V. POLICY/STRATEGY AND GENERAL RAILWAY TRANSPORT COST

1. Policy and Strategy
2. Evaluation (General Railway Transport Cost)

V. POLICY/STRATEGY AND GENERAL RAILWAY TRANSPORT COST

1. Policy and Strategy

Vehicle Operating Cost

1. General

Here, the V.O.C. is being calculated for to proceed the modal split as following terms.

i. Economic cost 1981/82 price, km

ii. Flat road

iii. Economic speed, here 48km/h

iv. Improved (paved) Highway

Referred following two books on the data and the methodology.

* Vehicle user costs, Pakistan, 1977

Central Roads Organization, Islamabad, January 1978

* A Research on the Direct Benefit by Road Arrangement

Japan's Ministry of Construction, Road Division, 1981, March

2. Classification of vehicle

The four vehicles selected to represent the existing vehicle fleet in Pakistan are,

i) Passenger car (car)

which includes jeeps, station wagons and minibus, TOYOTA Carrola.

ii) Light Commercial Vehicle (minibus)

For diesel minibus, 13 passengers

iii) Commercial Passenger Carrier (bus)

Bedford 52 seater bus, gross loaded weight 10 tons

iv) Commercial Goods Vehicle (truck)

Bedford truck, gross loaded weight 14 tons

Physical Characteristics at Existing Conditions*

Type	Fuel	Gross weight ton	Axle	Tyre	Load axle rear	Average vintage	Average life year	Annual average mileage
TOYOTA Carrola	Petrol	1.0	2	5	55	5.5	12	15.0^{10^3}
Ford minibus	Diesel	2.7	2	5	60	3.5	8	50.0
Bedford bus	Diesel	10.0	2	7	66	3.5	8	63.0
Bedford truck	Diesel	14.0	2	7	72	4.5	10	60.0

* Vehicle User Costs, Pakistan, 1977, p.1, Table 1.
adjusted Annual Average Mileage only.

Table presents the physical characteristics of the representative vehicles which will be used in operating cost calculations.

3. Data*

i) Cost of vehicle	1981/82 price	
(1) Toyota Carrola	128,000 Rp.	
(2) Mazda minibus	166,000	
(3) Bedford bus	295,000	
(4) Bedford truck	254,000	
ii) Cost of tyre	per tyre	
(1) Toyota Carrola	350	
(2) Mazda minibus	800	
(3) Bedford bus	1,500	
(4) Bedford truck	1,500	
iii) Cost of fuel	per litre	
(1) Petrol super	6.35 Rp.	} 5.52
regular	5.05	
(2) Diesel	3.15	
(3) Engine Oil	10.00	

4. Economic Cost

Economic cost is being estimated on the same ratios listed in Economic and Financial Costs*, based on the data in 3.

i) Vehicle	Rp.
(1) Toyota Carrola	56,393
(2) Mazda minibus	79,154
(3) Bedford bus	161,058
(4) Bedford truck	149,722
ii) Tyre	
(1) Car	224.42
(2) Minibus	511.79
(3) Bus	898.09
(4) Truck	962.51
iii) Fuel and Oil	per litre
(1) Petrol	2.30 Rp.
(2) Diesel	2.09
(3) Oil	9.32

5. Formula

The method of calculation and cost items constituent running cost are as follows.

* M.O.C. Field Survey Data, mid 1981.

* Vehicle Users Costs, Pakistan, 1977.

$Y = \Sigma X + Z$

where,

Y	:	Total running cost, Rp./km
ΣX	:	Direct cost Rp./km
X_1	:	Fuel cost
X_2	:	Oil cost
X_3	:	Tyre cost
X_4	:	Maintenance cost, Labour/Parts
X_5	:	Depreciation
X_6	:	Financial cost
Z	:	Indirect cost

Here, the indirect cost, generally calculated as the settled percentage to direct cost as the expense for personel, is being excluded as the character of using V.O.C.

Also, concerning finance cost, there exists the discussion if it is not necessary to include, since V.O.C. is in economic term, but the depreciation cost of vehicle is being included, considering the opportunity cost of fund.

The cost of the passenger on vehicle was being excluded, since usage of this V.O.C. is not for to calculate benefit.

i) Fuel cost

$X_1 = a_1/A_1$ a_1 : fuel unit cost after tax, Rp./litre

petrol diesel

(2.30 2.09)

A_1 : fuel consumption rate* litre/km

(0.083 0.098 0.224 0.274)

thus, km/litre

(12.05 10.20 4.46 3.65)

therefore, X_1 is to be calculated as follows.

car	minibus	bus	truck
(0.19	0.20	0.47	0.57)

ii) Oil cost

$X_2 = a_2X_1$ a_2 : oil/fuel consumption price ratio

a_2 (0.046 0.053 0.069 0.052)

Source: General Toll Road's Unit Price of Time Benefit
Japan's Ministry of Construction

therefore,

(0.0087 0.0106 0.0324 0.0296)

* "Fuel consumption on level tangent road at sea level"

Source: Kenya study for car, Project test for minibus, bus, truck.

iii) Tyre cost

$X_3 = \alpha a_3/A_2A_3$ α : number of tyre

car, minibus : 5

bus, truck : 7

a_3 : market price after tax

A_2 : life time km of tyre

A_3 : life time index of tyre

a_3	(224.42	511.79	898.09	962.51)	Rp.
A_2	(30,000	30,000	60,000	60,000)	Rp.
A_3	(0.79	0.83	0.83	0.83)	*

therefore,

(0.047   0.103   0.126   0.1358)

iv) Maintenance cost

(1) Part

As % of the cost of new vehicle

car	0.0261%
minibus	0.0560
bus	0.0560
truck	0.0491

Source: Vehicle User Costs, Pakistan, 1977, Table D, vehicle maintenance costs

therefore,

car	128,000 × 0.000261/1,000 = 0.0334
minibus	166,000 × 0.000560/1,000 = 0.09296
bus	295,000 × 0.000560/1,000 = 0.1652
truck	254,000 × 0.000491/1,000 = 0.124712

(2) Labour

Labour hours per 1,000 Km *

car	1.99 hour
minibus	16.44
bus	18.43
truck	18.65

* Source: General Toll Road's Unit Price of Time Benefit, 3-1, 3-2, Japan's Ministry of Construction

* Labour cost/km 2.85 Rp. in 1977 is being adjusted to 1982 cost, by the price escalation rate 7.4%.

therefore,

(0.008   0.067   0.075   0.076)

v) Depreciation

$$X_5 = \frac{0.9 \cdot (a_6 - a_3)}{A_4 \cdot A_3}$$

0.9 : vehicle depreciation rate

a_6 : vehicle price after tax

a_3 : price of type each 5 or 7

A_4 : Km standard life time of vehicle

A_3 : life time index of tyre

where vehicle price after tax Rp.

(56.393 79.154 161.058 149.722)

tyre price after tax Rp.

(1,122.1 2,558.98 6,286.63 6,737.57)

A_4 * 10^3 Km

(180 400 441 600)

A_3

(0.77 0.83 0.83 0.83)

therefore,

(0.3989 0.231 0.4228 0.287)

vi) Interest Payment

The cost of interest on the capital invested in the vehicle is expressed as a percentage of the cost of a new vehicle.

The ratio of interest used is the opportunity cost of capital of 12% per a.n.

This interest is calculated on the average vintage of vehicle type, which is a country such as Pakistan where the vehicle fleet is growing, is less than half the average life time of vehicles on the available evidence.

	Car	Minibus	Bus	Truck
Vehicle life year	12	8	7	10
Average vintage	5.5	3.5	3.0	4.5

As with depreciation cost higher speeds will result in higher annual kilometres, and thus higher speeds will result in lower interest cost per kilometre.

The calculation of the cost of interest per kilometre can be completed when the results of speed with hard date on the relationship between the average speed and the annual average kilometre which has been given in Table (next page).

Vehicle Depreciation Inputs

Vehicle Type	Average annual kilo 10^3	Average service life year	Average year round speed
Car	15.0	12	48
Minibus	50.0	8	45
Bus	63.0	7	42
Truck	60.0	10	38

The total cost of interest, given as the percentage of the cost of a new vehicle with types will be as follows:

	Car	Minibus	Bus	Truck	%
Total % interest	6.48	6.72	6.82	6.60	

$128{,}000 \times 0.0648/15{,}000 = 0.553$

$166{,}000 \times 0.0672/50{,}000 = 0.2231$

$295{,}000 \times 0.0682/63{,}000 = 0.3193$

$254{,}000 \times 0.0660/60{,}000 = 0.2794$

vii) Crew Cost

A paid car driver is estimated to earn a wage of Rp. 7,200 per year in 1977 including social benefits and his utilization also is supposed to be 49% of total car-hour utilization.

Mini bus	18,480 Rp.
Bus including conductor	38,220
Truck	18,480

1977 price is being adjusted to 1982 price by the price escalation rate of 7.4% per a.n.

(10,289 26,407 54,615 26,407) Rp.

Although, for passenger car, assuming 49% for working hours, 5,042 Rp. is being adopted.

$5{,}042/15{,}000 = 0.336$ Rp.

$26{,}407/50{,}000 = 0.528$

$54{,}615/63{,}000 = 0.669$

$26{,}407/60{,}000 = 0.44$

Rp./Km
1981/82 Price

	Car	Minibus	Bus	Truck
Fuel	0.19	0.20	0.47	0.57
Oil	0.0087	0.0106	0.0324	0.0296
Type	0.047	0.103	0.126	0.1358
Maintenance				
{ labour	0.008	0.067	0.075	0.076
{ parts	0.0334	0.09296	0.1652	0.1247
Depreciation	0.3989	0.231	0.4228	0.287
Capital cost	0.553	0.2231	0.3193	0.2794
Crew cost	0.336	0.528	0.669	0.44
Total	1.575	1.456	2.280	1.943

Estimate of Road Cost per Vehicle·km

1. Methodology

The method of dividing the total road cost, consisting of the initial construction cost and maintenance cost in economic term, by the total vehicle·km is being adopted in this report.

Whereas, the life time of road is being assumed 20 years.

2. Road Construction Cost

Road construction cost for main road (National Highway) is being estimated in financial term as 2,600,000. Rp/km in 1981/82 price, referring to "General Construction Cost of Roads and Bridges",

Where
- i. Right of way — 70m
- ii. Average height of embankment — 0.75–1.00m
- iii. Pavement width — 7.3m for double lanne
- iv. Thickness of pavement — 0.73–0.55m
  (Surface treatment + Base + Sub-base)

3. Composition of Main Items

The composition in main items of total cost is being estimated by breaking down as to follow the various Feasibility Study and Detail Design in Pakistan.

1.	Land Acquisition	12.5%
2.	Basic Costs	65%
3.	Construction Cost	22% of Basic Costs
4.	Supervision Fee	Basic Costs + Construction Cost of 2.5%
3.1	Formulation of Enbankment	19%

3.2	Sub-base	19%	
3.3	Base	33%	each basic costs
3.4	Surfacing	30%	

Where, land acquisition is considered to handle by the client directly, therefore it is being included to calculate ratio.

Following above break-down ratios of various items, financial cost of road construction is to be divided as follows.

		Rp/km	1981/82 price
1.	Land Acquisition	325,000	
2.	Basic Costs	1,690,000	
2.1	Formation of Embankment	(321,100)	
2.2	Sub-base	(321,100)	
2.3	Base	(557,700)	
2.4	Surfacing	(507,000)	
3.	Construction Cost	371,800	
4.	Supervision Fee	51,545	
	Total	2,607,324	

4. Estimate of Economic Cost

In order to calculate economic cost on the bases of financial cost, following procedures, assuming the typical cases, is being adopted.

i. Shadow price of foreign exchange position as 10% higher than official exchange rate. 10% is being adopted as to III IBRD Highway Improvement Project, ROMRI - RETI. are being used as to ditto p.181.

ii. Shadow price for labour cost

Skilled labour	1.25
Semi-Skilled labour	1.00
Un-Skilled labour	0.75

iii. Import duty and sales terms

Adjusted with the tables of tax and import duty

iv. Land

Neglected land acquisition cost

v. Salvage value

Neglected as in accordance with iv.

Thus, the economic cost by items is being calculated as follows.

		Financial	Economic
1.		325,000	
2.	2.1	321,100	277,507
	2.2	321,100	247,602
	2.3	557,700	426,315
	2.4	507,000	402,439
3.		371,800	313,529
4.		51,545	43,664
5.		169,000	134,259
	Total	2,607,324	1,845,315

5. Maintenance Cost

Maintenance cost per km of improved highway

Financial cost	0.018 million Rp/km. year*[1]
Economic cost	0.014 million Rp/km. year*[1]

Adjusted to 1981/82 price by 5 to price escalation which is supposed as the price escalation of construction material as the economic cost described in the source report in 1977/98 price.

$0.014\ (1 + 0.05)^4 = 0.017 \quad 10^6$ Rp/km·year

Here, considering life time as 20 years, the maintenance cost for 20 years becomes 340,000 Rp.

6. Road cost including maintenance cost for 20 years per/km

2,185,315 Rp.

7. Estimate of total vehicle·km

Traffic in 1981/82 by Traffic counts*[2]

Car & minibus	Bus	Truck
6,084,000	3,803,000	8,782,000

As the length of network in this study is 15,178 km, traffic per km are as follows.

Car & minibus	Bus	Truck	Total
401	251	579	1,231

In order to estimate the total for 20 years, following growth rates are being adopted, based on demand forecast in this study.

Passenger·km	1983–88	6.5%
	1989–2000	5.0%

*[1] Source: III I.B.R.D. Highway Improvement Project Rohri-Reti Section, p.194–6

*[2] Source: Progress Report II, p.91

Commodity ton·km	1983–88	7.7%
	1989–2000	6.1%

Therefore

$$\sum_{1982}^{2001} \text{Car \& minibus} \qquad 5{,}621{,}988^*$$

$$\sum_{1982}^{2001} \text{Bus} \qquad 3{,}512{,}760$$

Truck

$579\ (1 + 0.077)^8 = 1{,}048$

$(579 + 1{,}048)/2 = 814$

$814 \times 365 \times 8 = 2{,}376{,}880$

Also

$1{,}048\ (1 + 0.061)^{12} = 2{,}133$

$(1{,}048 + 2{,}133)/2 = 1{,}591$

$1{,}591 \times 365 \times 12 = 6{,}968{,}580$

$2{,}376{,}880 + 6{,}908{,}580 = 9{,}345{,}460$

Bus

$251\ (1 + 0.065)^8 = 415$

$(251 + 415)/2 = 333$

$333 \times 365 \times 8 = 972{,}360$

Also

$415\ (1 + 0.05)^{12} = 745$

$(415 + 745)/2 = 580$

$580 \times 365 \times 12 = 2{,}540{,}400$

$972{,}360 + 2{,}540{,}400 = 3{,}512{,}760$

Car & minibus

$401\ (1 + 0.065)^8 = 664$

$(401 + 664)/2 = 533$

$533 \times 365 \times 8 = 1{,}556{,}360$

$664\ (1 + 0.05)^{12} = 1{,}192$

$(664 + 1{,}192)/2 = 928$

$928 \times 365 \times 12 = 4{,}065{,}628$

$1{,}556{,}360 + 4{,}065{,}628 = 5{,}621{,}989$

* Source: Cost occasioning study by types of vehicle, Japan Road Cooperation

8. Estimate of the ratio for total cost by car and minibus, bus, and truck.

Car & minibus	1.00
Bus, truck	1.54*

Weighted above ratios by types of vehicle

Car & minibus	5,621,988
Bus + truck	3,512,760 + 9,345,460 = 12,858,220
	12,858,220 × 1.54 = 19,801,659

then, Car & minibus

2,185,315 Rp/(19,801,659 + 5,621,988) = 0.086

Bus and truck

0.086 × 1.54 = 0.132

therefore, total road cost including maintenance cost per vehicle·km.

Car & minibus	0.086 Rp.
Bus & truck	0.132 Rp.

Economic, 1981/82 price.

Estimate of Time Value by Commodity

1. Methodology

i. The cost, calculated, based on the opportunity cost in accordance with the time pass on the equivalent amounts of average leaded on a truck, indicated by money term.

ii. The cost initiated by the depreciation after a year with the different decreasing rate by commodity as its character.

It should be possible to calculate the time value per hour of a truck by commodity through the aggregation of i. and ii., divided by the numbers of day in a year and numbers of hour in a day.

Also, in order to convert to km term, time value per km can be calculated by dividing 48.

Where, 48 is being used, due to assume the 48k/h being the economic speed of truck.

2. Formula

$$\frac{1}{365 \cdot 24} wi \cdot v \cdot qi\,(r + li)$$

Where,
- wi : price of commodity i per ton
- v : maximum possible loaded amount per of truck
- qi : loading rate of commodity i
- r : interest rate
- li : depreciation rate of commodity i per year

* Source: Cost occasioning study by types of vehicle, Japan Road Cooperation

3. Data

i. wi,

Cement	1,195 Rp/ton	1981/82 price*
Fertilizer	2,965	
Coal/Coke		967
Iron/Steel		4,706
Phosphate Rock/Sulphur, Mining		1,097
Sugar		7,257
Wheat		2,229
Crude Oil & Petroleum Products		2,935
Edible Oil & Tallow		6,039
Other commodity (import)		14,286
Cotton		17,276
Rice		4,836
Fertilizer (export)		869
Petroleum (export)		2,346
Molasses		1,167
Other commodity (export)		22,540

ii. V Bedford Truck 10 Ton loading capacity

iii. V·qi*

Wheat	10.17
Rice	10.23
Cotton	7.37
Edible Oil	8.35
Sugar	9.35
Cement	11.10
Fertilizer	10.20
Iron & Steel	8.32
Mining	9.44
Coal & Coke	9.84
Petroleum	8.51
Others cargo	7.63
Firewood	8.36
Sugar Cone	7.58
Fruit & Vegetable	8.08
Live Stock	2.33

* Calculated, based on the Table in Progress Report II, p.32.

* Source: Progress I Refer Tables 2-1-11

iv. r

Here, 12% per a.n. is being used as 12% is generally admitted opportunity cost in Pakistan.

v. li*

1.	Wheat, Rice, Cotton	20%
2.	Edible Oil, Sugar	20%
3.	Cement, Fertilizer	10%
4.	Iron/Steel	5%
5.	Petroleum	5%
6.	Coal/Coke, Mining & Phosphate Rock	3%

vi. Calculation

		Rp/hour/Truck	Rs/hour/Ton
1.	Wheat	0.8280	0.0814
2.	Rice	1.807	0.1766
3.	Cotton	2.326	0.3156
4.	Fertilizer	0.760	0.0745
5.	Cement	0.333	0.0300
6.	Petroleum	0.485	0.0570
7.	Edible Oil	1.842	0.2206
8.	Sugar	2.479	0.2651
9.	Iron/Steel	0.760	0.0913
10.	Mining	0.1773	0.0188
11.	Coal/Coke	0.1629	0.0166
12.	Others	2.737	0.3587

* Estimated by mission through the discussion with businessmen in field survey.

Road Transport Cost

(DTC) is composed of Vehicle Operating Cost (VOC) and Road Cost (RDC).
DTC = VOC + RDC

VOC (RS/Vehicle·Km)		RDC (〃)	DTC (〃)	Average Load Facter	DTC (RS/Pass·Km, RS/Ton·km)
Car	1.575	0.086 (Car, Minibus)	1.661	3.0 Passengers	0.5537 RS/Pass·Km
Minibus	1.456		1.542	12.0	0.1285
Bus	2.280	0.132 (Bus, Truck)	2.412	40.0	0.0603
Truck	1.943		2.075	8.35 Tonne	0.2485 RS/TON·Km
Wheat				10.17	0.2040
Rice				10.23	0.2028
Cotton				7.37	0.2815
Edible Oil				8.35	0.2485
Sugar				9.35	0.2219
Cement				11.10	0.1869
Fertilizer				10.20	0.2034
Iron/Steel				8.32	0.2494
Mining				9.44	0.2198
Coal/Coke				9.84	0.2109
Petroleum				8.51	0.2438
Other Commodities				7.63	0.2720

General Road Transport Cost

	$GDTC = [DTC(VOC + RDC) + a/V] \times D$
Passengers	$(0.1285 + 1.28/Vb) \times D$
Upper Class (Car)	$(0.3411 + 1.78/Vc) \times D$
Lower Class (Bus)	$(0.0944 + 1.28/Vb) \times D$
Goods	$(0.2485 + 0.0814/Vt) \times D$
Wheat	$(0.2040 + 0.0814/Vt) \times D$
Rice	$(0.2028 + 0.1766/Vt) \times D$
Cotton	$(0.2815 + 0.3156/Vt) \times D$
Edible Oil	$(0.2485 + 0.2206/Vt) \times D$
Sugar	$(0.2219 + 0.2651/Vt) \times D$
Cement	$(0.1869 + 0.0300/Vt) \times D$
Fertilizer	$(0.2034 + 0.0745/Vt) \times D$
Iron/Steel	$(0.2494 + 0.0913/Vt) \times D$
Mining	$(0.2198 + 0.0188/Vt) \times D$
Coal/Coke	$(0.2109 + 0.0166/Vt) \times D$
Petroleum	$(0.2438 + 0.0570/Vt) \times D$
Others	$(0.2720 + 0.3587/Vt) \times D$

Note: DTC of Passenger is that of Minibus.
DTC of Upper-class is that of average of Car and Minibus.
DTC of Lower-class is that of average of Minibus and Bus.
$Vb = 40km/h$
$Vc = 60km/h$
$Vt = 50km/h$

Financial Cost of Pakistan Railways

(million. Rs)

	1981/82 (Budget)			1980/81
	Total	Labour	Material	Total
Expenditure	3,574.7	-	-	3,429.3
Working Expenses	3,041.0	1,265.2	1,775.8	2,872.5
General Administration	322.6	176.6	146.0	305.8
Operating Expenses	1,308.5	344.8	963.7	1,270.0
Fuel	818.4	-	818.4	815.4
Furnance Oil	309.7	-	309.7	797.4
Diesel Oil	487.9	-	487.9	
Other Fuel	0	-	0	0
Electric Power	15.0	-	15.0	12.1
Others	5.9	-	5.9	5.9
Operating Staff	344.8	344.8	-	318.6
Steam Loco	61.1	61.1	-	81.5
Diesel Loco	36.8	36.8	-	
Carriage and Wagons	29.8	29.8	-	28.7
Traffic	217.1	217.1	-	208.4
Operation other than Staff and Fuel	145.3	-	145.3	136.0
Repairs & Maintenance	1,127.5	594.8	532.7	1,030.9
Structural	365.6	288.8	76.8	330.6
Steam Loco	92.5	52.7	39.8	
Diesel Loco	202.9	54.8	148.1	286.6
Rail Car	28.8	7.8	21.0	
Carriage & Wagon	194.9	103.3	91.6	184.0
Electric Services	171.4	87.4	84.0	162.6
Equipment	71.3	0	71.3	67.1
Other Expenditures	282.4	149.0	133.4	265.8
Other Expenses	533.7			556.8
Interest	113.7			136.8
Depreciation Reserve Fund	420.0			420.0

