cost	Requirement of Special Equipment	Evaluation	
A	Common blasting	Large	Good	Low	No	X	Not recommended as its influence to public traffic is high
B	Excavation in association with controlled blasting (pre-blasting using 1/3 to 1/4 of explosive) and a hydraulic breaker	Medium	Fair	Fair	No	○	Recommended
C	Excavation in association with non-explosive demolition agent and a hydraulic breaker.	Small	Fair	High	No	△	Recommended for tunnel portals and upper part of hill
D	Excavation with special rock breaking equipment	Small	Good	High *	Yes	X	Not enough quantity for economical excavation

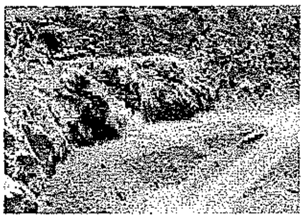
Note: * If quantity increases, the unit cost per cu.m. will be reduced.

- **A. Common Blasting by Explosive (ANFO)**

Drilling holes for filling explosives ⇨ Fill explosive (ANFO) ⇨ Blasting

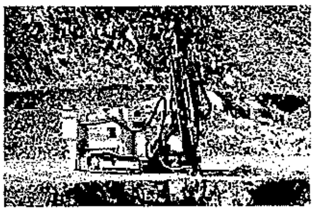


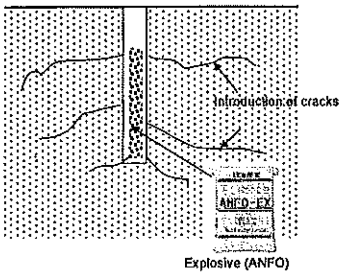


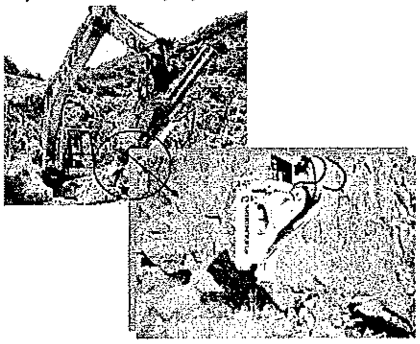


- **B. Excavation in association with controlled blasting (pre-blasting) and hydraulic breaker**

Drilling holes for filling explosives ⇨ Fill 1/3 - 1/4 of explosive for controlled blasting ⇨ Break of Rock by Hydraulic Breaker

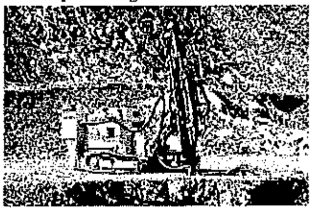


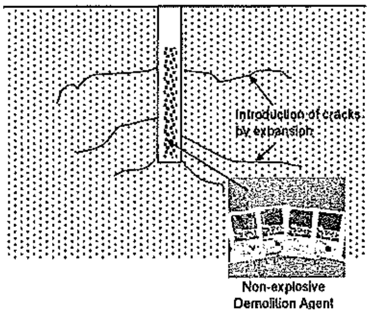


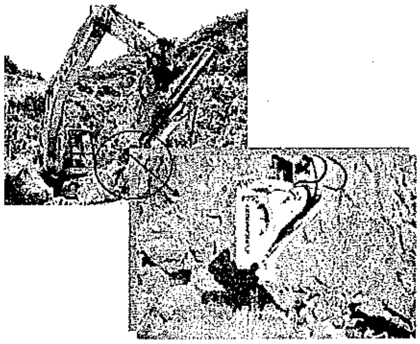


- **C. Excavation in association with non-explosive demolition agent and hydraulic excavator**

Drilling holes for filling non-explosive agent ⇨ Fill non-explosive demolition agent ⇨ Break of Rock by Hydraulic Breaker

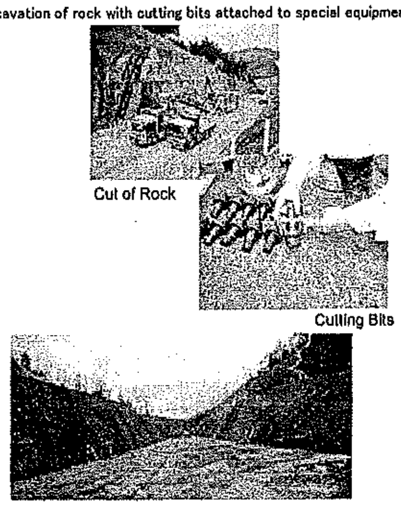






- **D. Excavation with special rock breaking equipment**

D.1 Suffice Minor
(Excavation of rock with cutting bits attached to special equipment)



Completion of Cut

D.2 Impact Breaker
(Combination of ripping and hydraulic breaker)

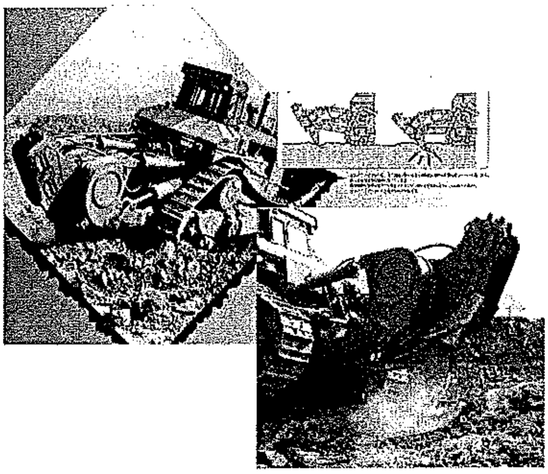


Figure 14.2.1 Representative Rock Excavation Method

Method A requires shut-down of traffic during blasting and clearing, therefore it is not recommended due to its substantial disturbance to public traffic. Method D is not cost-advantageous as the volume of rock excavation is approximately 200,000 m^3 for the Project and it is less than the economical volume necessary to introduce special equipment. The recommended method is a combination of Methods B and C. The cost of non-explosive demolition agent is very expensive compared with common explosives (ANFO), therefore, it should be used only for some selected sections and parts, like tunnel portals, upper part of the hill and near houses/buildings. Pre-split blasting method is also used together with the above rock excavation methods.

The excavation will be executed to minimize materials falling down to the existing roadway. Installation of temporary concrete barriers will be required along the roadway to prevent falling rocks from hitting the traffic (Figure 14.2.2). The 3m-wide left shoulder is strengthened to divert the traffic on that during rock excavation and provide space for temporary barriers.

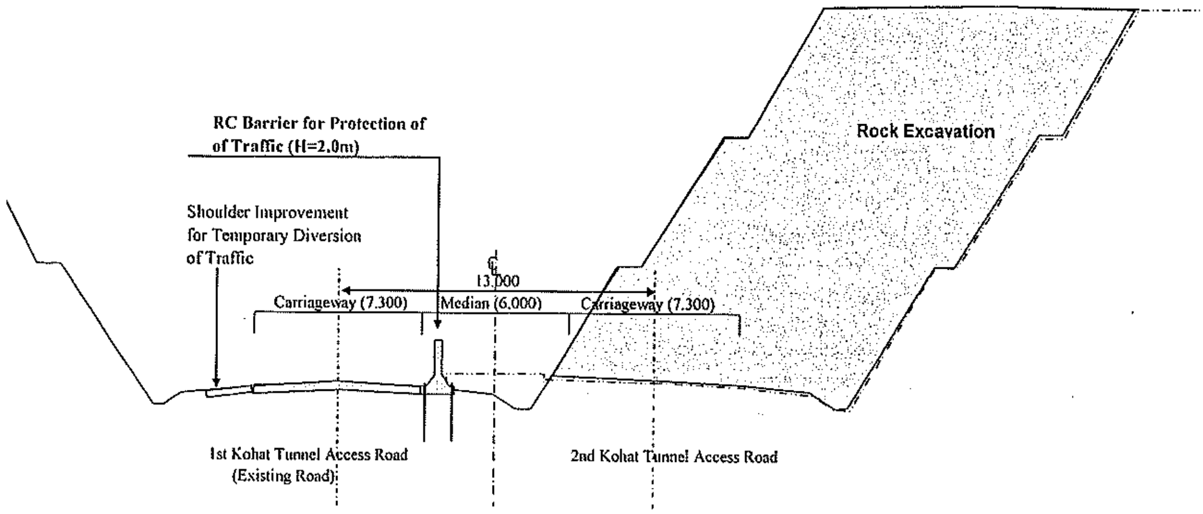


Figure 14.2.2 Temporary RC Barrier for Protection of Public Traffic

14.2.2 Distribution Plan for Cut and Fill Volume

(1) Excavation

The estimated total quantity of roadway excavation in common materials is 310,000 m^3. It is assumed that 5% of these materials (5,000 m^3) are not appropriate for embankment and to be wasted. The remaining quantities (101,000 m^3 of soil and 205,000 m^3 of rock) are to be used for the roadway embankment formation as broken-down in Table 14.2.3.

Table 14.2.3 Quantities of Roadway Excavation

Unit: m^3

Location From Sta	Location To Sta	Excavation Quantity m^3	Soil Total %	Soil Total	Soil Disposal	Soil For Fill	Rock %	Rock For Fill
South Section 1: Start Point (Sta.0+000) - Sta.15+000								
7+000	8+000	23,794	5%	1,190	59	1,130	95%	22,604
14+000	15+000	4,227	60%	2,536	127	2,409	40%	1,691
Sub-Total		28,021		3,726	186	3,540		24,295
South Section 2: Sta.15+000 - Sta.20+186.738 (South Portal)								
15+000	16+000	32,110	5%	1,606	80	1,525	95%	30,505
18+000	19+000	165,639	60%	99,383	4,969	94,414	40%	66,255
19+000	20+000	1,000	5%	50	3	48	95%	950
Sub-Total		198,749		101,039	5,052	95,987		97,710
North Section : Sta.18+132 (N.Portal) - End Point (Sta.25+906.255)								
18 +150	19+000	33,050	5%	1,652	83	1,570	95%	31,397
19+000	20+000	85	0%	-			100%	85
21+000	22+000	26,583	0%	-			100%	26,583
22+000	23+000	2,080	0%	-			100%	2,080
23+000	24+000	15,510	0%	-			100%	15,510
24+000	25+000	7,196	0%	-			100%	7,196
Sub-Total		84,503		1,652	83	1,570		82,850
Total		311,272		106,417	5,321	101,096		204,855

The estimated total quantity of tunnel excavation is 152,000 m^3 including the tunnel portals. It is assumed that 40% (61,000 m^3) is excavated from the south portal and 60% (91,000 m^3) from the north portal in accordance with the tunnel construction planning. Those materials will be used for the roadway embankment.

(2) Embankment

The total embankment quantity for roadway formation is estimated at 1,106,000 m^3. The materials are from the roadway excavation, tunnel excavation and borrow along the roadway as detailed in Table 14.2.4. The wasted rock materials (58,800 m^3) during the 1st Kohat Tunnel and Access Road construction within the ROW in the north section was deducted from the embankment quantity.

Table 14.2.4 Quantities of Roadway Embankment

Section	Location		Quantity
	From Sta.	To Sta.	m^3
South Section 1	0+000	15+000	425,007
South Section 2	15+000	20+187 (South Portal)	421,174
North Section	18+132 (North Portal)	25+906	260,168
Total			1,106,349

(3) Earthworks Distribution Plan

The earthworks distribution plan was made based on the above estimated excavation, waste and embankment quantities and earthworks cut/fill volume conversion factors (Table 14.2.5).

Table 14.2.5 Earthworks Cut/Fill Volume Conversion Factors

Type of Material	Compression Factor	Standard Factor *	2nd Kohat Tunnel & Access Road	
			Roadway	Tunnel
Soil				
Sand / Gravel	0.85 - 0.95	0.90		
Silt / Clay	0.85 - 0.95	0.90	0.90	
Silt / Clay with Gravel	0.90 - 1.00	0.90		
Silt / Clay with Rock	0.90 - 0.95	0.90		
Soft Rock				
Semi-rock	1.00 - 1.30	1.05		
Weathered Rock	0.95 - 1.05	1.00	1.00	1.00
Rock				
Hard	1.05 - 1.35	1.15	1.15	1.20
Very Hard	1.15 - 1.40	1.20		

Note: Based on Japanese Standards

Table 14.2.6 shows the earthworks distribution plan and Figure 14.2.3 indicates the balance of excavation and embankment by section.

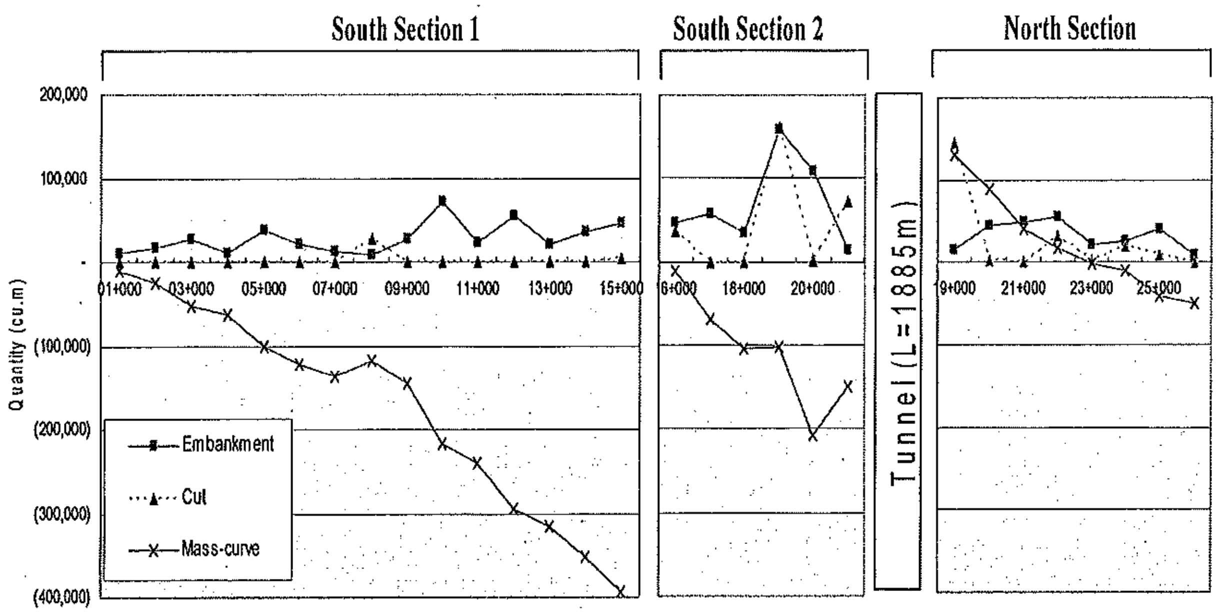
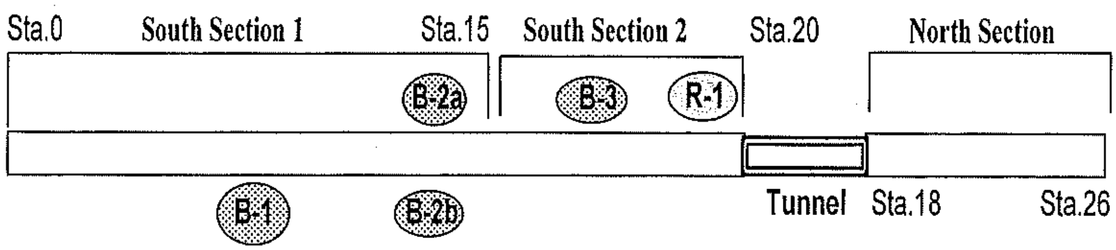


Figure14.2.3 Balance of Excavation and Embankment

Approximately 54% of the embankment materials are from borrow areas and the remainder is from the roadway and tunnel excavation. The borrow materials are available from the borrow areas developed under the 1st Kohat Tunnel and Access Road along the Project road in the case of tunnel south section (Figure 14.2.4).



Note: Refer to Subsection 6.5 in Chapter 6 as to Borrow Areas)

Figure 14.2.4 Location of Borrow Areas

The excavation quantity for the tunnel is estimated at 152,000 m^3 including tunnel portals. It is planed that approximately 40% of the tunnel length is excavated from the south portal and 60% from the north portal and those materials are used for the embankments, especially at the lower part of embankment on riverbed. However, there is still a shortage of 50,000 m^3 of materials for the north section. As there is no appropriate borrow areas in the north section, embankment materials should be hauled from the tunnel south section. The overburden soil for the planned rock quarry at Sta.19+500 (L) could be used as the borrow material for the north section.

As the design CBR of subgrade (1.0 m depth from the subgrade formation level) is 15%, theses materials are obtained from the designated borrow areas in principle.

Table 14.2.6 Summary of Earthworks Volume Distribution Plan

(Formation of Embankment from Roadway Excavation, Tunnel Excavation and Borrow)

South Section 1: Start Point (Sta.0+000) - Sta.15+000

Location		Embankment	Item 108a: In Common Material from Roadway Excavation			Item 108b: in Rock Material from Roadway Excavation			Item PS-14: Embankment from Tunnel Excavation			Item 108c: From borrow
From	To	Quantity	Q'ty in Orig.Ground	C.Factor	Q'ty after Compaction	Q'ty in Orig.Ground	C.Factor	Q'ty after Compaction	Q'ty in Orig.Ground	C.Factor	Q'ty after Compaction	at Sta.7+200 (R) / 14+300 (R/L)
Sta	Sta	m^3	m^3		m^3	m^3		m^3	m^3		m^3	m^3
0 + 000	1 + 000	10,128										
1 + 000	2 + 000	15,953										
2 + 000	3 + 000	26,539										
3 + 000	4 + 000	11,442										
4 + 000	5 + 000	36,925										
5 + 000	6 + 000	21,279										
6 + 000	7 + 000	13,548										
7 + 000	8 + 000	8,912	1,130	0.90	1,017	22,604	1.15	25,995				
8 + 000	9 + 000	26,788										
9 + 000	9 + 700	72,254										
10 + 700	11 + 000	23,638										
11 + 000	12 + 000	54,009										
12 + 000	13 + 000	20,892										
13 + 000	14 + 000	35,543										
14 + 000	15 + 000	47,159	2,409	0.90	2,169	1,691	1.15	1,945				
Total		425,007	3,540		3,186	24,295		27,939	-	1.15	-	393,882
Remarks: % to the total embankment quantity					0.7%			6.6%			0.0%	92.7%

South Section 2: Sta.15+000 - Sta.20+186.738 (South Portal)

Location		Embankment	Item 108a: In Common Material from Roadway Excavation			Item 108b: in Rock Material from Roadway Excavation			Item PS-14: Embankment from Tunnel Excavation*			Item 108c: From borrow
From	To	Quantity **	Q'ty in Orig.Ground	C.Factor	Q'ty after Compaction	Q'ty in Orig.Ground	C.Factor	Q'ty after Compaction	Q'ty in Orig.Ground	C.Factor	Q'ty after Compaction	at Sta.14+300 (R/L) / Sta.17+300 (L)
Sta	Sta	m^3	m^3		m^3	m^3		m^3	m^3		m^3	m^3
15 + 000	16 + 000	47,417	1,525	0.90	1,373	30,505	1.15	35,080				
16 + 000	17 + 000	57,700										
17 + 000	18 + 000	35,390										
1 8+ 000	19 + 000	158,456	94,414	0.90	84,973	66,255	1.15	76,194				
19 + 000	20 + 000	108,259							1,860	1.00	1,860	
20 + 000	20 + 100	13,953	48	0.90	43	950	1.15	1,093	58,943	1.20	70,731	
Total		421,174	95,987		86,388	97,710		112,367	60,802		72,591	149,829
Remarks: % to the total embankment quantity					20.5%			26.7%			0.0%	35.6%

Note: * 40% of the tunnel excavation from the south portal.

35.6%

North Section : Sta.18+132 (N.Portal) - End Point (Sta.25+906.255)

Location		Embankment	Item 108a: In Common Material from Roadway Excavation			Item 108b: in Rock Material from Roadway Excavation			Item PS-14: Embankment from Tunnel Excavation *			Item 108c: From borrow
From	To	Quantity	Q'ty in Orig.Ground	C.Factor	Q'ty after Compaction	Q'ty in Orig.Ground	C.Factor	Q'ty after Compaction	Q'ty in Orig.Ground	C.Factor	Q'ty after Compaction	at the tunnel south Sta.19+500 (L)
Sta	Sta	m^3	m^3		m^3	m^3		m^3	m^3		m^3	m^3
18+350	19+000	15,202	1,570	0.90	1,413	31,397	1.20	37,677	88,414	1.20	106,097	
19+000	20+000	44,328				85	1.20	101	2,789	1.00	2,789	
20+000	21+000	47,952										
21+000	22+000	55,217				26,583	1.20	31,899				
22+000	23+000	21,377				2,080	1.20	2,495				
23+000	24+000	26,057				15,510	1.20	18,612				
24+000	25+000	41,235				7,196	1.20	8,635				
25+000	25+350	8,800										
Total		260,168	1,570		1,413	82,850		99,420	91,203		108,886	50,448
Remarks: % to the total embankment quantity					0.5%			38.2%			0.0%	19.4%

Notes: 1. * 60% of the tunnel excavation form the north portal and 40% from the south portal.
2.**Deducted the quantity of 58,800 m3 for the waste of rock materials from Sta.22+000 to Sta.25+000 during the 1st Kohat Tunnel Access Road Construction

Source: JICA Study Team

14.2.3 Tunnel Construction

(1) Construction Methods

New Austrian Tunnelling Method (NATM) is one of the popular construction methods for mountainous tunnel constructions. The 1st Kohat Tunnel used NATM. The 2nd Tunnel has been also planned to apply the same method. The standard work flow of tunnel construction by NATM is shown in Figures 14.2.5 and 14.2.6.

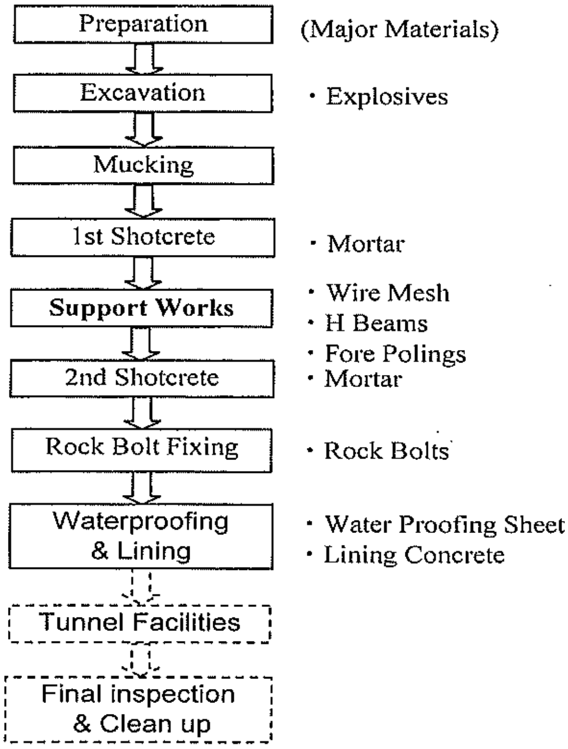


Figure 14.2.5 Standard Work Flow of NATM

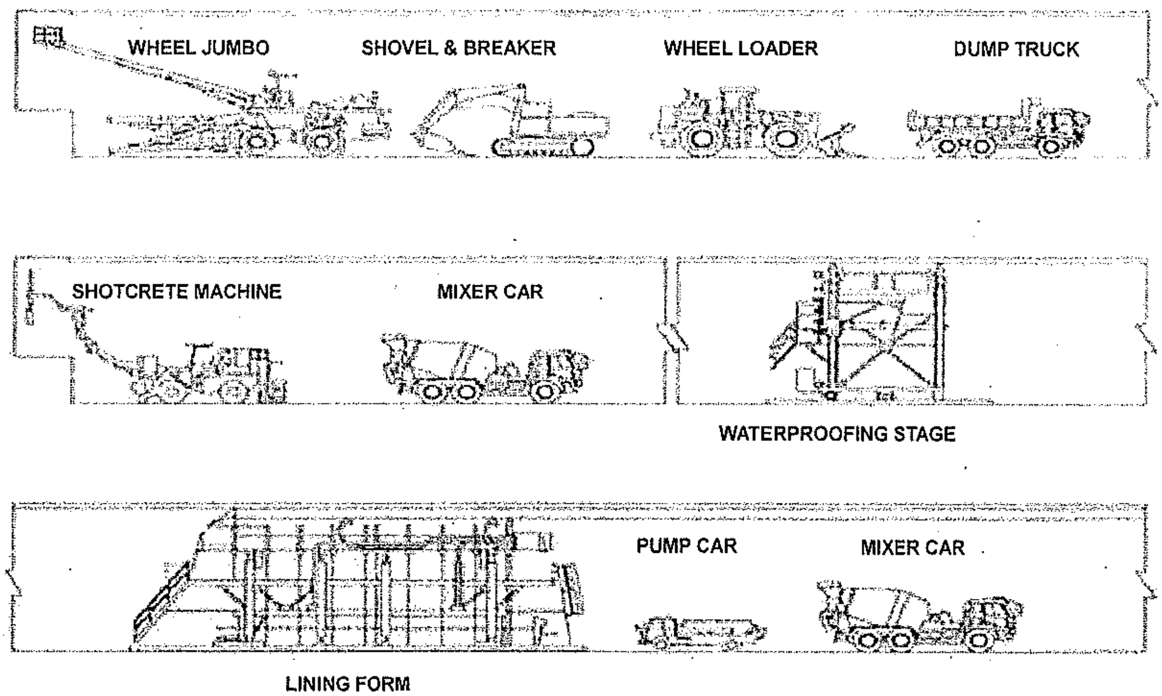


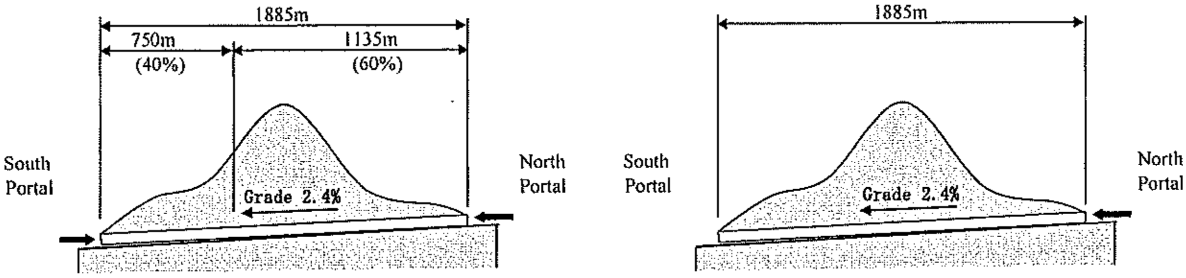
Figure 14.2.6 Construction Procedures

(2) Tunnel Construction Plans

Two alternative construction plans were studied. Alternative-A is the tunnel excavation from both portals and Alternative-B is the excavation from one-side from the north portal (Figure 14.2.7).

- Alternative-A: 1,135m (60%) from the north portal and 750 m (40%) from the south portal
- Alternative-B: 1,885m (100%) from the north portal

Note: As it takes about 9-10 months for movement of the tunnel control room and associated facilities, it needs to start the excavation form the north portal.



Alternative-A Excavation from Both Portals   **Alternative-B Excavation from One-side**

Figure 14.2.7 Alternative Tunnel Excavation Plans

(3) Major Equipment an Machines

The major equipment and machines to be used for the tunnel construction by work category are as listed up in Table 14.2.7

Table 14.2.7 Major Equipment and Machines for Tunnel Works

No	Works	Name of Machine	Type	Number of Equipment*	
				South Portal	North Portal
1	Excavation & Blasting	Drilling Machine	2 booms	2	2
		Drain Pump		-	2
2	Mucking	Wheel Loader	2.3 m^3	1	1
		Excavator	0.7 m^3	1	1
		Hydraulic Breaker		1	1
		Dump Tracks	20 t	3	3
3	First Shotcrete	Shotcrete Machine	6 m^3	2	2
		Tractor Head	30 t	1	1
		Track Mixer	6 m^3	Same Track Mixer with Item 7	
4	Support	Drilling Machine	2 booms	2	2
5	Second Shotcrete	Shotcrete Machine	6 m^3	Same machines with 1st Shotcrete	
		Tractor Head	30 t		
		Track Mixer	6 m^3		
6	Rock Bolt Installation	Drilling Machine	2 booms	1	1
		Grout Pump		1	1
7	Waterproof Sheet & Concrete Lining	Steel centre		1	1
		Concrete Pump	30m^3/hr	1	1
		Track Mixer	6 m^3	3	3

Note: * One set of equipment for one-side excavation (Alternative-B)

Two sets of the equipment are necessary for the construction plan Alternative A, excavation from both portals, and one set of the equipment for Alternative B, excavation from one side.

A concrete spread machine and a finisher are required for concrete pavement. Equipment necessary for preparation works including cranes and cargo trucks are common items with the roadway works.

(4) Ventilation during Construction

Either exhaust air duct or fresh air duct (Figure 14.2.8) can be used for ventilation during construction. Although exhaust air duct method is better with respect to environment inside of tunnel, fresh air duct method is commonly used because noise of the exhaust air duct method is large, and most of ventilators are not easy to install inside of tunnel.

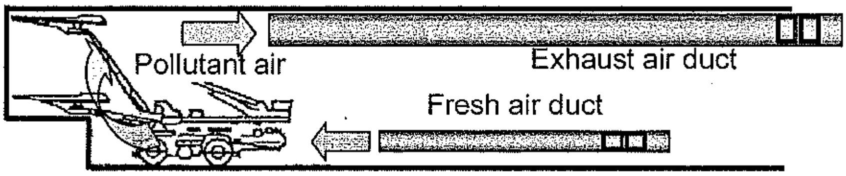


Figure 14.2.8 Ventilation Systems during Construction

The temperature at the Project site becomes more than 40 degrees in summer. When fresh air duct is installed outside of tunnel and it is heated, the air from outside could become more than 50 degrees in the tunnel. For that reason, the exhaust air duct method is planned for the 2nd Kohat Tunnel, which is the same method used for the 1st Kohat Tunnel. Local ventilator is installed on back of the face in order to supply fresh air and prevent pollutant air from diffusion to the face.

(5) Temporary Facilities

The following temporary facilities will be required for supporting the tunnel works.

- Electric facility
- Ventilation facility
- Air supplier
- Water supply
- Drain work
- Mud-water treatment
- Concrete plant
- Parking yard for machines and stock yard for materials
- Refuelling facility
- Lighting and communication facility, etc.

As water necessary for construction is available from the spring water (estimated to be 100 L to 200 L/min) at the tunnel south portal, no special facility is required except a storage tank.

(6) Construction Schedule

Table 14.2.8 shows the monthly construction speeds for the 2nd Kohat tunnel estimated based on the experience in the 1st Kohat tunnel construction. Two shifts work is applied for the tunnel construction.

Table 14.2.8 Construction Speeds of Tunnel Works

Section	Upper Half	Lower Half	Average
Portal	23 m	25 m	24 m
CI	79 m	111 m	95 m
CII	95 m	133 m	114 m
DI	42 m	45 m	44 m
Emergency Parking Area:	60 m	95 m	78 m
Lining	87 m		
Drainage	400 m		
Pavement	600 m		

Note: Average construction speed per month

The following Figure 14.2.9 shows a construction schedule of the tunnel civil works for Alternative-A by work category estimated based on the construction speeds in Table 14.3.2. Preparation and cleaning up require about one month each at the start and end of the construction. The tunnel excavation starts from the north portal. The construction from the south portal can start after 9-12months as the movement of tunnel control room is needed prior to start of the tunnel excavation. It needs 24.5 months for completion of the civil works. Tunnel facilities installation will require 9-12 months after the completion of tunnel civil works.

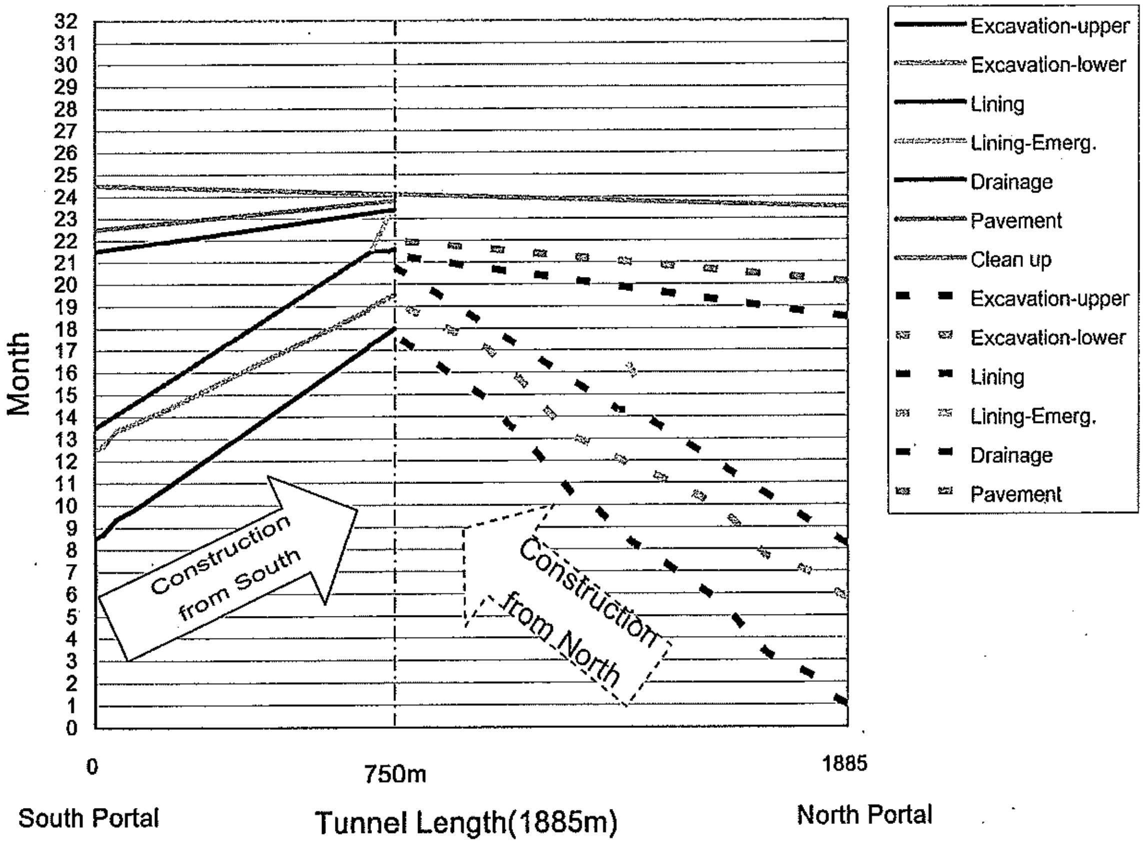


Figure 14.2.9 Construction Schedule for Alternative-A (Both-sides Excavation)

Figure 14.2.10 shows a construction schedule of the tunnel civil works for Alternative-B by work category estimated based on the construction speeds in Table 14.3.2. Preparation and cleaning up require about one month each at the start and end of the construction. The tunnel excavation starts from the north portal and proceeds to the south in one-way. It needs 32 months, 7 months more than Alternative-A, for completion of the civil works. Tunnel facilities installation will require 9-12 months after the completion of tunnel civil works.

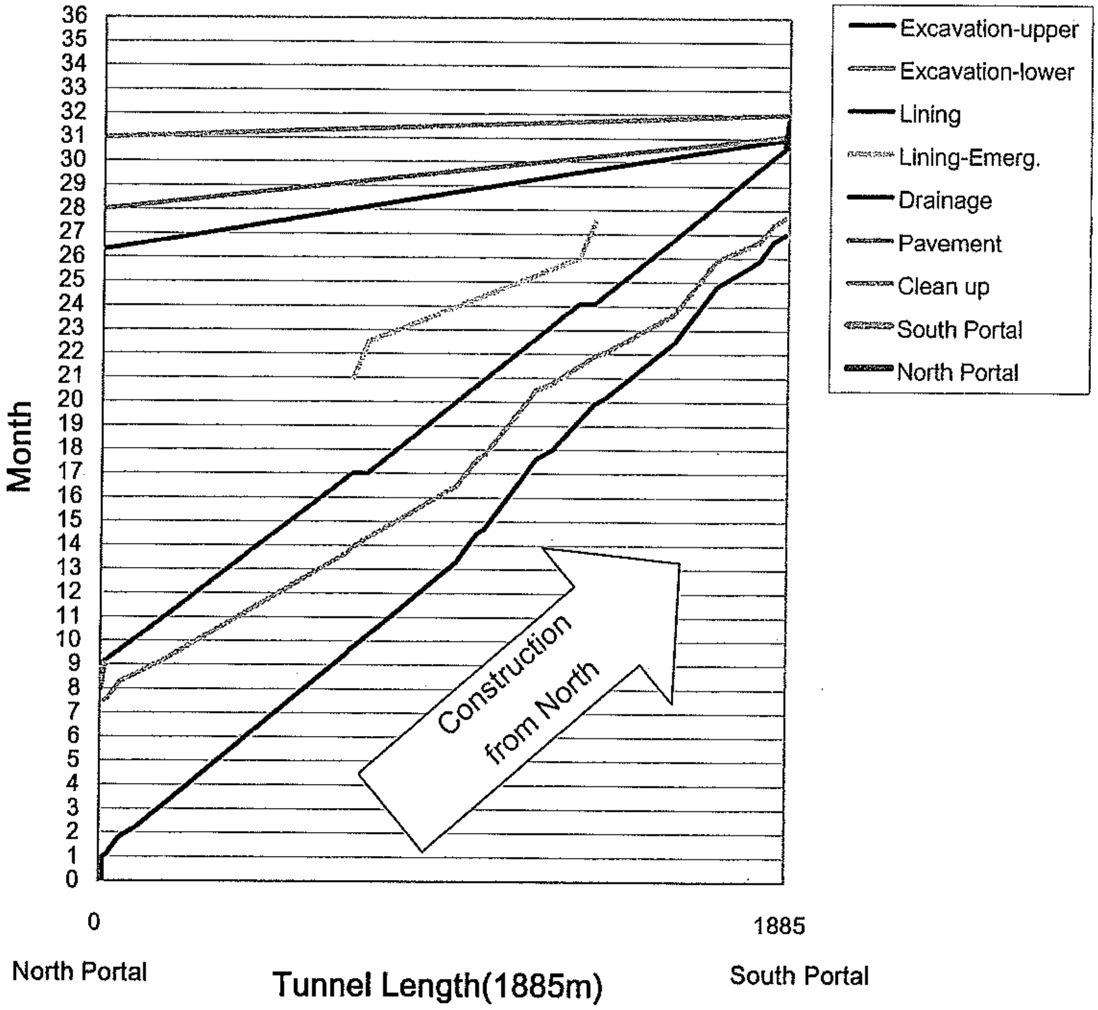


Figure 14.2.10 Construction Schedule for Alternative-B (One-side Excavation)

(7) Evaluation of Alternative Construction Plans

Evaluation of Alternative Construction Plans is summarized in Table 14.2.9. The tunnel construction works is on the Critical Path in the construction schedule and, therefore, Alternative A is recommended. The construction cost between Alternatives A and B is not much different. Though the former requires more machines but it can save the overhead expenses because of shorter construction period.

The estimated embankment quantify for the tunnel north section is 260,000 m^3 and the excavation quantity is 84,500 m^3. The shortage of embankment materials is required to obtain from borrow areas. However, as the tunnel north section is located in a tribal area, no appropriate borrow areas exist. The tunnel excavation materials (91,000m^3) from the north portal are planned to use for the embankments in the north section.

Table 14.2.9 Summary of Evaluation of Alternative Construction Plans

Item	Alternative A		Alternative B	
Construction Period	O	24.5 months	X	32 months
Equipment / Machines	X	2 sets	O	1 set
Drainage Pump	O	2 pumps (23 months)	X	2 pumps (30 months)
Construction Cost	Not much difference			
Use of excavated materials for the north section embankment	O	Easy	X	Difficult
Overall Evaluation	O	**Recommended**	X	Not recommended

Note: "O"; better than the other, "X": worse than the other

14.2.4 Moving of the Tunnel Control Center

Since the Existing Control Center yard occupy the South portal of planed 2nd Kohat Tunnel, Relocation of Existing Facilities yard is necessary and it is on a Critical Pass of the whole construction Schedule.

In front of the South portal of No.1 Kohat Tunnel west side is the only available space for it and to reclaim that area it is necessary to have a drainage for discharge the flow water from the valley. The procedure for the moving of the Control Center function, and it is necessary time span are shown in Figure14.2.11

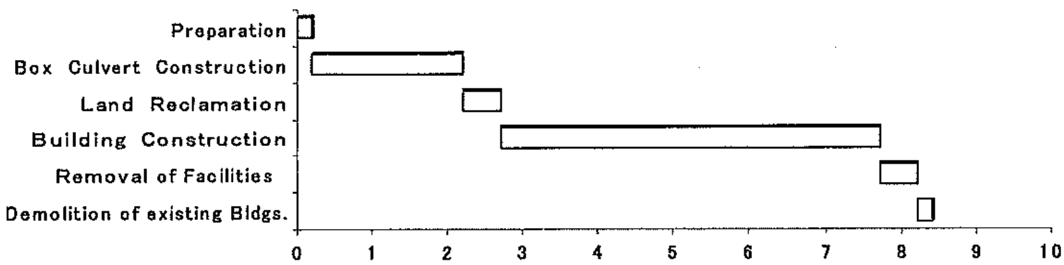


Figure 14.2.11 Construction Schedule before the Tunnel South portal Start

From this rough schedule, we can see that 9 months is necessary before Start the Tunnel excavation from South portal.

14.2.5 Bridge Construction

Nine bridges will be constructed for the 2nd Kohat Tunnel Access Road (Table 14.2.10). As Bridges No.3BR is over railways, No.3A R over N-80 (ADT about 4,300) and No.8R over the NWF road (ADT about 3,400), special care is necessary for public traffic control and maintaining safety during the construction. There is little traffic on the track under Bridge No.10R.

Table 14.2.10 Bridges for the 2nd Kohat Tunnel and Access Roads Project

No.	Station (at center)	Type	Length (m)	Span	Pile Length (m)	Remarks (Crossing)
1 R	2+736.245	PC Girder	120	4 - 30m Span	16	Over Jerma Minor River
2 R	4+735.415	PC Girder	50	2 - 25m Span	14	Over river
3A R	9+454.363	PC Girder	20	1 - 20m Span	20	Over railways
3B R	9+645.760	PC Girder	30	1-30m Span	21.5	Over N-80
9 R	14+800.000	RC Girder	12	1-12m Span	20	Over Bazi Khel Road
10 R	16+585.000	RC Girder	12	1-12m Span	20	Over a track
Kohat Tunnel*						
5 R	18+935.415	PC Girder	80	25m+30m+25m	20	Over Osti Khel Algad
8 R	19+088.355	PC Girder	20	1 - 20m Span	Spread Fd.	Over NWF Road
6A R	21+260.525	PC Girder	180	6-30m Span	12	Over Osti Khel Algad & Panderi Algada
7 R	25+388.915	PC Girder	40	2-20m Span	20	Over Mullah Khel Algad
Total:			564	m		

Notes: * Break at Sta. 20+186.738 /Sta.16+247.000 (-3,939.738)

The superstructure type composed of RC girders was designed for Bridges No.9R and PC girders for other bridges. PC girders are cast either near the bridge site or at a casting yard. Cranes will be the most appropriate equipment for erection of PC girders. The erection method (see the right photo) commonly used in Pakistan is not appropriate when considering safety of the construction and adverse effects on PC girders.

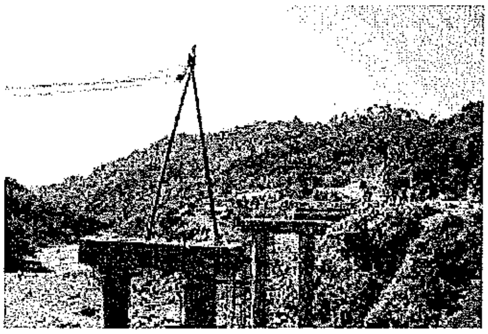


Photo: PC Beam Erection Method Common in Pakistan

Foundation piles are cast-in-place piles of 750 mm or 900 mm diameter. Piles for river bridges should be constructed in the dry season to avoid the risk of damage by floods. Foundation materials are sand, gravel, cobbles, boulders and clay. Earth-drilling equipment mounted on a clawer crane will be appropriate.

Those bridges are constructed beside the existing bridges and embankment. Part of the slope protection works and wing walls of the existing bridges are to be demolished. Temporary structure sustaining measures like a combination of steel sheet piles and steel anchors are necessary for the new bridge construction (Figure 14.2.12).

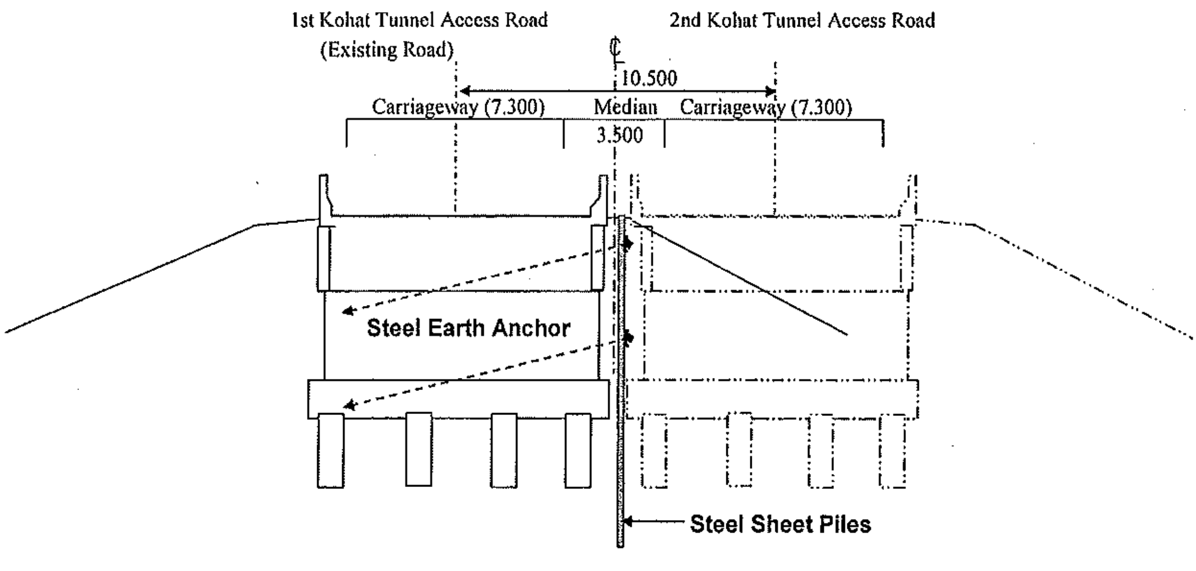


Figure 14.2.12 Temporary Structure Sustaining Measures for New Bridge Construction

14.2.6 Underpass Box Construction at Kohat Link Road IC

The construction of an underpass (box culverts) for the new On/Off-Ramps was planned for the Kohat Link Road IC. As the ADT on the main road is approximately 4,100 vehicles and that on the Off-Ramp to Kohat Town is 1,800, a safe construction plan for both traffics should be worked out.

The 1st construction step will be box culvert construction for the new two lanes. After its completion, the traffic on the existing main road will be diverted to the new lanes for construction of the underpass for the existing main road.

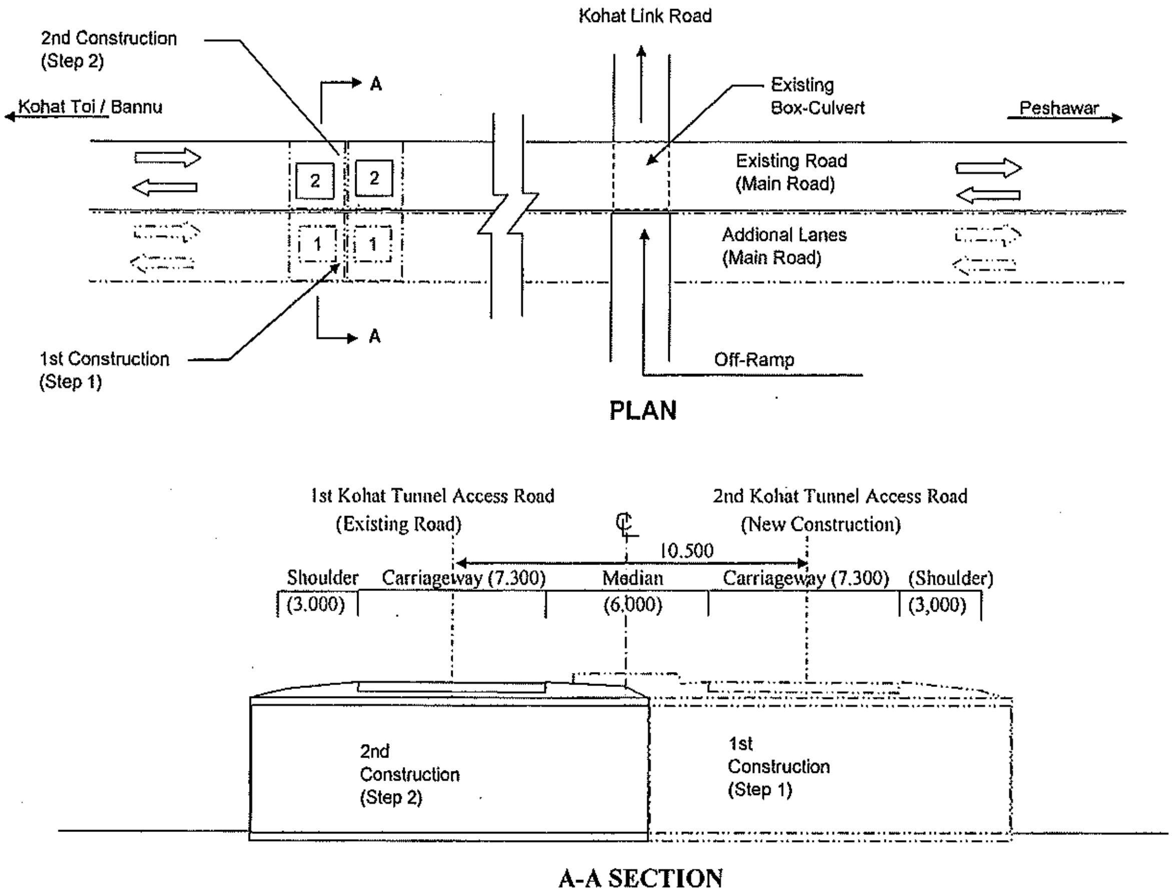


Figure 12.2.13 Construction Step of Underpass (Box culvert) for Kohat Link IC

14.2.7 Pavement Construction

The pavement construction shall follow the General Specifications of NHA. Job-mix design should be carried out with utmost care. Trial construction should be made prior to the pavement construction to minimize common problems affecting the pavement life and earlier development of rutting and cracks experienced in Pakistan.

The AC base course was designed to have two layers (8-10 cm thick each). As the maximum particle size of the asphalt concrete base is very large, 38 mm for Class B and 50mm for Class A and it is more than 1/2.5 of a pavement construction layer, a special care is required for application of Marshal Stability design at laboratory.

As the AC base is thick, special care and equipment are necessary to attain the specified density at the lower part. Combination of a heavy duty asphalt finisher and a vibration roller would be one of the appropriate compaction equipment.

Concrete pavement was designed for the tunnel section, its approaches and the toll plaza. The thickness of pavement is 30cm on lean concrete/aggregate base. Strict quality control is required during construction as the maintenance and repair works in the tunnel without influence on traffic are not easy.

14.3 Proposed Contract Packaging

One contract package is recommended for implementation of the 2nd Kohat Tunnel and Access Roads Project (Length 30.27km) including tunnel construction taking the estimated cost, length, construction period, work efficiency, excavated material distribution for embankment, etc. into consideration. International contractor(s) will be employed for the tunnel and access roads construction.

The major scope of civil works is as summarised in Table 14.3.1.

Table 14.3.1 Scope of Civil Works for Implementation of the Project

Item	Roadway Construction	Tunnel Construction
● Scope of Construction		
- Roadway Section	- Sta.0+000 - Sta.20+186.738 - Sta.18+132.000 - Sta.25+906.255	- Sta.16+247.000 - Sta.18+132.000
- Length	- 28.38 km	- 1885 m
- Carriageway Width	- 7.30 m (2-lanes)	- 7.30 m (2-lanes)
- Shoulder Width	- 1.00 m for inner shoulder and 3.00 m for outside shoulder	- 0.30 m (both sides) Gradient
- Median Width	- 6.0 m for tunnel south section 3.5 m for tunnel north section	
- Pavement	- AC Pavement (t=22-23 cm including AC Base)	- Cement Concrete pavement (t=30 cm)
- Bridges	9 Nos. (564 m in total)	
- Grade	- 4.8% (maximum)	- 2.4% (descending from the north to the south)
● Allied Facilities	- Intersections / Interchanges Kohat Toi Intersection (An additional turn-lane) Kohat Link Road IC (New On-Ramp, Off-Ramp and underpass) NWF (Sanda Basta) Road IC. (New bridge) Dara Adam Khel Intersection (An additional turn-lane) - Main Toll Plaza (extension)	- Emergency Areas 2 nos. including cross passages - Tunnel Control Room (move) - Ventilation (Installation of Jet Fans) - Lighting and other safety facilities

Note: A break at Tunnel South Portal, Sta.20+186.738/Sta.16+247.000 (-3,939.738)

14.4 Sources of Major Material

Possible procurement sources of material, for the construction are studied through the Pakistan market investigation. According to the investigation, it was found that common material used for the construction of road and RC structure can be procured in a domestic market.

On the other hand, a part of material, equipment, and manpower related to the construction works of tunnel and tunnel mechanical and electrical facilities must be procured International Market out side of Pakistan.

14.4.1 Natural material

Some borrow pits are surveyed. Filing materials suitable for embankment are available along the project site. Coarse aggregate is available from a quarry located at the west of the tunnel south portal. Fine aggregate for structural concrete is obtainable near Attock 70 km East of Peshawar. Details are descried in 6.6 Material Survey.

14.4.2 Concrete and Structural Material

Domestic cement satisfies the quality and quantity requirement.

Reinforcement: steel re-bars are procured in Pakistan. However, it is rather expensive at this moment because of the recent construction boom.

14.4.3 Asphalt and Fuels

Asphalt, Emulsified asphalt and Petrol, Diesel fuel and Kerosene are obtained in domestic market.

14.4.4 Tunnel special materials

Tunnel special materials such as Water protection sheet, special Rock bolts are not available in a domestic market. So it is necessary to procure international market.

14.4.5 Tunnel Mechanical and Electrical Facilities

Most of tunnel Mechanical and Electrical Facilities are necessary to obtain through international markets, such as Ventilation Machine, Lightings, Monitoring Equipments, Generators, telecommunication system, control systems and etc.

14.5 Construction Schedule

Figure 14.5.1 shows a construction schedule (bar chart) for the 2nd Kohat Tunnel and Access Roads construction. Required period for the roadway construction by work item was estimated based on the quantity, daily productivity, number of work-unit and working days per month set out in Table 14.5.1.