Source: "Railway Budget Estimates 1981–82" Railway Board

Average Lead, Average Load and Average Cost of Railways Traffic (1980/81)

Commodities	Average Lead (km)	Average Load (Tonnes)	Average Cost (PS/TKM)
Wheat	720	22.5	16.20
Rice	981	23.7	13.99
Cotton	875	15.7	19.60
Edible Oil	1,235	21.1	17.09
Sugar	920	24.4	14.33
Cement	716	23.9	16.77
Fertilizer	809	22.5	15.67
Iron/Steel	825	24.2	18.06
Mining	911	24.1	14.05
Coal/Coke	1,199	24.3	13.59
Petroleum	1,073	19.2	18.78
Other Commodities	571	19.0	19.74
Goods	696	-	17.83
Passenger	133	-	12.07

Conversion Factor

(1) Labor (Economic Wage Rate, EWR)

Skilled Labor 1

Un-skilled Labor 0.5 (refer "Interim Report (page 297)")

Assumption

No. of Skilled Labor : No. of Un-skilled Labor = 1:1

in Pakistan Railway

Then

EWR = (1 + 0.5)/2 = 0.750

(2) Material (except Fuel)

Standard Conversion Factor (SCF) is applied to materials except fuel

SCF = 0.851 (refer "Progress II" [Page 109])

(3) Fuel

a) Furnace Oil

Tax	35.2 RS/ton (Customs tax only, Sales Tax-free)
Price	1,300.79 RS/ton
Then	35.2/1,300.79 = 2.71%

b) Diesel Oil (H.S.D)

Tax	0.25 RS/L
Price	3.10 RS/L
Then	0.25/3.10 = 8.06%

Economic Cost of Pakistan Railways

(Million RS, 1981/82 Price)

Items	Economic Cost	Conversion Factor	Economic Cost
Labor	1265.2	0.750	948.9
Fuel			
Furnace Oil	309.7	0.9729	301.3
Diesel Oil	487.9	0.9194	448.6
Other Materiais	978.3	0.851	832.5
Working Expence	3,041.0	—	2,531.3
Interest	113.7	—	113.7
Depereciation reserve Fund	420.0	—	420.0
Total Cost	3,574.7	0.8574	3,065.0

Unit Cost of Pakistan Railways
by Passenger Class and Commodities

Unit; RS /Passenger or RS/Ton
D ; Distance km

	Financial Cost 1980/81	Financial Cost 1981/82	Economic Cost 1981/82
Passenger	1.550 + 0.1090·D	1.6087 + 0.1131·D	1.3793 + 0.0970·D
Upper class	3.967 + 0.3134·D	4.1173 + 0.3253·D	3.5302 + 0.2789·D
Lower class	1,067 + 0.0674·D	1.1074 + 0.0700·D	0.9495 + 0.0600·D
Goods	25.860 + 0.1412·D	26.840 + 0.1466·D	23.012 + 0.1257·D
Wheat	24.146 + 0.1285·D	25.061 + 0.1334·D	21.487 + 0.1144·D
Rice	22.923 + 0.1166 ·D	23,792 + 0.1210·D	20,399 + 0.1037·D
Cotton	34.600 + 0.1560·D	35.911 + 0.1619·D	30.790 + 0.1388·D
Edible Oil	25.744 + 0.1501·D	26.719 + 0.1558·D	22.909 + 0.1336·D
Sugar	22.262 + 0.1193·D	23.106 + 0.1238·D	19.811 + 0.1061·D
Cement	22.724 + 0.1359·D	23.585 + 0.1410·D	20.222 + 0.1209·D
Fertilizer	24.146 + 0.1269·D	25.061 + 0.1317·D	21.487 + 0.1129·D
Iron/Steel	30.687 + 0.1434·D	31.850 + 0.1488·D	27.308 + 0.1276·D
Mining	22.446 + 0.1387·D	23.296 + 0.1440·D	19.974 + 0.1235·D
Coal/Coke	22.354 + 0.1173·D	23.201 + 0.1217·D	19.893 + 0.1043·D
Petroleum	28.298 + 0.1616·D	29.370 + 0.1677·D	25.182 + 0.1438·D
Other Commodities	28.582 + 0.1474·D	29.665 + 0.1530·D	25.435 + 0.1312·D

(I) Unit Cost (1980/81)
Source: "Pakistan Railways Costing Data" 1982.4

(II) Total Financial Cost of PAKISTAN RAILWAYS
1980/81 3,429.3 M.Rs
1981/82 3,574.7 M.Rs } Ratio 1.03789

(III) Shadow Rate = 0.8574

General Railway Transport Cost (GRTC)

$$GRTC = (TMC + KMC \cdot D) + a(Tm + D/Vr) + (DTC + a/Vt) \cdot L$$

Passenger	$(1.3793 + 0.0970 \cdot D) + 1.28\ (Tw + D/Vp) + (0.1285 + 1.28/Vb) \cdot L \cdot 2$
Upper class	$(3.5302 + 0.2789 \cdot D) + 1.78\ (Tw + D/Vp) + (0.3411 + 1.78/Vc) \cdot L \cdot 2$
Lower class	$(0.9495 + 0.0600 \cdot D) + 1.28\ (Tw + D/Vp) + (0.0944 + 1.28/Vb) \cdot L \cdot 2$
Goods	$(n/2 \times 23.012 + 0.1257 \cdot D) + 0.0814\ (n \cdot Tm + D/Vr) + (0.2485 + 0.0814/Vt) \cdot L \cdot n$
Wheat	$(n/2 \times 21.487 + 0.1144 \cdot D) + 0.0814\ (n \cdot Tm + D/Vr) + (0.2040 + 0.0814/Vt) \cdot L \cdot n$
Rice	$(n/2 \times 20.399 + 0.1037 \cdot D) + 0.1766\ (n \cdot Tm + D/Vr) + (0.2028 + 0.1766/Vt) \cdot L \cdot n$
Cotton	$(n/2 \times 30.790 + 0.1388 \cdot D) + 0.3156\ (n \cdot Tm + D/Vr) + (0.2815 + 0.3156/Vt) \cdot L \cdot n$
Edible Oil	$(n/2 \times 22.909 + 0.1336 \cdot D) + 0.2206\ (n \cdot Tm + D/Vr) + (0.2485 + 0.2206/Vt) \cdot L \cdot n$
Sugar	$(n/2 \times 19.811 + 0.1061 \cdot D) + 0.2651\ (n \cdot Tm + D/Vr) + (0.2219 + 0.2651/Vt) \cdot L \cdot n$
Cement	$(n/2 \times 20.222 + 0.1209 \cdot D) + 0.0300\ (n \cdot Tm + D/Vr) + (0.1869 + 0.0300/Vt) \cdot L \cdot n$
Fertilizer	$(n/2 \times 21.487 + 0.1129 \cdot D) + 0.0745\ (n \cdot Tm + D/Vr) + (0.2034 + 0.0745/Vt) \cdot L \cdot n$
Iron/Steel	$(n/2 \times 27.308 + 0.1276 \cdot D) + 0.0913\ (n \cdot Tm + D/Vr) + (0.2494 + 0.0913/Vt) \cdot L \cdot n$
Mining	$(n/2 \times 19.974 + 0.1235 \cdot D) + 0.0188\ (n \cdot Tm + D/Vr) + (0.2198 + 0.0188/Vt) \cdot L \cdot n$
Coal/Coke	$(n/2 \times 19.893 + 0.1043 \cdot D) + 0.0166\ (n \cdot Tm + D/Vr) + (0.2109 + 0.0166/Vt) \cdot L \cdot n$
Petroleum	$(n/2 \times 25.182 + 0.1438 \cdot D) + 0.0570\ (n \cdot Tm + D/Vr) + (0.2438 + 0.0570/Vt) \cdot L \cdot n$
Others	$(n/2 \times 25.435 + 0.1312 \cdot D) + 0.3587\ (n \cdot Tm + D/Vr) + (0.2720 + 0.3587/Vt) \cdot L \cdot n$

Passenger
- L = 30km
- Tw = 0.5h
- Vp = 60km/h (Coach)
- Vb = 40km/h (Bus)
- Vc = 60km/h (Car)

Goods
- n = 1 or 2
- L = 30km
- Tm = 24h
- Vr = 30km/h (Wagon)
- Vt = 50km/h (Truck)

Break-even Distance between Road and Railway by Economic General Transport Cost

	by Economic General Transport Cost		by Fares between Road and Railways
Passenger	276		–
Upper class	428		–
Lower class	203		–
	One end	Both ends	One end
Goods	172	344	–
Wheat	213	426	280
Rice	213	426	320
Cotton	228	456	230
Edible Oil	217	434	230
Sugar	205	410	280
Cement	250	500	280
Fertilizer	208	416	320
Iron/Steel	193	386	680
Mining	177	354	130
Coal/Coke	156	312	280
Petroleum	214	428	840
Other Commodities	218	436	840

Variation of Break-even Distance

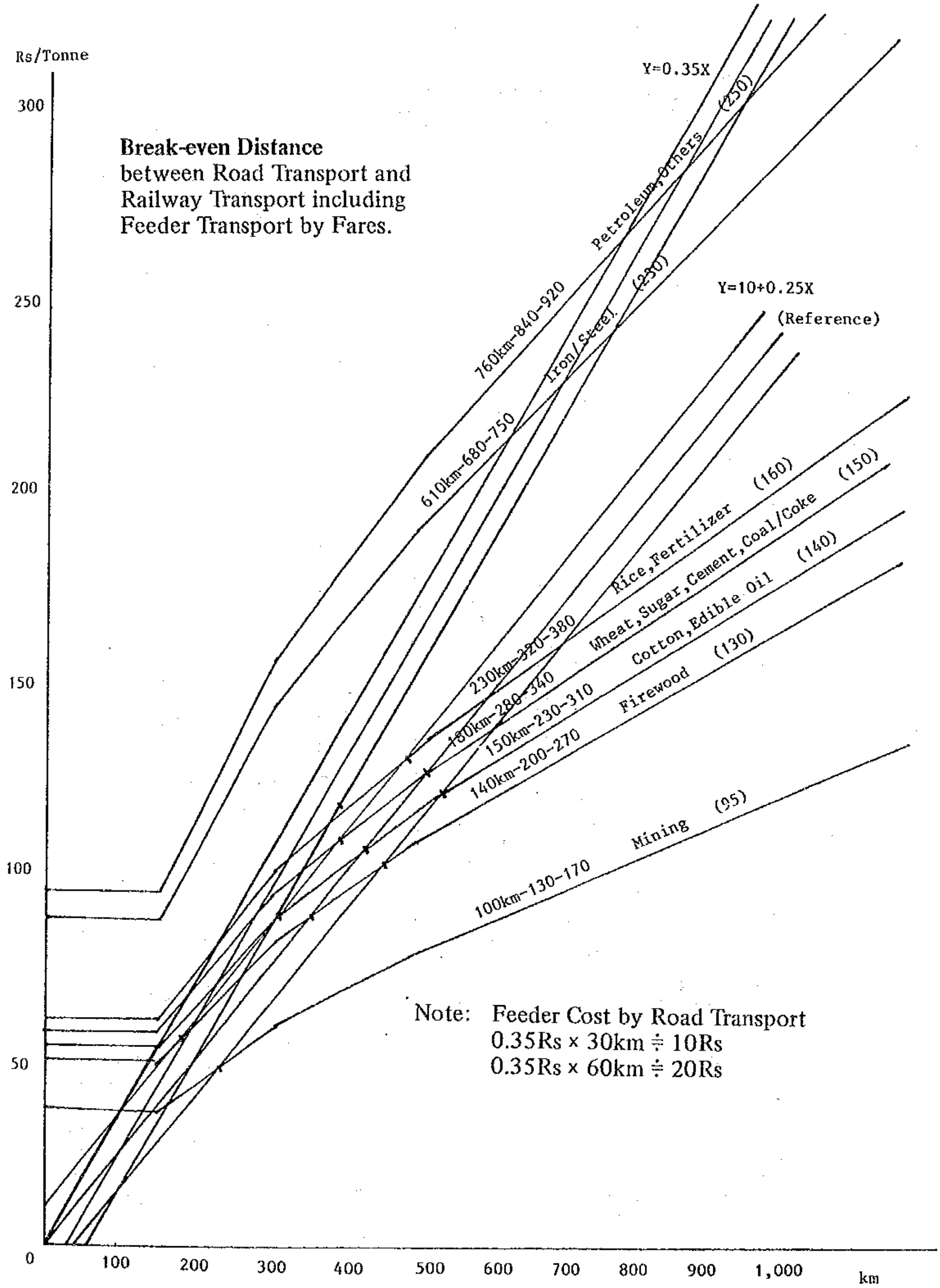
I. Case of Fare-Curve Y = 0.35X in Road Transport

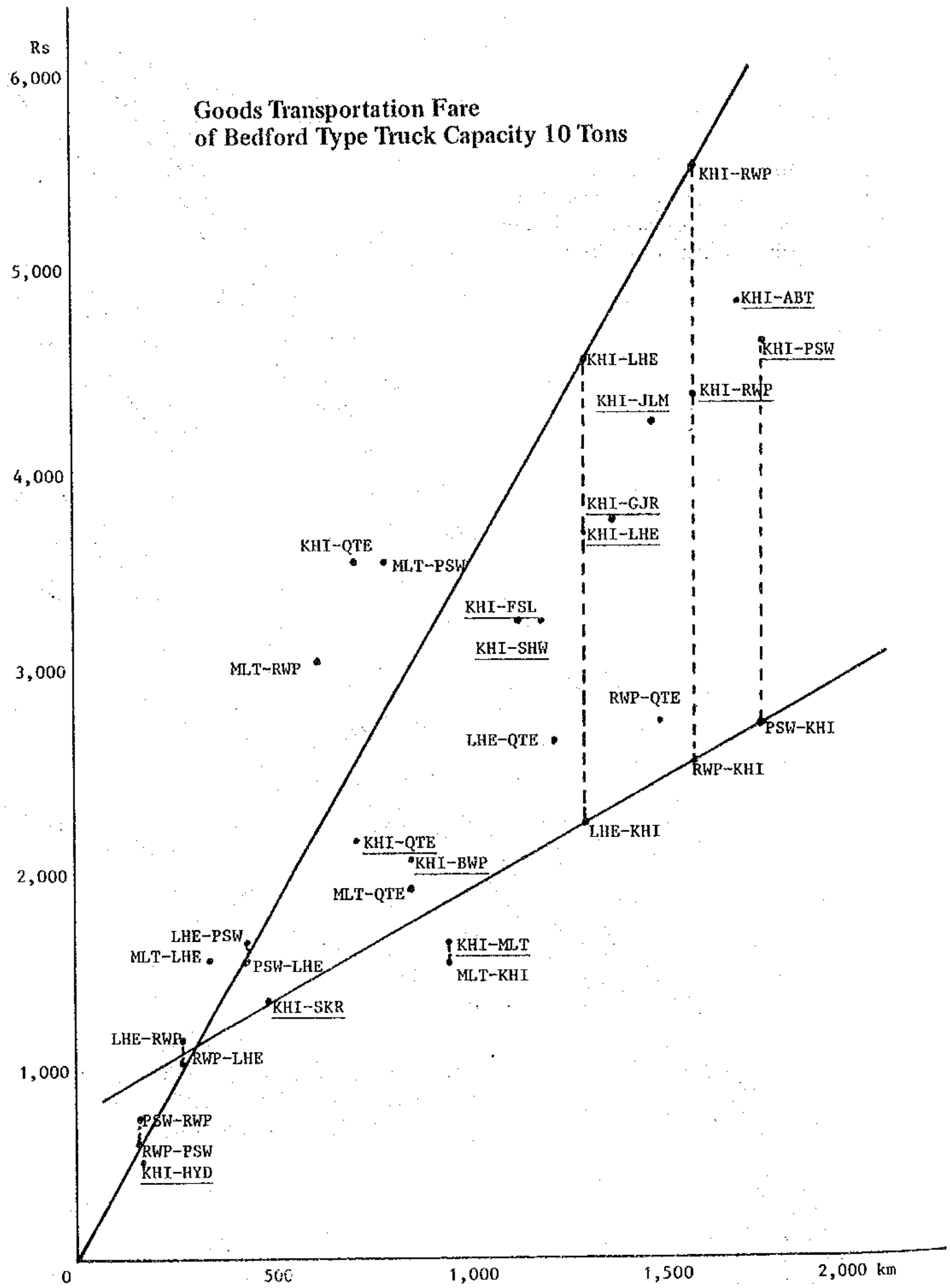
(KM)

Commodity	Between railway stations	includes feeder cost at one end	includes feeder cost at both ends
Mining	100	130	170
Firewood	140	200	270
Cotton, Edible Oil	150	230	310
Wheat, Sugar, Cement, Coal/Coke	180	280	340
Rice, Fertilizer	230	320	380
Iron/Steel	610	680	750
Petroleum, Others	760	840	920

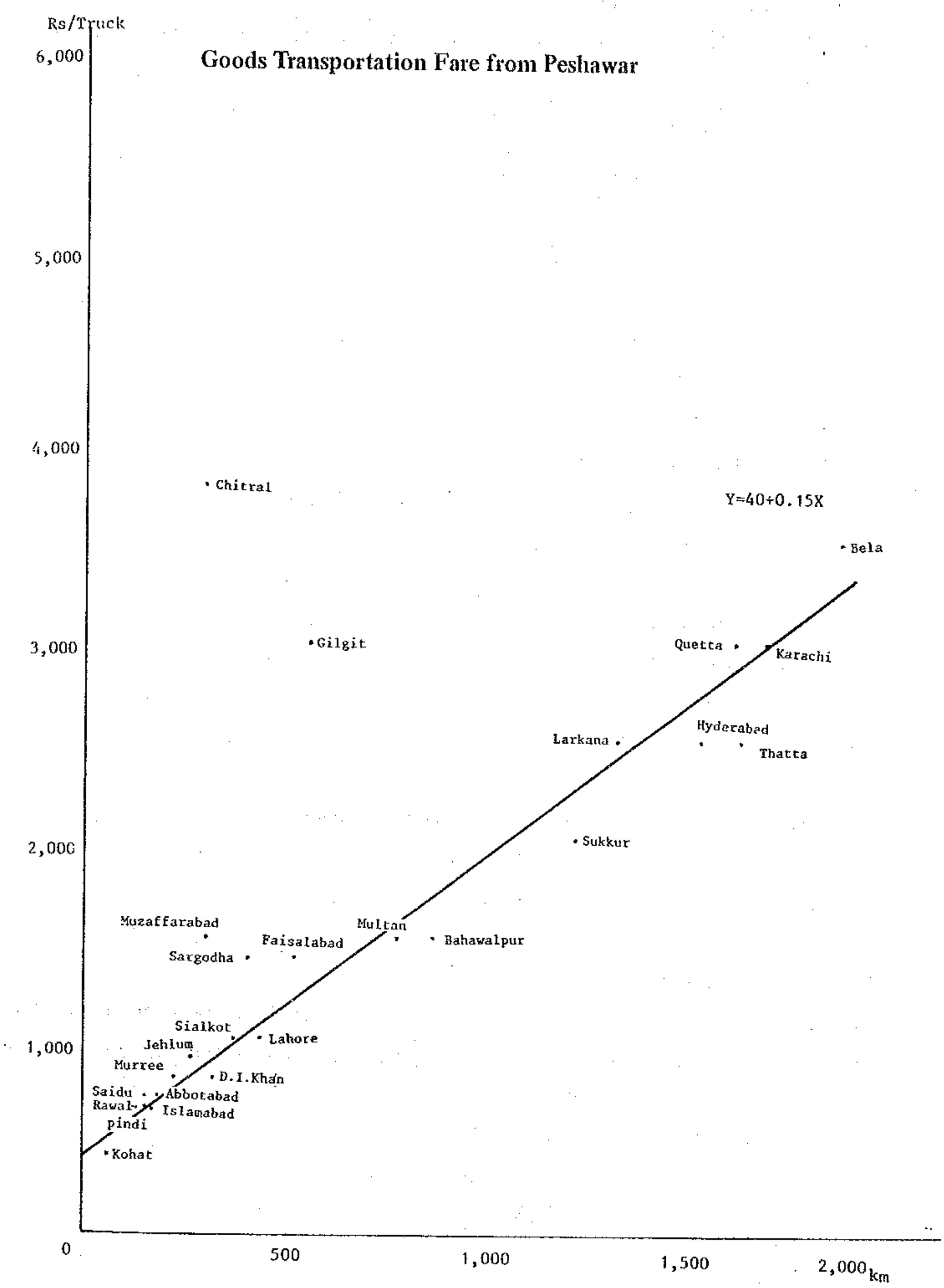
II. Case of Fare-Curve Y = 10 + 0.25X in Road Transport

Commodity	Between stations	includes feeder cost at one end	includes feeder cost at both ends
Mining	100	150	230
Firewood	180	350	440
Cotton, Edible Oil	320	420	520
Wheat, Sugar, Cement, Coal/Coke	380	500	590
Rice, Fertilizer	470	580	680
Iron/Steel	-	-	-
Petroleum, Others	-	-	-


Rs/Tonne
300
250
200
150
100
50
0
100
200
300
400
500
600
700
800
900
1,000
km
Break-even Distance
between Road Transport and
Railway Transport including
Feeder Transport by Fares.
Y=0.35X
Y=10+0.25X
(Reference)
Petroleum,Others (250)
760km-840-920
Iron/Steel (230)
610km-680-750
Rice,Fertilizer (160)
230km-320-380
Wheat,Sugar,Cement,Coal/Coke (150)
180km-280-340
Cotton,Edible Oil (140)
150km-230-310
Firewood (130)
140km-200-270
Mining (95)
100km-130-170
Note: Feeder Cost by Road Transport
0.35Rs × 30km ≑ 10Rs
0.35Rs × 60km ≑ 20Rs



Goods Transportation Fare
of Bedford Type Truck Capacity 10 Tons
Rs
6,000
5,000
4,000
3,000
2,000
1,000
0
500
1,000
1,500
2,000 km
KHI-RWP
KHI-ABT
KHI-PSW
KHI-LHE
KHI-RWP
KHI-JLM
KHI-GJR
KHI-LHE
KHI-QTE
MLT-PSW
KHI-FSL
KHI-SHW
MLT-RWP
RWP-QTE
PSW-KHI
LHE-QTE
RWP-KHI
LHE-KHI
KHI-QTE
KHI-BWP
MLT-QTE
LHE-PSW
MLT-LHE
PSW-LHE
KHI-MLT
MLT-KHI
KHI-SKR
LHE-RWP
RWP-LHE
PSW-RWP
RWP-PSW
KHI-HYD


Rs/Truck
6,000
Goods Transportation Fare from Peshawar
5,000
4,000
3,000
2,000
1,000
0
500
1,000
1,500
2,000km
Y=40+0.15X
Chitral
Bela
Gilgit
Quetta
Karachi
Larkana
Hyderabad
Thatta
Sukkur
Muzaffarabad
Multan
Faisalabad
Bahawalpur
Sargodha
Sialkot
Jehlum
Lahore
Murree
D.I.Khan
Saidu
Abbotabad
Rawal-
pindi
Islamabad
Kohat

2. Evaluation (General Railway Transport Cost)

(1) Formula of General Railway Transport Cost

General Railway Transport Cost (GTC) can be estimated on the following formula.

$$GTC = RLC + TC + FC$$

$$RLC = \sum_{l}\sum_{k} (TMC_k + KMC_k \cdot D_l) \cdot Q_{l,k}$$

$$TC = \sum_{l}\sum_{k} w_k \cdot (TT + D_l/V_l) \cdot Q_{l,k}$$

$$FC = \sum_{l}\sum_{k} (VOC_k + w_k/v_k) \cdot L \cdot Q_{l,k}$$

where,

RLC ; Railway Cost
TC ; Time Cost
FC ; Feeder Cost
l ; Index for OD pair
k ; Index for Passenger-class or Commodity-type
Q ; Traffic Volume
D ; Distance for Railway
TMC ; Terminal Cost
KMC ; Kilometric Cost
w ; Value of Time
TT ; Terminal Time
V ; Velocity of Railway
VOC ; Vehicle Operating Cost for Feeder Transport
v ; Velocity of Feeder Transport
L ; Distance for Feeder Transport

(2) Effects of Investment for Railway

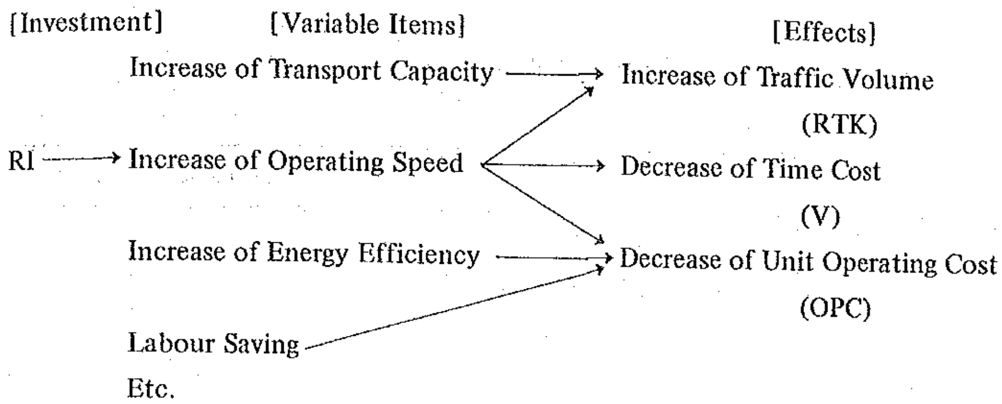
The investment for railway will decrease the unit cost of transport through the following effects, that is increase of transport capacity, increase of velocity, energy saving, decrease of unit operating cost and so on.