Table 14.5.1 Estimate of Construction Period for Roadway by Work Item

Work Item	Unit	Estimated Quantity	Daily Production	Number of Work Unit	Working-Day/Month	Required Period (month)
		a	b	c	d	e=/(b*c*d)
Clearing & Grubbing	m^2	516,000	20,000	1	22	1.2
Embankment from Roadway	m^3	570,000	600	2	22	21.6
Embankment from Borrow	m^3	584,000	1,000	2	22	13.3
Embankment from Tunnel Excavation*	m^3	181,000	253	2	22	16.3
Aggregate Subbase	m^3	49,000	300	1	22	7.4
Aggregate Base Course	m^3	51,000	300	1	22	7.7
Bituminous Base Course Plant Mix	m^3	37,000	200	1	15	12.3
Double Surface Treatment	m^2	105,000	1,200	1	22	4.0
Bituminous Wearing Course	m^3	11,000	200	1	15	3.7
Foundation Pile (Dia.750 mm/900 mm)	LM	5,300	10	2	22	12.0

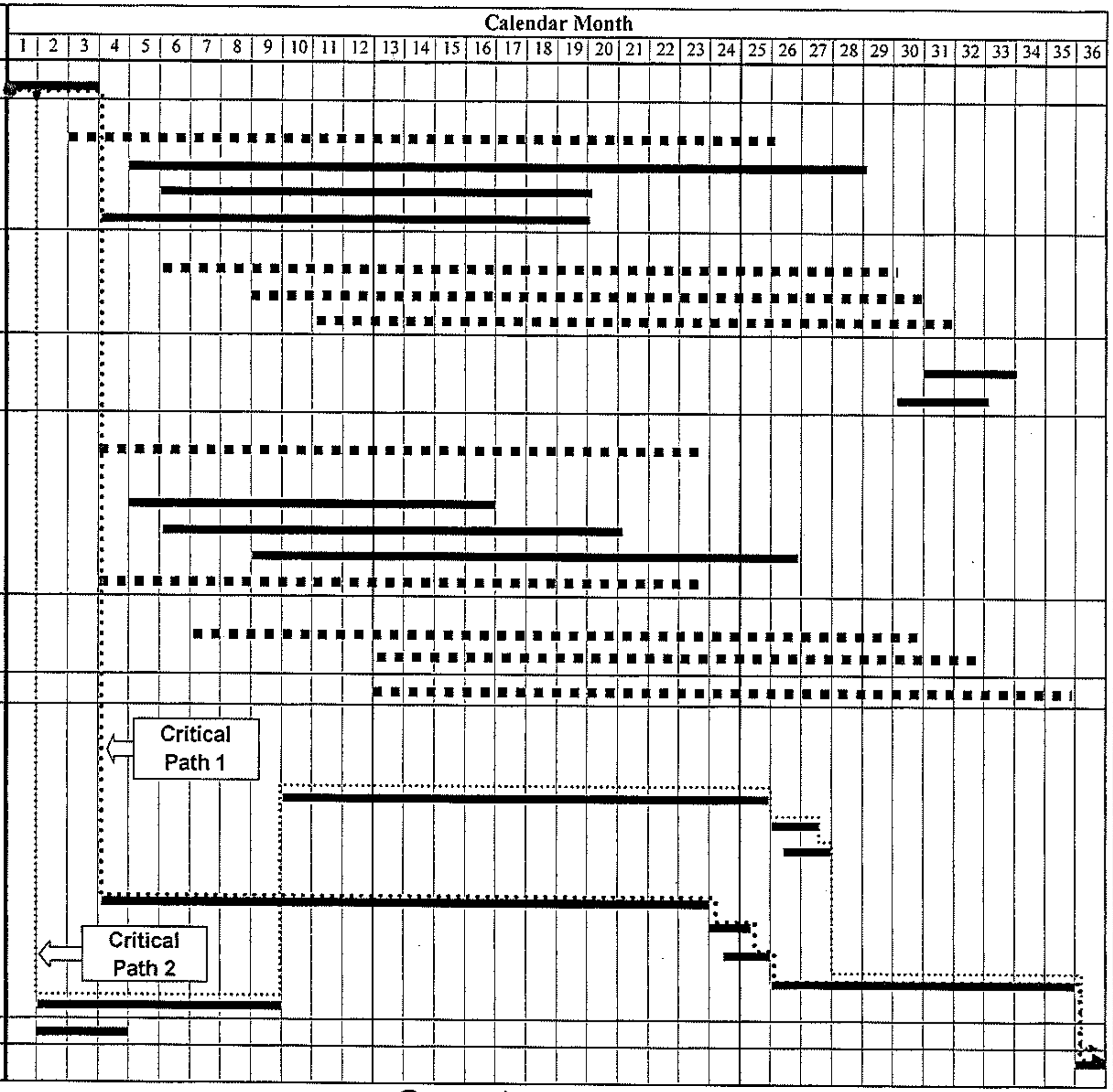
Note: Productivity of embankment construction with the materials from tunnel excavation depends on the tunnel construction progress.

It needs approximately 24 months for the tunnel civil works and 9 months for the tunnel facility installation as analyzed in Subsection 14.2.3. Together with mobilization (2-3 months) and demobilization (1 month), the total required construction period was estimated for a period of 36 months.

The tunnel construction is on the critical path. There are two critical paths in Figure 14.5.1. One is relocation of the tunnel control room at the south portal and the tunnel excavation should be commenced immediately after that. The other critical path is on the tunnel construction from the north portal. The roadway works including earthworks, pavement construction, bridge construction, etc. do not constitute critical paths.

As the tunnel geology are known well from the construction record and the geological report of the 1st Kohat Tunnel and Access Roads Project, the construction will not be delayed by geological uncertainty. It is also not much influenced by rains.

Bill No. / Works	Unit	Estimated Quantity
Mobilization and Preparatory Works		
1 Earthwork and Allied Activities		
• Clearing & Grubbing	m^2	516,000
• Embankment from Roadway	m^3	570,000
• Embankment from Borrow	m^3	584,000
• Embankment from Tunnel Excavation	m^3	181,000
2 Subbase and Base		
• Aggregate Subbase	m^3	49,000
• Aggregate Base Course	m^3	51,000
• Bituminous Base Course Plant Mix	m^3	37,000
3 Surface Source and Pavement		
• Double Surface Treatment	m^2	105,000
• Bituminous Wearing Course	m^3	11,000
4 Structures		
4A Box Culverts	LM	1,390
4B Bridges		
• Foundation Pile	L.M.	5,300
• Substructure		
• Superstructure		
4C Pipe Culverts	LM	620
5 Drainage and Erosion Works		
• Drainage		
• Slope Protection Works		
6 Ancillary Works		
7 Tunnel Works		
7A Civil Works		
From South Portal		
• Tunnel Excavation / Lining	LM	750
• Concrete Pavement	m^2	5,600
• Drainage	LM	3,770
From North Portal		
• Tunnel Excavation / Lining	LM	1,135
• Concrete Pavement	m^2	8,400
• Drainage	LM	3,770
7B Tunnel Facilities		
7C Building Work (Relocation of Control Room)		
8 Engineer's Facility.		
Clean-up and Demobilization		



Notes: ▬▬ Continuous Activities ■■■■■■■ Discontinue Activities ●••••▶ •·············→ Critical Path Activities

Figure 14.5.1 Construction Schedule for the 2nd Kohat Tunnel and Access Roads

Chapter 15 COST ESTIMATE

15.1 General

The general composition of the project cost is shown in Figure15.1.1. The project cost consists of construction cost, physical contingency, engineering cost for design and construction supervision, land acquisition and compensation cost, and administration cost. Construction cost consists of direct construction cost and indirect construction cost including the Contractor's overhead and profit, and tax and duties.

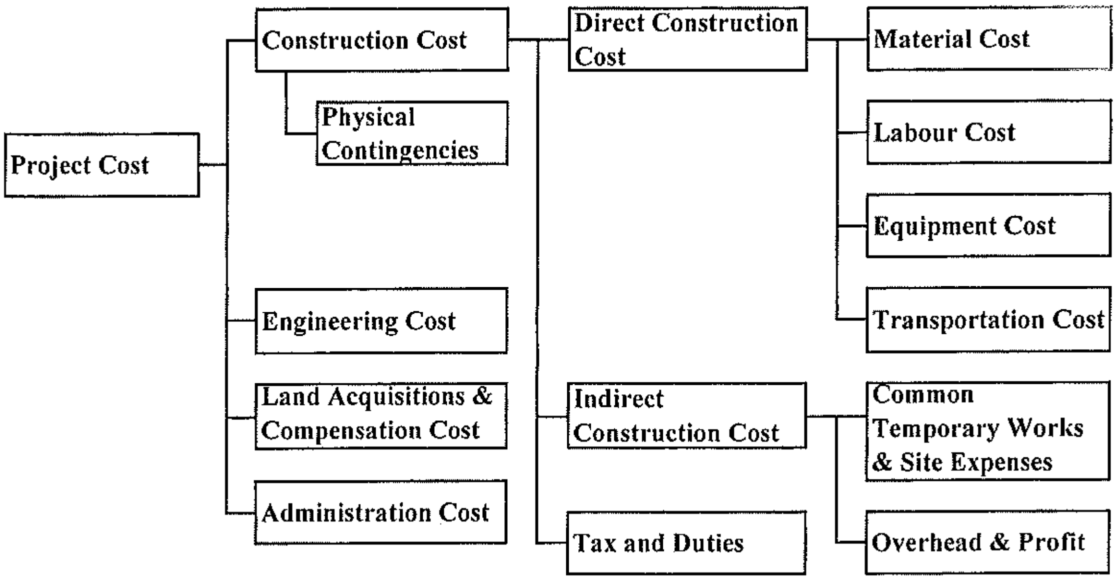


Figure 15.1.1 Composition of the Project Cost

As explained earlier, no additional land acquisition and compensation is required for the construction of the 2nd Kohat Tunnel and Access Roads, since the land required for 4-lane widening was already acquired.

The project cost was estimated in Pakistan Rupee at mid. 2006 price, and price contingency is not estimated. In converting the cost of import materials and equipment, an exchange rate of US$1.00 = Rs.60.0 = Japanese Yen 115.67 was used based on the following average rate during 1st February to 31st July 2006, as shown below.

		Average	High:	Low:	
USD1.00	= Rs.	59.975	60.360	58.950	(Pakistan Rupee)
USD1.00	= JYen	115.670	119.384	108.980	(Japanese Yen)
Rs.1.00	= JYen	1.930	1.990	1.835	(Japanese Yen)

In estimating the construction cost, it was assumed that the construction will be executed by an international contractor. The Pakistan contractors have experience in construction of highways and bridges, but no experience in tunnel construction. It was assumed that the Pakistan contractors will work as subcontractors of a qualified international contractor.

In analysing the unit prices, the NHA's Engineering Estimates were referred to, which estimate all the tax and duties and overhead and profit in the respective unit price of the direct construction cost items, and they were not estimated separately. The adopted overhead and profit was in average 25% of direct and indirect construction cost.

The project cost was estimated dividing the Project into the North and South Sections, since stage-wise construction is possible due to different traffic volume, and thus the different timing to reach the capacity.

15.2 Procurement Sources and Unit Rates

15.2.1 Procurement Sources

Possible procurement sources of materials, equipment and manpower for the construction were studied through the Pakistan market investigation. The investigation revealed that common materials, equipment, and manpower used for the construction of road and bridge structures can be procured in a domestic market, while those related to the tunnel construction have to be procured outside of Pakistan, as same situation as the 1st Kohat Tunnel and Access Road Construction Project.

15.2.2 Unit Rates of Construction Materials

Except tunnel construction related materials, most of materials can be procured locally as shown in Table 15.2.1.

Unit rates of construction materials which can be locally procured were studied based on the information obtained from contractors and suppliers in Pakistan. The unit rates of the major materials used in the construction cost estimate are shown in Table 15.2.2.

Table 15.2.1 Procurement Sources of Major Items

Items	Procurement Sources	
	Domestic	International
Cement	o	
Asphalt	o	
Emulsified asphalt	o	
Crusher run	o	
Sand	o	
Reinforcement	o	
Prestressing wire and anchorage	o	
Petrol	o	
Diesel fuel	o	
Kerosene	o	
Wood	o	
Tunnel Steel H-support	o	
Related materials to Tunnel		o

Remarks:

1) Cement: Domestic cement satisfies the quality and quantity requirement.

2) Reinforcement: Though it is rather expensive and not easy to obtain, considering the cost performance the steel re-bars are procured in Pakistan.

3) Tunnel Materials: Necessary to procure from international market. Procurement from Japan was recommended considering many experiences of tunnel construction.

Table 15.2.2 Unit Rate of Materials

S.No	Item and Description	condition	unit	Rate (Rs.)	Remarks
1	Cement: Ordinary Portland Cement	Ex factory	ton	5,640	
2	Asphalt : Gr-60-70	Ex factory	ton	27,925	(Bulk)
	Asphalt : Gr-60-70	Ex factory	ton	33,955	(Packet)
3	Sand : Fine - Course	at Site	m3	2,070	
4	Agregate : 2"-1.5", 3/4"-3/8"	at Site	m3	2,070	
5	Reinforcement bar: Gr-60	Ex factory	ton	45,000	ASTM-615
6	Pre-stressing wire strand: 3/8"-1/2"	at Site	ton	112,000	
7	H.S Diesel	ex pump	Litre	38.82	
8	Petrol	ex pump	Litre	58.80	
9	Keroseen Oil	Local Market	Litre	45	
10	Electric Charge	Commercial	KWh	10	
11	H- Shaped Steel	Ex factory	ton	(45,000-55,000)	(varies by shape)
12	Concrete Pipe Dia 300mm	Ex factory	Nos	1,750	8 ft long
13	Concrete Pipe Dia 900mm	Ex factory	Nos	10,781	8 ft long
14	Concrete Pipe Dia 1200mm	Ex factory	Nos	18,530	8 ft long
15	Rock Bolt L-3m	Local Market	Nos	1,450	25mm dia

The unit rates of import materials, mainly for tunnel construction, were referred to the Japanese market prices.

15.2.3 Unit Rates of Labour

Unit rates of labour were estimated based on the information from the local contractors. Table 15.2.3 shows the unit rates of Pakistan labours.

Table 15.2.3 Unit Rate of Labour

Item and description	Unit	Wages (Rs.)
Site Engineer	hr	450
General Forman	hr	250
Foreman earth work	hr	250
Foreman Concrete	hr	200
Foreman asphalt	hr	210
Foreman	hr	210
Supervisor	hr	200
Surveyor	hr	200
Assistant Surveyor	hr	130
Mason	hr	110
Carpenter	hr	110
Steel Binder / Cutting	hr	110
Highly Skilled Labour	hr	100
Helper	hr	100
Labour	hr	85

15.2.4 Unit Rates of Construction Equipment and Plants

Most of common construction equipment and plants can be procured in Pakistan. For these equipment and plants, operation costs were estimated based on the leasing prices, which include such costs as depreciation, operator, fuel and maintenance. The unit rates of locally available equipment and plants are shown in Table 15.2.4.

For the special equipment, mainly those required for tunnel construction, operation costs were estimated based on a depreciation basis.

Rate of the depreciation of equipment were assumed to be 60%-90% per Project, depending on the characteristics of equipment and their working conditions.

Table 15.2.4 Unit Rate of Equipment and Plants Operation

Item	Specification	Unit	Rate (Rs.)
Bulldozer	120HP(19ton)	hr	3,100
Bulldozer	90HP (15ton)	hr	2400
Front End (FE) loader	3.0 m3	hr	3,000
Front End (FE) loader	2.5 m3	hr	2,600
Excavator	Crawler type 0.9m^3	hr	2,100
Excavator	Crawler type 0.6m^3	hr	950
Dump Truck	18t	hr	1,150
Dump Truck	108t	hr	950
Motor grader	165HP	hr	2,450
Motor grade	140HP	hr	1,600
Tandem vibration roller	10-12 ton	hr	1,430
Tire roller	18-21 ton	hr	1,115
Concrete batching plant	20 m3/hr	hr	1779
Concrete transit mixer	6 m^3	hr	721
Truck Crane	50 ton	hr	12,500
Asphalt Finisher	4m wide	hr	3,400

15.2.5 Transportation Cost

For the import materials and equipment, their transportation routes were assumed as below, and cost of the transportation were estimated and included in the direct construction cost.

1) India - Project Site (if any)
2) International - Karachi - Project Site (eg. Tunnel facilities, etc.)

15.3 Cost Estimate

15.3.1 Construction Quantity Estimate

The quantities for the construction of the 2nd Kohat Tunnel and Access Roads Project were estimated based on the preliminary design in Chapter 11, the Preliminary Design Drawings (Volume II of the Feasibility Study Report) and the General Specifications Of NHA.

The quantities were categorised to the following Bill Numbers specified in the General Specifications of NHA, except Bill No.7, Tunnel Works.

- Bill No.1: Earthwork and Allied Activities
- Bill No.2: Subbase and Base
- Bill No.3: Surface Cource and Pavement
- Bill No.4: Structures
  - Bill No.4A: Box Culverts
  - Bill No.4B: Bridges
  - Bill Bo.4C: Pipe Culverts
- Bill No.5: Drainage and Erosion Works
- Bill No.6: Ancillary Works
- Bill No.7: Tunnel Works
  - Bill No.7A: Civil Works
  - Bill No.7B: Tunnel Facilities
  - Bill Bo.7C: Building Work
- Bill No.8: Engineer's Facility.

The work items for the tunnel works, which consist of civil works, tunnel facilities and building, followed those used in the 1st Kohat and Access Roads Project.

The quantities were estimated by road section: Section 1 from the start point of the Project (Kohat Toi Intersection) to Sta.15+000 (Kohat Link Road IC) and Section 2 from Sta.15+000 (Kohat Link Road) to the end point of the Project (Dara Adam Khel Intersection). The tunnel construction is a part of the Section 2. Table 15.3.1 shows the major quantities for Bill No.1 to Bill No.6 (roadway construction). Table 15.3.2 shows the major quantities for Bill No.7 (tunnel works).

Table 15.3.1 Quantities of Major Work Items for Bill No.1 to Bill No.6

(Roadway Construction)

Item	Description	Unit	Section 1* Start to Sta.15+000	Section 2** Sta.15+000 to End	Total
BILL NO.1: EARTHWORK AND ALLIED ACTIVITIES					
101	Clearing and Grubbing	m^2	233,580	282,333	515,913
106a	Disposal of unsuitable common Material	m^3	186	5,135	5,321
108a	Formation of Embankment from Roadway Excavation in common material	m^3	3,186	87,801	90,987
108b	Formation of Embankment from Roadway Excavation in Rock material	m^3	27,939	211,787	239,726
PS-14	Excavated Material from Tunnel to be used in Roadway Embankment including spreading, compacting Rolling, Watering and Testing	m^3	-	181,477	181,477
108c	Formation of Embankment from Borrow Excavation in Common Material with all leads	m^3	393,882	200,277	594,159
BILL NO.2: SUBBASE & BASE					
201	Granular Sub Base	m^3	25,245	23,513	48,758
202	Aggregate Base Course	m^3	27,257	23,959	51,216
203c	Bituminous Base Course Plant Mix (Class-A)	m^3	9,991	10,106	20,097
203d	Bituminous Base Course Plant Mix (Class-B)	m^3	9,064	7,828	16,892
BILL NO.3: SURFACE COURSE AND PAVEMENT					
304b	Double Surface Treatment	m^2	52,688	52,786	105,473
305a	Bituminous Wearing Course Class - A	m^3	5,465	5,041	10,506
310b	Reinforced Concrete Pavement (30cm thick)	m^2	-	4,205	4,205
BILL NO.4A: STRUCTURE, BOX CULVERTS					
107a	Structural Excavation in common Material	m^3	3,306	11,611	14,917
401a	Concrete Class A	m^3	2,233	5,733	7,966
404b	Reinforcement as per AASHTO M31 Grade-60	Tonne	226	617	843
BILL NO.4B: STRUCTURE, BRIDGES					
107a	Structural Excavation in Common Material	m^3	2,740	2,039	4,779
401a	Concrete Class A	m^3	1,082	1,391	2,473
401c	Concrete Class C	m^3	2,887	3,346	6,233
401d	Concrete Class D	m^3			
404b	Reinforcement as per AASHTO M31 Grade 60	Tonne	565	720	1,285
PS6-a	Prestressed Girders (20m - 30m span)		32	48	80
SS-44_414	RCC Girders: Concrete Class D (12m span)		4	4	4
407d	Cast in place Concrete Piles type				
	750 mm dia	L.M	1,680	2,265	3,465
	900 mm dia	L.M	1,272	585	1,857
BILL NO.4C: STRUCTURE, PIPE CULVERTS					
107a	Structural Excavation in common Material	m^3	244	55	299
401a	Concrete Class A	m^3	157	49	206
501i	Standard Strength Reinforced Concrete Pipe Culverts AASHTO M170 dia 910mm	L.M.	397	-	397
501j	Standard Strength Reinforced Concrete Pipe Culverts AASHTO M170 dia 1070mm	L.M.	-	96	96
BILL NO.5: DRAINAGE AND EROSION WORKS					
107a	Structural Excavation in Common Material	m^3	-	11,254	11,254
411b	Stone Masonry Random with mortar	m^3	-	7,663	7,663
509c	Riprap Class " C" (80mm thick)	m^2	161	1,991	2,152
509e	Grouted Riprap CLASS - A (300mm thick)	m^2	1,848	6,576	8,424
509f	Grouted Riprap Class B (500mm thick)	m^2	5,826	19,089	24,915
PS9-e	Concrete Class C to invert and slope of drainage ditch	m^3	729	474	1,204
BILL NO.6: ANCILLARY WORKS					
601d	Precast Concrete Curbstone	L.M	29,840	26,360	56,200
601g	Median Concrete Barrier	L.M	-	2,830	2,830
604a	Metal Guardrail	Each	4,608	6,080	10,687
PS16	Steel Wire mesh for safety netting	m^2	1,200	18,402	19,601

Notes: * Section 1 is from the Start Point to Sta.15+000 (Kohat Link Road)

** Section 2 is from Sta.15+000 (Kohat Link Road) to the End Point (Dara Adam Khel Intersection)

Table 15.3.2 Quantities of Major Work Items for Bill No.7 (Tunnel Works)

Item	Description	Unit	Quantity
BILL NO.7A : CIVIL WORK.S			
	EXCAVATION (ROCK)		
T.1-T.2	Excavation of CI class Rock CI	m^3	86,406
T.3-T.4	Excavation of CI class Rock CII	m^3	19,852
T.5-T.7	Excavation of CI class Rock DI	m^3	38,599
T.8-T.9	Excavation of Portal	m^3	7,148
	SHOTCRETE		
T.11-T.17	Shotcrete in CI, CII , DI and Portal Patterns	m^3	4,999
	ROCK REINFORCEMENT		
T.19-T.20	Rock Bolts 3m in length in CI and CII Rock	No	13,678
T.21-T.23	Rock Bolts 4m in length in DI Rock	No	9,670
T.24-T.28	Rock Bolts 2-4m in length in Portal, Substation	No	6,029
T.29-T.32	**STEEL RIBS**	Ton	382
	WATER PROOFING SYSTEM		
T.33	Water Proofing system in Tunnel lining	m^2	42,696
	TUNNEL LINING		
T.34-T.40	Concrete Class B to Tunnel Lining	m^3	15,818
	BACKFILL & ROADWORK'S		
T.47	Concrete Road Slab (t-300)	m^2	13,969
	DRAINAGE		
T.61	310mm (nominal) diameter	m	1,997
T.62	150mm (nominal) diameter side Drain	m	3,776
BILL NO.7B : TUNNEL FACILITIES			
	LIGHTING SYSTEM TUNNEL		
L.2-L4	Lighting Luminaire SON -T 70W - 250W	No	1,106
L.7-L.9	Cable PVC 10 mm^2-4C - 35mm^2-4C	L.M	24,213
L.10-L.14	Cable BC 6 mm^2 - 16 mm^2	L.M	27,099
L.23	Lighting Luminaire SON -T 150W	No	4
L.25-L.27	Cable PVC 16 mm^2 -2Core - 16 mm2-3Core	L.M	3,779
L.29-L.37	**TOLL PLAZA (For Extension)**		
	VENTILATION		
V.1	Jet Fan dia 1250 37 KW	No	
V.1a	Providing Jet Fan dia 1250 37Kw	No	6
V.1b	Mountaning of Jet Fan dia 1250	No	8
V.5	CO Meter	No	2
V.6	VI Meter (Projector & Receiver)	No	2
V.7	Air Speed Meter (Anemometer)	No	1
V.17-V.21	Cable for control 1.0 mm^2 10 C - 1.0 mm^2 20C	L.M	10,034
	SAFETY SYSTEM		
S.4	Big Type Extinguisher	No	5
S.9	Emergency Telephone & its Box	No	4
	POWER SUPPLY SYSTEM		
P.18	Diesel Engine Generator 300 KVA	No	1
	SUPERVISION & CONTROL SYSTEM		
C.1-C.12	Various Control Panels	No	9
C.13	Software	Item	1
BILL NO.7C : BUILDING WORK			
PBS.0	Yard preparation	L.S	1
PBS.0a	Removal of Existing Control rooms Facilities	L.S	1
PBS.3	Control Room and Substation	L.S	1

15.3.2 Construction Cost

Unit price of each work item was analyzed. For the estimation of unit prices of individual work items, input requirements of, materials, manpower and equipment were established. The official Pakistan cost estimate guideline, "Rate Analysis Formula for NHA CSR 2000 Road Works" was referred to for common highway and bridge construction works.

For the tunnel works, which are not included in the above guideline, unit price analysis was made referring to the cost estimate manuals issued by the Ministry of Construction, Japan.

The unit prices were established by adding indirect construction cost including temporary works & site expense, and overhead and profit.

The direct construction cost was then estimated by multiplying the respective unit price to the work quantity estimated in the preliminary design.

15.3.3 Physical Contingency

Physical contingency was estimated at 10% of total construction cost.

15.3.4 Engineering Cost

The engineering cost for preparation of detailed design, assistance in tendering and construction supervision was estimated at 10% of total construction cost.

15.3.5 Administration Cost

Administration cost which shall be the expenses of NHA was estimated at 1% of the sum of the construction cost and the engineering cost.

15.3.6 Project Cost

The total project cost was estimated at Rs.6,322.0 million (equivalent to US$ 105.5 million), as shown in Table 15.3.3.

Table 15.3.3 Summary of Project Cost

Description		Amount		(Unit: x1,000 Rs.)	
		South Section*	North Section**	Total	
I.	CONSTRUCTION COST				
1	Earthwork	194,044	402,898	596,942	(11.4%)
2	Subbase and Base Courses	173,042	166,053	339,095	(6.5%)
3	Surfacing	86,281	97,408	183,689	(3.5%)
4A	Structure: Box Culvert	68,106	179,653	247,759	(4.7%)
4B	Structure: Bridge	261,259	291,194	552,453	(10.6%)
4C	Structure: Pipe Culvert	17,432	13,003	30,435	(0.6%)
5	Drainage and Erosion Protection Wo	26,072	70,991	97,063	(1.9%)
6	Ancillary Works	99,091	149,326	248,417	(4.8%)
7A	Tunnel Civil Works		1,794,185	1,794,185	(34.3%)
7B	Tunnel Facilities		868,412	868,412	(16.6%)
7C	Building Works		118,011	118,011	(2.3%)
8	Engineer's Facility	27,760	124,534	152,294	(2.9%)
	TOTAL CONSTRUCTION COST	**953,087**	**4,275,668**	**5,228,755**	**(100.0%)**
II.	**PHYSICAL CONTINGENCY (10%)**	**95,309**	**427,567**	**522,876**	
III.	**ENGINEERING COST(10%)**	**95,309**	**427,567**	**522,876**	
IV.	**ADMINISTRATION COST(1%)**	**10,484**	**47,032**	**57,516**	
	TOTAL PROJECT COST	**1,154,189**	**5,177,834**	**6,332,023**	

Notes: * South Section: Construction of Access Road from Start Point to Sta.15+000 (Kohat Link Road IC)

** North Section: Construction of the 2nd Kohat Tunnel and Access Road from Sta.15+000 to End Point

15.4 Operation and Maintenance Costs

15.4.1 Operation and Maintenance Cost of Tunnel Facilities

(1) Routine Maintenance

From the record of the 1st Kohat Tunnel, an yearly operation and maintenance cost by the Maintenance Contractor and Operator (MC&O) is estimated at Rs.88,432,000, as an average of five years, which includes staff salaries, tunnel vehicles and operation and maintenance of tunnel facilities.

Table 15.4.1 Operation and Maintenance Expenditure of 1st Kohat Tunnel

Items	For 5 years (Rs.)	Rs./Year	Ratio
Staff Salaries	335,883,660	67,177,000	76.0%
Tunnel Vehicles	35,353,000	7,071,000	8.0%
Operation & maintenance Cost	70,921,281	14,184,000	16.0%
Total	442,157,941	88,432,000	100.0%

After opening of the 2nd Kohat Tunnel, operation and maintenance scope will be expanded but no big additional expenditure will be required, since it is considered that the present staff can work for the two tunnels. Extra expenditure of 5% was estimated making the yearly expenditure for routine maintenance Rs.92,953,000.

(2) Electricity

The following table shows the actual electricity cost in May 2006.

Table 15.4.2 Electricity Cost of 1st Kohat Tunnel

Items	For a month (Rs.)	Rs./Year	Ratio
Tunnel	843,532	10,122,000	82.5%
Toll Plaza	49,375	593,000	4.8%
Administration Building	74,695	896,000	7.3%
Staff Resident Camp	32,240	387,000	3.2%
North Emergency Building	22,013	264,000	2.2%
Total	1,021,855	12,262,000	100.0%

After opening of the 2nd Kohat Tunnel, ventilation load will be reduced significantly. As an addition to the routine expenditure, 50% of electricity cost for tunnel operation (Rs. 10,122,000 x 50% = Rs. 5,061,000) was estimated.

(3) Periodic Expenditure

Ten units of jet fans are used for the 1st Kohat Tunnel, which started their operation in 2003. Since their durable life is about 20 years, it is necessary to replace them with new ones in around 2023. Their procurement cost was calculated as the periodic expenditure.

In the same way, some parts of the facilities in the control system, such as electric panels, need to be replaced after 10 years operation. The amount equivalent to 50% of the control system facilities was estimated as the periodic expenditure.

Renewal of 10 jet fans (every 20 years): Rs.133, 443,000

Renewal of control system facilities (every 10 years): Rs.90, 971,000

15.4.2 Physical Maintenance of Road Facilities

The road maintenance is a program to preserve and repair the road facilities in its designed or accepted configuration. Maintenance programs for the Project road include road surfaces, shoulders, drainage facilities (culverts and roadside drains), slopes, bridges, tunnel, traffic markings, signs, etc. The budget of these maintenance works is allocated by the NHA head office.

The maintenance programs are categorised to routine maintenance and periodic maintenance. The routine maintenance is the works that may need to be undertaken each year. The periodic maintenance is the works to be undertaken at an interval of several years. These maintenance costs have been estimated on the following assumptions (Table 15.4.3).

Table 15.4.3 Maintenance Cost for the Project Road

Category	Works	Cost	Program
Routine Maintenance	Pavement & Shoulders (Patching, partial reconstruction, etc)	2% of Pavement Construction Cost*	Every Year
	Bridge/Culvert (Cleaning, joint repair, etc.)	0.5% of Pavement Bridge & Culvert Construction Cost*	
	Drainage, Slope & Ancillary Items (Guardrails, vegetation control, etc.)	2% of Drainage, Slope & Ancillary Items Construction Cost*	
Periodic Maintenance	AC Overlay on AC pavement (including leveling thickness)	5cm thick AC Overlay 7.5cm thick AC Overlay Construction Cost	At 11th year At 21st year
	AC Overlay on PCC Pavement for Tunnel Section	10cm thick AC Overlay Construction Cost	At 21st year

Note: * average % by year

Table 15.4.4 in the next page shows a breakdown of the maintenance costs by category, program, road section and year.

Rs.22 million (Rs.7.3 million/year) has been spent for 1.8km of shoulder maintenance and repair since the opening of the 1st Kohat Tunnel and Access Roads. Most of the shoulder damages were caused by passage for overtaking and parking of heavy vehicles on the shoulders and this situation will continue in future. This situation will be improved substantially after construction of the 2nd Kohat Tunnel Access Roads to a dual carriageway. The pavement maintenance cost for the existing road will also be reduced about 20-30% per year as the traffic is distributed from 2 lanes to 4 lanes.

Table 15.4.4 Physical Maintenance Cost Estimate

Unit: Rs 1000

Stage of Project	Year	Section 1 (South), Start Point - Kohat Link Road: Routine Maintenance: Pavement /Shoulder	Section 1: Routine Maintenance: Bridge/ Culvert	Section 1: Routine Maintenance: Drainage, Slope & Ancillary	Section 1: Periodic Maintenance (AC Overlay on ACP)	Section 1: Total	Section 2 (North), Kohat Link Road - End Point: Routine Maintenance: Pavement /Shoulder	Section 2: Routine Maintenance: Bridge/ Culvert	Section 2: Routine Maintenance: Drainage, Slope & Ancillary	Section 2: Periodic Maintenance (AC Overlay on ACP)	Section 2: Sub-Total	Section 2: Tunnel Section Periodic Maintenance (AC Overlay)	Section 2: Total	Grand Total (Sections 1+2)	Remarks (% to Civil Cost except tunnel construction)	Cost Saving for Maintenance of 1st Kohat Tunnel Access Roads: Shoulder * Repair with PCCP/ACP	Cost Saving: Pavement * Maintenance	Cost Saving: Total
FS	2006															7,300		
FA	2007															7,300		
DD	2008															7,300		
Tender	2009															7,300		
C1	2010															7,300		
C2	2011															7,300		
C3	2012															7,300		
OM1	2013	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM2	2014	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM3	2015	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM4	2016	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM5	2017	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM6	2018	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM7	2019	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM8	2020	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM9	2021	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM10	2022	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM11	2023	3,034	1,733	1,252	90,052	96,071	2,961	2,399	2,203	84,121	91,684		91,684	187,755	7.48%	7,300	1,200	8,500
OM12	2024	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM13	2025	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM14	2026	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM15	2027	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%	7,300	1,200	8,500
OM16	2028	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
OM17	2029	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
OM18	2030	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
OM19	2031	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
OM20	2032	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
OM21	2033	3,034	1,733	1,252	135,078	141,097	2,961	2,399	2,203	126,182	133,745	16,075	149,820	290,917	11.60%		1,200	1,200
OM22	2034	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
OM23	2035	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
OM24	2036	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
OM25	2037	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
OM26	2038	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
OM27	2039	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
OM28	2040	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
OM29	2041	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
OM30	2042	3,034	1,733	1,252		6,019	2,961	2,399	2,203		7,563		7,563	13,582	0.54%		1,200	1,200
Total		91,027	51,983	37,549	225,131	405,690	88,827	71,966	66,095	210,303	437,191	16,075	453,266	858,955	34.24%	109,500	18,205	145,500

Notes: The shoulder repair with PCC pavement or AC pavement is 1.8 km (0.6km/year) since the opening. This activity will continue up to approximately 25% of the shoulders are replaced with PCC Pavement.

Chapter 16. PROJECT EVALUATION

16.1 General

The existing Kohat Tunnel has been contributing to realizing smooth traffic flows on the National Highway No.55 (N-55) and will continue to enhance the balanced development in the regions/whole country.

However, as explained in the Chapter 5 in this report, the traffic speed particularly in the section of the existing 2-lane tunnel is frequently slow downed when one lane is occupied by heavy vehicles running ahead and the service level will go down to an unacceptable level in near future. In order to maintain the functions of N-55 and to raise the service level, construction of the 2nd Kohat Tunnel is proposed. The purpose of this Chapter is to investigate and/or confirm the justification of implementation of the Project from the point of view of national economy. In addition, a financial analysis was also carried out as a Toll Road (Toll Tunnel) comparing project costs with toll revenues.

The scope of the entire Project to be evaluated is defined as follows:

1) Section 1: Widening of the existing 2-lane road to 4-lane dual carriageway for the South Access Road (from stating point to the Kohat Link Road IC: 15.0 km).

2) Section 2: Construction of the 2nd Kohat Tunnel and widening of the existing 2-lane North Access Road to 4-lane dual carriage way (from the Kohat Link Road IC to the ending point: 15.3 km).

16.2 Economic Evaluation

16.2.1 Economic Costs

All the costs (and benefits as well) estimated at the market prices are necessary to convert into the economic terms in the economic evaluation by excluding such transfer items as taxes and duties. In this Study, the Standard Conversion Factor (SCF = 0.88*) which is generally used in Pakistan was applied to obtain the economic costs. The results of cost estimates at market prices (financial costs) are presented in Chapter 15 and compared with the economic costs as shown below:

(Note:*:"Islamabad-Muzaffarabad Road Project (N-75) PC-1 Proforma, Sep.2005, NHA")

Table 16.2.1 Economic Project Costs (Rs 1000, 2006 Prices)

Road Section	Items	Financial Cost	Economic Costs
Section 1 (South)	Construction	953,087	838,717
	Engineering	95,309	95,309
	Administration	10,484	10,484
	Physical Contingency	95,309	83,872
	Sub Total	**1,154,189**	**1,028,382**
Section 2 (North)	Construction	4,275,668	3,762,588
	Engineering	427,567	427,567
	Administration	47,032	47,032
	Physical Contingency	427,567	376,259
	Sub Total	**5,177,834**	**4,613,446**
Section 1 + 2	Construction	5,228,755	4,601,304
	Engineering	522,876	522,876
	Administration	57,516	57,516
	Physical Contingency	522,876	460,131
	GRAND TOTAL	**6,332,023**	**5,641,827**

Source: Study Team

The operation and maintenance costs (O & M) after opening the 4-lane roads are estimated as shown in Chapter 16 and converted into the economic costs as well.

16.2.2 Economic Benefits

(1) Quantification of Benefits

Benefits estimated quantitatively are user's benefits which are enjoyed by the expanded tunnel/access road users and classified into the following two types:

- Savings in Vehicle Operating Costs (VOC Savings)
- Savings in Travel Time Costs (TTC Savings)

The savings in traffic accident costs are also expected after opening the 2nd tunnel. However, no accidents in the existing tunnel were reported since its opening in 2003 and accident data on the existing old route via N-55 is not available. Therefore, saving benefits of traffic accidents were not estimated.

(2) "With" and "Without (W/O)" Comparison

The above benefits were estimated based on the "With and Without Project comparison method". "With Project" case means the situation that the Project is implemented and the 4-lane access roads and 2nd Kohat Tunnel are constructed. On the other hand, "Without Project" case means the present situation with 2-lane access roads and 2-lane Kohat Tunnel.

(3) Traffic Demand

The traffic demand of Project is one of the main factors for the project evaluation. The results of traffic demand forecast are shown in Chapter 7 and applied to the project evaluation. It should be noted, however, that the forecasted traffic demands of the Project are considered to be for the case of "With Project" and assumed that the traffic demands in "Without Project" are the same volume as the "With Project" case regardless the 4-lane tunnel and 4-lane access roads are constructed or not. In these circumstances, the forecasted traffic demands are commonly applied to the both "With" and "Without" Project cases taking into no considerations on the condition of diverted traffic from other routes which would use the worse/more congested and time consuming routes in "Without Project" case. Therefore, the benefits from the Project were estimated based on the only differences of vehicle speed between the case of 2-lane tunnel/ 2-lane access roads and 2nd tunnel with widened 4-lane access roads applying the same traffic demands.

(4) Calculation of Future Vehicle Speed under "With" and "Without" Project Situations

Speed surveys in the existing Kohat Tunnel were carried out by the Study Team in June 2006. The results revealed that the average speed in the Tunnel was 16.7 km/hour to the north direction and 30.9 km/hour to the south direction. The speed in the tunnel (and partly on the 2-lane access roads as well) is affected by the slow movements of heavy vehicles such as 3-4 axle trucks. The relationships between surveyed speed and traffic volume at that time (every 15 minute counting carried out by the Study Team in May 2006) are shown in Figure 16.2.1 and Figure 16.2.2.

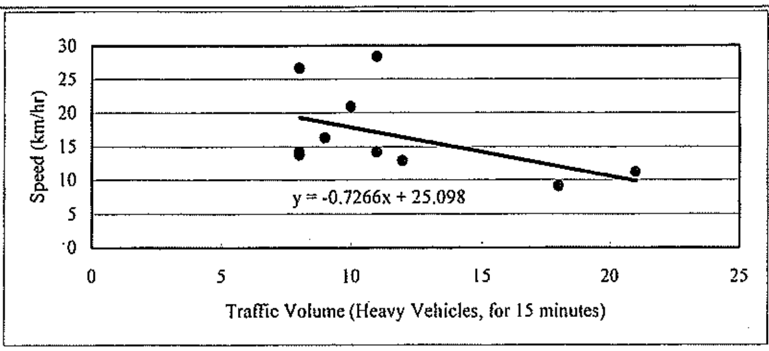
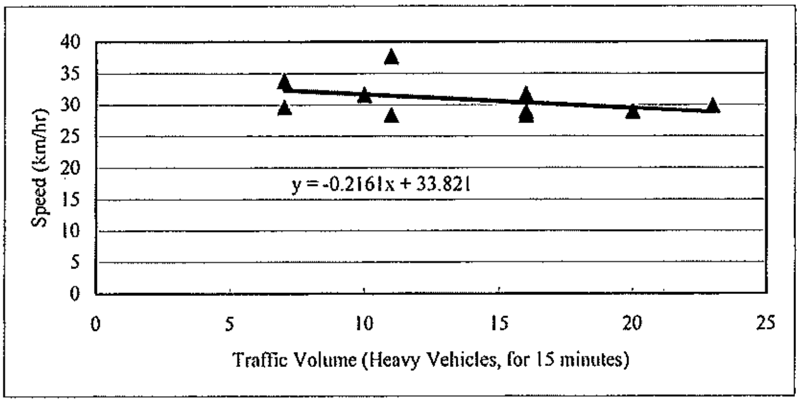


Figure 16.2.1 Speed and Traffic Volume (Heavy Vehicles in Tunnel): North Direction

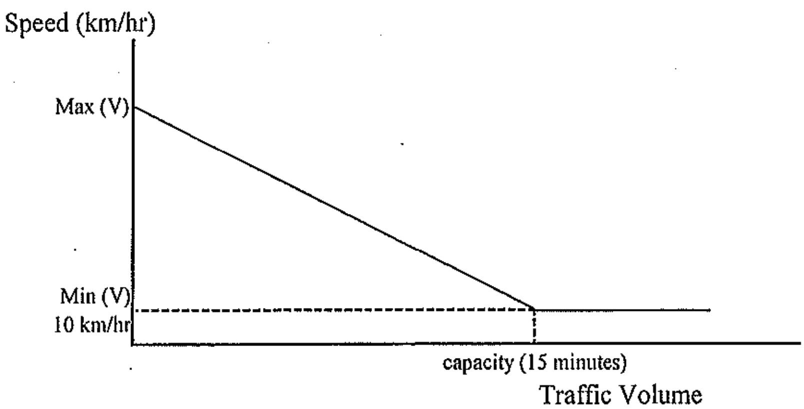


Source: Study Team

Figure 16.2.2 Speed and Traffic Volume (Heavy Vehicles in Tunnel): South Direction

The vehicle speed to the north direction (up-grade) in the tunnel goes down to 10 km/hour when the traffic volumes of heavy vehicles are around 20 vehicles per 15 minutes. On the other hand, vehicle speed to the south direction (down-grade) is almost flat with 30 km/hour of average speed although the negative relationship between speed and traffic volume (when traffic volume increases, travel speed goes down) is observed.

Based on the results above (parameters in Figure 16.2.1 and Figure 16.2.2) and taking into consideration traffic characteristics/ road conditions (speed of heavy vehicles and light vehicles, up-grade, down-grade, inside the tunnel and outside tunnel, etc.), the following type of formulas were established showing the relationship between traffic volume and travel speed (Q-V Formula):



Source: Study Team

Figure 16.2.3 Q-V Formula

The Q-V formulas above were established based on the following manners and conditions:

1) Road sections: 3 sections (Tunnel section, South Access and North Access roads)
2) Directions: 2 directions (from south to north, from north to south)
3) Vehicle Types: 2 types (heavy vehicles and light vehicles)
4) Number of lanes: 2 cases (existing 2-lane case and 4-lane case in future)

Therefore, total 24 formulas (3 x 2 x 2 x 2) were prepared as shown below:

Table 16.2.2 Q-V Formulas

Road Section	Vehicle Type	With or Without	Direction (S-N) Q-V Formula	Direction (N-S) Q-V Formula
Northern Access	Heavy (H)	W/O (2-lane)	V=-0.72657QH+30.0	V=-0.21615QH+35.0
		With (4-lane)	V=-0.72657QH+35.0	V=-0.21615QH+37.0
	Light (L)	W/O (2-lane)	V=-0.72657QH+40.0	V=-0.21615QH+40.0
		With (4-lane)	V=-0.22184QL+75.0	V=-0.23891QL+80.0
Tunnel Section	Heavy (H)	W/O (2-lane)	V=-0.72657QH+25.09821	V=-0.21615QH+30.0
		With (4-lane)	V=-0.72657QH+30.0	V=-0.21615QH+35.0
	Light (L)	W/O (2-lane)	V=-0.72657QH+25.09821	V=-0.21615QH+30.0
		With (4-lane)	V=-0.15358HL+55.0	V=-0.18771QL+65.0
Southern Access	Heavy (H)	W/O (2-lane)	V=-0.72657QH+30.0	V=-0.21615QH+35.0
		With (4-lane)	V=-0.72657QH+35.0	V=-0.21615QH+42.0
	Light (L)	W/O (2-lane)	V=-0.72657QH+80.0	V=-0.21615QH+80.0
		With (4-lane)	V=-0.25597QL+85.0	V=-0.27304QL+90.0

Source: Study Team

Note: V: Daily average speed, QH: Traffic of heavy vehicles (for every 15 minutes), QL: Traffic of light vehicles (for every 15 minutes)

The following points were also taken into account to decide the Q-V formulas:

1) The speed of light vehicles in the existing tunnel (W/O case) is dominated by the speed of heavy vehicles.
2) Light vehicles can overtake heavy vehicles when running outside the tunnel (on the access road sections).
3) Alignment of the south access road is better than the north access road and the grade is almost flat (0.53 % in average) and higher speed than the north access road is possible.
4) Controlled speed in the tunnel section is 40km/hr at present and 60km/hr in the case of the 2nd tunnel.
5) Controlled speed on the north and south access road are 80km/hr and 90km/hr respectively.
6) In the Q-V formula, minimum speed is set at 10km/hr.
7) Road capacity per 15 minutes is decided based on the capacity analysis explained in Chapter 7.

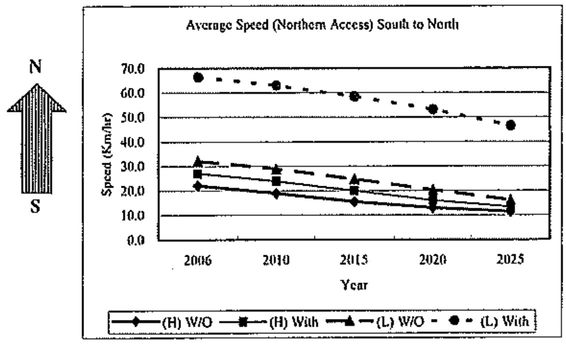
Applying the future traffic volumes to the Q-V formulas, future vehicle speed was calculated as shown in Figure 16.2.4 for both With and Without Project cases.

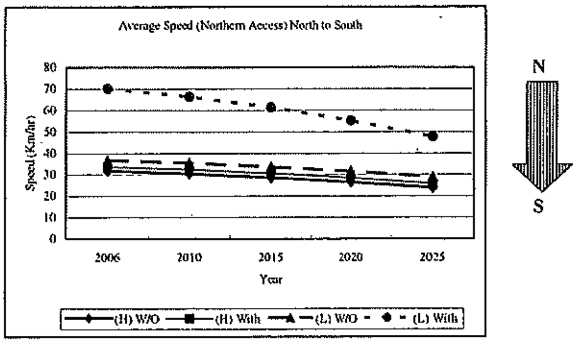
Daily Average Speed (Km/hr)
Northern Access Road
S ---> N

Vehicle Type	Condition	2006	2010	2015	2020	2025
Heavy Vehicle	(H) W/O	22.0	18.9	15.5	12.9	11.4
	(H) With	27.0	23.8	20.0	16.0	13.3
Light Vehicle	(L) W/O	32.0	28.8	24.7	20.3	16.1
	(L) With	66.4	63	58.5	53.1	46.5

Daily Average Speed (Km/hr)
Northern Access Road
N ---> S

Vehicle Type	Condition	2006	2010	2015	2020	2025
Heavy Vehicle	(H) W/O	31.6	30.3	28.5	26.4	23.8
	(H) With	33.6	32.3	30.5	28.4	25.8
Light Vehicle	(L) W/O	36.6	35.3	33.5	31.4	28.8
	(L) With	70.2	66.4	61.4	55.2	47.8



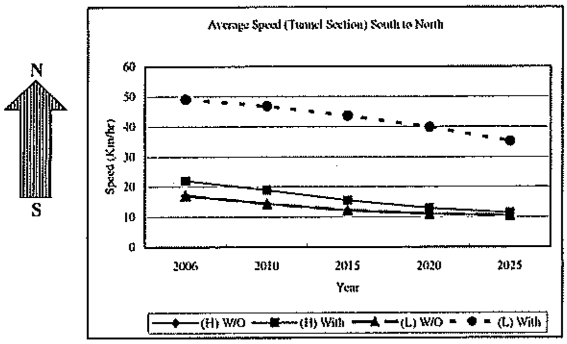


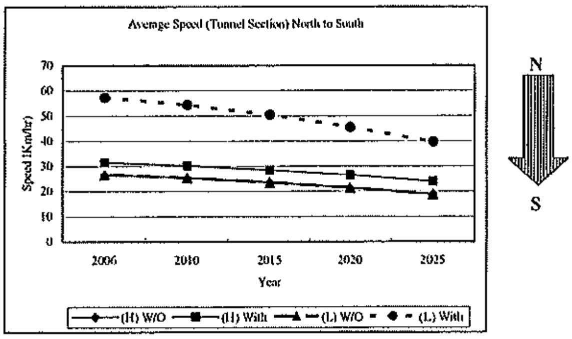
Daily Average Speed (Km/hr)
Tunnel Section
S ---> N

Vehicle Type	Condition	2006	2010	2015	2020	2025
Heavy Vehicle	(H) W/O	17.1	14.4	12.2	11.0	10.5
	(H) With	22.0	18.9	15.5	12.9	11.4
Light Vehicle	(L) W/O	17.1	14.4	12.2	11.0	10.5
	(L) With	49.0	46.7	43.6	39.8	35.2

Daily Average Speed (Km/hr)
Tunnel Section
N ---> S

Vehicle Type	Condition	2006	2010	2015	2020	2025
Heavy Vehicle	(H) W/O	26.6	25.3	23.5	21.4	18.8
	(H) With	31.6	30.3	28.5	26.4	23.8
Light Vehicle	(L) W/O	26.6	25.3	23.5	21.4	18.8
	(L) With	57.3	54.3	50.4	45.5	39.7



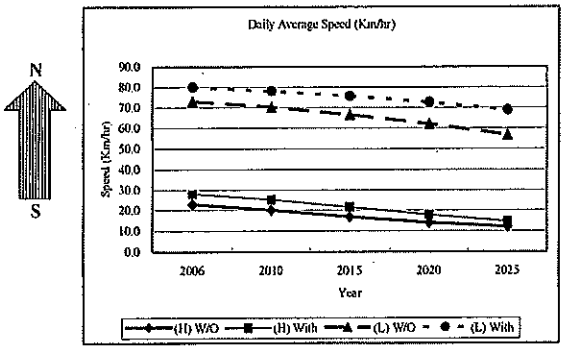


Daily Average Speed (Km/hr)
Southern Access Road
S ---> N

Vehicle Type	Condition	2006	2010	2015	2020	2025
Heavy Vehicle	(H) W/O	23.0	20.1	16.9	14.1	12.1
	(H) With	28.0	25.2	21.6	17.9	14.7
Light Vehicle	(L) W/O	73.0	70.2	66.6	62.1	56.8
	(L) With	80.1	78.2	75.7	72.6	68.9

Daily Average Speed (Km/hr)
Southern Access Road
N ---> S

Vehicle Type	Condition	2006	2010	2015	2020	2025
Heavy Vehicle	(H) W/O	32.2	31.2	29.9	28.2	26.1
	(H) With	39.2	38.2	36.9	35.2	33.1
Light Vehicle	(L) W/O	77.2	76.2	74.9	73.2	71.1
	(L) With	85.1	83.4	80.9	77.9	74.2



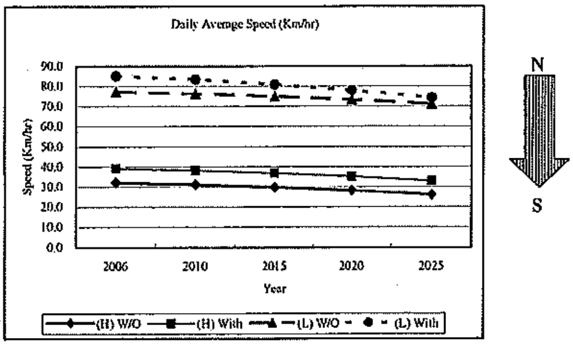


Figure 16.2.4 Calculation of Future Vehicle Speed by Road Section

(5) Vehicle Operating Costs (VOC)

The basic data of Vehicle Operating Costs are presented in PTPS Phase-I Study. As this basic data was calculated at the price of November 2005, some revisions were added in order to update to the present price level reflecting the recent sharp increase of petrol prices. The latest prices of fuel and engine oil are shown in Table 16.2.3.

Table 16.2.3 Updating Fuel Prices (Rs./litre)

Item		November 2005	August 2006	Increase %
Gasoline Super		56.37	57.78	2.5%
Diesel (HSD)		37.26	38.81	4.2%
Lubricant Oil	for Gasoline	187.10	211.8	13.2%
	for Diesel	193.30	218.30	12.9%

Source: CALTEX, PSO, Sitara-E-Hilly Co.ltd, Shell Pakistan, and Interviewed gas stands.

In addition to the above adjustments, the degree of grade of each road section of the Project was taken into account because the prepared VOC is applicable only for level tangent road section. As the project tunnel and access roads are located in the mountainous area, fuel consumption of vehicles will be affected by up-grade and down-grade. The necessary data for this adjustment is shown in Table 16.2.4.

Table 16.2.4 Adjustment of Fuel Consumption Rate for Rise and Fall

Rate of Rise (add Litre/1000km to level tangent road case)			
(meter/km)	Car, Jeep	Wagon, Minibus	Bus & Truck
	(+litre/1000km)	(+litre/1000km)	(+litr/1000km)
+10 (grade+1.0%)	17.22	31.39	49.29
+20 (2.0%)	34.43	62.77	98.58
+30 (3.0%)	51.65	94.15	147.87
+40 (4.0%)	68.86	125.54	197.16
+50 (5.0%)	86.08	156.92	246.45
Rate of Fall (subtract Litre/1000km from level tangent road case)			
	(-litre/1000km)	(-litre/1000km)	(-litre/1000km)
-10 (grade -1.0%)	9.22	13.49	20.72
-20 (2.0%)	18.45	27.58	41.45
-30 (3.0%)	27.67	41.38	62.17
-40 (4.0%)	36.89	55.17	82.90
-50 (5.0%)	46.12	68.96	103.62

Source: "Vehicle Operating Costs" NTRC-79, January 1985

The grade conditions of the Project Tunnel and the access roads are summarized below:

Table 16.2.5 Grade Conditions of the Project Tunnel and Access Roads (From South to North)

Section		Grade (%)
North Access	From North Portal to north end point (7.8 km)	-1.03%
Kohat Tunnel	Tunnel Section (1.885 km)	+2.40%
North Access	From Kohat Link Road to South Portal (5.6 km)	+2.52%
South Access	From start point to Kohat Link Road (15.0 km)	+0.53%

Source: Study Team

Based on the information of Table 16.2.4 and Table 16.2.5, the values of VOC on each road section of the Project were computed applying the following equations:

Table 16.2.6 Equations for VOC Calculation

Road Section	Average Grade (%) S-->N	Vehicle Type	Direction (S --> N)	Direction (N --> S)
North Access (after North Portal) 7.8 km	-1.03%	Car	$C=0.0023V^2-0.2858V+13.127$	$C=0.0023V^2-0.2858V+13.698$
		M.bus	$C=0.0049V^2-0.6468V+32.230$	$C=0.0049V^2-0.6468V+32.750$
		Bus	$C=0.0081V^2-1.0359V+50.592$	$C=0.0081V^2-1.0359V+52.141$
		2-axle	$C=0.0071V^2-0.8548V+37.155$	$C=0.0071V^2-0.8548V+38.173$
		3-axle	$C=0.0085V^2-1.0205V+44.479$	$C=0.0085V^2-1.0205V+45.303$
		Articulate	$C=0.0106V^2-1.2190V+53.850$	$C=0.0106V^2-1.2190V+55.192$
Tunnel & North Access (up to South Portal)	+2.40% & +2.54%	Car	$C=0.0023V^2-0.2858V+14.255$	$C=0.0023V^2-0.2858V+12.828$
		M.bus	$C=0.0049V^2-0.6468V+33.292$	$C=0.0049V^2-0.6468V+31.992$
		Bus	$C=0.0081V^2-1.0359V+53.777$	$C=0.0081V^2-1.0359V+49.904$
		2-axle	$C=0.0071V^2-0.8548V+39.247$	$C=0.0071V^2-0.8548V+36.703$
		3-axle	$C=0.0085V^2-1.0205V+46.174$	$C=0.0085V^2-1.0205V+44.120$
		Articulate	$C=0.0106V^2-1.2190V+56.609$	$C=0.0106V^2-1.2190V+53.267$
South Access (up to Kohat Link Road	+0.53%	Car	$C=0.0023V^2-0.2837V+13.217$	
		M.bus	$C=0.0049V^2-0.6420V+32.137$	
		Bus	$C=0.0080V^2-1.0269V+50.581$	
		2-axle	$C=0.0069V^2-0.8372V+36.769$	
		3-axle	$C=0.0084V^2-1.0053V+44.117$	
		Articulate	$C=0.0104V^2-1.1943V+53.263$	

Source: Study Team

Note: C=VOC, V=Average vehicle speed

(6) Travel Time Cost (TTC)

The saving in travel time cost is another important component of road/tunnel users' benefit. PTPS Phase-I estimated the unit value of travel time (Rs./hour/vehicle) at the 2005 price level. The revised/updated unit TTC was calculated applying the most recent data of per Capita GDP in FY2005/06 as shown below:

Table 16.2.7 Passenger Travel Time Cost (Rs./hour/vehicle:2006 prices)

Vehicle Type	Calculation Process	Time Cost /hour/person	Time Cost /hour/vehicle
Car	1) Previous JICA Study(*) in 1993: Time Value = Rs.21.02/hour/person 2) Growth rate of Per Capita GDP in current prices: 2006/1993=(Rs 46,954/Rs11,913)=3.94 3) Time Value of a main driver in 2006=Rs.21.02 x 3.94=**Rs.83.0/hour/person**	Rs.83.0 /hour/person	**Rs.166 /hour/vehicle** (No. of occupants = 2 persons
Mini Bus & Bus	1) Per Capita GDP (2005/06)=Rs.46,954/year 2) Working hours=25 days/month, 8 hour/day 3) Rs.46,954/12months/25days/8hours=Rs19.6/hour 4) 20% for work weighted at 1.00, 80% of non-work weighted at 0.5 5) Rs.19.6 x (0.2x1.0 + 0.8x0.5)=**Rs.12.0/hour/person**	Rs.12.0 /hour/person	Mini bus **Rs.204** /hour/vehicle (Occupants=17) Bus **Rs.540** /hour/vehicle (Occupants=45)

Source: (*) "The Study on National Transport Plan in the Islamic Republic of Pakistan", Final report, Feb.1995, JICA

In order to confirm the validity of the estimated time value above, a comparison with a different study was made as shown below.