These process will be briefly described as Fig. 1.

Fig. 1 Effects of Investment for Railway

$$GTC = OPC \cdot RTK + \frac{w \cdot RTK}{V} + RI$$

where OPC ; Unit Operating Cost = TMC + KMC
RTK ; Total Ton-km or Pax-km = D·Q
RI ; Investment for Railway



(3) Estimation of Unit Operating Cost of Railway

Unit operating costs of railway in two alternatives at year 2000 were estimated through the next steps based on the unit costs of railway which have been already estimated in the main Report.

(a) Divide the total cost of railway at year 1981 to that for passenger transport and goods transport.

(b) Estimate the operating costs of each case A, B at the year 2000 by keeping in view of the increasing ratio of traffic volume and the effects of investment. These values are that of 1981 price.

(c) Fuel Consumption costs at year 2000 were estimated as Table 2. by using the result of evaluation of energy consumption on another paragraph.

(d) Add the capital cost to operation cost after connecting the investment amount of each case to annual financial cost composed of depreciation and interest by using the straight line method.

(e) Divide the total cost by each traffic volume to get the unit operating cost including the capital cost of each alternative A, B at year 2000.

(f) Estimate the unit operating economic cost at year 2000 in each alternative by passenger and commodity-wise by using the ratio between unit cost of financial base at year 1981 and that of year 2000.

(g) Apply these railway unit cost of each alternative to the formula of GTC.

(h) Changes of velocity and terminal time based on the investment of each alternative were assumed as shown on Table 1.

Table 1. Changes of Velocity and Terminal Time

Items	Unit	1981	2000(A)	2000(B)
Velocity of Passenger Train (Vr)	km/h	47	47	53
Velocity of Goods Train (Vr)	km/h	30	25	37
Terminal Time of Loading/ Un-loading of Goods	h	72	36	24

Table 2. Fuel Consumption Cost of Railway

(MRS)

Category	1981(C)	2000(A)	2000(B)	A/C	B/C
Passenger	360.0 (344.9)	436.5 (418.2)	435.7 (417.4)	1.2125	1.2103
Goods	491.1 (470.5)	350.1 (335.4)	646.9 (619.7)	0.7129	1.3172
Total	851.1 (815.4)	786.6 (753.6)	1,082.6 (1,037.1)	0.9242	1.2720

Note: Figures in the parenthesis are adjusted based on the total cost which is real cost of PAKISTAN Railway at year 1980/81.

Table 3. Reference Data for Estimation of General Railway Transport Cost

	Items	Unit	1981(C)	2000(A)	2000(B)	A/C	B/C
Passenger	Traffic	10^3P*1	53,514	147,915	122,681	2,764	2,293
	Traffic	MPK	16,311	48,868	49,582	3,000	3,040
	Cost	MRS	2,000.6				
	Unit Cost	RS/PK	0.1227				
Goods	Traffic	10^3T*2	10,403	29,891	37,842	2,874	3,638
	Traffic	MTK	7,918	20,188	36,357	2,550	4,591
	Cost	MRS	1,428.6				
	Unit Cost	RS/TK	0.1804				
Total Cost		MRS	3,429.3				
Investment		MRS	1,100.0	3,837	6,723	3,488	6,112
Depreciation		MRS	420.0	1,465	2,566	3,488	6,112

Note: *1, *2 excluding intra-zonal traffic.

Railway Cost (1980/81)

(MRS)

Total Cost	3,429.3
General Administration	305.4
Fuel Consumption	815.4
Operating Staff	318.6
Repairs & Maintenance	1,030.9
Other Expenditure	538.6
Depreciation	420.0

Table 4. Estimation of Railway Unit Cost by Passenger and Goods

Passenger	1981(C)	2000(A)	2000(B)	A/C	B/C
General Administration	211.1	583.5	484.1	2.764	2.293
Fuel Consumption	344.9	418.2	417.4	1.2125	1.2103
Operating Staff	218.6	457.7	457.7	2.094	2.094
Repairs & Maintenance	601.4	1,662.3	1,379.0	2.764	2.293
Other Expenditures	379.6	1,049.2	870.4	2.764	2.293
Depreciation	245.0	914.8	1,337.5		
Total (MRS)	2,000.6	5,085.7	4,946.1		
Traffic Volume (MPK)	16,311	46,868	49,582		
Unit Cost (RS/PK)	0.1227	0.1041	0.0998	0.8484	0.8134
Goods	**1981(C)**	**2000(A)**	**2000(B)**	**A/C**	**B/C**
General Administration	94.7	272.2	344.5	2.874	3.638
Fuel Consumption	470.5	335.4	619.7	0.7129	1.3172
Operating Staff	100.0	209.4	209.4	2.094	2.094
Repairs & Maintenance	429.5	1,234.4	1,562.5	2.874	3.638
Other Expenditures	159.0	457.0	578.4	2.874	3.638
Depreciation	175.0	550.2	1,228.5		
Total (MRS)	1,428.6	3,058.6	4,543.0		
Traffic Volume (MTK)	7,918	20,188	36,357		
Unit Cost (RS/TK)	0.1804	0.1515	0.1250	0.8398	0.6929

VI. LISTING AND PRELIMINARY EVALUATION OF PROJECTS

VI. LISTING AND PRELIMINARY EVALUATION OF PROJECTS

1. Introduction to Preliminary Project Evaluation

1-1 Objectives and Approaches

The major objective of preliminary project evaluation in this Study is to provide some significant indicators for decision-makings in the later stages of preparing the master plan, plan of action and implementation programme.

As for the approach of project evaluation, the following ways will be basically applied.

(1) Economic analysis and/or financial analysis in quantitative terms will be conducted for those projects who require more than empirical discussions for their justification and comparative importance and whose major components of cost and benefits are measurable in reasonably reliable terms. For the evaluation of some important projects involving large uncertainty, sensitivity analysis will be applied.

(2) For a number of projects of the same kind which can not be evaluated one by one due to either the work limitation of the study or some unidentifiability of project formulation, a so-called screening analysis will be provided to typified projects for rough evaluation. In actual, road projects and some railway projects fall in this case.

(3) For those projects whose benefit components are either unmeasurable (intansible) or unavailable, descriptive evaluation will take place from an empirical point of view. One of the important aspects in such discussions would be the safety, which is prerequisite to the development of transport systems.

Incidentally, those projects of minor development/rehabilitation/improvement or the evidently justifiable projects will bypass the preliminary evaluation and be handed over directly to the later stages of planning. It should be also noted that project evaluation of this Study will not reach much detail and give just an insight of the concerned projects good for a planning purpose. Any projects proposed in this Study will, therefore, require a separate full feasibility study before implemented.

1-2 General Methodologies

While methodologies applied to any specific modes or projects will be introduced in the concerned parts as occasion calls, this subsection is limited to the discussion of ones which are commonly in use.

The decision criterion of cost benefit analysis which is of frequent use in the study is the internal rate of return. The internal rate of return criterion consists of calculating the discount rate at which a project has a net present value of zero. Such a discount rate is called internal rate of return (IRR)r, and only those projects whose IRR is higher than the pre-determined opportunity value of capital rate r are considered to be justifiable. In equation form, the IRR criterion may be expressed as:

$$\sum_{t=1}^{N} \frac{Bt-Ot}{(1+r)^t} - \sum_{t=1}^{N} \frac{Kt}{(1+r)^t} = 0,$$

where Bt designates benefit in t, and Ot operating cost, Kt capital investment and N project life. The financial interpretation of IRR would be the highest interest rate which the project can pay while redeeming the initial borrowing.

In estimating costs and benefits of economic analysis, border prices are adopted. Market prices of costs and benefits can be converted to border prices by applying the appropriate conversion factors to various broken-down traded and non-traded components (see below for the estimation of standard conversion factor as an example). For a reasonably small portion of the components whose international market prices are not identifiable, standard conversion factor is applied to convert to border prices. Also, border prices of labor can be obtained by multiplying its marginal productivity by the conversion factor for consumption.

Table 1-1 Trade Statistics (Total)

(Million Rupees)

Year	Value of imports M(t)	Value of exports X(t)	Value taxes on imports T(t)	Value taxes on exports D(t)
1976-77	23,012.2	11,293.9	6,074.2	180.4
1977-78	27,314.7	12,980.4	3,251.3	146.5
1978-79	36,388.1	16,925.0	10,065.7	279.3
1979-80	46,929.1	23,410.1	12,041.1	445.3
1980-81	53,543.7	29,279.5	13,354.3	706.5

Source: Central Board of Revenue, Statistical Bulletin.

Estimation of standard Conversion Factor

$$SCF(t) = \frac{M(t) + X(t)}{(M(t) + T(t)) + (X(t) - D(t))}$$

M(t): Value of imports
X(t): Value of exports
T(t): Value taxes on imports
D(t): Value taxes on exporters

$$SCF = \sum_{t} SCF(t)/N$$

N: Number of observed years

SCF = 0.351

To compare mutually exclusive projects, differential cost-benefit analysis is conducted. If the IRR on the hypothetical project, whose cost and benefit stream is the differential between those of the two mutually exclusive projects, is in excess of the pre-determined opportunity value of capital rate, the larger project is to be preferred to the former. Some further devices on cost-benefit analysis are also provided depending upon the conditions of preliminary evaluation works as can be seen later.

1-3 Appendix for General Methodologies

(1) Standard Conversion Factor

$$SCF(t) = \frac{M(t) + X(t)}{(M(t) + T(t)) + (X(t) - D(t))}$$

M(t): Value of imports

X(t): Value of exports

T(t): Value taxes on imports

D(t): Value taxes on exports

$$SCF = \sum_{t} SCF(t)/N$$

N: Number of observed years

SCF = 0.851

Table 1-2 Trade Statistics (Total)

(Million Rupees)

Year	Value of imports M(t)	Value of exports X(t)	Value taxes on imports T(t)	Value taxes on exports D(t)
1976-77	23,012.2	11,293.9	6,074.2	180.4
1977-78	27,814.7	12,980.4	8,251.3	346.5
1978-79	36,388.1	16,925.0	10,065.7	279.8
1979-80	46,929.1	23,410.1	12,041.1	445.8
1980-81	53,543.7	29,279.5	13,854.8	706.5

Source: Central Board of Revenue, Statistical Bulletin.

(2) Conversion Factor for Consumption

$$CFC(t) = \frac{Mc(t) + Xc(t)}{(Mc(t) + Tc(t)) + (Xc(t) - Dc(t))}$$

t: Year

Mc: Value of import for main consumer goods

Xc: Value of export for main consumer goods

Tc: Value taxes on import for main consumer goods

Dc: Value taxes on export for main consumer goods

$$CFC = \sum_{t} CFC(t)/N$$

N: Number of observed years

CFC = 0.894

Table 1-3 Trade Statistics (Main Consumer Goods)

(Million Rupees)

Year	Value of imports Mc(t)	Value of exports Xc(t)	Value taxes on imports Tc(t)	Value taxes on exports Dc(t)
1976-77	4,720.1	8,982.4	1,405.9	74.3
1977-78	6,721.5	9,318.0	2,234.5	114.7
1978-79	10,461.3	13,130.0	2,863.7	97.8
1979-80	8,623.4	15,331.9	3,079.2	162.3
1980-81	8,993.0	18,899.5	3,698.2	257.2

Source: Central Board of Revenue, Statistical Bulletin.

(3) **Conversion Factor for Machinery and Mechanical Appliances**

$$SCF(t) = \frac{Mm(t) + Xm(t)}{(Mm(t) + Tm(t)) + (Xm(t) - Dm(t))},$$

Mm(t): Value of imports for machinery and mechanical appliances
Xm(t): Value of exports for machinery and mechanical appliances
Tm(t): Value taxes on imports for machinery and mechanical appliances
Dm(t): Value taxes on exports for machinery and mechanical appliances

$$CFM = \sum_t CFM(t)/N$$

N: Number of observed years
SCF = 0.841

Table 1-4 Trade Statistics (Machinery and Mechanical Appliances)

(Million Rupees)

Year	Value of imports Mm(t)	Value of exports Xm(t)	Value taxes on imports Tm(t)	Value taxes on exports Dm(t)
1976-77	3,312.4	29.1	539.4	-
1977-78	4,146.5	44.6	858.3	-
1978-79	4,250.9	47.6	873.0	-
1979-80	5,589.9	60.2	1,048.1	-
1980-81	5,686.4	55.8	1,103.3	-

Source: Central Board of Revenue, Statistical Bulletin.

(4) Conversion Factor for Electric Machinery and Equipment

$$SCF(t) = \frac{Me(t) + Xe(t)}{(Me(t) + Te(t)) + (Xe(t) - De(t))}$$

Me(t): Value of imports for electric machinery and equipment

Xe(t): Value of exports for electric machinery and equipment

Te(t): Value taxes on imports for electric machinery and equipment

De(t): Value taxes on exports for electric machinery and equipment

$$CFE = \sum_t CFE(t)/N$$

N: Number of observed years

SCF = 0.761

Table 1-5 Trade Statistics (Electric Machinery and Equipment)

(Million Rupees)

Year	Value of imports Me(t)	Value of exports Xe(t)	Value taxes on imports Te(t)	Value taxes on exports De(t)
1976-77	1,302.4	12.2	376.5	-
1977-78	1,594.0	12.7	542.7	-
1978-79	1,698.5	44.7	543.7	-
1979-80	1,804.3	17.3	562.6	-
1980-81	1,915.3	37.0	626.2	-

Source: Central Board of Revenue, Statistical Bulletin.

(5) **Marginal Productivity of Unskilled Labour**

Economic wage rate of unskilled labour is measured based on its marginal productivity. Here are introduced two practical approaches to obtain the marginal productivity of unskilled labour.

1) The first approach, which is considered to be a more desirable one if calibrated under the availability of reliable data, places weights of casual labour's unemployment on its wage rates. Based on this approach, marginal productivity of unskilled labour "m" is expressed as:

$$m = \frac{\sum_{i}^{n} (Di/Si)\,Wi}{n}$$

where Wi: financial wage rate of casual labour during the period i
Si: supply of casual labour during i
Di: demand of casual labour during i
n: number of periods observed.

Since it is observed that the seasonal fluctuation of financial wage rate in Pakistan is not substantial for the purpose of such a study, this formula can be amended:

$$m = \frac{\sum_{i}^{n} (Di/Si)\,Wa}{n}$$

where Wa: average financial wage rate of casual unskilled labour of a year.

Table 1-6 provides the date for supply and demand of casual unskilled labour over four periods of a year. As a consequence,

m = 0.11 Wa.

Table 1-6 Supply and Demand of Casual Unskilled Labour

Period i	Supply Si.	Demand Di.
Jul.-Sep./1980	39,876	4,837
Oct.-Dec./1980	41,455	4,452
Jan.-Mar./1981	43,656	4,401
Apr.-Jan./1981	43,576	5,074

Source: Statistics Division, Monthly Statistical Bulletin.
Note: The original data is provided by the Provincial Directorates of Manpower/Labour Welfare.

2) The second approach, as an alternative for the first, assumes that GDP per capita in the agriculture sector can be substituted for the marginal productivity of unskilled labour. Since GDP per capita in the 1980/81 agriculture sector is Rs.5680, the marginal productivity can be estimated about Rs.18.3 per day. Given the financial wage rate of casual unskilled labour (Wa) of Rs.28.8/day (Jun. 1981, the average of Karachi and Lahore), the estimated marginal productivity is 0.653 of Wa.

Taking into consideration the outcomes of these two approaches, the discussion involving some manpower specialists of the Pakistan Government has led to the result: m = 0.5 Wa. The major considerations to reach this conclusion are:

1) The first approach seems to underestimate it, mostly because casual labours which are not reflected in the above table find it several times easier to be employed.
2) The second approach seems to overestimate it, partly because the higher income labours of agriculture tend to shift the result.
3) The empirical discussion has tried to quantify the above points and, as a result, the conclusion also happens to meet the rule of thumb.

In actual, the marginal productivity of unskilled labour will be multiplied by the conversion factor of consumption α to be converted to the border price.

2. Preliminary Evaluation of Road Projects

2-1 Road Project Optimum Timing Test

As a part of preliminary project evaluation, a system complex, named ROPOTT, has been developed to provide the basis for selecting the optimum timing of road projects. Actuated by the input of a case setting or a series of case settings, ROPOTT executes the examination of project timings in economic terms based upon the marginal benefit-cost ratio. This criterion defines the optimum timing of a project as the point in time when its net present value or its internal rate of return is at a maximum. The objective of ROPOTT is to offer some significant systematic criteria for the screening process of the projects with the potential benefits likely to offset their costs. In case of the projects whose net benefits are monotonously increasing over time, the marginal benefit cost ratio can be applied to provide the optimum implementation timings. This method is known as the first year rate of return test. The road projects in Pakistan are well-adapted for the application of this method, since they basically satisfy the condition of monotonously increasing net benefits. The first year rate of return test calculates the marginal benefit-cost ratio (r_1) and compares it with the appropriate discount rate (f). The result can be interpreted as:

(1) if $r_1 < \hat{f}$ premature to implement yet,

(2) if $r_1 > \hat{f}$ deferred too much, and

(3) if $r_1 = \hat{f}$ optimum timing to implement.

The mechanism of the model can be demonstrated as follows. Suppose the traffic (Xt) is increasing over time (t), and the benefits relate to unit cost savings (b), so that total benefits (Bt) are given by

$$Bt = bXt.$$

On the other hand, the annual unit maintenance costs (a) gives total operating costs (Ct):

$$Ct = aXt.$$

Subtracting the capital cost of the road (Ko), the net present value (Z(i)) is given by

$$Z(i) = \sum_{t=1}^{N=i} \frac{(b-a)Xt}{(1+\hat{f})^t} - \frac{Ko}{(1+\hat{f})^{i-1}}$$

where N = project life, $\hat{f}$ = discount rate and i = year of installation.

The optimum timing of a project is the point in time when its net present value is at a maximum. If this timing is defined as year i, the conditions of optimality for the NPV criterion can be represented by:

$$Z(i-1) < Z(i) \geqq Z(i+1)$$

$$\text{or} \quad \begin{cases} Z(i) - Z(i-1) > 0 \\ Z(i) - Z(i+1) \geqq 0 \end{cases}$$

Now,

$$Z(i)-Z(i-1) = \left\{ \sum_{t=i}^{N-1} \frac{(b-a)Xt}{(1+\hat{f})^t} - \frac{Ko}{(1+\hat{f})^{i-1}} \right\} - \left\{ \sum_{t=i-1}^{N+i-1} \frac{(b-a)Xt}{(1+\hat{f})^t} - \frac{Ko}{(1+\hat{f})^{i-2}} \right\}$$

$$= \frac{-(b-a)Xi\text{-}1 + \hat{f}Ko}{(1+\hat{f})^{i-1}}$$

and on the other hand,

$$Z(i)-Z(i+1) = \left\{ \sum_{t=i}^{N-1} \frac{(b-a)Xt}{(1+\hat{f})^t} - \frac{Ko}{(1+\hat{f})^{i-3}} \right\} \left\{ \sum_{t=i+1}^{N+i+1} \frac{(b-a)Xt}{(1+\hat{f})^t} - \frac{Ko}{(1+\hat{f})^{i}} \right\}$$

$$= \frac{(b-a)Xi - \hat{f}\,Ko}{(1+\hat{f})^i}$$

Therefore, the conditions of optimality can be rewritten as:

$$-(b-a)Xi\text{-}1 + \hat{f}Ko > 0$$

$$(b-a)Xi - \hat{f}Ko \geqq 0,$$

that is

$$\frac{(b-a)Xi\text{-}1}{Ko} < \hat{f} \leqq \frac{(b-a)Xi}{Ko}$$

Since (b-a)Xi-1 = Bi-1-Ci-1 and (b-a)Xi = Bi-Ci, it can be interpreted that the year whose first year return r_1 (net benefit Bi-Ci over capital cost Ko) equals or just exceeds the discount rate $\hat{f}$ is the optimum timing of the project. And it can be also observed from the above equation that this can be applied only when Xi-1 < Xi or verbally the traffic Xt is monotonously increasing.