Table 16.2.8 Comparison of Time Values

Study / Description	Islamabad-Muzaffarabad Road Project (N-75) Section, Sep.2005, NHA			This Study		
Vehicle Type	Car	Wagon /Minibus	Bus	Car	Wagon /Minibus	Bus
1) Passenger Time Value/hour/person	**Rs.82.15**	**Rs.32.86**	**Rs.32.86**	**Rs.83.0**	**Rs.12.0**	**Rs.12.0**
2) No. of occupants	2.6	14.0	40.0	2.0	17.0	45.0
3) Time Value/vehicle	**Rs.213.6**	**Rs.460.0**	**Rs.1,314.4**	**Rs.166**	**Rs.204**	**Rs.540**
4) Discounted to 25% (to reflect work and non-work time)	75%reduced Rs.53.4	75% reduced Rs.115.0	75% reduced Rs.328.6			
If the same rates of this JICA Study are applied:	0.466 x 3) = Rs.100	0.6 x 3) = Rs.276	0.6 x 3) = Rs.789			

Source: Study Team

As the value of travel time varies depending on the methodology/assumptions adopted and changeable year by year, it is necessary to check the effects of changed time values on the results of economic evaluation. Therefore, in this Study, sensitivity analyses were carried out assuming different values of travel time.

(7) Total Benefits Estimated

Results of benefit estimation are summarized in Table 16.2.9. As already explained, benefits which will accrue from the implementation of the Project will be born by the expansion of 2-lane tunnel/access roads to 4-lane and resulting speed up. The road surface is almost the same in "good condition" for both "With project" and "Without project" cases under the well maintained existing tunnel/access roads. This is one of reasons that the VOC saving benefit is lower than that of Time Cost saving in this Study, particularly in the north section of the Project.

Table 16.2.9 Estimated Benefits

(in Rs.million, 2006 prices)

	North Section (from Kohat Link Road to north end point (including the Tunnel)			South Section (from south start point up to Kohat Link Road)			Total of Project		
Year	Time Savings	VOC Savings	Sub total	Time Savings	VOC Savings	Sub total	Time Savings	VOC Savings	Total
2010	177.13	197.37	374.50	12.64	32.96	45.60	189.77	230.33	420.10
2015	358.31	303.87	662.18	25.27	51.89	77.16	383.27	355.76	739.03
2020	700.67	432.75	1,133.42	48.52	75.31	123.83	749.19	508.06	1,257.25
2025	1,301.35	575.57	1,876.93	84.21	104.47	188.68	1,385.56	680.04	2,065.60

Source: Study Team

16.2.3 Economic Evaluation

(1) Premises of the Evaluation

For the purpose of economic evaluation, the following preconditions were established:

1) Evaluation Cases:

Scenario 1: The North and South sections of the Project will be opened together with the 2nd Kohat Tunnel and 4-lane access roads at the beginning of 2013 in accordance with the Implementation Schedule.

Scenario 2: (Stage-wise construction) The North section including the 2nd Kohat Tunnel and 4-lane North Access Road will be opened at the beginning of 2013 and the South Access Road will be opened in 2020 (after 7 years) reflecting the results of traffic analysis which suggests that the traffic in the South Section will reach the LOS of E in 2020.

2) Evaluation period was set for 35 years (30 years after opening in the case of Scenario 1)
3) Opportunity Cost of Capital (Discount Rate) = 12%
4) No residual values were counted.

(2) Economic Cash Flows and Evaluation Indicators

The cost and benefit cash flows for the both scenarios are shown in Table 16.2.10 and Table 16.2.11. The following three (3) kinds of evaluation indicators were calculated

- Economic Internal Rate of Return (EIRR)
- Net Present Value (NPV)
- Benefit/Cost Ratio (B/C)

The results of evaluations are summarized as below:

Scenario	Indicator	
Scenario 1	EIRR	16.6%
	NPV (Rs.million)	2,342
	B/C	1.57
Scenario 2	EIRR	17.3%
	NPV (Rs.million)	2,476
	B/C	1.66

Source: Study Team

The results show that the implementation of the Project is economically feasible for the both scenarios. However, no big differences are observed between both cases.

Table 16.2.10 Cost Benefit Cash Flow (Scenario 1)

(North & South Sections 4-Lane Open in the same year 2013)

(Rs.Million)

Year	ECONOMIC COST					ECONOMIC	B-C	
	Construction	Engineering	Administration	O & M	COST	BENEFIT		
2006								
2007								
2008	0.00	64.14	9.41		73.54	0.00	-73.54	1
2009	0.00	78.43	12.03		90.46	0.00	-90.46	2
2010	1379.62	114.06	12.03		1505.70	0.00	-1505.70	3
2011	1840.91	133.12	12.03		1986.06	0.00	-1986.06	4
2012	1840.91	133.12	12.03		1986.06	0.00	-1986.06	5
2013				98.12	98.12	620.15	522.03	6
2014				98.12	98.12	684.00	585.88	7
2015				98.12	98.12	747.85	649.74	8
2016				98.12	98.12	851.43	753.32	9
2017				98.12	98.12	955.01	856.89	10
2018				98.12	98.12	1058.59	960.47	11
2019				98.12	98.12	1162.17	1064.05	12
2020				98.12	98.12	1265.75	1167.63	13
2021				98.12	98.12	1427.42	1329.30	14
2022				98.12	98.12	1589.09	1490.97	15
2023				448.87	448.87	1750.76	1301.88	16
2024				98.12	98.12	1912.43	1814.31	17
2025				98.12	98.12	2074.10	1975.98	18
2026				98.12	98.12	2177.38	2079.26	19
2027				98.12	98.12	2285.82	2187.70	20
2028				98.12	98.12	2392.39	2294.27	21
2029				98.12	98.12	2511.95	2413.83	22
2030				98.12	98.12	2624.93	2526.81	23
2031				98.12	98.12	2743.00	2644.88	24
2032				98.12	98.12	2866.38	2768.26	25
2033				342.17	342.17	2995.31	2653.14	26
2034				98.12	98.12	3130.05	3031.93	27
2035				98.12	98.12	3255.20	3157.08	28
2036				98.12	98.12	3385.36	3287.24	29
2037				98.12	98.12	3520.73	3422.61	30
2038				98.12	98.12	3661.51	3563.39	31
2039				98.12	98.12	3807.92	3709.80	32
2040				98.12	98.12	3960.19	3862.07	33
2041				98.12	98.12	3960.19	3862.07	34
2042				98.12	98.12	3960.19	3862.07	35
Total	5061.43	522.88	57.52	3538.27	9180.09	69337.19	60157.09	

N+S 4-Lane Open in the same year 2013
(Evaluation Period: 2008-2042)

EIRR (%)	16.6%	
NPV	2,342	Rs.million
B/C	1.57	

Opportunity Cost of Capital = 12%

Source: Study Team

Table 16.2.11 Cost Benefit Cash Flow (Scenario 2)

Stage-wise Construction
North Section: 4 Lanes Open in 2013
South Section: 4 Lanes Open in 2020 (Rs.Million)

Year	ECONOMIC COST					ECONOMIC BENEFIT	B-C	
	Construction	Engineering	Administration	O & M	COST			
2006								
2007								
2008		64.14	9.41		73.54	0.00	-73.54	1
2009		64.14	9.41		73.54	0.00	-73.54	2
2010	1379.62	99.77	9.41		1488.79	0.00	-1488.79	3
2011	1379.62	99.77	9.41		1488.79	0.00	-1488.79	4
2012	1379.62	99.77	9.41		1488.79	0.00	-1488.79	5
2013				92.82	92.82	550.85	458.03	6
2014				92.82	92.82	608.38	515.56	7
2015				92.82	92.82	665.92	573.10	8
2016		14.30	2.62	92.82	109.74	760.17	650.43	9
2017		14.30	2.62	92.82	109.74	854.41	744.68	10
2018	461.29	33.36	2.62	92.82	590.09	948.66	358.57	11
2019	461.29	33.36	2.62	92.82	590.09	1042.91	452.82	12
2020				98.12	98.12	1264.73	1166.61	13
2021				98.12	98.12	1426.40	1328.28	14
2022				98.12	98.12	1588.07	1489.95	15
2023				369.63	369.63	1749.74	1380.11	16
2024				98.12	98.12	1911.41	1813.29	17
2025				98.12	98.12	2073.08	1974.96	18
2026				98.12	98.12	2176.36	2078.24	19
2027				98.12	98.12	2284.80	2186.68	20
2028				98.12	98.12	2392.24	2294.13	21
2029				98.12	98.12	2511.80	2413.69	22
2030				177.36	177.36	2624.78	2447.42	23
2031				98.12	98.12	2742.85	2644.74	24
2032				98.12	98.12	2866.23	2768.12	25
2033				223.30	223.30	2995.17	2771.87	26
2034				98.12	98.12	3129.90	3031.79	27
2035				98.12	98.12	3255.06	3156.94	28
2036				98.12	98.12	3385.22	3287.10	29
2037				98.12	98.12	3520.58	3422.47	30
2038				98.12	98.12	3661.36	3563.25	31
2039				98.12	98.12	3807.78	3709.66	32
2040				216.98	216.98	3960.04	3743.06	33
2041				98.12	98.12	3960.04	3861.93	34
2042				98.12	98.12	3960.04	3861.93	35
Total	5061.43	522.88	57.52	3501.19	9143.02	68678.98	59535.96	

Stage Construction
N: 4 Lane Open 2013
S: 4 Lane Open 2020

EIRR (%)	**17.3%**	
NPV	**2,476**	Rs.million
B/C	**1.66**	

Opportunity Cost of Capital = 12%

Source: Study Team

16.2.4 Sensitivity Analysis

(1) Prepared Cases for Sensitivity Tests

The robustness of feasibility of the Project was tested by changing related factors within a probable range. The test cases prepared in this sensitivity analysis are as follows:

● Sensitivity Analysis 1 (Variations of Cost and Benefit)

Test 1: Project Cost: 10% up, Project Benefit: 10% down

Test 2: Project Cost: 20% up, Project Benefit: 20% down

● Sensitivity Analysis 2 (Variation of Evaluation Period)

Test 3: Evaluation Period: 20 years after first opening

● Sensitivity Analysis 3 (Variations of Unit Time Values)

Test 4: Unit Time Value: reduced by 20% from the original values

Test 5: Unit Time Value: reduced by 50% from the original values

(2) Results of Sensitivity Analysis

Results of the five tests are summarized in Table 16.2.12.

Table 16.2.12 Results of Sensitivity Analysis

Scenario	Tested Cases	EIRR (%)	NPV (Rs.million)	B/C
Scenario 1	Base Case	16.6	2,342	1.57
	Test 1: Cost: 10% up, Benefit: 10% down	14.4	1,284	1.28
	Test 2: Cost: 20% up, Benefit: 20% down	12.4	227	1.05
	Test 3: Evaluation Period: 20 years after first opening	15.2	1,239	1.30
	Test 4: Unit Time Value: reduced by 20%	15.2	1,546	1.38
	Test 5: Unit Time Value: reduced by 50%	12.8	352	1.09
Scenario 2	Base Case	17.3	2,476	1.66
	Test 1: Cost: 10% up, Benefit: 10% down	15.1	1,478	1.36
	Test 2: Cost: 20% up, Benefit: 20% down	13.0	480	1.11
	Test 3: Evaluation Period: 20 years after first opening	16.0	1,370	1.37
	Test 4: Unit Time Value: reduced by 20%	15.8	1,695	1.45
	Test 5: Unit Time Value: reduced by 50%	13.3	524	1.14

The results above indicate the robustness of the economical feasibility of the Project showing that the values of EIRR are higher than 12%, positive figures of NPV (NPV>0) and higher B/C than unity (B/C>1.0) in any cases prepared for the sensitivity analysis.

16.3 Financial Analysis

16.3.1 General

Financial analysis is, in general, carried out for the projects which generate revenues/income from projects. Unlike the economic analysis, the purpose of financial analysis is to investigate the financial viability of a project comparing the revenues with costs in terms of market prices (financial costs). It is noted that the financial analysis of the Kohat Tunnel Project was carried out only for the Scenario 1 (north and south sections open together in 2013). The toll revenues are generated from the north section (including the 2nd Tunnel) and the same amount of toll revenues are born in both Scenario 1 and 2.

16.3.2 Calculation of Toll Revenues

The toll structure of the existing Kohat Tunnel is presented in Table 16.3.1.

Table 16.3.1 Toll Structure of Existing Kohat Tunnel

Vehicle Type	Toll Level/vehicle
1) Car/Jeep	Rs.20
2) Hiace, F/Coach	Rs.80
3) Bus, 2-axle,3-axle truck	Rs.100
4) Articulated truck	Rs.150

Source: NHA

Toll revenues which will be born by the future traffic demand are shown in Table 16.3.2.

Table 16.3.2 Forecast of Toll Revenue

Year	Toll Revenue (Rs. Million)
2005 (Actual)	131.3
Forecast	
2006	165.9
2013	280.3
2015	316.5
2020	421.5
2025	548.3

Source: Study Team

16.3.3 Financial Evaluation

The financial cash flows are shown in Table 16.3.3. All cost items are expressed in terms of market prices (financial costs) and compared with future toll revenues. Financial Internal Rate of Return (FIRR) is computed at 4.7%, very low return to cover the total costs including investment cost unless some subsidies are given.

However, the Table 16.3.3 shows that the annual Operation and Maintenance costs (O & M cost) will be sufficiently covered by the annual toll revenues (O & M costs will be about 30-40% of the toll revenues). In addition, accumulated net surplus (revenue – O & M costs) after five years will reach more than Rs.1.0 billion under the constant price. If the inflation rate goes up more than 11% every year, net surplus will be lost.

Table 16.3.3 Financial Cash Flow

(North & South 4-Lane Open in the same year 2013)

2006 Constant Price (Rs.Million)

Year	FINANCIAL COST					TOLL	BALANCE			Accumulated
	Construction	Engineering	Administration	O & M	COST	REVENUE				Surplus
2006										
2007										
2008	0.00	64.14	9.41		73.54	0.00	-73.54	1		
2009	0.00	78.43	12.03		90.46	0.00	-90.46	2		
2010	1567.74	114.06	12.03		1693.83	0.00	-1693.83	3		
2011	2091.94	133.12	12.03		2237.09	0.00	-2237.09	4		
2012	2091.94	133.12	12.03		2237.09	0.00	-2237.09	5	(O & M)/R	
2013				111.49	111.49	280.32	168.83	6	39.8%	168.83
2014				111.49	111.49	298.54	187.05	7	37.3%	355.88
2015				111.49	111.49	316.46	204.96	8	35.2%	560.84
2016				111.49	111.49	335.44	223.95	9	33.2%	784.78
2017				111.49	111.49	355.57	244.07	10	31.4%	1028.86
2018				111.49	111.49	376.90	265.41	11		
2019				111.49	111.49	399.52	288.02	12		
2020				111.49	111.49	421.49	310.00	13		
2021				111.49	111.49	444.67	333.18	14		
2022				111.49	111.49	469.13	357.64	15		
2023				510.08	510.08	494.93	-15.15	16		
2024				111.49	111.49	522.15	410.66	17		
2025				111.49	111.49	548.26	436.77	18		
2026				111.49	111.49	575.67	464.18	19		
2027				111.49	111.49	604.46	492.96	20		
2028				111.49	111.49	634.68	523.19	21		
2029				111.49	111.49	666.41	554.92	22		
2030				111.49	111.49	696.40	584.91	23		
2031				111.49	111.49	727.74	616.25	24		
2032				111.49	111.49	760.49	649.00	25		
2033				388.83	388.83	794.71	405.88	26		
2034				111.49	111.49	830.47	718.98	27		
2035				111.49	111.49	863.69	752.20	28		
2036				111.49	111.49	898.24	786.75	29		
2037				111.49	111.49	934.17	822.68	30		
2038				111.49	111.49	971.54	860.04	31		
2039				111.49	111.49	1010.40	898.90	32		
2040				111.49	111.49	1050.81	939.32	33		
2041				111.49	111.49	1050.81	939.32	34		
2042				111.49	111.49	1050.81	939.32	35		
Total	5751.63	522.88	57.52	4020.76	10352.78	19384.92	9032.14			

N+S 4-Lane Open in the same year 2013
(Evaluation Period: 2008-2042)

FIRR (%)	4.7%

Source: Study Team

16.4 Impacts of the 2nd Kohat Tunnel

The construction of the 2nd Kohat Tunnel is expected to provide significant impacts in various aspects on both national and regional levels. Major impacts/ indirect benefits that will be generated from the 2nd Kohat Tunnel are summarised as below:

(1) Impacts on National Level

The Indus Highway (N-55) is one of important North – South Axes in Pakistan together with the N-5. However, the existing Indus Highway is a 2-lane highway except for a limited 4-lane section in the south of Peshawar. The Government of Pakistan is now promoting widening 2-lane national highways to 4-lane carriageways to strengthen the national road network, especially putting priority on the North – South Axes. The construction of the 2nd Kohat Tunnel and the 4-lane Access Roads will contribute to the formation of a part of the North – South Corridor providing the safety/well maintained 4-lane carriageways in such a steep mountainous area difficult to pass for heavy vehicles. In addition, the 2nd Kohat Tunnel as part of the North – South Corridor meets with the concept/ vision of National Trade Corridor (NTC), the strategic framework initiated by the Prime Minister of Pakistan in August 2005, for reducing costs of doing business by raising the trade and transport logistics chains in Pakistan to international service levels. Pakistan (and the Kohat Tunnel as well) is situated at the geographically strategic location to provide links to international trade with Afghanistan and land-locked Central Asian countries to its sea ports. Therefore, the 2nd Kohat Tunnel will contribute to the formation of NTC by increasing the Pakistan's transport competitiveness.

(2) Impacts on Regional Level

The existing Kohat Tunnel opened in 2003. As only three years has past after opening, the impacts of the first tunnel (existing tunnel) are still on-going and are not yet 100% realised at this moment. The expected impacts/effects of the 2nd Kohat Tunnel in addition to the first tunnel on the regional level (Kohat City, NWFP and surrounding provinces) are briefly explained below in general manners:

1) Promotion of Regional Economic Development

The construction of the 2nd Kohat Tunnel will increase the accessibility to/from Peshawar, the provincial capital, to/from the border with Afghanistan and to more long distance province such as Punjab. This increase of accessibility will raise the development potential of the region and will result in expansion of opportunities of employments, business and social activities.

2) Better Services of Public Transport

The possibility to provide new bus services via Tunnel under the operation with reliable time schedule and frequent services will be enhanced by the 2nd Kohat Tunnel. In that case, regional people who have no private cars can expand their daily activities in commuting and attending schools in Peshawar and in other areas.

3) Accessibility to Medical Services and other Public Facilities

With the construction of the 2nd Kohat Tunnel, patients in emergency can be sent more quickly to hospitals more qualified and with better medical facilities in Peshawar.

Finally, it should be emphasised that without the 2nd Kohat Tunnel, the functions of the National Highway N-55 will not be maintained and expected positive impacts on the regional/national economy explained above will be reduced or lost.

16.5 Conclusions

The implementation of the Project is economically feasible with 16%-17% of EIRR. The results of sensitivity analysis also show the robustness of the strong feasibility of the Project. In the analysis, two scenarios were prepared for the evaluation and the Scenario 2 (Stage-wise construction of the south access road) indicates higher EIRR than Scenario 1. However, there is no significant difference between two scenarios (EIRRs of Scenario 1 and 2 are at 16.6% and 17.3% respectively).

The results of financial analysis indicated the quite low return with 4.7% of FIRR and investment cost can not be covered by the future toll revenue. However, annual operation and maintenance costs will be sufficiently covered by the toll revenues.

Chapter 17. Project Implementation Plan

17.1 Implementation Plan of the Project

17.1.1 General

The 1st Kohat Tunnel and Access Roads between Kohat Toi and Dara Adam Khel was constructed with financial assistance of JBIC. The procurement of the Consultant and the Contractor was quite typical in accordance with the JBIC guidelines. Though the financial source of the construction of the 2nd Kohat Tunnel is not defined yet, it is natural to assume that a similar implementation system as the 1st Kohat Tunnel would be employed.

17.1.2 Executing Agency

NHA under the Ministry of Communication will be the executing agency responsible for construction and operation/maintenance of the Project.

For the detailed design and construction stage, a project management unit will be established in NHA, headed by a Project Director. The project management unit will represent NHA and work as the Employer of the Project.

As mentioned in Chapter 12, it is assumed that the operation and maintenance of the 2nd Kohat Tunnel will be carried out by expanding the present system for the 1st Kohat Tunnel. The Chief Operating Officer of NHA will be responsible for controlling the operation and maintenance works to be carried out by the Management Contractor & Operation (MC&O).

17.1.3 Expected Financial Source

Considering the budgetary constraint of NHA, it was assumed that the Project will be implemented with foreign financial assistance similarly to the other highway network development projects in Pakistan, undoubtedly JBIC who financed the construction of the 1st Kohat Tunnel being one of the most possible sources.

Recognising the urgency of the Project, given the situation that the tunnel traffic is approaching the capacity of the 1st Kohat Tunnel, the Pakistan Government should start to define a possible donor agency/country and apply for financial assistance for the Project as early as possible based on this Feasibility Study.

17.2 Considerations on Construction Phasing

At present, the Indus Highway is a 2-lane highway, with a limited 4-lane section in the south of Peshawar (refer to Figure 19.1.1). The Pakistan Government has a plan to upgrade the Indus Highway (N55) to a 4-lane highway, by widening or construction of additional carriageway for its entire length between Kotri and Peshawar. Currently, three sections have been proposed to ADB and Japan for financial assistance for additional carriageway construction, which include Sehwan - Rotodero (200 km), Ratodero - Shikarpur (44 km) and Malana Junction - Sarai Gambila (117 km). The remaining 2-lane sections will be upgraded to 4-lane one after another (refer to Chapter 3).

The need to upgrade the Indus Highway to 4-lane highway is further heightened under the National Trade Corridor (NTC) implementation program, recently formulated with a vision to enhance Pakistan's transport competitiveness, to promote regional trade and cooperation with Afghanistan and land-locked Central Asian Republics, and to let Pakistan a transit hub in the region, by making full use of the Pakistan's ideal location and its ports potential.

The highway sector improvement program to increase the capacity will represent a major share of the investment program to support NTC. Under the NTC implementation program, NHA has finalized the route plan of NTC from Karachi to Torkhum that has been approved by the Prime Minister. The route plan includes construction of additional carriageway to convert the existing 2-lane Indus Highway to 4-lane for the Dadu - Ratodero - Shikarpur section.

The implementation of the 2nd Kohat Tunnel and Access Roads construction is along the line of conversion of the Indus Highway to a 4-lane highway.

As discussed in Chapter 7, it is forecasted that the traffic in the North Section (15.2 km) between the Kohat Link Road IC and Dara Adam Khel, including the 1st Kohat Tunnel, is approaching the capacity, and construction of the additional 2-lane is urgent, while the traffic in the South Section (15.0 km) between Kohat Toi and the Kohat Link Road IC is still under the capacity. This situation is illustrated in Table 17.2.1.

Table 17.2.1 Capacity of the 1st Kohat Tunnel and Access Roads

Year	Annual Growth Rate (%)	South Section (Kohat Toi - Kohat Link Road IC)				North Section (Link Road IC - Dara Adam Khel)		
		Kohat Toi - N80: L=9.6km		N80 - Link Road IC: L=5.4km		L=15.2km including 2nd Kohat Tunnel		
		AADT (veh/day)	LOS of Access Road	AADT (veh/day)	LOS of Access Road	AADT (veh/day)	LOS of Tunnel Section	LOS of Access Road
2006-07		4,647		5,887	B	7,366		
2007-08	10.0	5,112	B	6,476		8,103	D	C
2008-09	9.0	5,572		7,059		8,832		
2009-10	8.0	6,017		7,623	C	9,538		
2010-11	7.0	6,469		8,195		10,254		
2011-12	6.5	6,922		8,769		10,972		
2012-13	6.5	7,372	C	9,339		11,685		D
2013-14	6.5	7,851		9,946		12,444		
2014-15	6.5	8,361		10,592		13,253		
2015-16	6.0	8,863		11,228		14,048	E	
2016-17	6.0	9,394		11,901	D	14,891		
2017-18	6.0	9,958		12,615		15,785		
2018-19	6.0	10,556		13,372		16,732		
2019-20	6.0	11,189		14,174		17,736		
2020-21	5.5	11,804	D	14,954		18,711		E
2021-22	5.5	12,453		15,777		19,740		
2022-23	5.5	13,138		16,644		20,826		
2023-24	5.5	13,861		17,560	E	21,971	F	
2024-25	5.5	14,623		18,525		23,180		
2025-26	5.0	15,355	E	19,452		24,339		F

As discussed in the next section, the possible opening of the 2nd Kohat Tunnel is the beginning of 2013 at the earliest, even a quick decision is made by the Pakistan Government to implement it with high priority.

At that time, the 1st Kohat Tunnel will be in Level of Service (LOS) E operation, i.e. operation in capacity, and the access road of the North Section (Kohat Link Road IC - Dara Adam Khel) in LOS D at which traffic flow is becoming unstable, freedom to manoeuvre within the traffic stream is noticeably limited, and even minor incidents can create queuing.

The operation of the South Section will be LOS C, in 2013. However, considering that its northern part (N80 – Kohat Link Road IC) will reach LOS D shortly, and the southern part (Kohat Toi – N80) in 4-5 years after completion of the 2nd Kohat Tunnel, there is no strong reason to postpone the construction of the South Section in stage-wise separately from the North Section, other than that the related investment can be postponed for several years only.

As analyzed in Chapter 16, stage-wise construction will increase the EIRR, but the increment is so small as to be negligible (0.7% only).

Therefore, it is recommended to construct the 2nd Kohat Tunnel and the entire length of the access road between Kohat Toi and Dara Adam Khel at once.

Avoidance of the twice tendering process will be an associated merit of the simultaneous construction. The engineering services cost and the NHA's administration cost will be optimized.

17.3 Implementation Schedule

17.3.1 Before commencement of construction

After completion of this feasibility study, several steps need to be cleared before commencement of construction. It is noted that land acquisition and compensation is not required for the construction of the 2nd Kohat tunnel because the necessary land for additional 2-lane construction was already secured along the entire stretch of the Project including the North and South Access Roads. The Project escapes from this normally difficult and time consuming process.

(1) Project screening by the Pakistan government

The project will be submitted by NHA/MOC to the higher committee with high priority, for review and approval for application to the appropriate donor agency/country. The time required for this procedure depends on the official procedure of the Pakistan Government. It is assumed to take at least three months for this step.

(2) Application for external financial assistance

The Pakistan Government will apply to the appropriate donor agency/country for financial assistance to the Project.

(3) Conclusion of external financial assistance

This procedure normally starts from receiving a fact-finding mission from the donor agency/country, followed by dialogue between the Pakistan government and the donor agency/country and receiving the appraisal mission. After the appraisal is successfully completed, financial assistance will be pledged and the loan agreement be concluded.

This is a lengthy step which normally takes nearly a year.

(4) Selection of the Consultant

The Consultant who will prepare the detailed design and tender documents, assist NHA for tendering, and provide construction supervision, will be selected in accordance with the guideline of the donor agency. Normally the selection of the Consultant will be through international competitive bidding. The time required for this step will be six months including time required for approval process by the Pakistan government and the donor agency.

(5) Detailed design and tender documents

The Consultant will carry out the detailed design and prepare the tender documents for procurement of the Contractor for construction of the Project. The tasks will include review of the feasibility study recommendations, detailed topographic survey and geotechnical investigations, detailed design of tunnel civil and electrical and mechanical (E&M) works and the access roads, preparation of the tender documents and the Engineer's cost estimate. Nine months will be required for this step.

(6) Procurement of the Contractor

The Contractor will be procured through international competitive bidding in accordance with the guideline of the donor agency. For the projects of this type and scale, the selection will be made through separate pre-qualification and tendering among the pre-qualified tenderers. As same as the 1st Kohat Tunnel, one contract package involving all civil and E&M works will be formulated.

This step involves pre-qualification, pre-qualification evaluation, tender including reply to the bidders' questionnaires and preparation of the addendum to the tender document, tender opening and tender evaluation, contract negotiation and signing of the contract, and approval process necessary by the Pakistan government and the donor agency. The time required for this step will be 10 months. A part of prequalification could be overlapped with the step (5) above.

17.3.2 Construction

After signing of the contract, the construction will be started. The construction period is estimated at 36 months for the North Section (north of the Kohat Link Road IC) including the 2nd Kohat Tunnel, and 24 months for the South Section.

17.3.3 Implementation Schedule

The implementation schedule of the Project is shown in Figure 17.3.1. The estimated opening of the 2nd Kohat Tunnel will be at the earliest at the beginning of 2013. According to the traffic forecast and capacity analysis discussed in Chapter 7, the tunnel traffic should have reached the capacity of the 1st Kohat Tunnel before the above opening year. Therefore, it is strongly recommended to send the Project to the screening process in the Pakistan Government and expedite the application for financial assistance to appropriate donor agency/country, soon after the completion of this feasibility study.

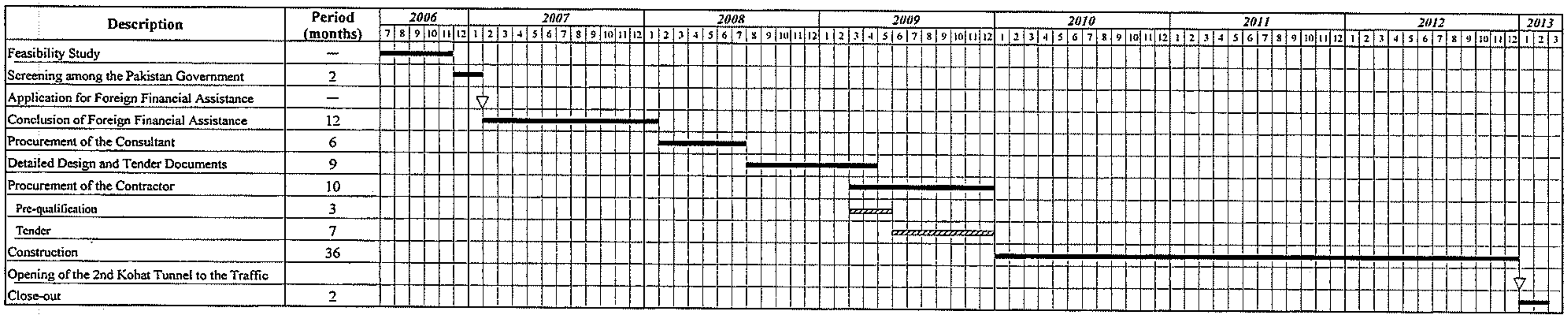


Figure 17.3.1 Implementation Schedule

17.4 Annual Fund Requirements

Based on the construction cost estimated in Chapter 15, and the implementation schedule, the annual fund requirements for construction of the Project are estimated as shown in Table 17.4.1.

Table 17.4.1 Annual Fund Requirements

Item		2008	2009	2010	2011	2012	Total
Foreign Currency Portion (US$ 1,000)							
1. Construction Cost (2006 price)				16,628	22,187	22,187	61,002
2. Price Escalation	0.0% p.a.			0	0	0	0
3. Physical Contingency	(1+2) x 10%			1,663	2,219	2,219	6,101
4. Constructiion Cost Total	1+2+3			18,291	24,406	24,406	**67,103**
5. Engineering Services		980	980	1,247	1,664	1,664	6,535
6. F.C. Portion Total	4+5	980	980	19,538	26,070	26,070	73,638
Local Currency Portion (Rs.1,000)							0
A. Construction Cost (2006 price)				427,543	570,547	570,545	1,568,635
B. Price Escalation	6.0% p.a.			112,220	192,974	238,784	543,978
C. Physical Contingency	(A+B) x 10%			53,976	76,352	80,933	211,261
D. Constructiion Cost Total	A+B+C			593,739	839,873	890,262	**2,323,874**
E. Engineering Services		19,632	19,631	24,946	33,284	33,283	130,776
F. Administration		784	784	15,250	20,349	20,349	57,516
G. L.C. Portion Total	D+E+F	20,416	20,415	633,935	893,506	943,894	2,512,166
Total (US$ 1,000)	6+G	1,320	1,320	30,104	40,962	41,802	115,508

Note: Exchange Rate: US$1.00 = Rs. 60.0
Assumed Foreign Currency Portion:
For Construction Cost: 70%
For Engineering Services: 75%
Assumed Price Escalation:
Foreign Currency Portion: 0.0% p.a
Local Currency Portion: 6.0% p.a

Chapter 18. Conclusions and Recommendations

The Final Report of PTPS Master Plan Study was submitted in March 2006. In this report, the 2nd Kohat Tunnel Construction Project was recommended as one of the priority projects to be selected for the next medium Term Development Framework (MTDF), or in parallel with the current MTDF, in view of their contribution to national economy, alleviation of traffic congestion and safety improvement.

18.1 The Condition of the Existing Kohat Tunnel and Access Road

The existing tunnel (1st Kohat Tunnel) and both access roads were completed and became operational in June, 2003. Up to now, no accident has been recorded in the tunnel by the severe vehicle checking by NHA monitoring and management. Traffic volume at the Kohat tunnel was increased by 12.4% from 2004 to 2005. For the period from January to May, the increase rate was 21.8% from 2005 (Jan-May) to 2006 (Jan-May).

The existing tunnel was constructed as a 2-lane (single carriageway road) at 2.2% up grade to the north. The design speed of the Kohat tunnel is 60 km/hour. Vehicle running speed has been controlled at 40km/hour and overtaking is not allowed in the tunnel for safety. However, the actual travel speed is 16.7 km/hour and it takes 7-8 minutes for the northbound traffic forming platoons behind slow-moving trucks, which cannot be broken up since passing maneuvers are not possible. The travel speed for the south bound traffic is 30.9 km/hour, that is less than the controlled speed, even though down-grade traffic.

Taking the above situation into consideration, the feasibility study of 2nd Kohat Tunnel Construction Project was selected by JICA as the most appropriate priority project in view of urgency, technical complexity, and the fact that the 1st Kohat Tunnel is named as the Pakistan-Japan friendship tunnel.

The feasibility study was commenced from the end of April, 2006. Hereinafter, major conclusions and recommendations of the study are introduced.

18.2 Traffic Analysis

The current traffic passing through the Kohat tunnel is 7,370 veh/day and it will continue to increase at a high percentage. Future traffic volume was forecast based on the analysis of the PTPS traffic survey, NHA's toll collection data, and supplemental traffic surveys carried out in the study. The future tunnel traffic is estimated to be 14,050 veh/day in 2015 and 24,340 veh/day in 2025.

The capacity analysis based on Highway Capacity Manual (Transportation Research Board, National Research Council, USA) revealed that the level of service of the existing Kohat Tunnel is already LOS of "D" level in a peak hour, and will experience LOS of "E" level within a few years.

The traffic on the Access Road in the south of the Kohat Link Road IC, located 4.6 km south of the tunnel (nearly the mid point of the entire Project length), will be 80% of the tunnel traffic and experience LOS of "D" level in 2013.

18.3 Preliminary Design

(1) Access Road

New 2-lane access road is designed beside the existing two lane access road within the already acquired ROW. Northern access road is 7,780m in length and southern access road is 20,607m in length.

In the design of southern access road, transition curves are employed in its horizontal alignment. Four intersections and ten bridges are planned.

(2) Tunnel

The location of south portal is shifted from the original plan proposed in the design stage of the 1st tunnel, to the western direction by 40m from the economical and technical view points. The distance between two tunnels will be 30m centre-to-centre. The location of north portal is same as the original plan. It is proposed to lower the elevation of the south portal because of technical reasons. As a result, the grade of the 2nd tunnel will be 2.4%, 0.2% steeper than the 1st tunnel. Since the 2nd tunnel will be used for the southbound traffic in down grade, this grade will not affect traffic flow and safety.

The same tunnel opening and cross section as the 1st tunnel is adopted.

(3) Tunnel Facility Works

For the tunnel facilities such as ventilation, lighting, power supply and emergency facilities, the same systems employed in the 1st tunnel will be adopted from economical and easy maintenance view points.

Since the planned tunnel portal will be located just behind the existing control room, it is necessary to relocate the existing control room and substation prior to starting tunnel excavation.

Two tunnels will be connected by two cross passages, which will be used for evacuation of tunnel users in case of accidents in the tunnels.

18.4 Environmental Study

The results of the IEE showed no major environment impacts were observed. Moreover, there do not appear to be any resettlement issues as the necessary ROW is already acquired by NHA. Based on the EIA law in Pakistan, this project would require a full scale EIA. However, considering that the project has the same nature as the widening project, NHA has to discuss with NWFP EPA whether an EIA will be necessary.

18.5 Construction Plan and O&M Plan

As the tunnel construction works is on the critical path in the construction schedule, the plan of tunnel excavation from both portals is recommended. New Austrian Tunnelling Method (NATM) will be applied for tunnel excavation and support. For the widening of the access road, construction method of hard rock excavation keeping traffic on the existing access road was examined. Excavation in association with controlled blasting and a hydraulic breaker is recommended.

Three years of construction schedule is considered to be most realistic and reasonable. Due to the technical complexity of the project, construction works are recommended to be conducted by a qualified international contractor.

NHA has contracted the operation and maintenance of the 1st Kohat Tunnel and Access Roads to a private company as Maintenance Contractor & Operator (MC&O) since its opening in May 2003 under overall supervision of NHA. As the current operation and maintenance system has worked well, the present system of operation and maintenance will be applied expanding the scope of works of MC&O to cover both tunnels

18.6 Cost Estimates

On the basis of the preliminary design and established unit prices, the project cost was estimated at approximately 6,332 million Pakistan rupees using ICB conditions at mid 2006 prices. At the same time, future operation and maintenance cost was estimated based on the operation record of the existing tunnel.

18.7 Project Evaluation

The economic evaluation was made by the conventional discounted cash flow methodology, and EIRR of the Project is confirmed as 16.6%. The major economic benefits quantified were the vehicle operation cost saving and travel time saving. The results of sensitivity analysis also show the robustness of the strong feasibility of the Project.

Financial evaluation was carried out the revenue using the current toll rates of the existing tunnel. The result shows FIRR of 4.7%. The investment cost cannot be covered by the future toll revenue. However, annual operation and maintenance costs will be sufficiently covered by the toll revenue.

These result indicated that the Project is feasible and sustainable.

18.8 Project Implementation Plan

The need to upgrade the Indus Highway to 4-lane highway is further heightened under the National Trade Corridor program. Stage-wise construction scheme of the Project (postpone the construction of the section in the south of the Kohat Link Road IC) was examined to attain higher EIRR, but the increment is so small as to be negligible (0.7% only).

Therefore, it is recommended to construct the 2nd Kohat Tunnel and Access Roads between Kohat Toi and Dara Adam Khel at once.

Implementation schedule is prepared on the basis that the Project will be implemented with foreign financial assistance. The estimated opening of the 2nd Kohat Tunnel will be at the earliest at the beginning of 2013.

18.9 Recommendation

(1) Construction of the 2nd Kohat Tunnel is viable from the macro-economic perspective. It will contribute to the development of the regional economy as well as national economy and have great significance in terms of developing a part of the National Trade Corridor. Moreover, at the earliest possible opening of the 2nd Kohat Tunnel in 2013, the tunnel traffic should have reached the capacity of the 1st Kohat Tunnel. Therefore, the Project should be an urgent project to be implemented at the earliest opportunity.

(2) Prior to undertaking the next step of implementation, NHA has to discuss with NWFP EPA whether an EIA is required for the Project. If required, NHA should prepare the EIA and receive Environmental Clearance from the EPA of NWFP. NHA/MOC should send this project to the screening process in the Government and expedite the application for financial assistance to appropriate donor agency/country, as soon as this feasibility study is completed. Since the 1st Kohat Tunnel and Access Roads Project was financed by JBIC, JBIC will be one of the most possible sources.

(3) Fortunately, no major accident has ever been experienced in Kohat tunnel since its opening, however, the Pakistan Government is requested to continue to take the following actions to keep and ensure smooth and safe highway operation.

- to reinforce control systems to eliminate truck overloading
- to establish education systems for drivers to keep safe driving with good driving manners.

Appendix A. LAND ACQUISITION & RESETTLEMENT

A-1 Introduction

It is predicted that no additional land acquisition or resettlement will be required since the extra land required for additional carriageway construction was already acquired during the land acquisition for the first tunnel and is marked on site by wire fencing. This appendix describes the legal framework and procedure that applies in Pakistan and is followed in any such cases.

A-2 Basic Approach

Large areas of land are sometimes needed for construction of roads. Pakistan rural areas are essentially a feudal society and such a construction often physically divides societies and communities. Some property values next to a road are degraded and the owners receive no benefits from the road. Local residents may feel the benefits are for road users i.e. persons remote from that area, and such major schemes require social justification. A major social issue is resettlement. Relocation of informal services such as food vendors can present them with an opportunity, but this must be explained to them, particularly when they see no benefits to them from the new road, even though compensation is paid for loss of income.

Land may be acquired by the government for projects of national interest. Compensation is paid for loss of land. For large land owners this is an opportunity but for small land owners it can represent a loss of income and livelihood. If land is currently under private ownership, or if activities are taking place on the land which generates revenue, then compensation is paid in accordance with the prevailing market price and legislation.

A-3 Legal Framework on Land Acquisition and Resettlement

The Land Acquisition Act (LAA) of 1894 covers all aspects of land acquisition and resettlement in Pakistan. In addition the Government has recently issued the "*Resettlement and Rehabilitation of Project Affected Persons Ordinance / Act 2003*" and the *"National Resettlement and Rehabilitation Policy 2003"*.

These laws and guidelines require compensation for lost assets to be paid to both titled and non-titled holders. The absence of formal titles does not constitute a bar to assistance, with assets valued at replacement cost. Resettlement assistance is given for loss of income and affected livelihoods. The regulations require special measures and assistance for vulnerable groups such as female-headed households, disabled persons, small farmers and the poor.

The resettlement principles provide compensation and resettlement assistance to *all* affected persons and businesses, including the informal squatters/encroachers on the project corridor of impact (COI). The basic resettlement principles and guidelines include the following:

- The Affected Persons (APs) are defined as those who stand to lose income as a consequence of the improvements of the road.
- All APs are equally eligible for compensation, irrespective of their ownership status, to ensure that those affected by the project should be at least as well off, if not better off, than they would have been without the Project
- The compensation packages shall reflect market-based replacement costs for all physically measurable losses
- APs will be systematically informed and consulted about the project. The project resettlement plan will be made available in both English and Urdu to the APs and

communities.

- The consultative process shall include not only those affected, but also representatives of the local governments of the areas where the project is located, community leaders, and social development organizations, such as NGOs or CBOs.

All of these details should be included and addressed in a Resettlement Plan. The Resettlement Plan should be prepared when the exact details of the necessary land acquisition and moving of affected persons is finalised.

A-4 Legal Procedure for Land Acquisition and Compensation

The Land Acquisition Act 1894, (with regular amendments) is the core legal tool used by the Government of Pakistan and its Provincial Governments, for acquiring private lands for "public" purposes. The process is initiated by a preliminary notice under Section 4 of LAA served by the District Land Acquisition Collector (LAC) expressing the desire to "enter upon" broadly identified private lands for surveying and soil-testing for the specified public purpose. Then, under Section 5, marking and measurement of the land is performed and an assessment made of compensation. The final declaration for possession is issued under Section 17 of the Act, having issued the awards to be made to individual owners.

Under this Act, only legal owners and tenants officially registered with the Land Revenue Department, or possessing formal lease agreements, are considered "eligible" for land compensation. Following the Act (S.5), cash compensation is assessed on the basis of three - five years average registered market rate, and is paid to the landowners for their lands being acquired. Land acquisition is to be completed in a total of 52 weeks (See table below)

General Timeframe for Land Acquisition in Pakistan

LAA Process	Agency Responsible	Timeline
Land Acquisition Proposal to Revenue Dept; project description, location, extent of land to be acquired.	Pak-EPA	Week 1-2
Publication of Notice expressing the intent to acquire the land under Section 4	Revenue Department (Each District)	Week 3-4
Field survey, inventory of assets under Section 5	Revenue Department	Week 5-20
Declaration for possession under Section 6	Revenue Department	Week 21-22
Compensation assessment & award preparation	Revenue Department	Week 23-24
Dispute/Objections (Grievance Redressal)	Aggrieved parties	Week 25-26
Possession of land, marking, clearance	Revenue Department	Week 23-52
Disbursement of compensation	Revenue Department	Week 23-52
Land acquisition to be completed in a total of 52 weeks (One Year)		

According to LAA, in case of a delay in payment of the compensation, the owner is eligible for 15% solatium, or "compulsory acquisition surcharge", plus 8% compound interest per annum from the date of notification (under Section 6).

In the 1960-70s, for some major projects in Pakistan, such as Mangla and Tarbela Dams, and the Capital City of Islamabad, the government gave a "land for land option" for "persons interested"[1]. The affected families were given house plots and agricultural land, and provided free transportation for moving household effects and salvaged construction materials.[2]

[1] The LAA uses a legal term – "persons interested" - for all persons currently using or benefiting from land being acquired. In resettlement terms, they are "affected persons - APs."

[2]. "Land Acquisition and Resettlement Policy and Practices in Pakistan – A Review." Report prepared under ADB-SSTA No. 3679 "*Social Impact and Resettlement Analysis for the Pakistan Roads Sector Development Project*", August 2001.

A-5 Land Acquisition and Resettlement Plan

(1) Approach

All land acquisition and resettlement will follow the procedures laid down in the Land Acquisition Act. This is a well established process and much experience in resolving any issues already exists among local government. The Resettlement Plan can only be prepared when the details of the land necessary for the project acquisition and the need to move any affected persons has been decided after consultation and is finalised.

(2) Tribal Areas

The rules laid down under the LAA only apply to the four provinces and the capital areas. The situation in tribal areas is different and comes under separate legislation. The procedure is similar but the means of evaluating compensation is not based on individual assessment of land, structures etc but is based on a fixed percentage of the capital costs of the project. This percentage is generally fixed by government but the disbursement of the funds is made through elected tribal leaders whose lands are affected. These leaders decide how the funds shall be divided among deserving persons. This procedure often involves a *Jirga*, a meeting of the tribal elders, during which everyone is entitled to express an opinion. These meetings are held under the auspices of the federally appointed Commissioner for the tribal area or agency.

(3) Grievances Redress Committees

The LAA enables aggrieved APs to represent their cases to the Land Acquisition Collector (LAC) or refer to a court of law for redress, and seek higher rates of compensation.

(4) Right of Way

The Right of Way for National highways is 220 ft (66m) minimum, for Provincial Highways is 110 feet (33.5 m), while for Rural Access Roads it is 66 feet (20.1 minimum). In fact, only the respective "formation widths" need actually be repossessed, while the remaining land can be left with the original landowners, or occupants. For a resettlement plan, only the corridors of immediate impact (COII), or the "Formation Widths" required for widening the roads need to be considered. This can minimize involuntarily resettlement.

(5) By-passes

By passes can be a good way to relieve inner city congestion, but often locals complain because their roadside businesses suffer. As they live over their shops or nearby their businesses, they do not want to relocate to a ring road. They may protest and slow down land acquisition. However, in Kohat, interviews with villagers have indicated that they are in favour of a new bypass as it removes traffic congestion from the town centre.

(6) "Illegal" Squatters and Encroachments

Many roadside shops and businesses are located within the "right-of-way" of roads, even though the land is owned by government. Road projects can impact on these, particularly if road widening is necessary.

According to legal procedures, the shops and businesses would be considered "illegal" squatters and encroachments and, therefore, ineligible for any compensation for loss of structures and/or businesses. However, in many project-specific cases, the Government of

Pakistan has assisted project-affected persons even without any legal titles.[3]

(7) Indigenous Persons

Any transport scheme that may impact on indigenous persons must have a full study on these impacts. Indigenous persons who may lose land, income, and livelihood or have their traditional way of life disturbed must be given extra attention. Pakistan has many tribal areas (e.g. NWFP, FATA, Northern Areas) but the number of Indigenous Persons is limited and mainly restricted to Balochistan.

(8) Monuments of Historical, Cultural, Religious or Community Value

Any structures of historical, cultural, religious or community value must be treated with utmost caution and all attempts made to avoid any impacts. Work should be conducted with sensitivity to the values of the original monument. Any discoveries made during construction should be reported to the local authorities, and advice sought from Antiquities Department and Ministry of Cultural and Religious Affairs. This is the responsibility of the contractor. The project proponent (NHA) is responsible for checking the contractor observes these requirements.

(9) Road side Graves

It is common in rural areas for deceased villagers to be buried in graves which are located close by the side of the road. It is claimed that this is a favourable location and it is very difficult to disturb them for road widening. However, often these are placed there deliberately when it is known a road will be improved to increase compensation when the road is widened. This matter requires firm but delicate handling.

A-6 Entitlement to Compensation

Persons affected by land acquisition or relocation of small businesses, structures and assets are entitled to a combination of compensation and resettlement assistance. This depends on the nature of ownership rights, lost assets, extent of impact, and vulnerability of the affected persons. In general, APs will be entitled to five types of compensation and resettlement assistance that helps them restore their livelihoods to at least the pre-project level :

- Compensation for loss of land, standing crops or trees
- Compensation for the loss or damage of commercial structures and immovable assets
- Assistance for livelihood restoration due to loss of farmland, and farming income, to tenants
- Assistance for livelihood restoration against loss of business by Small Business Enterprise owners, or loss of wages by employees
- Compensation for the relocation and restoration of cultural or community structures

Landowners and tenants of the acquired lands are considered as "entitled" persons when compensation is paid. For community structures, the compensation will be paid to the leader of the community group who use the structures.

Resettlement assistance is extended to the APs not covered under the compensation plan, that is non-title-holders, encroachers and squatters, business employees and other vulnerable groups. The following Entitlement Matrix provides further details regarding losses, entitled persons, and entitlements.

[3] E.g. ADB/World Bank-funded *Ghazi Barotha Hydropower Project* (1997); World Bank-funded *Mangla and Tarbela Dams* (1962); and ADB-funded *Sukkur Bridge Project* (1996).

Entitlement Matrix

#	Type of Losses	Entitlement
1	Partial loss of agricultural land, crops and trees by owners & (sharecrop / lease) tenants	▪ Cash compensation based on current market replacement value, plus 15% Compulsory Acquisition Surcharge (CAS). ▪ Cash compensation for loss of crops/trees at the market value ▪ Compensation to tenants at mature crop value crop-share ▪ Encroachers / squatters are not eligible for compensation for land on Road ROW but eligible for cash compensation for lost assets
2	Total / major loss of agricultural land by owners / tenants	▪ Financial assistance (grant/loan) and / or job opportunities in the project for an immediate restoration of livelihood (This will be in addition to the "cash compensation" paid under item No. 1)
3	Loss of commercial /other structures/ installations by owners (SBEs, tube-wells, livestock-sheds, etc.)	▪ Compensation for loss at full replacement cost on current value ▪ All salvageable materials will be allowed for rebuilding purposes ▪ Shops / SBE owners once paid due compensation will not be allowed to reestablish within the active ROW of the project roads ▪ Compensation for all other immovable assets on replacement value, plus installation costs (salvageable materials allowed) ▪ Where necessary, adequate transportation and labour costs will be paid, especially to the most vulnerable persons (poor / women)
4	Loss of business premise by renters / tenant	▪ One-time cash assistance equivalent to 2-months rent to the renters for alternative premise for re-establishing businesses ▪ If necessary, adequate transportation & labour costs will be paid
5	Income assistance for loss of business by shops / SBE owners / tenants	▪ One-time assistance, a lump sum grant; based on the nature of business and type and size of losses, the following range will apply: (i) small business up to Rs. 2,000; (ii) medium business up to Rs. 3,500; and large business up to Rs. 10, 000.
6	Loss of wages by SBE employees	▪ Wages for 30 to 60 days at local wage rate (or latest wages) ▪ Family workers in SBEs will not be paid any compensation; they are already covered by income assistance under #5. ▪ Special assistance to vulnerable persons, like, the poor, disabled and women-headed HH – one-time lump sum grant of Rs 1,000
7	Loss of cultural / community structures / installations	▪ Cash compensation at replacement value to patrons / user group leaders for rehabilitation / rebuilding of the affected part / whole, including construction / installation costs (salvageable material will be allowed for free for reuse in reconstruction / restoration) ▪ If not feasible, then the project will rebuild / restore at its own cost

A-7 Organizational Framework

(1) Stakeholders Meetings and Disclosure

Stakeholders meetings must be held to give disclosure on proposed road improvements. Meetings provide the affected persons an opportunity to voice their concerns about relocation, assistance to restore businesses and maintain livelihood sources. A consultative approach should identify measures to minimize displacement and reduce disruption of livelihoods.

(2) Disclosure of Resettlement Plan

The Resettlement Plan (RP) should be disclosed to stakeholders immediately following the appraisal of any scheme. The RP should be made available to local government councils and local offices as a "public" document. The affected persons should be informed about their entitlements well in advance of receiving payments, and be given time to prepare for their actual relocation.

A-8 Monitoring and Evaluation

A monitoring and evaluation program is necessary to check the "before" and "after" effects of the project. A socio-economic survey should be conducted on APs, such as passengers or drivers, the number being a representational sample, to assess the living conditions before the project, and then again after resettlement or restoration. The minimum objective is that standards of living are returned to those that existed before the project. As such road projects are part of a poverty alleviation strategy it is hoped that living conditions after the resettlement will be better than before.