In applying the optimum timing test of road projects the basic model explained above will be expanded as well as revised in use of such supplemental criteria as B/C ratio and net present value (NPV), as introduced in the subsequent subsection.

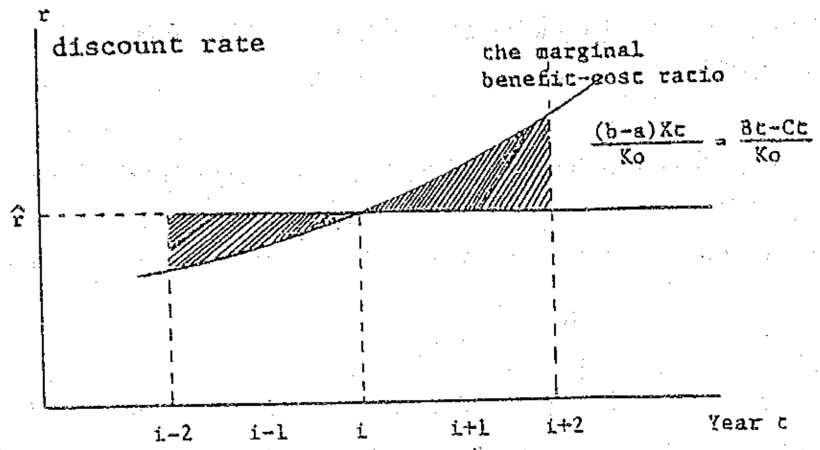


Fig. 2-1 Optimum Project Timing

2-2 Application and Major Outcomes

(1) Application

The flow of preliminary evaluation for the road projects is shown in Figure 2-2. The road network in this study consists of 208 links, which mean 832 projects (=208 x 4) to be evaluated for two cases (Case A, Case B) and for two target years (1987/88, 1999/2000). These projects were evaluated in terms of IRR, B/C, NPV and were also tested in terms of the optimum implementation timing.

The following data and assumption were adopted for the evaluation.

1) Benefit stream is estimated for the difference of vehicle operating cost (VOC) and time difference between with and without senerio, assuming 20 years project life.

2) VOC tables prepared by MOC in 1981 are adopted, which gives financial cost by cost items and by vehicle type for improved and unimproved roads as a function of velocity. It is, therefore, necessary to convert to economic cost and to assume modification factors as to the terrein and the type of surface.

3) Economic benefits of time saving by types of vehicle are 5.89, 56.26 and 10.70 Rs/hour for car, bus and truck respectively, where the time saving by truck includes both the crew fee and freight.

4) The annual phasing for road projects is carried out on the basis of the size of the projects, as follows.

5) First year return is calculated for the testing of the optimum implementation timing.

6) The discount rate is assumed to be 12%, for the calculation of B/C, NPV and optimum timing.

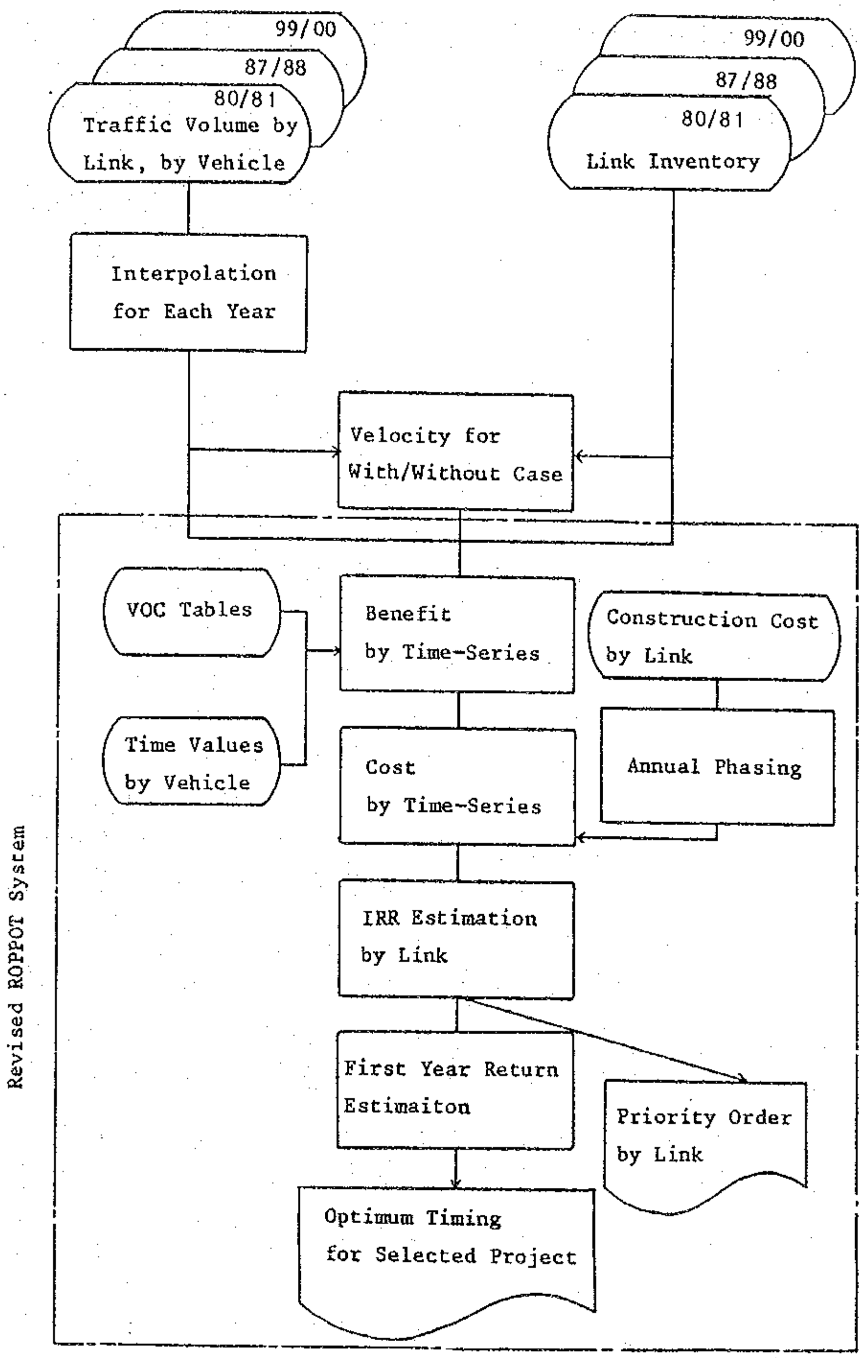


Fig. 2-2 Preliminary Evaluation for the Road Projects

(2) Major Outcomes

Table 2-1 shows the sample output of the evaluation system, where IRR, discounted benefits, discounted cost, B/C, NPV, priority order with B/C, cost stream, first year return for the optimum implementation and optimum timing are displayed for each project.

These informations are utilized for the priority rating and the annual phasing for 5th Plan projects, after testing the sensitivity for several discount rates.

Table 2-1 Sample Output of Road Project Evaluation

*** OPTIMUM TIMING BY ROAD LINK *** (IMPROVEMENT FOR MASTER PLAN B --ECONOMIC --)

DATE 82-11-22 TIME 13:28:36 PAGE = 25
DISCOUNT RATIO 12.0%

			1987/88 PLAN						CONSTRUCTION COST				1ST	OPTIMUM
SEQ	LINK-NO	LENGTH	IRR	BENEFIT	COST	B/C	B-C	PRIORITY	1ST	2ND	3RD	4TH	Y.R.	TIMING
1	52001	160	46.9	3763.53	479.99	7.84	3283.54	15	195.42	341.98	341.98	97.71	0.54	83/84
2	52002	15	70.0	643.75	51.76	12.44	591.99	3	30.10	50.17	20.07		0.93	83/84
3	52003	55	42.8	1197.89	186.45	6.42	1011.44	21	75.91	132.84	132.84	37.95	0.49	83/84
4	52004	38	33.6	491.49	122.82	4.00	368.68	65	71.43	119.05	47.62		0.27	83/84
5	52005	68	41.7	1576.34	261.74	6.02	1314.60	30	106.56	186.48	186.48	53.28	0.48	83/84
6	52006	132	54.1	3619.52	335.15	10.80	3284.38	7	136.45	238.79	238.79	68.22	0.70	83/84
7	52007	22	49.6	819.34	105.11	7.80	714.23	16	61.13	101.88	40.75		0.50	83/84
8	52008	109	31.2	1467.30	344.29	4.26	1123.01	55	140.17	245.30	245.30	70.08	0.18	83/84
9	52009	13	0.0	0.0	19.33	0.0	-19.33	173	11.24	18.73	7.49		****	*****
10	51001	48	40.2	282.53	90.54	3.12	192.00	85	52.66	87.76	35.10		0.47	83/84
11	51002	100	33.2	469.76	184.42	2.55	285.34	99	75.08	131.39	131.39	37.54	0.48	83/84
12	51003	12	41.4	122.59	22.72	5.40	99.87	38	13.21	22.02	8.81		0.26	83/84
13	51004	70	37.8	478.01	129.24	3.70	348.77	73	52.62	92.08	92.08	26.31	0.43	83/84
14	51005	18	10.4	114.20	125.66	0.91	-11.46	144	73.08	121.80	48.72		0.13	84/85
15	51006	75	60.2	1026.45	120.98	8.48	905.48	10	70.36	117.26	46.91		0.65	83/84
16	51007	44	49.9	1360.93	160.41	8.48	1200.52	11	65.31	114.29	114.29	32.65	0.64	83/84
17	51008	13	81.2	221.34	19.81	11.17	201.53	5	11.52	19.20	7.68		1.24	83/84
18	51009	79	56.4	1136.29	149.67	7.59	986.63	17	60.93	106.63	106.63	30.47	0.88	83/84
19	51010	40	41.4	574.71	131.64	4.37	443.07	52	53.59	93.79	93.79	26.80	0.58	83/84
20	51011	37	54.5	996.79	125.96	7.91	870.83	13	73.26	122.09	48.84		0.63	83/84
21	51012	130	43.9	1311.11	201.79	6.50	1109.32	20	82.16	143.77	143.77	41.08	0.45	83/84
22	51013	67	33.9	2437.50	570.73	4.27	1866.78	54	232.36	406.63	406.63	116.18	0.33	83/84
23	51014	32	32.5	578.70	138.59	4.18	440.10	62	56.43	98.75	98.75	28.21	0.29	83/84
24	51015	15	18.8	314.99	178.36	1.77	136.63	121	72.62	127.08	127.08	36.31	0.13	83/84
25	51016	52	17.3	723.06	453.14	1.60	269.92	125	184.49	322.85	322.85	92.24	0.13	84/85
26	51017	38	27.6	829.01	272.50	3.04	556.52	86	110.94	194.15	194.15	55.47	0.24	83/84

3. Listing and Preliminary Evaluation of Railway Projects

3-1 Approaches of Preliminary Evaluation

Types of the railway projects widely range from electrification, track and station development, signalling improvement to rolling stock provision. Correspondingly, the approaches of preliminary evaluation vary from differential cost-benefit analysis, marginal cost-benefit analysis, cost comparison analysis to descriptive analysis.

It seems more appropriate that the applied methodologies are introduced together with the concerned major outcomes in the subsequent subsection.

3-2 Methodologies and Major Outcomes of Preliminary Evaluation

(1) Electrification

The major benefits of electrification as compared with dieselization, in theory, include better energy efficiency, less maintenance cost of locomotives and increased line capacity, particularly better performance in gradient sections. More specifically, the energy cost of EL is 62% of DEL in a financial term and 53% of DEL in an economic term. Also, the maintenance cost of EL is 0.6% of the cost of a new EL per 10,000 km, while that of DEL is 1.9% in the analogous term.

While a number of railway line sections in Pakistan are coming up under discussion, first of all, a generalized model can be introduced to test the optimum timing of electrification projects over any double track sections of flat terrain. Taking into account such costs as the development and maintenance costs of electrification ground equipments, the acquisition and maintenance costs of EL and DEL, and the energy cost of electricity and diesel, the model indicates the number of trains at an optimum electrification timing under the different conditions. As for the mechanism of marginal cost-benefit ratio which is known as the first year return, the explanation provided in Subsection 2-1 can be referred to.

Table 3-1 and Figure 3-1 present results of the model in tabulated and graphical forms, respectively. On the other hand, the number of trains and the share of goods trains for the concerned section in 1999/2000 are projected as:

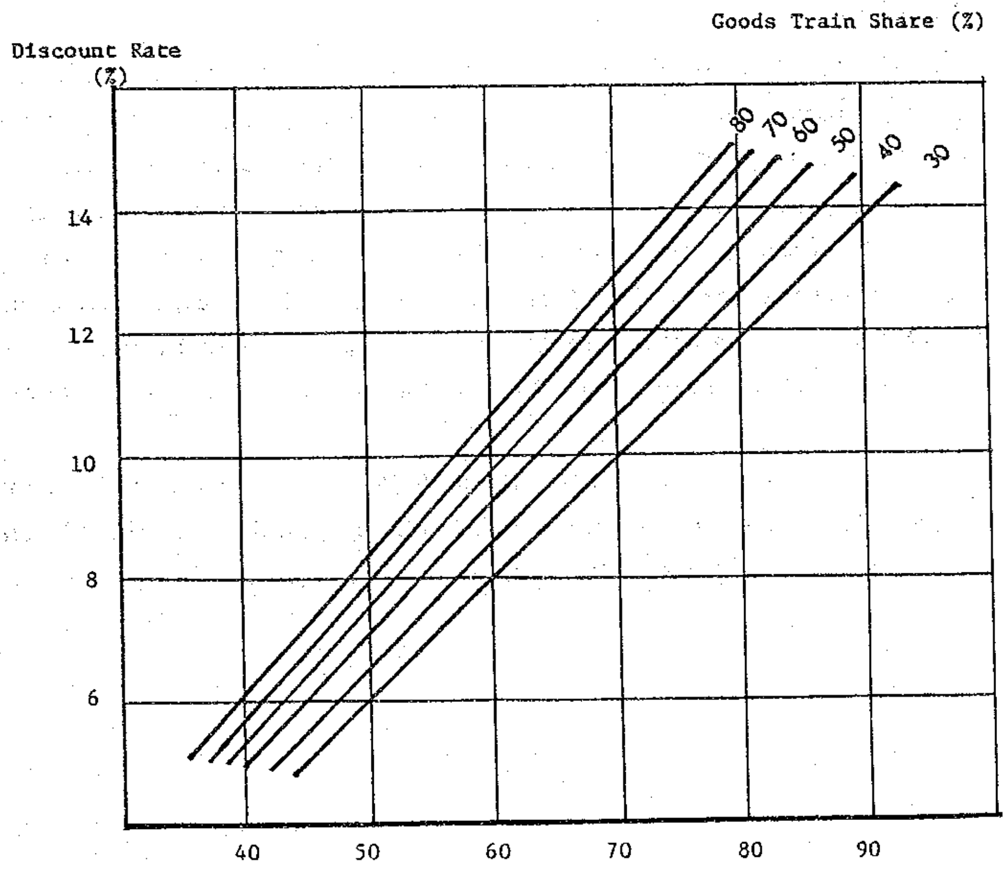
Table 3-1 Optimum Electrification Timing of Flat Double Track Section

(Number of Trains)

Discount Rate (%)	Share of Goods Trains (%)					
	80	70	60	50	40	30
14	75	78	80	83	88	92
12	67	69	72	75	79	83
10	58	60	63	65	70	73
8	49	51	53	55	59	62

Note: Number of trains for both ways.

Source: Study Team



Source: Study Team

Fig. 3-1 Optimum Electrification Timing of Flat Double Track Section

	(Number of trains)	(Goods train share)
Kiamari - Rohri	122-132	51-55 %
Rohri - Samasata	158	63 %
Samasata - Khanewal via Chord	101	80 %
Samasata - Khanewal via Loop	58-68	34-41 %
Lahore - Lala Musa	82-90	61-58 %

Since the discount rate (the opportunity value of capital) for railway projects can be estimated to be somewhere around 12%, it can be understood from Table 3-1 that all above sections with one exception are justified for electrification by 1999/2000. It is most desirable if these electrification projects are implemented at the number of trains indicated in Table 3-1. If not, they are recommended to be implemented as early as possible after the number of trains exceeds the ones indicated in Table 3-1.

From a point of view of train operation beside the traffic volume factor pointed out above, the chord line of Samasata - Khanewal is recommended to be electrified at a relatively early point of time. Although the loop line of Samasata - Khanewal does not reach the train number required for electrification even by 1999/2000, the electrification of this section is also preferred from an operational point of view by considering it as a set project with the chord line electrification. Incidentally, the Sher Shah - Mahmud Kot section is proposed to be electrified also from an operational point of view to ensure the smooth operation of tank wagons carrying liquid products from Mahmud Kot.

Since the project environments of electrification in the Sibi - Kolpur and Lala Musa - Rawalpindi sections do not fit the conditions of optimum electrification timing test model, that is, double track of flat terrain, these two important projects are analyzed independently from the generalized model. They take differential cost-benefit analysis between the two mutually exclusive cases of electrification and diesel operation. These two sections have relatively small traffic volume and do not seem to fully enjoy the usual benefits of electrification against its development cost of ground facilities. Due to the desirable performance of EL on the gradient sections, however, electrification in these sections is expected to save the provision of some supplemental locomotives which are required otherwise if diesel operation is continued.

The differential cost-benefit analysis applied to the electrification project of the Sibi-Kolpur section during the 6th Plan period is conducted with the IRR of 10.9%. While such other benefits as regional development effect of Baluchistan regions can be also seen, it can not be quite convinced that the project is feasible, yet. However, if regenerative brakes are introduced to take advantage of the steep slopes, a considerable amount of electricity can be saved. Table 3-2 is the economic cost-benefit stream of electrification project of the section with regenerative brake systems. The resulting IRR is 12.5% and proves the economic feasibility of project. The electrification project of Sibi - Kolpur section therefore

Table 3-2 Economic Cost and Benefit Stream of Sibi-Kolpur Electrification Project (with Regenerative Brake Systems)

(Million Rupees)

Year	Electrification				Diesel		
	Ground Equipment	EL	Elect-ricity	Total	DEL	Diesel	Total
1	89.79	-	-	89.79	-	-	-
2	209.98	183.78	-	393.76	298.98	-	298.98
3	1.20	21.84	3.98	27.02	23.88	11.35	35.23
4	1.20	21.99	4.57	27.77	40.89	12.54	53.43
5	1.20	22.15	4.98	28.33	41.70	13.77	55.47
6	1.20	22.31	5.08	28.59	25.89	14.13	40.02
7	1.20	22.46	5.50	29.16	59.52	15.40	74.92
8	1.20	22.62	5.91	29.74	44.12	16.71	60.83
9	1.20	22.78	6.34	30.32	28.32	18.05	46.37
10	1.20	22.94	6.47	30.60	45.33	18.53	63.86
11	1.20	23.09	6.91	31.20	46.14	19.94	66.08
12	1.20	23.25	7.35	31.80	30.33	21.39	51.72
13	1.20	23.41	8.10	32.71	63.96	23.78	87.74
14	1.20	23.56	8.58	33.34	48.56	26.25	74.81
15	1.20	23.72	9.00	33.93	32.75	27.81	60.57
16	1.20	3.46	9.00	13.66	16.55	27.81	44.36
17	1.20	3.46	9.00	13.66	16.55	27.81	44.36
18	1.20	3.46	9.00	13.66	16.55	27.81	44.36
19	1.20	3.46	9.00	13.66	16.55	27.81	44.36
20	1.20	3.46	9.00	13.66	16.55	27.81	44.36
21	1.20	3.46	9.00	13.66	16.55	27.81	44.36
22	1.20	3.46	9.00	13.66	16.55	27.81	44.36
23	Δ119.91	Δ179.49	-	Δ299.40	Δ275.23	-	Δ275.23

Source: Study Team

is recommended to be implemented during the 6th Plan period with the system design of regenerative brakes.

The electrification of Lala Musa - Rawalpindi section is proposed to be implemented during the 8th Plan period. This project is also expected to experience the benefit of saving the energy and supplemental locomotives. The differential cost-benefit analysis with the resulting IRR of 16.0% insists that the electrification during the 8th Plan period in this section is preferable to the continuation of diesel operation.

(2) **Improvement of Terminals and Stations**

In order to cater for the new programs of innovative train operation, a few projects of terminal and station improvement are proposed. One of the innovative programs is the introduction of 3,000-ton traction. Since 104 wagons will be hauled for one train in this program, the improvement of terminals at Karachi City and Lahore and the sidetrack extension and improvement at a number of way stations are required. While the initial cost of such improvement is Rs. 56 million, the procurement cost of a smaller number (30) of 3,000-HP ELs is less than that of 44 2,000-HP ELs which are otherwise needed by approximately Rs. 178 million. Based upon this cost comparison analysis, and in further consideration of such effect of train number reduction, 3,000-ton traction program is recommended.

The container transport is another innovative program introduced to railway, requiring the development of Lahore Dry Port. This is a part of the adopted intermodal containerization program which holds the IRR of 14.3% as will be introduced in subsection 4-1, and is in turn a prerequisite to the containerization program. Similarly, the goods terminal improvement project is involved in the railway transport enhancement program through the development of base stations. This project aims at increasing the goods handling capacity of such base stations by improving their arrival/departure and loading/unloading tracks. This project is prerequisite to the railway transport enhancement program which, designed as Case B, is selected in the evaluation of master plan alternatives.

(3) **Improvement of Signalling**

The objectives of signalling improvement projects are firstly to ensure the security of train operation through the introduction of more reliable systems, and then to increase the average train speeds by quicker interlocking systems and clearer signals. The standards applied as criteria to make signalling improvement plans can be summarized as follows using Table 3-3.

The highest priority is given on the signalling improvement of main line single track sections. In order to maintain the security and increase the line capacity of such sections for rapidly increasing traffic, the 3-b systems have to be improved to 4-c. Some main line single track sections with large volume of traffic are to be provided with 4-c systems even

Table 3-3 Combination of Major Train Control Systems

Interlocking Systems	Block Working Systems		
	Token Block	Tokenless Block	Automatic Block Signalling
Standard-I	1-a	1-b	1-c
Standard-II	2-a	2-b	2-c
Standard-III	3-a	3-b	3-c
Relay Interlocking	4-a	4-b	4-c

during the 6th Plan period. The next priority is given to the improvement projects from 3-b to 4-c over the main line double track sections. This is followed by the improvement of some busiest branch line from 3-a,b to 4-c, and then that of other major branch lines from 2-a,b to 3-b.