Appendix B. Bore Hole Logs

Project :	Kohat Tunnel # 02			*Location:*	North Portal
Hole No.	BH-01	*Date Started*	16-06-06	*Sheet*	1 of 2
Ref. Elevation	726.20m	*Date Completed*	18-06-06	*Coordinates*	
Core Diameter	76 mm	*Type of Boring*	Straight Rotary	*Ground Water Depth*	Nil
Bit Design	-	*Bearing*	-	*Angle*	-
Driller	Fazal	*Geologist*	Munir Khan	*Engineer:*	Behram Khan

Depth (m)	*Core Recovery* Run No.	*Core Recovery* Recovery %	*Core Recovery* R.Q.D. %	*Rock Symbol*	*Description of Material*	*Drilling Fluid Recovery %*	*Dia of Casing /hole*	*Remarks*
	1	100	-		Yellowish grey firm Clayey SILT, with trace fine Gravels, slightly plasticity			
1	2	100	-					
	3	96	-		Shale: Dark brown, soft to fairly soft, very fine to fine grained, highly weathered, slightly plasticity, fine gravels also present			
2	4	100	-					
3	5	96	-					
4					Light brown, highly weathered Shale			
5	6	98	-		Shale: Dark brown, moderately hard, highly weathered			
	7	96	-					
6	8	97	-		Shale: Reddish brown to dark brown, fairly hard, fine grained, slightly to moderately weathered, very closely jointed. Joint surface are smooth, Calcite vein also present at places	80%		
6.5, 7	9	80	-					
8	10	72	-					
	11	90	-					
9	12	90	-					
10	13	90	-		Shale: Reddish brown to dark brown, fairly hard, fine grained, slightly weathered, very closely jointed			
11	14	84	-		Shale: Reddish brown to dark brown, fairly hard, fine grained, slightly weathered, very closely jointed, iron staining on joints & fractured surface	85%		
12	15	80	-					
13, 14	16	80	-		-Do-			
15	17	90	-					

End of Borehole at 15.0 m depth

Project :	Kohat Tunnel # 02		*Location:*	South Portal	
Hole No.	BH-02	*Date Started*	09-06-06	*Sheet*	1 of 2
Ref. Elevation	672.00m	*Date Completed*	13-06-06	*Coordinates*	
Core Diameter	76 mm	*Type of Boring*	Straight Rotary	*Ground Water Depth*	Nil
Bit Design	-	*Bearing*	Vertical	*Angle*	-
Driller	Fazal	*Geologist*	Munir Khan	*Engineer:*	Behram Khan

Depth (m)	*Core Recovery* Run No.	Recovery %	R.Q.D. %	*Rock Symbol*	*Description of Material*	*Drilling Fluid Recovery %*	*Dia of Casing /hole*	*Remarks*
0–2 (1)	DS-1	-	-		Sandy Gravel with some Cobbles trace Boulders. Gravels are poorly graded platy & crushed, Sand is grey medium to coarse grained.			
2	1	80	-		Limestone: Light grey to dark grey, fine grained, slightly to moderately weathered, weathering surface are yellowish brown joint, closely jointed, rough stained. Fine material & Calcite filled on jointed surface & fractured, very small Calcite vein also present.	60%		
3	2	78	58					
	3	100	60					
4	4	98	37		Joint Angle: 3.18 -3.24m = 45° 3.75-3.78m = 50° 3.93-4.12m = 70° 4.77-4.79m = 50° 4.79-4.88m = vertical 5.39-5.41m = 45° 5.87-5.90m = 55°			
4.4–5	5	95	64					
5.45–6	6	92	31		Fragmented from 2.0- 2.5m, 5.45-5.76m, 10.0-10.25m Self penetration 8.0 - 8.70m, 9.75-10.0m			
6.15	7	-	-		Gravels with Sandy Silt, 7.82-7.83m=30°, 9.31-9.34m=50°			
6.5	8	98	54		Limestone: Light grey to dark grey fine grained. Fresh to slightly weathered. Joints closely jointed, rough, stained, Clay & Calcite filled with joint and fractured surface.	55%		
7	9	72	21					
8	10	25	14					
9	11	97	74					
10	12	77	43		Limestone: Light grey to dark grey fine grained. Fresh to slightly weathered. Joints closely jointed, rough, stained, Clay & Calcite filled with joint and fractured surface.			
11	13	87	37		Joint Angle: 10.52 -10.57m = 50° 12.22-12.27m = 45°			
12–13					Limestone: Light grey to dark grey, fine to medium grained, Calcite vein also present. Fresh to slightly weathered, closely jointed, stained rough Calcite & fine material filled with joint surface	2%		
14–15					Self penetration 14.0 -14.30m, 13.1-13.2m Joint Angle: 12.37 -12.38m = 45° 12.37-12.38m = 45° 12.74-12.76m = 30° 12.80-12.82m = 45°, 13.4-13.43m = 45°, 13.69-13.74mm= 70°			

End of Borehole at 15.0 m depth

Project :	Kohat Tunnel # 02	*Location:*	Bridge No. 4	EL=597.00m	
Borehole No:	BH-03	*Date Started*	18-06-06	*Sheet :-*	1 of 2
Type of Boring	Percussion	*Date Completed*	23-06-06	*Ground Water Depth*	Nil
Driller	Zulfiqar	*Logged By:*	Munir Khan	*Engineer:*	Behram Khan

Depth (ft.)	Description of Material	Symbol/ Classification	Sample No.	SPT Blows	N.M.C	Atterberg Limits			Grain Size Analysis				
						L.L%	P.L%	P.I%	Cobble%	Gravel%	Sand%	Silt%	Clay%
--	Sandy Gravels with some Cobbles trace Boulders												
--- 1			DS-1	-	-	-	-	-	-	-	-	-	-
--													
--- 2	Reddish brown, Gravels with Shale, trace Cobble. Shale is reddish brown, slightly plasticity, Gravel is poorly graded												
--													
--- 3			DS-2	-	-	-	-	-	-	-	-	-	-
--													
--- 4													
--													
--- 5	**Shale:** Reddish brown, very hard Shale, highly weathered, slightly plasticity												
--													
--- 6													
--			SPT-1	60	8.2	32.6	21.1	11.5	-	-	8.4	40.4	51.2
--- 7													
--													
--- 8	-Do-		SPT-2	81	6.7	27.8	18.5	9.3	-	-	9.1	42.5	48.4
--													
--- 9													
--	-Do-		SPT-3	R	6.6	30.0	19.9	10.1	-	-	10.3	43.0	46.7
--- 10													
--													
--- 11			SPT-4	R	-	-	-	-	-	-	-	-	-

After 11.0m coring started

Project :	Kohat Tunnel # 02	**Location:**	Jerma Bridge No. 1	EL=447.00m	
Borehole No:	BH -04	**Date Started**	23-06-06	**Sheet :-**	1 of 3
Type of Boring	Percussion	**Date Completed**	24-06-06	**Ground Water Depth**	14.5m
Driller	Zulfiqar	**Logged By:**	Munir Khan	**Engineer:**	Behram Khan

Depth (ft.)	Description of Material	Symbol/ Classification	Sample No.	SPT Blows	N.M.C	Atterberg Limits L.L%	P.L%	P.I%	Grain Size Analysis Cobble%	Gravel%	Sand%	Silt%	Clay%
	Sandy Gravels with little cobbles												
1	Light brown, firm Clay, moist medium to highly plasticity		SPT-1	7	18.5	28.5	10.5	-	-	-	8.6	35.0	55.0
3	Sandy Silty Gravels with little Cobbles, trace Clay, Gravels are well graded, rounded to subrounded, few are platy & elongated. Sand is grey medium to coarse grained. Cobbles are subrounded to subangular of sedimentary & metamorphic origin		DS-1	-	-	28.2	17.0	11.2	-	56.4	12.1	10.0	21.5
4			DS-2	-	-	23.2	14.0	9.2	-	56.7	14.9	14.0	14.4
6			DS-3	-	-	23.2	13.1	10.1	-	52.6	16.2	15.0	16.2
7			DS-4	-	-	21.5	12.9	8.6	-	59.9	13.9	16.0	10.2
8			DS-5	-	-	21.7	14.0	7.7	-	66.0	20.4	9.0	4.6
			SPT-2	41	19.2	28.5	18.0	10.5	-	-	-	36.0	64.0
9	Reddish brown, hard Clay , trace fine Gravels, medium plasticity												
10	[illegible] Cobbles + trace Silt		DS-6	-	-	25.6	16.0	9.6	-	50.7	17.7	14.2	17.4
	Gravely Clay with little Cobbles trace Sand												
11	Light brown, Sandy Silty Gravels with little Cobbles, slightly plasticity trace Clay. Gravels are poorly graded, rounded to subrounded, few are platy, Silt is light brown, Sand is Grey medium to coarse grained.												
14			DS-7	-	-	21.9	14.7	7.2	-	70.0	18.0	5.8	6.2
15	Gravel with Cobbles trace coarse Sand + Silt. Gravels are poorly graded, fine to medium Gravels, rounded to subround3ed, few are platy of sedimentary & metamorphic origin. Cobbles are subrounded to												
18			DS-8	-	-	-	-	-	-	99.7	0.3	-	-
20													
21	Gravels with Cobbles trace Sand & Silt Boulders Gravels are well graded, rounded to subrounded, angular to subangular, few are platy Cobbles are subrounded to subangular, Sand is medium to coarse grained												
22			DS-9	-	-	-	-	-	-	99.8	0.2	-	-
25													

End of Borehole at 25.0 m

Appendix C. Ventilation Design Calculation Sheets

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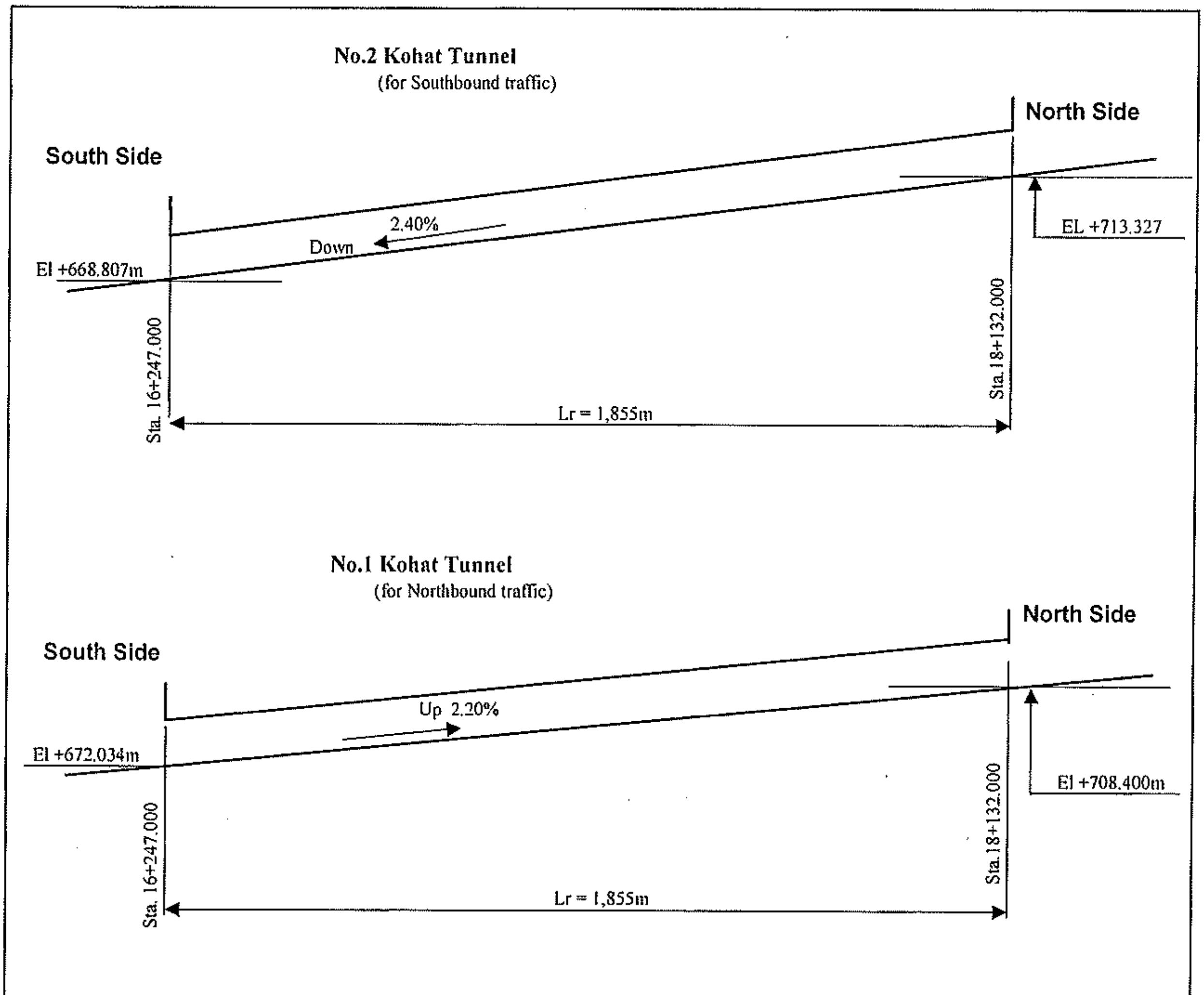
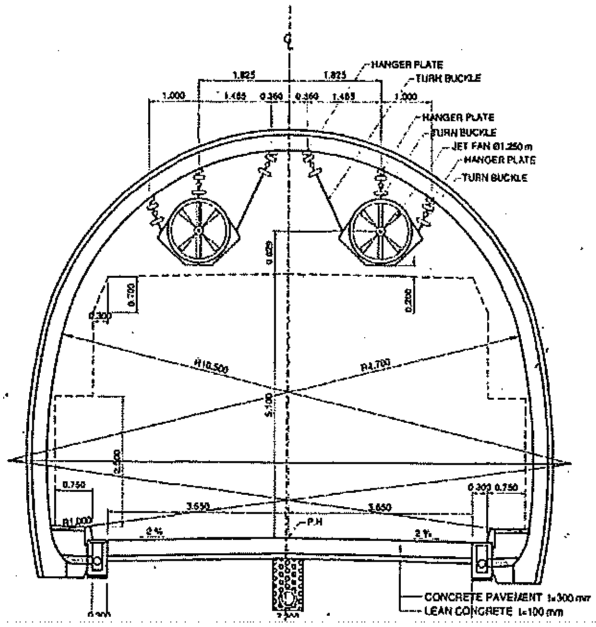
C-1 Design Condition

		Condition			Remark
①	Rank of Road	National Highway			
②	Aria Distinction	Local, Mountainous			
③	Tunnel Name	#1. Kohat Tunnel	#1. Kohat Tunnel	#2. Kohat Tunnel	
④	Length of Tunnel	L= 1,885 m	L= 1,885 m	L= 1,885 m	Average El m
⑤	Gradient	2.2 %	2.2 %	2.4 %	Single gradient S.to N.
⑥	Traffic direction	Two-way traffic with each one-lane	Up word, One-way traffic with two-lanes	Down word, One-way traffic with two-lanes	
⑦	Design Traffic vol.	11,685 Veh./d.	5,531 Veh./d.	6,154 Veh./d.	In 2013 760 Veh./h.
		(33,760)	15,981 Veh./d.	17,779 Veh./d.	2032 2,194 Veh./h.
⑧	Traffic Composition	With Diesel engine P 40 %			
		With Gasoline Engine Pg 60 %			
	Heavy Veh. Ratio	Heavy Veh. Ratio Pt 26.5 %			
⑨	Deigned Traffic Speed	40 km/h	60 km/h	60 km/h	
⑩	Traffic Speed				
⑪	Ventilation's Target	Soot and Carbon mono Oxide (CO)			
⑫	Co-efficient for emission	Heavy veh. 5.1 m2 km Standard Dev. 2.3			
		Small veh. 0.5 m2 km Standard Dev. 0.7			
⑫	Design visibility for Soot	60km/h: τ= 40 %			
⑬	Permissible CO	100 ppm			
⑭	Calculation Year of Exhaust gas emission	Year 2013 & 2032			
⑮	Pressure difference both Portals	Equivalent to natural wind v=2.5m/s			
⑯	Air velocity in a tunnel	less than 8 m/s	12 m/s	12 m/s	
⑰	Tunnel Inner Section Area	Section area Ar= 61.8 m2			
		Hydraulic Dia. Dr= 8.24 m			Dr = 4 x Ar / (Perimeter L

C-2 Tunnel Profile and Cross Section



Profile



Tunnel Cross Section Dimension	
Section area	Ar= 61.8 (m2)
Hydraulic Dia.	Dr= 8.24 (m)

Cross Section

C-3 Design Traffic Volume

Calculation Lot			KOHAT Tunnels			Remarks
			No.1 Kohat T.	No.1.K.T	No.2.K.T	
Traffic Direction			Two-way traffic with each one-lane	One-way traffic with two lane Northbound	Southbound	
Designed Year			2,013			
Design Traffic Volume	: Designed Year 2013		11,685	5,531	6,154	
Design Traffic Volume	: Designed Year 2032		33,760	15,981	17,779	
Design Traffic Speed Vd(km/h)			40	60	60	
Design Heavy vehicle ratio			26.5	26.5	26.5	Data by PTPS-I
Design Traffic capacity	Basic Traffic Capa. CB(pcu/h)	2-way 2500veh/h :One-w. 2200veh/h x line	2,500	4,400	4,400	
	Coefficient, Lane width: γL	more than 3.25m: 1.0	1.00	1.00	1.00	(Lw=3.65m)
	Coefficient, Side allowance:γc	0.3m	0.918	0.918	0.918	
	Coeff, Heavy veh. to equiv. Traffic ET	Gradient, less than 3%	2.02	1.718	1.718	
	Coefficient, Heavy vehicles ratio: γT	=100/(100-PT+ET×PT)	0.787	0.840	0.840	
	Coefficient, Surrounding road:γI	Not urbanized, 1.0	1.00	1.00	1.00	
	Max. Traffic Capacity: (Veh./h)	=CB×γL×γc×γT×γI	1,806	3,393	3,393	
	Ratio, Traffic Vol./ Capacity	Q/C: local 0.75	0.75	0.75	0.75	
	Design Traffic Capacity:CD (veh/h)	=C×Q/C	1,355	2,545	2,545	
	Ratio, Traffic V./ Design V.	Vs/Vd=	0.79	0.79	0.79	
	Traffic Velocity	Vs=Vd*(Vs/Vd)	32	47.4	47.4	
Design Traffic Volume (Veh./h)	Design Traffic V.:ADDT(veh/day)		11,685	15,981	17,779	
	Coefficient, K* D (%)	Peak hour traffic ratio: 6.5%	11.8	11.8	11.8	
	Coefficient, D (%)	Local 55%	55	55	55	
	Design Hourly T.vol. DHV(veh/h)	=ADDT×K/100×D/100	758	1,037	1,154	
	Ratio,Traffic Vol/ Capacity	Q/C	0.42	0.31	0.34	
	Ratio, Traffic V./ Design V.	Vs/Vd=	0.902	0.915	0.905	
	Traffic Velocity	Vs=Vd*(Vs/Vd)	36	55	54	

C-4 Necessary Fresh Air Volume

For Soot

Symbol and description		Unit	No1. Kohat Both way			No1. Kohat Northbound		No2.Kohat Southbound	
L:	Length of Tunnel	(m)	1885	1885	1885	1885	1885	1885	1885
	Gradient			2.20%	2.20%	2.20%	2.20%	2.40%	2.40%
	Directional ratio	Northbound	47.38%						
		Year		2013	2032	2013	2032	2013	2032
N:	Traffic Volume	(Veh/hour)	2012	760	2195	357	1040	403	1155
			2032						
q:	Unit air volume	(m3/seckm-Veh	0.1054	0.1054	0.1054	0.111	0.111	0.0674	0.0674
Ki:	Gradient coefficient	non dimension	1.70	1.98	1.98	1.98	1.98	0.55	0.55
			0.57	0.57	0.57				
Kh:	Altitude coefficient	non dimension	1.09	1.09	1.09	1.09	1.09	1.09	1.09
Q:	Fresh are requirement	(m3/sec)		203.8	588.5	161.2	469.6	30.7	88.0

Here:

$Q = q \times N \times L \times (1/1000) \times Ki \times Kh$

For Carbon Monoxide

Symbol and description		Unit	No1. Kohat Both way			No1. Kohat Northbound		No2.Kohat Southbound	
q:	Unit air volume	(m3/seckm-Veh)	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Ki:	Gradient coefficient	non dimension	1.00	1	1	1	1	1	1
Kh:	Altitude coefficient	non dimension	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Q:	Fresh are requirement	(m3/sec)		33.8	97.6	15.9	46.3	17.9	51.4

C-5 Gradient Coefficient

Gradient	Heavy & Light Veh. (KS,KL)	Veh. Class Velocity Gradient	Light Vehicles (KS) 40km/h~70km/h	80km/h	100km/h	120km/h~140km/h	Heavy vehicles (KL) 40km/h	50km/h	60km/h	63km/h	70km/h	80km/h
0	1.00	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
-0.1	0.98	0.1	1.02	1.02	1.02	1.02	1.04	1.04	1.04	1.04	1.04	1.04
-0.2	0.95	0.2	1.05	1.05	1.05	1.05	1.08	1.08	1.08	1.08	1.08	1.08
-0.3	0.93	0.3	1.07	1.07	1.07	1.07	1.13	1.13	1.13	1.13	1.13	1.13
-0.4	0.91	0.4	1.09	1.09	1.09	1.09	1.19	1.19	1.19	1.19	1.19	1.19
-0.5	0.89	0.5	1.12	1.12	1.12	1.12	1.24	1.24	1.25	1.25	1.25	1.26
-0.6	0.86	0.6	1.14	1.14	1.14	1.14	1.30	1.30	1.31	1.31	1.31	1.32
-0.7	0.84	0.7	1.16	1.16	1.16	1.16	1.36	1.36	1.37	1.37	1.38	1.39
-0.8	0.82	0.8	1.19	1.19	1.19	1.19	1.42	1.43	1.44	1.44	1.45	1.46
-0.9	0.80	0.9	1.21	1.21	1.21	1.21	1.49	1.50	1.50	1.50	1.52	1.53
-1.0	0.78	1.0	1.24	1.24	1.24	1.24	1.56	1.57	1.58	1.58	1.59	1.61
-1.1	0.76	1.1	1.26	1.26	1.26	1.26	1.63	1.64	1.65	1.65	1.67	1.69
-1.2	0.74	1.2	1.29	1.29	1.29	1.29	1.71	1.72	1.73	1.73	1.75	1.78
-1.3	0.72	1.3	1.31	1.31	1.31	1.31	1.79	1.80	1.82	1.82	1.84	1.88
-1.4	0.70	1.4	1.34	1.34	1.34	1.34	1.88	1.89	1.91	1.91	1.94	1.98
-1.5	0.68	1.5	1.37	1.37	1.37	1.37	1.97	1.99	2.02	2.02	2.05	2.10
-1.6	0.66	1.6	1.40	1.40	1.40	1.40	2.08	2.10	2.13	2.13	2.17	2.23
-1.7	0.64	1.7	1.43	1.43	1.43	1.43	2.19	2.21	2.25	2.25	2.30	2.37
-1.8	0.63	1.8	1.46	1.46	1.46	1.46	2.31	2.34	2.38	2.39	2.44	2.53
-1.9	0.61	1.9	1.50	1.50	1.50	1.50	2.44	2.48	2.53	2.54	2.60	2.70
-2.0	0.60	2.0	1.53	1.53	1.53	1.53	2.58	2.63	2.69	2.70	2.78	2.89
-2.1	0.59	2.1	1.57	1.57	1.57		2.74	2.79	2.86	2.88	2.97	3.11
-2.2	0.57	2.2	1.61	1.61	1.61		2.91	2.97	3.06	3.08	3.18	3.35
-2.3	0.56	2.3	1.65	1.65	1.65		3.09	3.17	3.27	3.29	3.41	3.61
-2.4	0.55	2.4	1.70	1.70	1.70		3.30	3.38	3.50	3.53	3.67	3.91
-2.5	0.54	2.5	1.74	1.74	1.74		3.52	3.62	3.76	3.80	3.96	4.24
-2.6	0.54	2.6	1.79	1.79	1.79		3.77	3.89	4.05	4.10	4.29	4.61
-2.7	0.53	2.7	1.85	1.85	1.85		4.04	4.18	4.38	4.43	4.65	5.03
-2.8	0.52	2.8	1.90	1.90	1.90		4.34	4.51	4.74	4.80	5.06	5.50
-2.9	0.52	2.9	1.96	1.96	1.96		4.68	4.87	5.14	5.22	5.52	6.04
-3.0	0.51	3.0	2.03	2.03	2.03		5.06	5.29	5.60	5.69	6.04	6.66
-3.1	0.51	3.1	2.10	2.10			5.49	5.75	6.12	6.23	6.64	
-3.2	0.50	3.2	2.17	2.17			5.97	6.28	6.71	6.84	7.32	
-3.3	0.50	3.3	2.25	2.25			6.52	6.88	7.39	7.54	8.10	
-3.4	0.50	3.4	2.33	2.33			7.14	7.56	8.16	8.34	9.00	
-3.5	0.49	3.5	2.41	2.41			7.85	8.35	9.05	9.26	10.04	
-3.6	0.49	3.6	2.50				8.65	9.24	10.07	10.32		
-3.7	0.48	3.7	2.60				9.58	10.27	11.24	11.54		
-3.8	0.47	3.8	2.70				10.63	11.44	12.59	12.95		
-3.9	0.47	3.9	2.81				11.84	12.79	14.14	14.56		
-4.0	0.45	4.0	2.92				13.22	14.33	15.92	16.43		

In case of Kohat Tunnel , Gradient Coefficients are:

Heavy Vehicles Ratio: 26.5

Traffic direction	Gradient (%)	Velocity for Design Traffic Volume km/h 40-60 Light V. KiS	50km/h Heavy V. KiL	60km/h Heavy V. KiS	55km/h Equiv. KiEqui.	Velocity for Design Traffic Capacity km/h 40-60 Light V. KiS	40km/h Heavy V. KiL	50km/h Heavy V. KiS	47km/h Equiv. KiEqui.
Northbound (Upward)	2.2	1.61	2.97	3.06	1.98	1.61	2.91	2.97	1.97
Southbound (Downward)	-2.4	0.55	0.55	55.00	0.55	0.55	0.55	0.55	0.55

C-6 Altitude Coefficient

Coefficient for Altitude is shown in figure below.

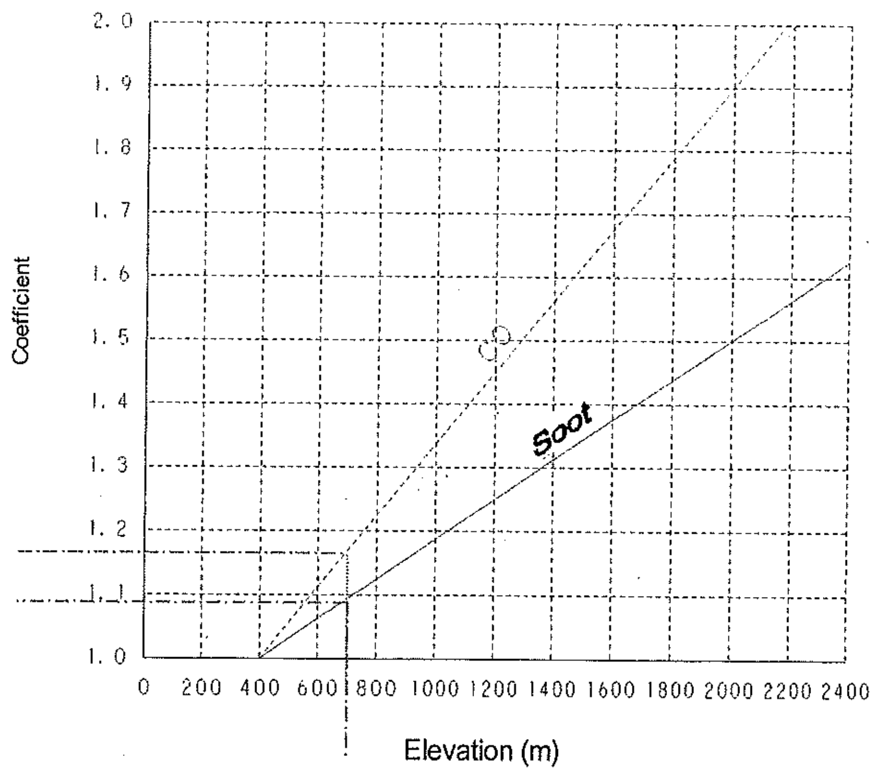
And from this Figure, Coefficient for Soot and CO: Khs to Altitude is
Given by following formula

$$\text{Soot Khs} = 1.0 + \frac{1.5 - 1.0}{2000\text{-}400} \times (H\text{-}400) = 1.0 + 0.0003125 \times (H\text{-}400)$$

$$\text{CO Khs} = 1.0 + \frac{1.9 - 1.0}{2000\text{-}400} \times (H\text{-}400) = 1.0 + 0.0005625 \times (H\text{-}400)$$

Average Elevation of the both Tunnel is almost same.

Elevation	South Portal = 668.807	
	North Portal = 713.327	
	Average T altit.=	691.067 m
Soot: Khs	=1.0 + 0.0003125×(Talti - 400)	1.091
CO : Khs	=1.0 + 0.0005625×(Talti - 400)	1.164



C-7 Unit Air Volume for Fresh Air requirement (1/2)

qs: Calculation Design Traffic Vol. 2013 Both way Gradient 2.20%

In Put Data						1
Cross Sectional Area	Ar=	61.8 (m^2)				1
Heavy Vehicle Ratio	Pt=	26.5 (%)		γL=	0.265	1
Design Target Visibility	τ=	40 (%)				1
Vehicle Velocity	Light: VTS	45 km/h	Velocity Coeff.	Light V. KVS=	1.00	1
	Heavy: VTL	45 km/h		Heavy V. KVL=	1.00	1
Gradient	i=	2.20%		Altitude: Kh=	1.09	1
Gradient Coef.	Light V. KS=	1.61				1
	Heavy V. KL=	2.91				1
						1
Average Soot Exhaust: Heavy Veh,	μL=	5.61	m^2/Veh./km	Tt=	3600	1
Average Soot Exhaust: Light Veh,	μS=	0.55	m^2/Veh./km			1
Stan. Deviation S.E. :heavy Veh.	σL=	2.53	m^2/Veh./km			1
Stan. Deviation S.E. :light Veh.	σS=	0.77	m^2/Veh./km			1
Rate of micro Soot: Heavy Veh.	RL=	18	%			1
Rate of micro Soot: Light Veh.	RS=	9	%			1
Calculation of Unit Air Volume:						1
μ1={μL*RL*KVL*KL*Kh}+μL*(1-RL)					7.80318	1
σ1={σL*RL*KVL*KL*Kh}+σL*(1-RL)					3.51908	1
μ2={μS*RS*KVS*KS*Kh}+μS*(1-RS)					0.58737	1
σ2={σS*RS*KVS*KS*Kh}+σS*(1-RS)					0.82231	1
μ=γL*μ1+(1-γL)*μ2					2.4996	1
σ^2=γL*{σ1^2+(μ1-μ)^2}+(1-γL)*{σ2^2+(μ2-μ)^2}					13.9203	1
σ=SQRT(σ^2)					3.7310	1
K=-1/100*Ln(τ/100)					0.00916	1
qs=((3*σ+SQRT(9*σ^2+8*μ*K*Ar*1000))/(SQRT(8*Tt*Ar*1000)*K))^2					0.1054	1

qs: Calculation Design Traffic Vol. 2013 Downward Gradient -2.2%

In Put Data						2
Cross Sectional Area	Ar=	61.8 (m^2)				2
Heavy Vehicle Ratio	Pt=	26.5 (%)		γL=	0.265	2
Design Target Visibility	τ=	41 (%)				2
Vehicle Velocity	Light: VTS	45 km/h	Velocity Coeff.	Light V. KVS=	1.00	2
	Heavy: VTL	45 km/h		Heavy V. KVL=	1.00	2
Gradient	i=	2.200%		Altitude: Kh=	1.09	2
Gradient Coef.	Light V. KS=	0.57				2
	Heavy V. KL=	0.57				2
						2
Average Soot Exhaust: Heavy Veh,	μL=	5.61	m^2/Veh./km	Tt=	3600	2
Average Soot Exhaust: Light Veh,	μS=	0.55	m^2/Veh./km			2
Stan. Deviation S.E. :heavy Veh.	σL=	2.53	m^2/Veh./km			2
Stan. Deviation S.E. :light Veh.	σS=	0.77	m^2/Veh./km			2
Rate of micro Soot: Heavy Veh.	RL=	18	%			2
Rate of micro Soot: Light Veh.	RS=	9	%			2
Calculation of Unit Air Volume:						2
μ1={μL*RL*KVL*KL*Kh}+μL*(1-RL)					5.22759	2
σ1={σL*RL*KVL*KL*Kh}+σL*(1-RL)					2.35754	2
μ2={μS*RS*KVS*KS*Kh}+μS*(1-RS)					0.53125	2
σ2={σS*RS*KVS*KS*Kh}+σS*(1-RS)					0.74376	2
μ=γL*μ1+(1-γL)*μ2					1.7758	2
σ^2=γL*{σ1^2+(μ1-μ)^2}+(1-γL)*{σ2^2+(μ2-μ)^2}					6.1753	2
σ=SQR(σ^2)					2.4850	2
K=-1/100*Ln(τ/100)					0.00892	2
qs=ROUND(((3*σ+SQRT(9*σ^2+8*μ*K*Ar*1000))/(SQRT(8*Tt*Ar*1000)*K))^2					0.0677	2

C-8 Unit Air Volume for Fresh Air requirement (2/2)

qs: Calculation   Design Traffic Vol.   2013   Upward   Gradient   2.20%

In Put Data						3
Cross Sectional Area	Ar=	61.8	(m²)			3
Heavy Vehicle Ratio	Pt=	26.5	(%)	γL=	0.265	3
Design Target Visibility	τ=	41	(%)			3
Vehicle Velocity: Light: VTS		55	km/h	Velocity Coeff.: Light V. KVS=	1.00	3
Vehicle Velocity: Heavy: VTL		55	km/h	Velocity Coeff.: Heavy V. KVL=	1.00	3
Gradient	i=	2.200%		Altitude: Kh=	1.09	3
Gradient Coef.: Light V.	KS=	1.61				3
Gradient Coef.: Heavy V.	KL=	3.01				3
						3
Average Soot Exhaust: Heavy Veh,	μL=	5.61	m²/Veh./km	Tt=	3600	3
Average Soot Exhaust: Light Veh,	μS=	0.55	m²/Veh./km			3
Stan. Deviation S.E. :heavy Veh.	σL=	2.53	m²/Veh./km			3
Stan. Deviation S.E. :light Veh.	σS=	0.77	m²/Veh./km			3
Rate of micro Soot: Heavy Veh.	RL=	18	%			3
Rate of micro Soot: Light Veh.	RS=	9	%			3
Calculation of Unit Air Volume:						3
μ1={μL*RL*KVL*KL*Kh}+μL*(1-RL)					7.91325	3
σ1={σL*RL*KVL*KL*Kh}+σL*(1-RL)					3.56872	3
μ2={μS*RS*KVS*KS*Kh}+μS*(1-RS)					0.58737	3
σ2={σS*RS*KVS*KS*Kh}+σS*(1-RS)					0.82231	3
μ=γL*μ1+(1-γL)*μ2					2.5287	3
σ^2=γL*{σ1^2+(μ1-μ)^2}+(1-γL)*{σ2^2+(μ2-μ)^2}					14.3253	3
σ=SQR(σ^2)					3.7849	3
K=-1/100*Ln(τ/100)					0.00892	3
qs=ROUND(((3*σ+SQRT(9*σ^2+8*μ*K*Ar*1000))/(SQRT(8*Tt*Ar*1000)*K))^2					0.1110	3

qs: Calculation   Design Traffic Vol.   2013   Downward   Gradient   -2.40%

In Put Data						4
Cross Sectional Area	Ar=	61.8	(m²)			4
Heavy Vehicle Ratio	Pt=	26.5	(%)	γL=	0.265	4
Design Target Visibility	τ=	41	(%)			4
Vehicle Velocity: Light: VTS		56	km/h	Velocity Coeff.: Light V. KVS=	1.00	4
Vehicle Velocity: Heavy: VTL		56	km/h	Velocity Coeff.: Heavy V. KVL=	1.00	4
Gradient	i=	-2.400%		Altitude: Kh=	1.09	4
Gradient Coef.: Light V.	KS=	0.55				4
Gradient Coef.: Heavy V.	KL=	0.55				4
						4
Average Soot Exhaust: Heavy Veh,	μL=	5.61	m²/Veh./km	Tt=	3600	4
Average Soot Exhaust: Light Veh,	μS=	0.55	m²/Veh./km			4
Stan. Deviation S.E. :heavy Veh.	σL=	2.53	m²/Veh./km			4
Stan. Deviation S.E. :light Veh.	σS=	0.77	m²/Veh./km			4
Rate of micro Soot: Heavy Veh.	RL=	18	%			4
Rate of micro Soot: Light Veh.	RS=	9	%			4
Calculation of Unit Air Volume:						4
μ1={μL*RL*KVL*KL*Kh}+μL*(1-RL)					5.20558	4
σ1={σL*RL*KVL*KL*Kh}+σL*(1-RL)					2.34761	4
μ2={μS*RS*KVS*KS*Kh}+μS*(1-RS)					0.53018	4
σ2={σS*RS*KVS*KS*Kh}+σS*(1-RS)					0.74225	4
μ=γL*μ1+(1-γL)*μ2					1.7692	4
σ^2=γL*{σ1^2+(μ1-μ)^2}+(1-γL)*{σ2^2+(μ2-μ)^2}					6.1231	4
σ=SQR(σ^2)					2.4745	4
K=-1/100*Ln(τ/100)					0.00892	4
qs=ROUND(((3*σ+SQRT(9*σ^2+8*μ*K*Ar*1000))/(SQRT(8*Tt*Ar*1000)*K))^2					0.0674	4

C-9 Calculation of Jet Fan Numbers

Tunnel Name		No.1 Kohat		No.1 Kohat		No.2 Kohat		Remarks
Year	In:	2013	2032	2013	2032	2013	2032	
	stage			Initial	Final	Initial	Final	
Tunnel length		1885	1885	1885	1885	1885	1885	
	Vt=	45	45	60	60	60	60	
Traffic Direction		Both		Northbound		Southbound		
Traffic Volume		760	2195	360	1039	400	1156	
Air Requi.	Qm3/s	203.8	588.5	161.2	469.6	30.7	88.0	
								Ar=61.8m2
Air Speed		3.30	9.52	2.61	7.60	0.50	1.42	Dr=8.24m
Pressure	ΔPR	47.76	398.22	29.88	253.56	1.08	8.90	
Losses	ΔPMTW	27.45	27.45	27.45	27.45	27.45	27.45	
in	ΔPt	-98.79	-688.82	65.90	70.53	101.26	254.95	
Tunnel	ΔP Total	173.989	1114.481	-8.58	210.48	-72.73	-218.59	
	ΔPj	19.132	14.672	19.626	16.051	21.139	20.475	
Number of Jet Fans		9.1	76.0	-0.4	13.1	-3.4	-10.7	Ptoal/PJ
		10	imposible	(2)	14	(2)	(2)	
Detail Calculation		(Sheet9-1)	(Sheet9-2)	(Sheet9-3)	(Sheet9-4)	(Sheet9-5)	(Sheet9-6)	

Note:

Note:	ΔPr	: Frictional losses at the Inlet and exit portals
	ΔPmte	: Atmospheric back-pressure
	ΔPt	: Piston effect force
	ΔP total	: Total of the ΔPr + ΔPmte + ΔPt
	ΔPj	: Jet fan ascend-pressures

C-10 Detail Calculation of necessary Jet Fan Nos. (1/3)

1

In put Data					
Tunnel Length	Lr(m)=	1,885	Co-eff Outlet P. loss		1
Tunnel Cross Area	Ar(m²)=	61.8	Co-eff Inlet P. loss	ζe=	0.6
Hydraulic Dia.	Dr(m)=	8.24	Co-eff Friction P. loss	λ=	0.025
Design Traffic Vol.	N (Veh./h)=	760	Air density	ρ=	1.2
Heavy Veh. Ratio	Pt(%)=	26.5	JF-1000 Spout Ar.	Aj1(m²)=	0.83
Traffic Velocity	VT(km/h)=	45	JF-1250 Spout Ar.	Aj2(m²)=	1.23
	Vt(m/s)=	12.500			
Light Veh. Proj Ar.	Ac(m²)=	2.31	Co-eff for JF Ascend	Kj=	1
Heavy Veh. Proj. Ar.	At(m²)=	7.11	Co-eff standard N. Board	ζh=	0
Directional Veh. Ratio	Y1:Y2=60:40		Nos. of Notice Board	Zh=	0
	Y1:Y2=50:50		JF Spout air speed	Uj(m/s)=	30
	Y1:Y2=40:60		Natural wind velocity	Un(m/s)=	-2.5
One way Direction	Y1:Y2=100:0		Directional Veh. Ratio	Y1=	47
				Y2=	53
Calculation of Jet Fan numbers					
Light Veh Resist. Co.	ζc =	0.0786×Ac/Ar×100+0.35=			0.644
Heavy Veh Resist. Co.	ζt =	0.0786×At/Ar×100+0.35=			1.254
Equiv. Resist Area	Am(m²)=	(1-Pt/100)×Ac×ζc+Pt/100×At×ζt =			3.456
Req. Vent Air	Qreq(m³/s)=				203.80
Necessary wind Vel.	Ur(m/s)=	Qreq/Ar			3.298
P. Losses in Tunnel	ΔPr(Pa)=	(1+ζe+λ×Lr/Dr+ζh×Zh)×ρ/2×Ur^2			47.757
Atmospheric back P.	ΔPm(Pa)=	(1+ζe+λ×Lr/Dr)×ρ/2×Un^2			27.446
Piston effect Force P.	ΔPt(Pa)=	Am/Ar×ρ/2× {n1×(Vt-Ur)^2-n2×(Vt+Ur)^2}			-98.786
	n1(Nos.)=	N*Lr/1000/VT*Y1/100			14.963
	n2(Nos.)=	N*Lr/1000/VT*Y2/100			16.873
Jet Fan Ascend Pressures					
JF-1000	ΔPj1(Pa)=	Kj×ρ/2×Uj^2×2×Aj1/Ar×(1-Ur/Uj)			12.910
JF-1250	ΔPj2(Pa)=	Kj×ρ/2×Uj^2×2×Aj2/Ar×(1-Ur/Uj)			19.132
Fixed Jet Fan Nos.	JF-1000	ZF1=			
	JF-1250	ZF2=			
JF-1250 Nos. Req.		Z2=(ΔPr+ΔPm-ΔPt)/ΔPj2		9.1	

2

In put Data					
Tunnel Length	Lr(m)=	1,885	Co-eff Outlet P. loss		1
Tunnel Cross Area	Ar(m²)=	61.8	Co-eff Inlet P. loss	ζe=	0.6
Hydraulic Dia.	Dr(m)=	8.24	Co-eff Friction P. loss	λ=	0.025
Design Traffic Vol.	N (Veh./h)=	2,195	Air density	ρ=	1.2
Heavy Veh. Ratio	Pt(%)=	26.5	JF-1000 Spout Ar.	Aj1(m²)=	0.83
Traffic Velocity	VT(km/h)=	45	JF-1250 Spout Ar.	Aj2(m²)=	1.23
	Vt(m/s)=	12.500			
Light Veh. Proj Ar.	Ac(m²)=	2.31	Co-eff for JF Ascend	Kj=	1
Heavy Veh. Proj. Ar.	At(m²)=	7.11	Co-eff standard N. Board	ζh=	0
Directional Veh. Ratio	Y1:Y2=60:40		Nos. of Notice Board	Zh=	0
	Y1:Y2=50:50		JF Spout air speed	Uj(m/s)=	30
	Y1:Y2=40:60		Natural wind velocity	Un(m/s)=	-2.5
One way Direction	Y1:Y2=100:0		Directional Veh. Ratio	Y1=	53
				Y2=	47
Calculation of Jet Fan numbers					
Light Veh Resist. Co.	ζc =	0.0786×Ac/Ar×100+0.35=			0.644
Heavy Veh Resist. Co.	ζt =	0.0786×At/Ar×100+0.35=			1.254
Equiv. Resist Area	Am(m²)=	(1-Pt/100)×Ac×ζc+Pt/100×At×ζt =			3.456
Req. Vent Air	Qreq(m³/s)=				588.500
Necessary wind Vel.	Ur(m/s)=	Qreq/Ar			9.523
P. Losses in Tunnel	ΔPr(Pa)=	(1+ζe+λ×Lr/Dr+ζh×Zh)×ρ/2×Ur^2			398.219
Atmospheric back P.	ΔPm(Pa)=	(1+ζe+λ×Lr/Dr)×ρ/2×Un^2			27.446
Piston effect Force P.	ΔPt(Pa)=	Am/Ar×ρ/2× {n1×(Vt-Ur)^2-n2×(Vt+Ur)^2}			-688.816
	n1(Nos.)=	N*Lr/1000/VT*Y1/100			48.731
	n2(Nos.)=	N*Lr/1000/VT*Y2/100			43.215
Jet Fan Ascend Pressures					
JF-1000	ΔPj1(Pa)=	Kj×ρ/2×Uj^2×2×Aj1/Ar×(1-Ur/Uj)			9.901
JF-1250	ΔPj2(Pa)=	Kj×ρ/2×Uj^2×2×Aj2/Ar×(1-Ur/Uj)			14.672
Fixed Jet Fan Nos.	JF-1000	ZF1=			0
	JF-1250	ZF2=			0
JF-1250 Nos. Req.		Z2=(ΔPr+ΔPm-ΔPt-ΔPj1×ZF1-ΔPj2×ZF2)/ΔPj2		76.0	

C-11 Detail Calculation of necessary Jet Fan Nos. (2/3)

3

In put Data						3
Tunnel Length	Lr(m)=	1,885	Co-eff Outlet P. loss		1	3
Tunnel Cross Area	Ar(m^2)=	61.8	Co-eff Inlet P. loss	ζe=	0.6	3
Hydraulic Dia.	Dr(m)=	8.24	Co-eff Friction P. loss	λ=	0.025	3
Design Traffic Vol.	N (Veh./h)=	357	Air density	ρ=	1.2	3
Heavy Veh. Ratio	Pt(%)=	26.5	JF-1000 Spout Ar.	Aj1(m^2)=	0.83	3
Traffic Velocity	VT(km/h)=	55	JF-1250 Spout Ar.	Aj2(m^2)=	1.23	3
	Vt(m/s)=	15.278				3
Light Veh. Proj Ar.	Ac(m^2)=	2.31	Co-eff for JF Ascend	Kj=	1	3
Heavy Veh. Proj. Ar.	At(m^2)=	7.11	Co-eff standard N. Board	ζh=	0	3
Directional Veh. Ratio	Y1:Y2=60:40		Nos. of Notice Board	Zh=	0	3
	Y1:Y2=50:50		JF Spout air speed	Uj(m/s)=	30	3
	Y1:Y2=40:60		Natural wind velocity	Un(m/s)=	-2.5	3
One way Direction	Y1:Y2=100:0		Directional Veh. Ratio	Y1=	100	3
				Y2=	0	3
Calculation of Jet Fan numbers						3
Light Veh Resist. Co.	ζc =	0.0786×Ac/Ar×100+0.35=			0.644	3
Heavy Veh Resist. Co.	ζt =	0.0786×At/Ar×100+0.35=			1.254	3
Equiv. Resist Area	Am(m^2)=	(1-Pt/100)×Ac×ζc+Pt/100×At×ζt =			3.456	3
Req. Vent Air	Qreq(m^3/s)=				161.20	3
Necessary wind Vel.	Ur(m/s)=	Qreq/Ar			2.608	3
P. Losses in Tunnel	ΔPr(Pa)=	(1+ζe+λ×Lr/Dr+ζh×Zh)×ρ/2×Ur^2			29.879	3
Atmospheric back P.	ΔPm(Pa)=	(1+ζe+λ×Lr/Dr)×ρ/2×Un^2			27.446	3
Piston effect Force P.	ΔPt(Pa)=	Am/Ar×ρ/2× {n1×(Vt-Ur)^2-n2×(Vt+Ur)^2}			65.903	3
	n1(Nos.)=	N*Lr/1000/VT*Y1/100			12.235	3
	n2(Nos.)=	N*Lr/1000/VT*Y2/100			0.000	3
Jet Fan Ascend Pressures						3
JF-1000	ΔPj1(Pa)=	Kj×ρ/2×Uj^2×Aj1/Ar×(1-Ur/Uj)			6.622	3
JF-1250	ΔPj2(Pa)=	Kj×ρ/2×Uj^2×Aj2/Ar×(1-Ur/Uj)			19.626	3
						3
	JF-1000					3
Fixed Jet Fan Nos.	JF-1250					3
		ΔPr(Pa)+ΔPmtr-ΔPt				3
						3
JF-1250 Nos. Req.		Z2=(ΔPr+ΔPm-ΔPt)/ΔPj2		-0.4	No Need	3
						3

4

In put Data						4
Tunnel Length	Lr(m)=	1,885	Co-eff Outlet P. loss		1	4
Tunnel Cross Area	Ar(m^2)=	61.8	Co-eff Inlet P. loss	ζe=	0.6	4
Hydraulic Dia.	Dr(m)=	8.24	Co-eff Friction P. loss	λ=	0.025	4
Design Traffic Vol.	N (Veh./h)=	1,040	Air density	ρ=	1.2	4
Heavy Veh. Ratio	Pt(%)=	26.5	JF-1000 Spout Ar.	Aj1(m^2)=	0.83	4
Traffic Velocity	VT(km/h)=	55	JF-1250 Spout Ar.	Aj2(m^2)=	1.23	4
	Vt(m/s)=	15.278				4
Light Veh. Proj Ar.	Ac(m^2)=	2.31	Co-eff for JF Ascend	Kj=	1	4
Heavy Veh. Proj. Ar.	At(m^2)=	7.11	Co-eff standard N. Board	ζh=	0	4
Directional Veh. Ratio	Y1:Y2=60:40		Nos. of Notice Board	Zh=	0	4
	Y1:Y2=50:50		JF Spout air speed	Uj(m/s)=	30	4
	Y1:Y2=40:60		Natural wind velocity	Un(m/s)=	-2.5	4
One way Direction	Y1:Y2=100:0		Directional Veh. Ratio	Y1=	100	4
				Y2=	0	4
Calculation of Jet Fan numbers						4
Light Veh Resist. Co.	ζc =	0.0786×Ac/Ar×100+0.35=			0.644	4
Heavy Veh Resist. Co.	ζt =	0.0786×At/Ar×100+0.35=			1.254	4
Equiv. Resist Area	Am(m^2)=	(1-Pt/100)×Ac×ζc+Pt/100×At×ζt =			3.456	4
Req. Vent Air	Qreq(m^3/s)=				469.600	4
Necessary wind Vel.	Ur(m/s)=	Qreq/Ar			7.599	4
P. Losses in Tunnel	ΔPr(Pa)=	(1+ζe+λ×Lr/Dr+ζh×Zh)×ρ/2×Ur^2			253.563	4
Atmospheric back P.	ΔPm(Pa)=	(1+ζe+λ×Lr/Dr)×ρ/2×Un^2			27.446	4
Piston effect Force P.	ΔPt(Pa)=	Am/Ar×ρ/2× {n1×(Vt-Ur)^2-n2×(Vt+Ur)^2}			70.530	4
	n1(Nos.)=	N*Lr/1000/VT*Y1/100			35.644	4
	n2(Nos.)=	N*Lr/1000/VT*Y2/100			0.000	4
Jet Fan Ascend Pressures						4
JF-1000	ΔPj1(Pa)=	Kj×ρ/2×Uj^2×2×Aj1/Ar×(1-Ur/Uj)			10.831	4
JF-1250	ΔPj2(Pa)=	Kj×ρ/2×Uj^2×2×Aj2/Ar×(1-Ur/Uj)			16.051	4
						4
	JF-1000	ZF1=			0	4
Fixed Jet Fan Nos.	JF-1250	ZF2=			0	4
						4
						4
JF-1250 Nos. Req.		Z2=(ΔPr+ΔPm-ΔPt-ΔPj1×ZF1-ΔPj2×ZF2)/ΔPj2		13.1		4
						4

C-12 Detail Calculation of necessary Jet Fan Nos. (3/3)

5

In put Data					
Tunnel Length	Lr(m)=	1,885	Co-eff Outlet P. loss		1
Tunnel Cross Area	Ar(m²)=	61.8	Co-eff Inlet P. loss	ζe=	0.6
Hydraulic Dia.	Dr(m)=	8.24	Co-eff Friction P. loss	λ=	0.025
Design Traffic Vol.	N (Veh./h)=	403	Air density	ρ=	1.2
Heavy Veh. Ratio	Pt(%)=	26.5	JF-1000 Spout Ar.	Aj1(m²)=	0.83
Traffic Velocity	VT(km/h)=	55	JF-1250 Spout Ar.	Aj2(m²)=	1.23
	Vt(m/s)=	15.278			
Light Veh. Proj Ar.	Ac(m²)=	2.31	Co-eff for JF Ascend	Kj=	1
Heavy Veh. Proj. Ar.	At(m²)=	7.11	Co-eff standard N. Board	ζh=	0
Directional Veh. Ratio	Y1:Y2=60:40		Nos. of Notice Board	Zh=	0
	Y1:Y2=50:50		JF Spout air speed	Uj(m/s)=	30
	Y1:Y2=40:60		Natural wind velocity	Un(m/s)=	-2.5
One way Direction	Y1:Y2=100:0		Directional Veh. Ratio	Y1=	100
				Y2=	0
Calculation of Jet Fan numbers					
Light Veh Resist. Co.	ζc =	0.0786×Ac/Ar×100+0.35=			0.644
Heavy Veh Resist. Co.	ζt =	0.0786×At/Ar×100+0.35=			1.254
Equiv. Resist Area	Am(m²)=	(1-Pt/100)×Ac×ζc+Pt/100×At×ζt =			3.456
Req. Vent Air	Qreq(m³/s)=				30.700
Necessary wind Vel.	Ur(m/s)=	Qreq/Ar			0.497
P. Losses in Tunnel	ΔPr(Pa)=	(1+ζe+λ×Lr/Dr+ζh×Zh)×ρ/2×Ur^2			1.084
Atmospheric back P.	ΔPm(Pa)=	(1+ζe+λ×Lr/Dr)×ρ/2×Un^2			27.446
Piston effect Force P.	ΔPt(Pa)=	Am/Ar×ρ/2× {n1×(Vt-Ur)^2-n2×(Vt+Ur)^2}			101.260
	n1(Nos.)=	N*Lr/1000/VT*Y1/100			13.812
	n2(Nos.)=	N*Lr/1000/VT*Y2/100			0.000
Jet Fan Ascend Pressures					
JF-1000	ΔPj1(Pa)=	Kj×ρ/2×Uj^2×2×Aj1/Ar×(1-Ur/Uj)			14.265
JF-1250	ΔPj2(Pa)=	Kj×ρ/2×Uj^2×2×Aj2/Ar×(1-Ur/Uj)			21.139
Fixed Jet Fan Nos.	JF-1000	ZF1=			0
	JF-1250	ZF2=			0
JF-1250 Nos. Req.		Z2=(ΔPr+ΔPm-ΔPt-ΔPj1×ZF1-ΔPj2×ZF2)/ΔPj2		-3.4	No Need

6

In put Data					
Tunnel Length	Lr(m)=	1,885	Co-eff Outlet P. loss		1
Tunnel Cross Area	Ar(m²)=	61.8	Co-eff Inlet P. loss	ζe=	0.6
Hydraulic Dia.	Dr(m)=	8.24	Co-eff Friction P. loss	λ=	0.025
Design Traffic Vol.	N (Veh./h)=	1,155	Air density	ρ=	1.2
Heavy Veh. Ratio	Pt(%)=	26.5	JF-1000 Spout Ar.	Aj1(m²)=	0.83
Traffic Velocity	VT(km/h)=	55	JF-1250 Spout Ar.	Aj2(m²)=	1.23
	Vt(m/s)=	15.278			
Light Veh. Proj Ar.	Ac(m²)=	2.31	Co-eff for JF Ascend	Kj=	1
Heavy Veh. Proj. Ar.	At(m²)=	7.11	Co-eff standard N. Board	ζh=	0
Directional Veh. Ratio	Y1:Y2=60:40		Nos. of Notice Board	Zh=	0
	Y1:Y2=50:50		JF Spout air speed	Uj(m/s)=	30
	Y1:Y2=40:60		Natural wind velocity	Un(m/s)=	-2.5
One way Direction	Y1:Y2=100:0		Directional Veh. Ratio	Y1=	100
				Y2=	0
Calculation of Jet Fan numbers					
Light Veh Resist. Co.	ζc =	0.0786×Ac/Ar×100+0.35=			0.644
Heavy Veh Resist. Co.	ζt =	0.0786×At/Ar×100+0.35=			1.254
Equiv. Resist Area	Am(m²)=	(1-Pt/100)×Ac×ζc+Pt/100×At×ζt =			3.456
Req. Vent Air	Qreq(m³/s)=				88.000
Necessary wind Vel.	Ur(m/s)=	Qreq/Ar			1.424
P. Losses in Tunnel	ΔPr(Pa)=	(1+ζe+λ×Lr/Dr+ζh×Zh)×ρ/2×Ur^2			8.904
Atmospheric back P.	ΔPm(Pa)=	(1+ζe+λ×Lr/Dr)×ρ/2×Un^2			27.446
Piston effect Force P.	ΔPt(Pa)=	Am/Ar×ρ/2× {n1×(Vt-Ur)^2-n2×(Vt+Ur)^2}			254.946
	n1(Nos.)=	N*Lr/1000/VT*Y1/100			39.585
	n2(Nos.)=	N*Lr/1000/VT*Y2/100			0.000
Jet Fan Ascend Pressures					
JF-1000	ΔPj1(Pa)=	Kj×ρ/2×Uj^2×2×Aj1/Ar×(1-Ur/Uj)			13.816
JF-1250	ΔPj2(Pa)=	Kj×ρ/2×Uj^2×2×Aj2/Ar×(1-Ur/Uj)			20.475
Fixed Jet Fan Nos.	JF-1000	ZF1=			0
	JF-1250	ZF2=			0
JF-1250 Nos. Req.		Z2=(ΔPr+ΔPm-ΔPt-ΔPj1×ZF1-ΔPj2×ZF2)/ΔPj2		-10.7	No Need