(4) Others

The other projects which, as a matter of fact, have pretty much share of the proposed budget include track works and rolling stock provisions. The programs for track renewal and rolling stock provision are made to support the safe and smooth implementation of projects introduced above in consideration of the present inventories. Finally, the requirement for track doubling is dependent on the single track line capacity n, which is the function of station-to-station running time ($\frac{1}{2}(\frac{1}{v_1}+\frac{1}{v_2})$), block handling time t, and the traffic intensity f:

$$n = \frac{1{,}440\ f}{\frac{1}{2}\left(\frac{1}{v_1}+\frac{1}{v_2}\right)+t.}$$

While the exact future line capacity of single track cannot be determined due to some uncertainty about the progress of operation condition improvement, the entire main line between Karachi and Rawalpindi is proposed to be doubled based upon the present performance and future operation policy.

3-3 LISTING AND PRELIMINARY EVALUATION OF EACH PROJECT

Signalling Improvement, Karachi City – Samasata
Signalling Improvement, Samasata – Khanewal
Signalling Improvement, Khanewal – Lahore
Signalling Improvement, Lahore – Rawalpindi
Signalling Improvement, Rawalpindi – Peshawar Cant
Signalling Improvement, Rohri – Sibi
Signalling Improvement, Sibi – Quetta
Signalling Improvement, Khanewal – Faisalabad
Signalling Improvement, Faisalabad – Wazirabad
Signalling Improvement, Shorkot Cant – Sargodha
Signalling Improvement, Sher Shah – Kundian
Electrification, Kiamari – Rohri
Electrification, Rohri – Samasata
Electrification, Samasata – Khanewal
Electrification, Lahore – Lala Musa
Electrification, Lala Musa – Rawalpindi
Electrification, Sibi – Kolpur
Electrification, Sher Shah – Mahmud Kot
Track Doubling, Lodhran – Khanewal and Piran Ghaib – Khanewal
Track Doubling, Khanewal – Raiwind
Track Doubling, Shahdara Bagh – Lala Musa
Track Doubling, Lala Musa – Rawalpindi
Track Doubling, Lodhran – Sher Shah
Track Renewal, Karachi City – Lala Musa
Track Renewal, Lala Musa – Peshawar Cant
Track Renewal, Rohri – Quetta
Track Renewal, Khanewal – Faisalabad
Track Renewal, Shorkot – Sargodha
Track Renewal, Sher Shah – Kundian
Track Renewal, Branch Lines
Container Transportation
Goods Terminal Improvement
Introduction of 3,000^{t} Traction
Expansion of EL Fleet, Khanewal – Lahore
Rehabilitation of ELs
Expansion of DEL Fleet
Re-engining of DELs

Acquisition of Passenger Coaches
Replacement of Passenger Coaches
Introduction of High Speed Goods Train
Acquisition of Additional Wagons
Replacement of Wagons

1. **Project Name: Signalling Improvement, Karachi City – Samasata**

2. **Project Description**

2-1 **Objective**

KYC-SMA section is to be equipped with automatic block and relay interlocking.

2-2 **Description**

Automatic block has already been installed in KYC-HDR section and relay interlocking in KYC-KOT and PNL-KBB sections. Therefore, the project components are:

Automatic block	HDR-SMA	631 km
Relay interlocking	KOT-PNL	36 stations
	other	19 stations

0.52 x 631 = 328 (FEC 151) mil. Rs

7.3 x 55 = 402 (FEC 241) mil. Rs

(48.1 ÷ 101 x 1.1 = 0.52, Improved Signalling Works Oct. 1981)

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**7th Plan period**
3-2 **Time required for project completion**	**60 months**

4. **Cost of Project (Rupees in million)** **730 (FEC 392)**

5. **Preliminary Evaluation**

The objectives of signalling improvement projects are firstly to ensure the security of train operation through the introduction of more reliable systems, and to increase the average train speeds by quicker interlocking systems and clearer signals. The increase of average train speeds will also result in the expansion of line capacity.

This project sections fall in the second criterion described in "Basic Criteria for Signalling Improvement". The existing systems in the project sections need to be upgraded to the systems of relay interlocking and automatic block at an earliest time after the 6th Plan period.

*** Basic Criteria for Signalling Improvement ***

The combination of major train control system in Pakistan can be categorized as shown in Table W-1, along the two dimensions, namely block working systems and interlocking systems.

Table W-1 Combination of Major Train Control Systems

Interlocking Systems	Block Working Systems		
	Token Block	Tokenless Block	Automatic Block Signalling
Standard-I	1-a	1-b	1-c
Standard-II	2-a	2-b	2-c
Standard-III	3-a	3-b	3-c
Relay Interlocking	4-a	4-b	4-c

In use of this table, the standards applied as criteria to make signalling improvement plans can be summarized as follows.

(1) The highest priority is given on the signalling improvement of main line single track sections with busy traffic. These sections have a large and rapidly-increasing number of trains with relatively high speeds, and sometimes could be a bottleneck of main line in terms of line capacity. The existing 3-b systems in such sections have to be improved to 4-c at an earliest time possible.

(2) The next priority is given to the main line double track sections which also have a large and rapidly-increasing number of trains with relatively high speeds. The existing 3-b systems in some parts of such sections need to be improved to 4-c systems at an earliest time after the 6th Plan period.

(3) Thirdly, the signalling systems in remaining main line sections with gradually increasing traffic need to be upgraded. These sections are at present equipped mainly with 1-a, 1-b, 3-a or 3-b, and are proposed to be improved to 4-b before the year 1999/2000.

(4) The above projects are followed by the improvement of some busy branch lines from 1-a, 3-a,b to 4-c.

(5) On the other hand, the other major branch lines presently with 1-a, 2-a,b are proposed to be upgraded to 3-b. In any case, the systems 1-a or 2-a should be tried to be eliminated from all the positively-retained railway lines by the year 1999/2000.

1. **Project Name: Signalling Improvement, Samasata – Khanewal**

2. **Project Description**

2-1 **Objective**

Automatic block and relay interlocking are to be installed in SMA-KWL section (both chord and loop lines).

2-2 **Description**

The following works are to be implemented concurrently with electrification:

Automatic block	chord line	121 km
	loop line	136 km
Relay interlocking	chord line	17 stations
	loop line	17 stations

0.52 x 257 = 133.6 (FEC 61.4) mil. Rs

7.3 x 34 = 248.2 (FEC 148.9) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**1984/85**
3-2 **Time required for project completion**	**36 months**

4. **Cost of Project (Rupees in million)** **381 (FEC 210)**

5. **Preliminary Evaluation**

The objectives of signalling improvement projects are firstly to ensure the security of train operation through the introduction of more reliable systems, and to increase the average train speeds by quicker interlocking systems and clearer signals. The increase of average train speeds will also result in the expansion of line capacity.

This project sections fall in the first criterion described in "Basic Criteria for Signalling Improvement." The existing systems in the project sections need to be upgraded to the systems of relay interlocking and automatic block at an earliest time during the 6th Plan period.

1. **Project Name: Signalling Improvement, Khanewal – Lahore**

2. **Project Description**

2-1 Objective

Automatic block and relay interlocking are to be installed in KWL-LHR section.

2-2 Description

The section which is at present equipped with tokenless block and S-III interlocking is improved to:

Automatic block	285 km
Relay interlocking	42 stations

0.52 x 285 = 148 (FEC 68) mil. Rs

7.3 x 42 = 307 (FEC 184) mil. Rs

3. **Time of Implementation**

3-1 Prospective timing of project start	1983/84
3-2 Time required for project completion	36 months

4. **Cost of Project (Rupees in million)** 455 (FEC 252)

5. **Preliminary Evaluation**

The objectives of signalling improvement projects are firstly to ensure the security of train operation through the introduction of more reliable systems, and to increase the average train speeds by quicker interlocking systems and clearer signals. The increase of average train speeds will also result in the expansion of line capacity.

This project sections fall in the first criterion described in "Basic Criteria for Signalling Improvement". The existing systems in the project sections need to be upgraded to the systems of relay interlocking and automatic block at an earliest time during the 6th Plan period.

1. **Project Name: Signalling Improvement, Lahore – Rawalpindi**

2. **Project Description**

2-1 **Objective**

Automatic block and relay interlocking are to be installed in LHR-RWP section.

2-2 **Description**

The section which is at present equipped mainly with tokenless block and S-I or S-III interlocking is improved to:

Automatic block	SDR-RWP	282 km
Relay interlocking		50 stations

Then, Automatic block is installed between LHR and SDR

0.52 x 282 = 146 (FEC 67) mil. Rs

7.3 x 50 = 365 (FEC 219) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**8th Plan period**
3-2 **Time required for project completion**	**48 months**

4. **Cost of Project (Rupees in million)** **511 (FEC 286)**

5. **Preliminary Evaluation**

The objectives of signalling improvement projects are firstly to ensure the security of train operation through the introduction of more reliable systems, and to increase the average train speeds by quicker interlocking systems and clearer signals. The increase of average train speeds will also result in the expansion of line capacity.

This project section falls in the third criterion described in "Basic Criteria for Signalling Improvement". The existing systems in the project section need to be upgraded to the systems of relay interlocking and automatic block before the year 2000.

1. **Project Name: Signalling Improvement, Rawalpindi – Peshawar Cant.**

2. **Project Description**

2-1 Objective

Automatic block and relay interlocking are to be installed in RWP-PSC section.

2-2 Description

The section which is now equipped mainly with token block and S-I or S-III interlocking are improved to:

Automatic block	174 km
Relay interlocking	28 stations

0.52 x 174 = 90 (FEC 41) mil. Rs

7.3 x 28 = 204 (FEC 123) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**8th Plan period**
3-2 **Time required for project completion**	**36 months**

4. **Cost of Project (Rupees in million)** **294 (FEC 164)**

5. **Preliminary Evaluation**

The objectives of signalling improvement projects are firstly to ensure the security of train operation through the introduction of more reliable systems, and to increase the average train speeds by quicker interlocking systems and clearer signals. The increase of average train speeds will also result in the expansion of line capacity.

This project section falls in the third criterion described in "Basic Criteria for Signalling Improvement". The existing systems in the project section need to be upgraded to the systems of relay interlocking and automatic block before the year 2000.

1. **Project Name: Signaling Improvement, Rohri – Sibi**

2. **Project Description**

2-1 **Objective**

Automatic block and relay interlocking are to be installed in ROH-SIB section.

2-2 **Description**

The section which is at present partially equipped with token or tokenless block and S-I or S-III interlocking is improved to:

Automatic block 244 km

Relay interlocking 27 stations

0.52 x 244 = 127 (FEC 58) mil. Rs

7.3 x 27 = 197 (FEC 118) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**8th Plan period**
3-2 **Time required for project completion**	**36 months**

4. **Cost of Project (Rupees in million)** **324 (FEC 176)**

5. **Preliminary Evaluation**

The objectives of signalling improvement projects are firstly to ensure the security of train operation through the introduction of more reliable systems, and to increase the average train speeds by quicker interlocking systems and clearer signals. The increase of average train speeds will also result in the expansion of line capacity.

This project section falls in the third criterion described in "Basic Criteria for Signalling Improvement".

The existing systems in the project section need to be upgraded to the systems of relay interlocking and automatic block before the year 2000.

1. **Project Name: Signalling Improvement, Sibi – Quetta**

2. **Project Description**

2-1 Objective

Automatic block and relay interlocking are to be installed in SIB-QTA section.

2-2 Description

The section is at present equipped mainly with token block and S-I interlocking. The following project components should be implemented concurrently with electrification:

Automatic block 141 km

Relay interlocking 23 stations

0.53 x 141 = 73 (FEC 34) mil. Rs

7.3 x 23 = 168 (FEC 101) mil. Rs

3. **Time of Implementation**

3-1 Prospective timing of project start	**1986/87**
3-2 Time required for project completion	**36 months**

4. **Cost of Project (Rupees in million)** **241 (FEC 135)**

5. **Preliminary Evaluation**

The objectives of signalling improvement projects are firstly to ensure the security of train operation through the introduction of more reliable systems, and to increase the average train speeds by quicker interlocking systems and clerer signals. The increase of average train speeds will also result in the expansion of line capacity.

This project section basically falls in the third criterion described in "Basic Criteria for Signalling Improvement".

The existing systems in the project section need to be upgraded to the systems of relay interlocking and automatic block. In view of the steep gradient and the electrification project timing of section, the signalling improvement is preferred to be implemented during the 6th Plan period.

1. **Project Name: Signalling Improvement, Khanewal – Faisalabad**

2. **Project Description**

2-1 Objective

Automatic block and relay interlocking are to be installed in KWL-FSLD section.

2-2 Description

The section which is at present equipped with token block and S-I interlocking is provided with:

Automatic block 170 km

Relay interlocking 25 stations

0.52 x 170 = 88 (FEC 49) mil. Rs

7.3 x 25 = 183 (FEC 110) mil. Rs

3. **Time of Implementation**

3-1 Prospective timing of project start	**8th Plan period**
3-2 Time required for project completion	**36 months**

4. **Cost of Project (Rupees in million)** **271 (FEC 159)**

5. **Preliminary Evaluation**

The objectives of signalling improvement projects are firstly to ensure the security of train operation through the introduction of more reliable systems, and to increase the average train speeds by quicker interlocking systems and clearer signals. The increase of average train speeds will also result in the expansion of line capacity.

This project section, where 12 to 18 trains are estimated to run in 1999/2000, falls in the fourth criterion described in "Basic Criteria for Signalling Improvement". The existing systems in this project section need to be upgraded to the systems of relay interlocking and automatic block before the year 1999/2000.

1. **Project Name: Signalling Improvement, Faisalabad – Wazirabad**

2. **Project Description**

2-1 **Objective**

Tokenless block and S-III block with color light signals are to be installed in FSLD-WZD section.

2-2 **Description**

The section which is now equipped mainly with token block and S-I interlocking and partially with tokenless block and S-III interlocking is provided with:

Tokenless block 9 stations

Color light signals 16 stations

1.6 x 9 = 15 (FEC 6) mil. Rs

2.9 x 16 = 46 (FEC 25) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start** **8th Plan period**

3-2 **Time required for project completion** **24 months**

4. **Cost of Project (Rupees in million)** **61 (FEC 31)**

5. **Preliminary Evaluation**

The objectives of signalling improvement projects are firstly to ensure the security of train operation through the introduction of more reliable systems, and to increase the average train speeds by quicker interlocking systems and clearer signals. The increase of average train speeds will also result in the expansion of line capacity.

This project section falls in the fifth criterion described in "Basic Criteria for Signalling Improvement".

The existing systems in the project section need to be upgraded to the systems of Standard-III interlocking and tokenless block before the year 1999/2000.

1. **Project Name: Signalling Improvement, Shorkot Cant – Sargodha**

2. **Project Description**

2-1 **Objective**

Tokenless block and S-III interlocking with color light signals are to be installed in SKO-SRQ section.

2-2 **Description**

The present system of Paper block and S-I in the section is replaced with:

Tokenless	14 stations
Color light	14 stations

4.5 x 14 = 63 (FEC 32) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**8th Plan period**
3-2 **Time required for project completion**	**24 months**

4. **Cost of Project (Rupees in million)** **63 (FEC 32)**

5. **Preliminary Evaluation**

The objectives of signalling improvement projects are firstly to ensure the security of train operation through the introduction of more reliable systems, and to increase the average train speeds by quicker interlocking systems and clearer signals. The increase of average train speeds will also result in the expansion of line capacity.

This project section falls in the fifth criterion described in "Basic Criteria for Signalling Improvement".

The existing systems in the project section need to be upgraded to the systems of Standard-III interlocking and tokenless block before the year 1999/2000.

1. **Project Name: Signalling Improvement, Sher Shah – Kundian**

2. **Project Description**

2-1 **Objective**

SSH-MHK section is to be provided with automatic block and relay interlocking, and MHK-KDA with tokenless.

2-2 **Description**

The present system of token or paper block and no interlocking in the section is replaced with:

Automatic block	50 km
Relay interlocking	10 stations
Tokenless block	23 stations
Color light	23 stations

0.52 x 50 = 26 (FEC 12) mil. Rs

7.3 x 10 = 73 (FEC 44) mil. Rs

4.5 x 23 = 104 (FEC 52) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**8th Plan period**
3-2 **Time required for project completion**	**36 months**

4. **Cost of Project (Rupees in million)** **203 (FEC 108)**

5. **Preliminary Evaluation**

The objectives of signalling improvement projects are firstly to ensure the security of train operation through the introduction of more reliable systems, and to increase the average train speeds by quicker interlocking systems and clearer signals. The increase of average train speeds will also result in the expansion of line capacity.

This project sections basically fall in the fifth criterion described in "Basic Criteria for Signalling Improvement". The existing systems in the MHK-KDA section need to be upgraded to the systems of Standard-III interlocking and tokenless block before the year 1999/2000. On the other hand, a special attention is to be paid to the SSH-MHK section, since a large quantity of liquid products are estimated to be carried from MHK. Consequently from a train operational point of view, the SSH-MHK section is proposed to be equipped with the systems of relay interlocking and automatic block before the year 1999/2000.

1. **Project Name: Electrification, Kiamari – Rohri**

2. **Project Description**

2-1 Objective

KMR-ROH section is to be electrified in association with the provision of related locomotives and workshop.

2-2 Description

When the electrification between KMR and LHR is completed, 3,000^t traction will be enabled. The Project components include:

Electrification KMR-ROH	480 km x 2 x 2.16 =	2,074	(FEC 1,120) mil. Rs
Loco shed KYC, HDR (advance)		150	(FEC 53) mil. Rs
Loco workshop LHR		1,000	(FEC 350) mil. Rs
Locos (high power)	30 x 26.8 =	804	(FEC 571) mil. Rs
(ordinary)	93 x 22.3 =	2,074	(FEC 1,473) mil. Rs

3. **Time of Implementation**

3-1 Prospective timing of project start	**8th Plan period**
3-2 Time required for project completion	**7 years**

4. **Cost of Project (Rupees in million)** **6,102 (FEC 3,567)**

5. **Preliminary Evaluation**

The major benefits of electrification as compared with dieselization include better energy efficiency, less maintenance cost of locomotives and increased line capacity. More specifically, the energy cost of EL is 62% of DEL in a financial term and 53% of DEL in an economic term. Also, the maintenance cost of EL is 0.6% of the cost of a new EL per 10,000 km, while that of DEL is 1.9% in an analogous term.

The economic justificability of electrification project of Kiamari-Rohri section can be examined by applying the generalized model of testing the optimum implementation timing of electrification projects. The share of goods trains on the project section in the year 1999/2000 is estimated to be 51% (Karachi – Hyderabad) to 55% (Hyderabad – Rohri). Since the discount rate (the opportunity value of capital) for railway projects can be reasonably assumed to be 12%, the model indicates that the nnumber of trains at the optimum electrification timing is 73 (Hyderabad – Rohri) to 75 (Karachi – Hyderabad).

On the other hand, the number of trains on the project section in the year 1999/2000 is estimated to be 122 (Karachi - Hyderabad) to 132 (Hyderabad - Rohri). This estimated number of trains far exceeds the one at the optimum electrification timing. In consequence, the electrification between Kiamari and Rohri can be understood as justifiable before 1999/2000, and it is most desirable from an economic point of view if this electrification project is implemented at the indicated number of trains (72 to 75). If not, it is recommended to be implemented as early as possible after the number of trains exceeds the indicated one.

The Optimum Timing Test of Electrification Projects

While a number of railway line sections in Pakistan are coming up under discussion, a generalized model has been developed to test the optimum timing of electrification projects over any double track sections of flat terrain. Taking into account the major initial and maintenance costs of electrification and dieselization in economic terms, the model indicates the number of trains at an optimum electrification timing under the different conditions.

In case of the railway line electrification projects whose net benefits are monotonously increasing over time, the marginal benefit-cost ratio can be applied to provide the optimum implementation timings. This method is known as the first year rate of return test. The first year rate of return test calculates the marginal benefit-cost ratio (r_1) and compares it with the appropriate discount rate ($\hat{r}$). The result can be interpreted as:

(1) if $r_1 < \hat{r}$ premature to implement yet,

(2) if $r_1 > \hat{r}$ deferred too much, and

(3) if $r_1 = \hat{r}$ optimum timing to implement.

In applying this method to electrification projects, it is modified to the marginal differential cost ratio between the two mutually exclusive cases, namely electrification and the continuation of diesel operation. The mechanism of the model can be demonstrated as follows. Suppose the number of trains (Xt) is increasing over time (t), and the unit operating and maintenance cost of continuing diesel operations (b) gives the total operating costs of diesel operation (Bt) by:

$$Bt = bXt.$$

On the other hand, the annual unit operating and maintenance costs of the electrified case (a) gives total operating costs (Ct) of electrified system:

$$Ct = aXt.$$

Subtracting the capital cost of the electrification (Ko), the net present value (Z(i)) is given by:

$$Z(i) = \sum_{t=i}^{N-i} \frac{(b-a)Xt}{(1+\hat{r})^t} - \frac{Ko}{(1+\hat{r})^{i-1}}$$

where N = project life, $\hat{r}$ = discount rate and i = year of installation.

The optimum timing of a project is the point in time when its net present value is at a maximum. If this timing is defined as year i, the conditions of optimality for the NPV criterion can be represented by:

$$Z(i-1) < Z(i) \geqq Z(i+1)$$

or

$$\begin{cases} Z(i) - Z(i-1) > 0 \\ Z(i) - Z(i+1) \geqq 0 \end{cases}$$

Now,

$$Z(i)-Z(i-1) = \left\{ \sum_{t=i}^{N+1} \frac{(b-a)Xt}{(1+\hat{r})^t} - \frac{Ko}{(1+\hat{r})^{i-1}} \right\} - \left\{ \sum_{t=i-1}^{N+i-1} \frac{(b-a)Xt}{(1+\hat{r})^t} - \frac{Ko}{(1+\hat{r})^{i-2}} \right\}$$

$$= \frac{-(b-a)Xi\text{-}1 + \hat{r}Ko}{(1+\hat{r})^{i-1}}$$

and on the other hand,

$$Z(i)-Z(i+1) = \left\{ \sum_{t=i}^{N+1} \frac{(b-a)Xt}{(1+\hat{r})^t} - \frac{Ko}{(1+\hat{r})^{i-3}} \right\} - \left\{ \sum_{t=i+1}^{N+i+1} \frac{(b-a)Xt}{(1+\hat{r})^t} - \frac{Ko}{(1+\hat{r})^{i}} \right\}$$

$$= \frac{(b-a)Xi - \hat{r}Ko}{(1+\hat{r})^{i}}$$

Therefore, the conditions of optimality can be rewritten as:

$$\left\{ \begin{array}{l} -(b-a)Xi\text{-}1 + \hat{r}Ko > 0 \\ (b-a)Xi - \hat{r}Ko \geqq 0, \end{array} \right\}$$

that is

$$\frac{(b-a)Xi\text{-}1}{Ko} < \hat{r} \leqq \frac{(b-a)Xi}{Ko}$$

Since (b-a)Xi-1 = Bi-1-Ci-1 and (b-a)Xi = bi-Ci, it can be interpreted that the year whose first year return r_1 (net benefit Bi-Ci over capital cost Ko) equals or just exceeds the discount rate $\hat{r}$ is the optimum timing of the project.

And it can be also observed from the above equation that this can be applied only when Xi-1 < Xi or verbally the number of trains Xt is monotonously increasing.

Applying the assumptions described below, the optimum timing of electrification can be obtained by:

$$N = \frac{3.0542\,\hat{r} + 0.0122}{0.0026 + 0.0023\,g + 0.0107\,\hat{r}},$$

here $\hat{r}$ = discount rate and g = share of goods trains. Table W-2 and Figure W-2 present results of the model in tabulated and graphical forms, respectively.

Applied Assumptions

(1) Economic development cost of electrification ground equipments 3.0542 mil. Rs/km

(2) Economic maintenance cost of electrification ground equipment 0.0122 mil. Rs/km

(3) Economic acquisition cost of EL 0.0317 N mil. Rs/km

(4) Economic annual maintenance cost of EL 0.0004 N mil. Rs/km

(5) Economic acquisition cost of DEL 0.0848 N mil. Rs/km

(6) Economic annual maintenance cost of DEL 0.0014 N mil. Rs/km

(7) Economic annual consumption cost of electricity

N (0.0017 + 0.0025 g) mil. Rs/km
(g = share of goods trains)

(8) Economic annual consumption cost of diesel

N (0.0032 + 0.0048 g) mil. Rs/km

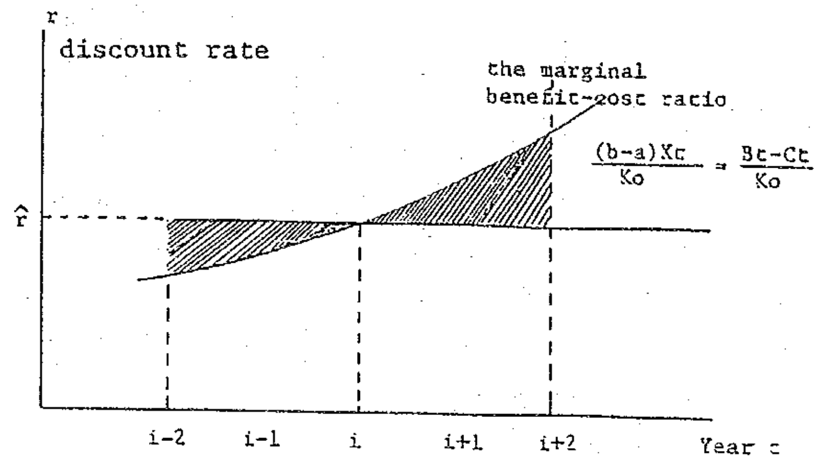


Fig. W-1 Optimum Project Timing

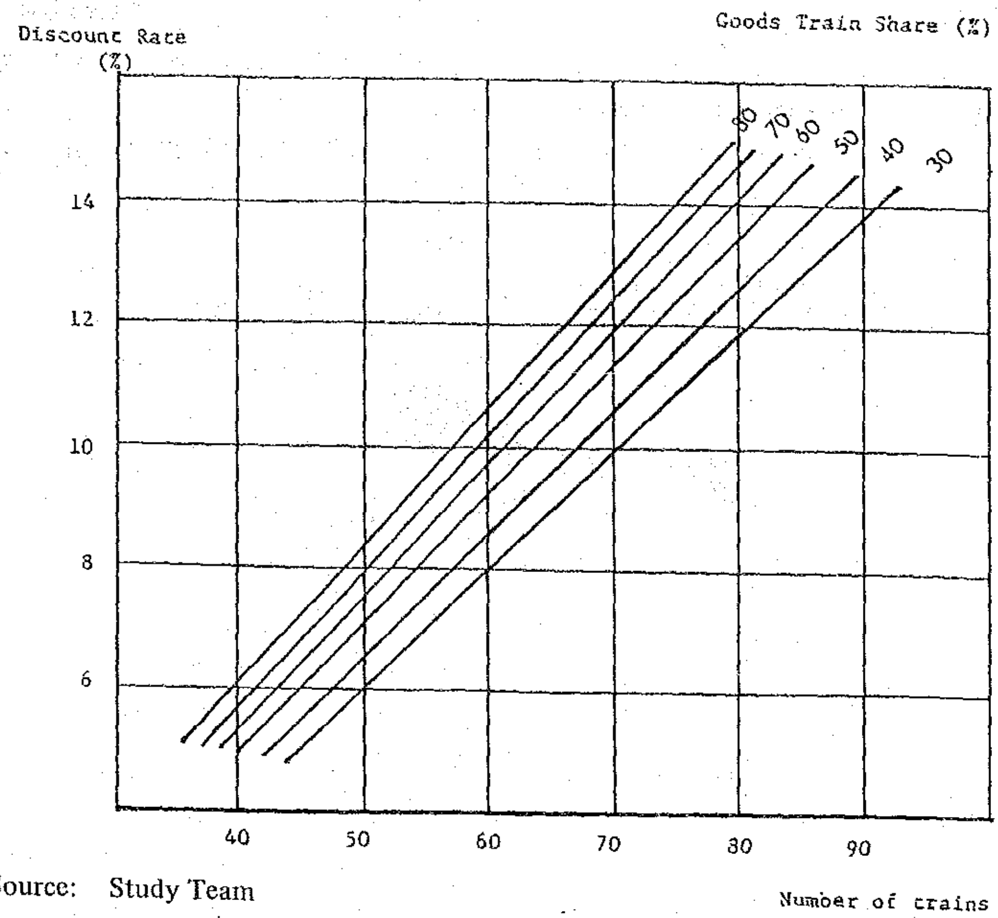
Table W-2 Optimum Electrification Timing of Flat Double Track Section

(Number of Trains)

Discount Rate (%)	Share of Goods Trains (%)					
	80	70	60	50	40	30
14	75	78	80	83	88	92
12	67	69	72	75	79	83
10	58	60	63	65	70	73
8	49	51	53	55	59	62

Note: Number of trains for both ways

Source: Study Team



Source: Study Team

Fig. W-2 Optimum Electrification Timing of Flat Double Track Section

1. **Project Name: Electrification, Rohri – Samasata**

2. **Project Description**

2-1 **Objective**

ROH-SMA section is to be electrified in association with the provision of related locos and loco shed.

2-2 **Description**

The project components include:

Electrification ROH-SMA	333 km x 2 x 2.16	= 1,439 (FEC 777) mil. Rs
Loco shed ROH		100 (FEC 35) mil. Rs
Locos (ordinary)	105 x 22.3	= 2,347 (FEB 1,667) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start** — **7th Plan period**

3-2 **Time required for project completion** — **60 months**

4. **Cost of Project (Rupees in million)** — **3,886 (FEC 2,479)**

5. **Preliminary Evaluation**

The major benefits of electrification as compared with dieselization include better energy efficiency, less maintenance cost of locomotives and increased line capacity. More specifically, the energy cost of EL is 62% of DEL in a financial term and 53% of the DEL in an economic term. Also, the maintenance cost of EL is 0.6% of the cost of a new EL per 10,000 km, while that of DEL is 1.9% in an analogous term.

The economic justificability of electrification project of Rohri – Samasata section can be examined by applying the generalized model of testing the optimum implementation timing of electrification projects. The share of goods trains on the project section in the year 1999/2000 is estimated to be 63%. Since the discount rate (the opportunity value of capital) for railway projects can be reasonably assumed to be 12%, the model indicates that the number of trains at the optimum electrification timing is 72.

On the other hand, the number of trains on the project section in the year 1999/2000 is estimated to be 158. This estimated number of trains far exceeds the one at the optimum electrification timing. In consequence, the electrification between Rohri and Samasata can be understood as justifiable before 1999/2000, and it is most desirable from an economic point of view if this electrification project is implemented at the indicated number of trains (72). If not, it is recommended to be implemented as early as possible after the number of trains exceeds the indicated one.

1. **Project Name: Electrification, Samasata – Khanewal**

2. **Project Description**

2-1 **Objective**

Both lines of SMA-KWL section are to be electrified in association with the provision of related locos and shed.

2-2 **Description**

SMA-KWL (Chord) and MUL-KWL portions of the electrification project section are also to be doubled concurrently. The project components include:

Electrification (doubled)	185 km x 2 x 2.16	=	799	(FEC 431) mil. Rs
(single)	72 km x 2.16	=	156	(FEC 84) mil. Rs
Loco shed MUL		=	100	(FEC 35) mil. Rs
Locos (ordinary)	45 x 22.3	=	1,004	(FEC 713) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**1983/84**
3-2 **Time required for project completion**	**48 months**

4. **Cost of Project (Rupees in million)** **2,059 (FEC 1,263)**

5. **Preliminary Evaluation**

The major benefits of electrification as compared with dieselization include better energy efficiency, less maintenance cost of locomotives and increased line capacity. More specifically, the energy cost of EL is 62% of DEL in a financial term and 53% of DEL in an economic term. Also, the maintenance cost of EL is 0.6% of the cost of a new EL per 10,000 km, while that of DEL is 1.9% in an analogous term.

The economic justificability of electrification project of Samsata – Khanewal section can be examined by applying the generalized model of testing the optimum implementation timing of electrification projects. The share of goods trains on the project section is estimated to be 80% (Chord line) and 34 to 41% (Loop line). Since the discount rate (the opportunity value of capital) for railway projects can be reasonably assumed to be 12%, the model indicates that the number of trains at the optimum electrification timing is 67 (Chord line) and 79 to 81 (Loop line).

On the other hand, the number of trains on the project section in the year 1999/2000 is estimated to be 101 (Chord line) and 58 to 68 (Loop line). As the estimated train number on the chord line far exceeds the one at the optimum electrification timing, the electrification of chord line can be understood as justifiable before 1999/2000. However, the estimated number of train on the loop line is a little below the one at the optimum electrification timing. From a purely economic point of view, the electrification of loop line can not be justified before 1999/2000.

It is from a point of view of train operation that the chord line is recommended to be electrified at a relatively early point of time, and that the loop line is proposed to be electrified concurrently. Sandwiched between the already electrified section of Khanewal – Lahore and the double track section of Karachi – Samasata, the smooth operation of both passenger and goods trains in this project section is preferred to be achieved by the proposed projects. Electrification of the chord line only is not realistic from a train operational point of view, and the electrification of loop line needs to be regarded as a set project with the chord line electrification.

1. **Project Name: Electrification, Lahore – Lala Musa**

2. **Project Description**

2-1 **Objective**

LHR-LLM section is to be electrified in association with the provision of related locos and shed.

2-2 **Description**

The section is to be electrified concurrently with the implementation of track doubling. The project components include:

Electrification (doubled)	132 km x 2 x 2.38	=	629	(FEC 340)	mil. Rs
Loco shed (advance) LLM			50	(FEC 18)	mil. Rs
Locos (ordinary)	22 x 22.3	=	491	(FEC 348)	mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**7th Plan period**
3-2 **Time required for project completion**	**36 months**

4. **Cost of Project (Rupees in million)** **1,170 (FEC 706)**

5. **Preliminary Evaluation**

The major benefits of electrification as compared with dieselization include better energy efficiency, less maintenance cost of locomotives and increased line capacity. More specifically, the energy cost of EL is 62% of DEL in a financial term and 53% of DEL in an economic term. Also, the maintenance cost of EL is 0.6% of the cost of a new EL per 10,000 km, while that of DEL is 1.9% in an analogous term.

The economic justificability of electrification project of Lahore – Lala Musa section can be examined by applying the generalized model of testing the optimum implementation timing of electrification projects. The share of goods trains on the project section in the year 1999/2000 is estimated to be 58% (Wazirabad – Lala Musa) to 61% (Lahore – Wazirabad). Since the discount rate (the opportunity value of capital) for railway projects can be reasonably assumed to be 12%, the model indicates that the number of trains at the optimum electrification timing is 73 (Wazirabad – Lala Musa) and 72 (Lahore – Wazirabad).

On the other hand, the number of trains on the project section in the year 1999/2000 is estimated to be 90 (Wazirabad – Lala Musa) and 82 (Lahore – Wazirabad). This estimated number of trains exceds the one at the optimum electrification timing. In consequence, the electrification between Lahore and Lala Musa can be understood as justifiable before 1999/2000, and it is desirable from an economic point of view if this electrification project is implemented at the indicated number of trains.

1. **Project Name: Electrification, Lala Musa – Rawalpindi**

2. **Project Description**

2-1 **Objective**

LLM-RWP section is to be electrified in association with the provision of related locos and shed.

2-2 **Description**

JMR-MNA and CKL-RWP portions of the project section has already been doubled. JMR-MNA portion of the project section requires additional locos for goods trains due to the gradient. The project components include:

Electrification	161 km x 2.38 =	382 (FEC 206) mil Rs
Loco shed (advance) RWP		50 (FEC 18) mil. Rs
Locos (ordinary)	28 x 22.3 =	624 (FEC 443) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**8th Plan period**
3-2 **Time required for project completion**	**36 months**

4. **Cost of Project (Rupees in million)** **1,055 (FEC 667)**

5. **Preliminary Evaluation**

The major benefits of electrification as compared with dieselization include better energy efficiency, less maintenance cost of locomotives and increased line capacity. More specifically, the energy cost of EL is 62% of DEL in a financial term and 53% of DEL in an economic term. Also, the maintenance cost of EL is 0.6% of the cost of a new EL per 10,000 km, while that of DEL is 1.9% in an analogous term.

Since the project environments of electrification in the Lala Musa – Rawalpindi section do not fit the conditions of optimum electrification timing test model, that is, double track of flat terrain, this project is analyzed independently from the generalized model analysis. It takes differential cost-benefit analysis between the two mutually exclusive cases of electrification and diesel operation.

The forecasted traffic volume in 1999/2000 on this section is shown in Table W - 3. The number of trains to cater for this traffic volume is 54 (daily, for both ways), of which 16 are passenger trains and 38 are goods trains. This traffic volume on the project section

Table W-3 Forecasted Annual Traffic Volume on the LLM-RWP Section in the Year 1999/2000

	passengers (PAX)	goods (tons)
up	4,922,000	6,205,830
down	4,922,000	2,595,420

Source: Study Team

is relatively small, and does not appear to fully enjoy the usual benefits of electrification against its development cost of ground facilities. Due to the desirable performance of EL on the gradient section, however, electrification in this section is expected to save more energy than in an electrification project on flat terrain and also the provision of some supplemental locomotives which are required otherwise if diesel operation is continued.

Table W-4 presents the economic cost-benefit stream of electrification project of the section. The resulting internal rate of return is estimated to be 16.0%. In consequence, it is indicated that the electrification of this section during the 8th Plan period is preferable to the continuation of diesel operation.

Table W-4 Economic Cost and Benefit Streams of LLM-RWP Electrification Project

(Million Rupees)

Year	Electrification				Diesel		
	Ground Equipment	EL	Elect-ricity	Total	DEL	Diesel	Total
1	81.02	-	-	81.02	-	-	-
2	189.05	443.32	-	632.37	510.92	-	510.92
3	1.08	4.87	26.44	32.39	17.78	49.91	67.69
4	1.08	4.87	26.44	32.39	17.78	49.91	67.69
5	1.08	4.87	26.44	32.39	17.78	49.91	67,69
6	1.08	4.87	26.44	32.39	17.78	49.91	67.69
7	1.08	4.87	26.44	32.39	17.78	49.91	67,69
8	1.08	4.87	26.44	32.39	17.78	49.91	67.69
9	1.08	4.87	26 44	32.39	17,78	40.91	67.69
10	1.08	4.87	26.44	32.39	17.78	49.91	67.69
11	1.08	4.87	26.44	32.39	17.78	49.91	67.69
12	1.08	4.87	26.44	32.39	17.78	40.91	67.69
13	1.08	4.87	26.44	32.39	17.78	49.91	67.69
14	1.08	4.87	26.44	32.39	17.78	49.91	67.69
15	1.08	4.87	26.44	32.39	17.78	49.91	67.69
16	1.08	4.87	26,44	32.39	17.78	49.91	67.69
17	1.08	4.87	26.44	32.39	17.78	49,91	67.69
18	1.08	4.87	26.44	32.39	17.89	49.91	67.69
19	1.08	4.87	26.44	32.39	17.78	49.91	67.69
20	1.08	4.87	26.44	32.39	17.78	49.91	67.69
21	1.08	4.87	26.44	32.39	17.78	49.91	67.79
22	1.08	4.87	26.44	32.39	17.78	49.91	67.69
23	Δ108.03	Δ177.33	-	Δ286.36	Δ153.28	-	-

Source: Study Team

1. **Project Name: Electrification, Sibi – Kolpur**

2. **Project Description**

2-1 **Objective**

SIB-KLR section is to be electrified in association with the provision of related locos and shed.

2-2 **Description**

ABG-KLR portion of the project section has already been doubled. The long and high gradient portion is competent for regenerative brake. The project components include:

Electrification	138 km x 3.07	=	424 (FEC 229) mil. Rs
Loco shed SIB			100 (FEC 35) mil. Rs
Locos (regenerative)	22 x 28.8	=	634 (FEC 450) mil. Rs

3. ***Time of Implementation***

3-1 **Prospective timing of project start**	**1985/86**
3-2 **Time required for project completion**	**36 months**

4. ***Cost of Project (Rupees in million)*** **1,158 (FEC 714)**

5. **Preliminary Evaluation**

The major benefits of electrification as compared with dieselization include better energy efficiency, less maintenance cost of locomotives and increased line capacity. More specifically, the energy cost of EL is 62% of DEL in a financial term and 53% of DEL in an economic term. Also, the maintenance cost of EL is 0.6% of the cost of a new EL per 10,000 km, while that of DEL is 1.9% in an analogous term.

Since the project environments of electrification in the Sibi – Kolpur section do not fit the conditions of optimum electrification timing test model, that is, double track of flat terrain, this project is analyzed independently from the generalized model analysis. It takes differential cost-benefit analysis between the two mutually exclusive cases of electrification and diesel operation.

The forecasted traffic volume on this section up to the year 1999/2000 is shown in Table W - 5. The number of trains to cater for the traffic volume of 1999/2000 is 50 (daily, for both ways), of which 6 are passenger trains and 44 are goods trains. This traffic volume on the project section is relatively small, and does not appear to fully enjoy the usual benefits of electrification against its development cost of ground facilities. Due to the desirable performance of EL on the gradient section, however, electrification in this section is expected to save more energy than in an electrification project on flat terrain and also the provision of some supplemental locomotives which are required otherwise if diesel operation is continued. Moreover, since the slope over the Abigum – Kolpur section is so steep, the number of trains will be obliged to increase by 10% if diesel operation is continued than the electrified case.

Table W-5 Forecasted Annual Traffic Volume on the SIB-KLR Section

	Goods (thousand tons)		Passengers (thousand PAX)	
	up	down	up	down
1987/88	715	1,209	440	440
1988/89	772	1,329	462	462
1989/90	834	1,460	482	482
1990/91	901	1,605	511	511
1991/92	973	1,764	537	537
1992/93	1,051	1,938	564	564
1993/94	1,135	2,130	593	593
1994/95	1,226	2,341	623	623
1995/96	1,324	2,573	655	655
1996/97	1,430	2,828	688	688
1997/98	1,544	3,107	724	724
1998/99	1,667	3,415	760	760
1999/00	1,796	3,771	798	798

Source: Study Team

As a matter of fact, the electrification project of this section is proposed to be implemented at an early point of time as analyzed below. Table W - 6 presents the economic cost-benefit stream of electrification project of the section on the assumption that the electrified operation will be open in 1987/88. The resulting internal rate of return in this case (without regenerative breaks) is estimated to be 10.9%. While some other benefits including the regional development effect of Baluchistan areas can be also seen, it can not be quite convinced that the project is feasible, yet.

However, if regenerative brake systems are introduced to take advantage of the steep slopes, a considerable amount -roughly 30%- of electricity can be saved for no substantial extra cost. Table W - 7 is the economic cost-benefit stream of electrification project of the section with regenerative brake systems. The resulting internal rate of return is 12.5% and proves the economic feasibility of project. While the detail study including the plan of locomotive shed systems should be conducted before actual implementation of the project, the electrification project of Sibi – Kolpur section is recommended to be implemented in the late 6th Plan period with the system design of regenerative brakes.

Table W-6 Economic Cost and Benefit Stream of Sibi-Kolpur Electrification Project (without Regenerative Brakes)

(Million Rupees)

Year	Electrification				Diesel		
	Ground Equipment	EL	Electricity	Total	DEL	Diesel	Total
1	89.79	-	-	89.79	-	-	-
2	209.98	183.78	-	393.76	298.98	-	298.98
3	1.20	21.84	5.78	28.81	23.88	11.35	35.23
4	1.20	21.99	6.55	29.74	40.89	12.54	53.43
5	1.20	22.15	7.17	30.52	41.70	13.77	55.47
6	1.20	22.31	7.38	30.88	25.89	14.13	40.02
7	1.20	22.46	8.03	31.69	59.52	15.40	74.92
8	1.20	22.62	8.70	32.52	44.12	16.71	60.83
9	1.20	22.78	9.38	33.36	28.32	18.05	46.37
10	1.20	22.94	9.65	33.78	45.33	18.53	63.86
11	1.20	23.09	10.37	34.67	46.14	19.94	66.08
12	1.20	23.25	11.12	35.57	30.33	21.39	51,72
13	1.20	23.41	12.32	36.93	63.96	23.78	87,74
14	1.20	23.56	13.13	37.89	48.56	26.25	74.81
15	1.20	23.72	13.92	38.84	32.75	27.81	60.57
16	1.20	3.46	13.92	18.58	16.55	27.81	44.36
17	1.20	3.46	13.92	18.58	16.55	27.81	44.36
18	1.20	3.46	13.92	18.58	16.55	27.81	44.36
19	1.20	3.46	13.92	18.58	16.55	27.81	44.36
20	1.20	3.46	13.92	18.58	16.55	27.81	44.36
21	1.20	3.46	13.92	18.58	16.55	27.81	44.36
22	1.20	3.46	13.92	18.58	16.55	27.81	44.36
23	119.91	179.49	-	299.40	275.23	-	275.23

Source: Study Team

Table W-7 Economic Cost and Benefit Stream of Sibi-Kolpur Electrification Project (with Regenerative Brake Systems)

(Million Rupees)

Year	Electrification				Diesel		
	Ground Equipment	EL	Elect-ricity	Total	DEL	Diesel	Total
1	89.79	-	-	89.79	-	-	-
2	209.98	183.78	-	393.76	298.98	-	298.98
3	1.20	21.84	3.98	27.02	23.88	11.35	35.23
4	1.20	21.99	4.57	27.77	40.89	12.54	53.43
5	1.20	22.15	4.98	28.33	41.70	13.77	55.47
6	1.20	22.31	5.08	28.59	25.89	14.13	40.02
7	1.20	22.46	5.50	29.16	59.52	15.40	74.92
8	1.20	22.62	5.91	29.74	44.12	16.71	60.83
9	1.20	22.78	6.34	30.32	28.32	18.05	46.37
10	1.20	22.94	6.47	30.60	45.33	18.53	63.86
11	1.20	23.09	6.91	31.20	46.14	19.94	66.08
12	1.20	23.25	7.35	31.80	30.33	21.39	51.72
13	1.20	23.41	8.10	32.71	63.96	23.78	87.74
14	1.20	23.56	8.58	33.34	48.56	26.25	74.81
15	1.20	23.72	9.00	33.93	32.75	27.81	60.57
16	1.20	3.46	9.00	13.66	16.55	27.81	44.36
17	1.20	3.46	9.00	13.66	16.55	27.81	44.36
18	1.20	3.46	9.00	13.66	16.55	27.81	44.36
19	1.20	3.46	9.00	13.66	16.55	27.81	44.36
20	1.20	3.46	9.00	13.66	16.55	27.81	44.36
21	1.20	3.46	9.00	13.66	16.55	27.81	44.36
22	1.20	3.46	9.00	13.66	16.55	27.81	44.36
23	Δ119.91	Δ179.49	-	Δ299.40	Δ275.23	-	Δ275.23

Source: Study Team

1. **Project Name: *Electrification, Sher Shah – Mahmud Kot***

2. **Project Description**

2-1 **Objective**

SSH-MHK section is to be electrified in association with the provision of related locos.

2-2 **Description**

Liquid product is transported to MHK by pipeline from KYC. The project components include:

Electrification	50 km x 2.16 =	108 (FEC 58) mil. Rs
Loco	1 x 22.3 =	22 (FEC 16) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**8th Plan period**
3-2 **Time required for project completion**	**24 months**

4. **Cost of Project (Rupees in million)** **130 (FEC 74)**

5. **Preliminary Evaluation**

The estimated number of trains on this section in 1999/2000 is 14 (daily, for both ways), of which 12 are goods trains. This is far below the required number of trains to economically justify the electrification. It is from an operational point of view that the Sher Shah – Mahmud Kot section is proposed to be electrified. The major intention by electrification is to ensure the smooth operation of tank wagons carrying liquid products from Mahmud Kot.

1. **Project Name: Track Doubling, Lodhran – Khanewal and Piran Ghafb – Khanewal**

2. **Project Description**

2-1 **Objective**

LON-KWL and PGB-KWL sections are to be doubled.

2-2 **Description**

The project components include:

Track doubling	LON-KWL	91 km
	PGB-KWL	38 km

129 km x 6.0 = 774 (FEC 106) mil. Rs

(Rail 0.64 ÷ 1.61 x 1.27 x 1.3 x 1.25 = 0.82 per km

PC-1. Rehabilitation, Mar., 1977)

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**1983/84**
3-2 **Time required for project completion**	**48 months**

4. **Cost of Project (Rupees in million)** 774 (FEC 106)

5. **Preliminary Evaluation**

The requirement for track doubling is dependent on the capacity of single track line n. n is, in theory, the function of station-to-station running time $(\frac{1}{2}(\frac{1}{V_1}+\frac{1}{V_2}))$, block handling time t, and the traffic intensity f:

$$n = \frac{1,440\,f}{\frac{1}{2}(\frac{1}{V_1}+\frac{1}{V_2}) + t}$$

Longest station-to-station distances on the main line are around 10 km, and its present average running time is estimated 10 to 15 minutes depending on the traffic composition and running conditions. At the same time, it appears to take 1.5 to 5 minutes for block handling depending upon the system types of block working and interlocking. As for the traffic intensity, while the basic coefficient may be assumed to be 0.7, further allowance needs to be kept depending upon the operation conditions. While the exact future line capacity of single track cannot be determined due to some uncertainty mentioned above, those sections with more than 50 trains per day need to be examined for a potential track doubling project.

Since the LON - KWL and PGB - KWL sections are estimated to have nearly 100 and 70 trains, respectively, in the year 1999/2000, they need to be doubled. Since these are the sections sandwiched between the double track section and the electrified section, an early implementation is preferred from a train operational point of view.

1. Project Name: Track Doubling, Khanewal – Raiwind

2. Project Description

2-1 Objective

KWL-RND section is to be doubled in association with the provision of related equipments.

2-2 Description

KWL-LHR portion of the project section has already been electrified. The project components include:

Doubling	245 km x 6.0	=	1,470 (FEC 206) mil. Rs
Electrification	245 km x 2.16	=	529 (FEC 286) mil. Rs

3. Time of Implementation

3-1 Prospective timing of project start	7th Plan period
3-2 Time required for project completion	60 months

4. Cost of Project (Rupees in million)	1,999 (FEC 492)

5. Preliminary Evaluation

The requirement for track doubling is dependent on the capacity of single track line n. n is, in theory, the function of station-to-station running time $(\frac{1}{2}(\frac{1}{V_1}+\frac{1}{V_2}))$, block handling time t, and the traffic intensity f:

$$n = \frac{1{,}440\, f}{\frac{1}{2}(\frac{1}{V_1}+\frac{1}{V_2}) + t}$$

Longest station-to-station distances on the main line are around 10 km, and its present average running time is estimated 10 to 15 minutes depending on the traffic composition and running conditions. At the same time, it appears to take 1.5 to 5 minutes for block handling depending upon the system types of block working and interlocking. As for the traffic intensity, while the basic coefficient may be assumed to be 0.7, further allowance needs to be kept depending upon the operation conditions. While the exact future line capacity of single track cannot be determined due to some uncertainty mentioned above, those sections with more than 50 trains per day need to be examined for a potential track doubling project.

The project section is estimated to have more than 130 trains in the year 1999/2000, and definitely needs to be doubled. Since this is an already-electrified section, 7th Plan period seems to be early enough as an implementation timing.

1. **Project Name: Track Doubling, Shahdara Bagh – Lala Musa**

2. **Project Description**

2-1 **Objective**

SDR-LLM section is to be doubled.

2-2 **Description**

The project components include:

Doubling SDR-LLM 126 km

126 x 6.0 = 756 (FEC 106) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**7th Plan period**
3-2 **Time required for project completion**	**48 months**

4. **Cost of Project (Rupees in million)** **756 (FEC 106)**

5. **Preliminary Evaluation**

The requirement for track doubling is dependent on the capacity of single track line n. n is, in theory, the function of station-to-station running time ($\frac{1}{2}(\frac{1}{V_1}+\frac{1}{V_2})$), block handling time t, and the traffic intensity f:

$$n = \frac{1{,}440\ f}{\frac{1}{2}(\frac{1}{V_1}+\frac{1}{V_2}) + t}$$

Longest station-to-station distances on the main line are around 10 km, and its present average running time is estimated 10 to 15 minutes depending on the traffic composition and running conditions. At the same time, it appears to take 1.5 to 5 minutes for block handling depending upon the system types of block working and interlocking. As for the traffic intensity, while the basic coefficient may be assumed to be 0.7, further allowance needs to be kept depending upon the operation conditions. While the exact future line capacity of single track cannot be determined due to some uncertainty mentioned above, those sections with more than 50 trains per day need to be examined for a potential track doubling project.

The project section is estimated to have nearly 90 trains in the year 1999/2000, and needs to be doubled. Taking into account the traffic volume, the project is proposed to be implemented during the 7th Plan period.

1. **Project Name: Track Doubling, Lala Musa – Rawalpindi**

2. **Project Description**

2-1 Objective

LLM-RWP section is to be doubled.

2-2 Description

By the time the project is to be implemented, the section will be already electrified. The project components include:

Track doubling	152 km x 6.0	= 910 (FEC 246) mil. Rs
Electrification	152 km x 2.38	= 360 (FEC 195) mil. Rs

3. **Time of Implementation**

3-1 Prospective timing of project start	**8th Plan period**
3-2 Time required for project completion	**60 months**

4. **Cost of Project (Rupees in million)** **1,270 (FEC 441)**

5. **Preliminary Evaluation**

The requirement for track doubling is dependent on the capacity of single track line n. n is, in theory, the function of station-to-station running time $(\frac{1}{2}(\frac{1}{V_1} + \frac{1}{V_2}))$, block handling time t, and the traffic intensity f:

$$n = \frac{1{,}440\, f}{\frac{1}{2}(\frac{1}{V_1} + \frac{1}{V_2}) + t}$$

Longest station-to-station distances on the main line are around 10 km, and its present average running time is estimated 10 to 15 minutes depending on the traffic composition and running conditions. At the same time, it appears to take 1.5 to 5 minutes for block handling depending upon the system types of block working and interlocking. As for the traffic intensity, while the basic coefficient may be assumed to be 0.7, further allowance needs to be kept depending upon the operation conditions. While the exact future line capacity of single track cannot be determined due to some uncertainty mentioned above, those sections with more than 50 trains per day need to be examined for a potential track doubling project.

The project section is estimated to have 54 trains in the year 1999/2000, and traffic-wise it remains controversial if the section is to be doubled by then. Taking into consideration the existence of gradient segments, it is desirable to be doubled. Also from a train operational point of view, this project is favored since it will enable the doubling of almost entire main line between Karachi and Rawalpindi by the year 1999/2000.

1. **Project Name: Track Doubling, Lodhran – Sher Shah**

2. **Project Description**

2-1 **Objective**

LON-SSH section is to be doubled.

2-2 **Description**

The project components are:

Doubling	72 km x 6.0	= 430	(FEC 60) mil. Rs
Electrification	72 km x 2.16	= 155	(FEC 84) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**8th Plan period**
3-2 **Time required for project completion**	**36 months**

4. **Cost of Project (Rupees in million)** — **585 (FEC 144)**

5. **Preliminary Evaluation**

The requirement for track doubling is dependent on the capacity of single track line n. n is, in theory, the function of station-to-station running time $(\frac{1}{2}(\frac{1}{V_1}+\frac{1}{V_2}))$, block handling time t, and the traffic intensity f:

$$n = \frac{1{,}440\,f}{\frac{1}{2}(\frac{1}{V_1}+\frac{1}{V_2}) + t}$$

Longest station-to-station distances on the main line are around 10 km, and its present average running time is estimated 10 to 15 minutes depending on the traffic composition and running conditions. At the same time, it appears to take 1.5 to 5 minutes for block handling depending upon the system types of block working and interlocking. As for the traffic intensity, while the basic coefficient may be assumed to be 0.7, further allowance needs to be kept depending upon the operation conditions. While the exact future line capacity of single track cannot be determined due to some uncertainty mentioned above, those sections with more than 50 trains per day need to be examined for a potential track doubling project.

The project section is estimated to have 58 trains in the year 1999/2000, and traffic-wise it remains controversial if the section is to be doubled by then. Considering the plan that the adjacent sections will be doubled by then, this section is also desired from a train operational point of view to be doubled by the year 1999/2000.

1. **Project Name: Track Renewal, Karachi City – Lala Musa**

2. **Project Description**

2-1 **Objective**

Track in KYC-LLM section is to be renewed.

2-2 **Description**

Since 451 km out of the total requirement of 2,370 km is scheduled to be renewed during 5th Plan, the balance will be 1,919 km. The project components include:

100^{lb} rail, 2,640 sleepers/mile, 12" ballast

1,919 x 2.29 = 4,395 (FEC 1,845) mil. Rs

6th Plan period (20%) 879

7th Plan period (30%) 1,319

8th Plan period (50%) 2,197

(PC-1 Rehabilitation, March, 1977.

1.93 ÷ 1.61 mile/km x 1.91 = 2.29 mil. Rs/km

FEC 811 ÷ 1,932 = 42%)

3. ***Time of Implementation***

3-1	**Prospective timing of project start**	**Phase I 1983/84**
3-2	**Time required for project completion**	**60 months**

4. ***Cost of Project (Rupees in million)*** **4,395 (FEC 1,846)**

5. **Preliminary Evaluation**

The track and rail renewal program including this project has been formulated mainly from an engineering point of view in consideration of the existing inventories and the construction plans. In order to ensure the safe and smooth operation of trains, this track renewal project is a prerequisite.

1. **Project Name: Track Renewal, Lala Musa – Peshawar Cant**

2. **Project Description**

2-1 **Objective**

Track in LLM-PSC section is to be renewed.

2-2 **Description**

Since 72 km out of the total requirement of 330 km are scheduled to be renewed in 5th Plan, the project requirement is 258 km. The project components are:

90lb rail, 2,514 sleepers/mile, 10" ballast,

258 x 1.46 = 377 (FEC 188) mil. Rs

6th Plan period (33%) 126

7th Plan period (33%) 126

8th Plan period (33%) 125

PC-I Rehabilitation Mar. 1977

1.23 mil. Rs/mile ÷ 1.61 x 1.91 = 1.46,

FEC: 613 ÷ 1,228 = 50%)

3. **Time of Implementation**

3-1 **Prospective timing of project start** — **Phase I 1983/84**

3-2 **Time required for project completion** — **60 months**

4. **Cost of Project (Rupees in million)** — **377 (FEC 188)**

5. **Preliminary Evaluation**

The track and rail renewal program including this project has been formulated mainly from an engineering point of view in consideration of the existing inventories and the construction plans. In order to ensure the safe and smooth operation of trains, this track renewal project is a prerequisite.

1. **Project Name: Track Renewal, Rohri – Quetta**

2. **Project Description**

2-1 **Objective**

Track in ROH-QTA section is to be renewed.

2-2 **Description**

Since no segment has been renewed in the section during the 5th Plan period, the project requirement is 422 km. The project components include:

90^{lb} rail, 2,514 sleepers/mile, 10" ballast,

422 x 1.46 = 616 (FEC 308) mil. Rs

6th Plan period (20%) 123

7th Plan period (30%) 185

8th Plan period (50%) 308

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**Phase I 1983/84**
3-2 **Time required for project completion**	**60 months**

4. ***Cost of Project (Rupees in million)*** **616 (FEC 308)**

5. **Preliminary Evaluation**

The track and rail renewal program including this project has been formulated mainly from an engineering point of view in consideration of the existing inventories and the construction plans. In order to ensure the safe and smooth operation of trains, this track renewal project is a prerequisite.

1. **Project Name: Track Renewal, Khanewal – Faisalabad**

2. **Project Description**

2-1 **Objective**

Track in KWL-FSLD section is to be renewed.

2-2 **Description**

Since no segment has been renewed in this section during the 5th Plan period, the project requirement is 170 km. The project components are:

90^{lb} rail, 2,514 sleepers/mile, 10" ballast,

170 x 1.46 = 248 (FEC 104) mil. Rs

6th Plan period (20%)	50
7th Plan period (30%)	74
8th Plan period (50%)	124

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**Phase I 1985/86**
3-2 **Time required for project completion**	**36 months**

4. **Cost of Project (Rupees in million)** **248 (FEC 104)**

5. **Preliminary Evaluation**

The track and rail renewal program including this project has been formulated mainly from an engineering point of view in consideration of the existing inventories and the construction plans. In order to ensure the safe and smooth operation of trains, this track renewal project is a prerequisite.

1. **Project Name: Track Renewal, Shorkot – Sargodha**

2. **Project Description**

2-1 Objective

Track in SKO-SRQ section is to be renewed.

2-2 Description

Since no segment has been renewed in this section during the 5th Plan period, the project requirement is 166 km. The project components are:

90lb rail, 1,514 sleepers/mile, 10" ballast,

166 x 1.46 = 243 (FEC 121) mil. Rs

7th Plan period (50%) 121

8th Plan period (50%) 122

3. **Time of Implementation**

3-1 Prospective timing of project start **7th - 8th Plan period**

3-2 Time required for project completion

4. **Cost of Project (Rupees in million)** **243 (FEC 121)**

5. **Preliminary Evaluation**

The track and rail renewal program including this project has been formulated mainly from an engineering point of view in consideration of the existing inventories and the construction plans. In order to ensure the safe and smooth operation of trains, this track renewal project is a prerequisite.

1. **Project Name: Track Renewal, Sher Shah – Kundian**

2. **Project Description**

2-1 **Objective**

Track in SSH-KDA section is to be renewed.

2-2 **Description**

Since no segment has been renewed in this section during the 5th Plan period, the project requirement is 302 km. The project components include:

90^{lb} rail, 2,514 sleepers/mile, 10″ ballast,

302 x 1.46 = 441 (FEC 220) mil. Rs

6th Plan period (0%)

7th Plan period (50%) 220

8th Plan period (50%) 221

3. **Time of Implementation**

3-1 **Prospective timing of project start** — **7th - 8th Plan period**

3-2 **Time required for project completion**

4. **Cost of Project (Rupees in million)** — **441 (FEC 220)**

5. **Preliminary Evaluation**

The track and rail renewal program including this project has been formulated mainly from an engineering point of view in consideration of the existing inventories and the construction plans. In order to ensure the safe and smooth operation of trains, this track renewal project is a prerequisite.

1. **Project Name: Rail Renewal, Branch Lines**

2. **Project Description**

2-1 **Objective**

Rails on branch lines are to be renewed.

2-2 **Description**

The total project requirement is

1,919 x 0.9 = 1,727 km.

The project components include:

90lb new and used rail, 12% new sleepers

1,727 x 0.32 = 553 (FEC 66) mil. Rs

6th Plan period (20%) 111

7th Plan period (30%) 166

8th Plan period (50%) 276

(0.27 ÷ 1.61 x 1.91 = 0.32, 33.6 ÷ 271 = 12%)

3. **Time of Implementation**

3-1 **Prospective timing of project start** — **Phase I 1983/84**

3-2 **Time required for project completion** — **60 months**

4. **Cost of Project (Rupees in million)** — **553 (FEC 66)**

5. **Preliminary Evaluation**

The track and rail renewal program including this project has been formulated mainly from an engineering point of view in consideration of the existing inventories and the construction plans. In order to ensure the safe and smooth operation of trains, this track renewal project is a prerequisite.

1. **Project Name: Container Transportation**

2. **Project Description**

2-1 **Objective**

Lahore Dry Port is to be constructed in association with the provision of related wagons concurrently with the extension of Karachi Port.

2-2 **Description**

Karachi container terminal is expected to start the operation by 1987/88. Correspondingly, two 2,000^t trains are programmed to be operated starting in 1987/88, and four 3,000^t trains in 1999/2000. The project components are:

	1987/1988	1999/2000
Dry Port	459 (FEC 227) mil. Rs	1,101 (FEC 596) mil. Rs
Wagons	157 (FEC 42) mil. Rs	393 (FEC 106) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start** — **Phase I 1984/85**

3-2 **Time required for project completion** — **48 months**

4. **Cost of Project (Rupees in million)** — **1,494 (FEC 702)**

5. **Preliminary Evaluation**

The container transport is an innovative program introduced to railway, requiring the development of Lahore Dry Port. This is a part of the adopted intermodal containerization program which holds the IRR of 14.3% as shown in Table W - 8.

Table W-8 Costs/Benefits and IRR - Shadow Price (Karachi Port - Feedback Ratio 30%)

IRR = 14.3% (Unit; '000 Rs)

No.	Fiscal Year	Costs				Benefits			
		Total	Construction	Equipment	Operation/ Maintenance	Total	Reduction in Ships' Staying Cost	Reduction in Cargo Handling Cost	Reduction in Time Cost
1	1982/'83	11,692	11,692						
2	'83/'84	77,240	77,240						
3	'84/'85	225,591	225,591						
4	'85/'86	306,633	306,633						
5	'86/'87	482,110	148,460	333,650					
6	'87/'88	12,672			12,672	71,468	53,896	4,732	12,840
7	'88/'89	21,394			21,394	117,374	70,072	25,186	22,117
8	'89/'90	33,848			33,848	238,392	160,806	44,025	33,561
9	'90/'91	43,778			43,778	270,904	177,180	49,807	43,916
10	'91/'92	43,778			43,778	270,904	177,180	49,807	43,916
11	'92/'93	43,778			43,778	270,904	177,180	49,807	43,916
12	'93/'94	43,778			43,778	270,904	177,180	49,807	43,916
13	'94/'95	43,778			43,778	270,904	177,180	49,807	43,916
14	'95/'96	43,778			43,778	270,904	177,180	49,807	43,916
15	'96/'97	43,778			43,778	270,904	177,180	49,807	43,916
16	'97/'98	43,778			43,778	270,904	177,180	49,807	43,916
17	'98/'99	43,778			43,778	270,904	177,180	49,807	43,916
18	'99/2000	43,778			43,778	270,904	177,180	49,807	43,916
19	2000/'1	43,778			43,778	270,904	177,180	49,807	43,916
20	'1 /'2	43,778			43,778	270,904	177,180	49,807	43,916
21	'2 /'3	43,778			43,778	270,904	177,180	49,807	43,916
22	'3 /'4	43,778			43,778	270,904	177,180	49,807	43,916
23	'4 /'5	43,778			43,778	270,904	177,180	49,807	43,916
24	'5 /'6	43,778			43,778	270,904	177,180	49,807	43,916
25	'6 /'7	43,778			43,778	270,904	177,180	49,807	43,916
26	'7 /'8	43,778			43,778	270,904	177,180	49,807	43,916
27	'8 /'9	43,778			43,778	270,904	177,180	49,807	43,916
28	'9 /'10	43,778			43,778	270,904	177,180	49,807	43,916
29	'10/'11	43,778			43,778	270,904	177,180	49,807	43,916
Total		2,090,514	769,616	333,650	987,248	6,116,210	4,005,560	111,989	990,762

Source: Feasibility Study Report on the Introduction of Containerization in the Islamic Republic of Pakistan, 1982.

1. **Project Name: Goods Terminal Improvement**

2. **Project Description**

2-1 **Objective**

15 base goods terminals are to be improved.

2-2 **Description**

Goods terminals are to be improved in order to reduce the train occupancy time by more efficient goods handling. The project components include:

	1987/88	1999/2000
LHR	200 (FEC 30) mil. Rs	399 (FEC 69) mil. Rs
KYC	214 (FEC 32) mil. Rs	428 (FEC 73) mil. Rs
SMA and other 5 stations		527 (FEC 90) mil. Rs
PSC and other 7 stations		524 (FEC 89) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**Phase I 1984/85**
3-2 **Time required for project completion**	**48 months**

4. **Cost of Project (Rupees in million)** **1,878 (FEC 321)**

5. **Preliminary Evaluation**

The goods terminal improvement project is involved in the railway transport enhancement program through the development of base stations. This project aims at increasing the goods handling capacity of such base stations by improving their arrival/departure and loading/unloading tracks. This project is prerequisite to the railway transport enhancement program which, designated as Case B, is selected in the evaluation of master plan alternatives.

1. **Project Name: Introduction of 3,000^t Traction**

2. **Project Description**

2-1 *Objective*

3,000^t *traction is to be achieved between KYC and LHR. For this purpose, station* sidetracks need to be extended.

2-2 **Description**

KYC and LHR stations need terminal improvement project, while LON, KWL, SWAL and RND stations require doubling works. Then, 13 stations between KYC and LON are to be improved. The project components can be summarized as:

	1987/88	1999/2000
SMA and other 3 stations	17 (FEC 3) mil. Rs	17 (FEC 3) mil. Rs
KOT and other 8 stations		39 (FEC 7) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start** — **Phase I 1987/88**

3-2 **Time required for project completion** — **12 months**

4. ***Cost of Project (Rupees in million)*** — ***56 (FEC 10)***

5. **Preliminary Evaluation**

The introduction of 3,000-ton traction is one of the railway improvement programs. Since 104 wagons will be hauled for one train in this program, the improvement of terminals at Karachi City and Lahore and the sidetrack extension and improvement at a number of way stations are required.

While the initial cost of such improvement is Rs. 56 million, the procurement cost of a smaller number (30) of 3,000-HP ELs is less than that of 44 2,000-HP ELs which are otherwise needed by approximately Rs. 178 million. Based upon this cost comparison analysis, and in consideration of such further effects as train number reduction, the 3,000-ton traction program is recommended.

1. **Project Name: Expansion of EL Fleet, Khanewal – Lahore**

2. **Project Description**

2-1 **Objective**

Additional ELs are to be provided for the expansion of transport capacity.

2-2 **Description**

Requirement of ELs for the traffic volume in 1999/2000 is 77. Out of these, 29 locos are already in use, and consequently 48 locos are to be newly procured. Also, LHR loco shed is to be expanded correspondingly. The project components can be summarized as:

locos	48 x 22.3 =	1,070 (FEC 760) mil. Rs
shed		100 (FEC 35) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**7th Plan period**
3-2 **Time required for project completion**	**36 months**

4. **Cost of Project (Rupees in million)** **1,170 (FEC 860)**

5. **Preliminary Evaluation**

The provision program of rolling stock including this project has been formulated in consideration of traffic volumes, turn-around times and the existing fleet inventories. In order to ensure the safe and smooth operation of trains supported by various projects proposed in this Study, this provision project of rolling stock is a prerequisite.

1. **Project Name: Rehabilitation of ELs**

2. **Project Description**

2-1 **Objective**

29 ELs which are presently in use are to be rehabilitated.

2-2 **Description**

These 29 ELs will be 30 years old by the year 1999/2000, and required to be rehabilitated.

29 x 22.3 x 0.4 = 259 (FEC 147) mil. Rs

3. **Time of Implementation**

3-1 **Prospective timing of project start**	**8th Plan Period**
3-2 **Time required for project completion**	**24 months**

4. **Cost of Project (Rupees in million)** — **259 (FEC 147)**

5. **Preliminary Evaluation**

The provision program of rolling stock including this project has been formulated in consideration of traffic volumes, turn-around times and the existing fleet inventories. In order to ensure the safe and smooth operation of trains supported by various projects proposed in this Study, this provision project of rolling stock is a prerequisite.

1. **Project Name: Expansion of DEL Fleet**

2. **Project Description**

2-1 **Objective**

Additional DELs are required for expansion of transport capacity.

2-2 **Description**

The total number of DELs required for traffic volume of the year 1999/2000 is 617. Since 474 locos are presently in use, additional 143 locos are to be provided. 30 3,000-HP locos are to be procured for heavy traction. The project components can be summarized as:

30 x 25.7 = 771 (FEC 455) mil. Rs

113 x 23.4 = 2,644 (FEC 1,877) mil. Rs, 2,106 (FEC 1,495)

3. **Time of Implementation**

3-1 **Prospective timing of project start** — Phase I 1983/84

3-2 **Time required for project completion** — 60 months

4. **Cost of Project (Rupees in million)** — 3,415 (FEC 2,332)

5. **Preliminary Evaluation**

The provision program of rolling stock including this project has been formulated in consideration of traffic volumes, turn-around times and the existing fleet inventories. In order to ensure the safe and smooth operation of trains supported by various projects proposed in this Study, this provision project of rolling stock is a prerequisite.

1. **Project Name: Re-engining of DELs**

2. **Project Description**

2-1 **Objective**

DELs in present use are to be re-engined by 1999/2000.

2-2 **Description**

85DELs have been recently re-engined. The remaining 389 DELs are to be re-engined.

	Total	1987/88
	389 x 13.63 = 5,302 (FEC 3,024) mil. Rs	682

(PC-1 42 loco Rehabilitation 11.957 x 1.14 = 13.63

6.82 ÷ 11.957 = 57% FEC)

3. **Time of Implementation**

3-1 **Prospective timing of project start** Phase I 1983/84

3-2 **Time required for project completion** 60 months

4. **Cost of Project (Rupees in million)** 5,302 (FEC 3,240)

5. **Preliminary Evaluation**

The provision program of rolling stock including this project has been formulated in consideration of traffic volumes, turn-around times and the existing fleet inventories. In order to ensure the safe and smooth operation of trains supported by various projects proposed in this Study, this provision project of rolling stock is a prerequisite.

1. **Project Name: Acquisition of Passenger Coaches**

2. **Project Description**

2-1 **Objective**

Additional passenger coaches are to be provided.

2-2 **Description**

The coach formations of passenger trains are:

Long distance (more than 700 km)	15 coaches (1 x ACC + 14 x 2nd class)	1,260 seats
Short distance	15 coaches (seat coaches)	1,440 seats
DL trains	5 coaches	450 seats

Since 2,061 coaches are available at present out of the total requirement of 2,674, the requirement of additional acquisition is 613 coaches.

Total	1987/88
613 x 3.47 = 2,127 (FEC 574) mil. Rs	212 mil. Rs

(PC-1 Procurement Passenger Coaches –750 coaches, Apr. 1976, Average of –ACC and 2nd– 1.67 (FEC 27%) mil. Rs, elevation LHR, RWP 2.08)

3. **Time of Implementation**

3-1 **Prospective timing of project start** — **Phase I 1983/84**

3-2 **Time required for project completion** — **60 months**

4. **Cost of Project (Rupees in million)** — **2,127 (FEC 574)**

5. **Preliminary Evaluation**

The provision program of rolling stock including this project has been formulated in consideration of traffic volumes, turn-around times and the existing fleet inventories. In order to ensure the safe and smooth operation of trains supported by various projects proposed in this Study, this provision project of rolling stock is a prerequisite.

1. **Project Name: Replacement of Passenger Coaches**

2. **Project Description**

2-1 **Objective**

A half of present passenger coaches are to be replaced.

2-2 **Description**

750 coaches out of the present fleet of 2,061 coaches have been replaced in 5th Period. Approximately half of the remaining fleet needs to be replaced due to overaging.

(2,061 - 750) x 0.5 = 655

	Total	1987/88
655 x 3.47 =	2,273 (FEC 614)	682

3. **Time of Implementation**

3-1 **Prospective timing of project start** Phase I 1983/84

3-2 **Time required for project completion** 60 months

4. **Cost of Project (Rupees in million)** 2,273 (FEC 614)

5. **Preliminary Evaluation**

The provision program of rolling stock including this project has been formulated in consideration of traffic volumes, turn-around times and the existing fleet inventories. In order to ensure the safe and smooth operation of trains supported by various projects proposed in this Study, this provision project of rolling stock is a prerequisite.

1. **Project Name: Introduction of High Speed Goods Train**

2. **Project Description**

2-1 Objective

High speed goods trains are to be introduced between KYC and LHR in association with the improvement of related facilities.

2-2 Description

5 high speed trains are planned to be operated between KYC and LHR hauling 3,000^{t} of wagons. They are designed to run at average speed of 50 km/h.

104^{cars} x 0.5$^{large\ sized}$ x 5^{trains} x 5^{days} x 1.2^{spare} = 1,560

	Total	1987/88
1,560 x 0.83 =	1,295 (FEC 350) mil. Rs	259

3. **Time of Implementation**

3-1 Prospective timing of project start — **Phase I 1987/88**

3-2 Time required for project completion — **24 months**

4. **Cost of Project (Rupees in million)** — **1,295 (FEC 350)**

5. **Preliminary Evaluation**

The provision program of rolling stock including this project has been formulated in consideration of traffic volumes, turn-around times and the existing fleet inventories. In order to ensure the safe and smooth operation of trains supported by various projects proposed in this Study, this provision project of rolling stock is a prerequisite.

1. **Project Name: Acquisition of Additional Wagons**

2. **Project Description**

2-1 Objective

Additional wagons are to be provided.

2-2 Description

The total requirement is estimated to be 38,608 based upon the present operating conditions. The project requirement can be obtained as follows:

Additional	38,608 - 34,740 = 3,868
Bogie wagon basis	3,868 x 0.5 = 1,934
High speed wagons	1,560 have already been provided.

(1,934 - 1,560) x 0.83 = 310 (FEC 84) mil. Rs

3. **Time of Implementation**

3-1 Prospective timing of project start	8th Plan period
3-2 Time required for project completion	24 months

4. **Cost of Project (Rupees in million)** 310 (FEC 84)

5. **Preliminary Evaluation**

The provision program of rolling stock including this project has been formulated in consideration of traffic volumes, turn-around times and the existing fleet inventories. In order to ensure the safe and smooth operation of trains supported by various projects proposed in this Study, this provision project of rolling stock is a prerequisite.

1. **Project Name: Replacement of Wagons**

2. **Project Description**

2-1 **Objective**

Wagons of present use are to be replaced or improved.

2-2 **Description**

A half of the present fleet is to be replaced with high speed wagons, while another half is to be improved to medium speed wagons. The project components can be summarized as:

Improvement	38,608 x 0.5 = 19,304	
Replacement	34,740 - 19,304 = 15,436	
	Total	1987/88
19,304 x 0.1 = 1,930 (FEC 521) mil. Rs		
15,436 x 0.83 = 6,406 (FEC 1,730) mil. Rs		641

3. **Time of Implementation**

3-1 **Prospective timing of project start** — **Phase I 1985/86**

3-2 **Time required for project completion** — **36 months**

4. **Cost of Project (Rupees in million)** — **8,336 (FEC 2,251)**

5. **Preliminary Evaluation**

The provision program of rolling stock including this project has been formulated in consideration of traffic volumes, turn-around times and the existing fleet inventories. In order to ensure the safe and smooth operation of trains supported by various projects proposed in this Study, this provision project of rolling stock is a prerequisite.

4. Listing and Preliminary Evaluation of Port Projects

4-1 Approaches and Methodologies of Preliminary Evaluation

Preliminary evaluation of the port projects in this Study also takes various approaches depending upon the types and study environments of projects. They vary from the introduction of economic/financial analyses, cost comparison analysis to the provision of descriptive analysis. Besides, the discussion often involves queueing theory for the justification of proposed projects to meet the estimated future demands. Queueing theory allows verification of the required number of berths taking into account the probability distribution of vessels' inter-arrival and service times which, in turn, considers peak/off-peak and other factors.

Let λ the mean arrival rate (expected number of arriving vessels per day), μ the mean service rate (expected number of served vessels per day) and S the number of berths. The ratio, $\rho = \lambda/S\mu$, is called the traffic intensity since it represents the average fraction of time that the berths will need to be busy serving vessels in order to keep up with the incoming vessels.

When ρ is less than 1.0, the system will approach a steady-state condition where its statistical properties are in statistical equilibrium. However, when $\rho \geqq 1.0$, the berths are unable to keep up with incoming traffic and statistical equilibrium cannot be achieved. Incidentally, $1/\lambda$ and $1/\mu$ can be interpreted as the expected interarrival time and expected service time, respectively.

As no significant attempt is made to control the arrivals in Pakistan, every time period of fixed length has the same probability of an arrival occurring. This can be referred to as "random arrivals". Mathematically, this stochastic process can be expressed as the number of arrivals falling in a Poisson process with parameter λ. It is also equivalent to say that interarrival times, represented by T_1, has an exponential distribution with parameter λ. Its probability density function is

$$f_{T_1}(t) = \lambda e^{-\lambda t}$$

Arising from a certain variety of vessel sizes, loads and some other factors, on the other hand, service time T_2 has a certain degree of variability somewhere between the great variability of the exponential distribution and the zero variability of the degenerate distribution. A probability that fills in this middle ground is called the Erlang distribution of phase 2 or 3, expressed as:

$$f_{T_2}(t) = \frac{(\mu k)^k}{(k-1)!} t^{k-1} e^{-k\mu t}$$ (see Figure 3-4-1).

The Erlang distribution of phase 1 can be understood as the exponential distribution while that of phase ∞ as the degenerate distribution, and at the same time the standard deviation for the kth phase Erlang distribution is $\frac{1}{\sqrt{k} \cdot \mu}$ against those of $\frac{1}{\mu}$ for the exponential distribution and zero for the degenerate distribution.

Phase k of the Erlang distribution is the "shape parameter" determining the degree of variability. The Erlang distribution of phase k with the mean of $\frac{1}{\mu}$ can be understood as the sum of k probability variables each of which follows an independent exponential distribution with the mean of $\frac{1}{k\mu}$. For a practical purpose in comprehensive transport analysis, the Erlang distributions of phase 2 and 3 do not make so significant differences.

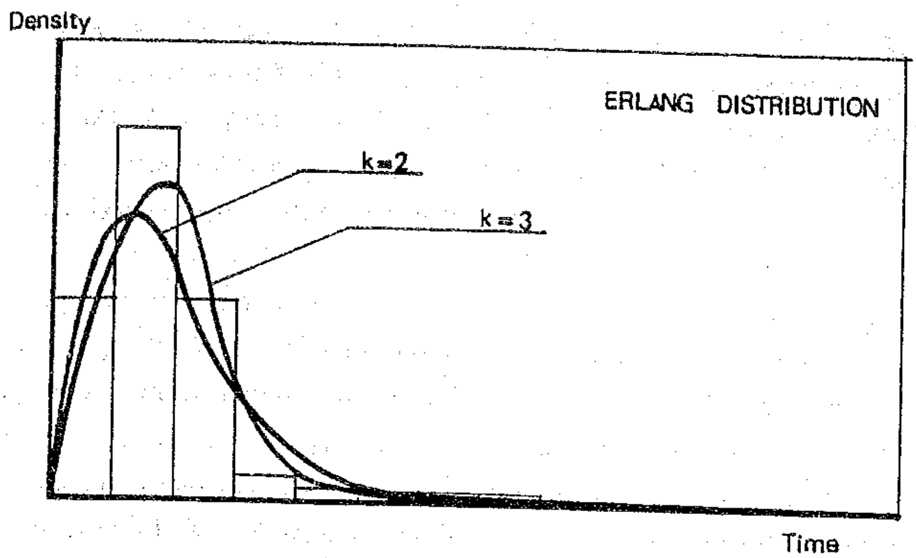


Fig. 4-1 **Berth Occupancy Time of Tankers at Karachi Port**

Table 4-1 can be referred to in order to obtain the expected length Lq for the berths system with $M/E_3/S$ behavior, that is,random arrival and Erlang service time. Then the expected waiting time Wq can be estimated as $Wq = Lq/\lambda$.

Table 4-1 Expected Length of Queue for $M/E_3/S$

ρ	S				
	1	2	3	4	5
0.10	0.74074E-02	0.14829E-02	0.31947E-03	0.71166E-04	0.16161E-04
0.20	0.33333E-01	0.11975E-01	0.46423E-02	0.18660E-02	0.76599E-03
0.30	0.85714E-01	0.41923E-01	0.22024E-01	0.11991E-01	0.66699E-02
0.40	0.17778E 00	0.10620E 00	0.67576E-01	0.44429E-01	0.29808E-01
0.50	0.33333E 00	0.22975E 00	0.16697E 00	0.12481E 00	0.94971E-01
0.55	0.44815E 00	0.32724E 00	0.25061E 00	0.19688E 00	0.15720E 00
0.60	0.60000E 00	0.46098E 00	0.36945E 00	0.30284E 00	0.25196E 00
0.65	0.80476E 00	0.64697E 00	0.53948E 00	0.45890E 00	0.39539E 00
0.70	0.10889E 01	0.91164E 00	0.78740E 00	0.69617E 00	0.61433E 00
0.75	0.15000E 01	0.13027E 01	0.11609E 01	0.10490E 01	0.95669E 00
0.80	0.21333E 01	0.19155E 01	0.17552E 01	0.16264E 01	0.15179E 01
0.85	0.32111E 01	0.29722E 01	0.27929E 01	0.26461E 01	0.25206E 01
0.90	0.54000E 01	0.51395E 01	0.49405E 01	0.47751E 01	0.46316E 01
0.95	0.12033E 02	0.11751E 02	0.11532E 02	0.11347E 02	0.11184E 02
0.98	0.32013E 02	0.31717E 02	0.31486E 02	0.31288E 02	0.31115E 02
0.99	0.65340E 02	0.65040E 02	0.64804E 02	0.64603E 02	0.64425E 02

Source: Hillier and Yu, Queueing Tables and Graphs

4-2 Major Outcomes of Preliminary Evaluation

(1) Full Container Terminal

The development project of full container terminal is perhaps one of the largest projects in the port sector of Pakistan. The major quantifiable benefits include: 1) reduction in cargo handling costs by raising cargo handling productivity through mechanization and containerization, 2) reduction in ship costs for berth waiting time and for loading/unloading cargo, mainly through increases in cargo handling capacity and productivity, 3) reduction of transport period, inland transport period, and port area freight accumulation through the increase of efficiency of inland transportation, and 4) reduction in container rental fees through the shortening of transport periods. Among the other benefits are contribution to the country's economic development, cargo damage reduction, packing cost reduction and so on.

Taking into account the major quantifiable benefits, economic analysis is conducted in the Feasibility Study of the Introduction of Containerization. If Karachi Port is selected as the development site, the internal rate of return for the containerization development project of the port terminal is calculated to be 16.2% (if the costs related to railway facilities are included, 14.3% as shown in Table 4-2). In the case that Port Qasim is assumed to be the development site, on the other hand, it comes down to 13.9% (if the costs related to railway facilities are included, 12.2%). Both results recognizably exceed the opportunity value of capital, and the project is considered to be justifiable from an economic point of view.

As for the site selection, Karachi Port is considered to be more advantageous for the containerization development of port terminal than Port Qasim. This can be partly observed from the results of economic analysis which are reported to be well established figures. In addition, since almost all existing port-related functions, facilities and know-how are situated in and around Karachi Port, selecting Port Qasim for a container port is considered likely to result in roundabout transportation of upcountry containers and container cargoes, that is, to Port Qasim, to the Karachi Port area and then to upcountry. Furthermore, it is discussed that from a liner operators' point of view, Karachi Port will be more favorable in consideration of the lower tariff levels and some other conditions of facilities and services.

On the assumption that 1) Karachi Port is selected as the port development site, 2) the interest rate of loan for both foreign and local currency portions is 11.6%, and 3) the current tariff will be raised by 25% on and after 1982/83, the financial rate of return is calculated to be 11.2%. It is analysed that the increase of current tariff is by any means necessary.

Table 4-2 Costs/Benefits and IRR - Shadow Price (Karachi Port - Feedback Ratio 30%)

IRR = 14.3% (Unit; '000 Rs)

No.	Fiscal Year	Costs				Benefits			
		Total	Construction	Equipment	Operation/ Maintenance	Total	Reduction in Ships' Staying Cost	Reduction in Cargo Handling Cost	Reduction in Time Cost
1	1982/'83	11,692	11,692						
2	'83/'84	77,240	77,240						
3	'84/'85	225,591	225,591						
4	'85/'86	306,633	306,633						
5	'86/'87	482,110	148,460	333,650					
6	'87/'88	12,672			12,672	71,468	53,896	4,732	12,840
7	'88/'89	21,394			21,394	117,374	70,072	25,186	22,117
8	'89/'90	33,848			33,848	238,392	160,806	44,025	33,561
9	'90/'91	43,778			43,778	270,904	177,180	49,807	43,916
10	'91/'92	43,778			43,778	270,904	177,180	49,807	43,916
11	'92/'93	43,778			43,778	270,904	177,180	49,807	43,916
12	'93/'94	43,778			43,778	270,904	177,180	49,807	43,916
13	'94/'95	43,778			43,778	270,904	177,180	49,807	43,916
14	'95/'96	43,778			43,778	270,904	177,180	49,807	43,916
15	'96/'97	43,778			43,778	270,904	177,180	49,807	43,916
16	'97/'98	43,778			43,778	270,904	177,180	49,807	43,916
17	'98/'99	43,778			43,778	270,904	177,180	49,807	43,916
18	'99/2000	43,778			43,778	270,904	177,180	49,807	43,916
19	2000/'1	43,778			43,778	270,904	177,180	49,807	43,916
20	'1 /'2	43,778			43,778	270,904	177,180	49,807	43,916
21	'2 /'3	43,778			43,778	270,904	177,180	49,807	43,916
22	'3 /'4	43,778			43,778	270,904	177,180	49,807	43,916
23	'4 /'5	43,778			43,778	270,904	177,180	49,807	43,916
24	'5 /'6	43,778			43,778	270,904	177,180	49,807	43,916
25	'6 /'7	43,778			43,778	270,904	177,180	49,807	43,916
26	'7 /'8	43,778			43,778	270,904	177,180	49,807	43,916
27	'8 /'9	43,778			43,778	270,904	177,180	49,807	43,916
28	'9 /'10	43,778			43,778	270,904	177,180	49,807	43,916
29	'10/'11	43,778			43,778	270,904	177,180	49,807	43,916
Total		2,090,514	769,616	333,650	987,248	6,116,210	4,005,560	111,989	990,762

Source: Feasibility Study Report on the Introduction of Containerization in the Islamic Republic of Pakistan, 1982.

(2) Liquid Berths

A new oil berth is proposed to be constructed at Karachi Port replacing the two existing berths, namely No. 2 which is a temporary structure and No. 3 which is deteriorated. If the proposed project is not implemented, ρ for berths No. 1 and No. 4 in and after 1985/86 is estimated to be 1.23 (λ = 0.96, μ = 0.48, 300 day operation per year), and the system will be unable to keep up with the incoming traffic. With the proposed project, on the other hand, ρ for the three berths including the proposed is estimated as 0.90 (λ = 1.06), indicating that the system is assumed to approach the statistical equilibrium. In consequence, the proposed project is required early in the 6th Five Year Plan period. Incidentally, since Wq is estimated to be 4.7 days based upon $M/E_3/S$ (Lq = 4.94), efforts are most encouraged to reduce Wq by various short-term and long-term devices including the handling rate increase.

Based upon the Policy that liquid products beyond 10 million tons per year will be handled at Qasim Port, an oil berth needs to be developed at Qasim Port before flowing demand reaches a considerable amount. One oil berth of 1.5 million ton capacity proposed to be constructed by 1988 aims at meeting this demand.

The rest of demand for liquid berth at Qasim Port can be estimated as shown in Table 4-3. Handling this demand by the buoy berth at the outer anchorage area instead of the conventional oil berth presumably at Bundal Island is advantageous under the given conditions in the respects including the following:

1) The total construction cost is estimated less.
2) The congestions in the channel expected in the long-term future can be partly eased.
3) The navigation of tankers along the channel of approximately 15 km portion can be saved.
4) The security from accidents can be maintained due to avoidance of large tankers coming into the channel.

The first point can be further elaborated based upon cost comparison analysis in use of queueing theory as follows. If four conventional berths are planned for the year 2000, ρ is estimated to be 1.03 (the apparent service rate = 0.38), while ρ for five berths is 0.82. Therefore, five berths are actually required, and four berths seem to be the least requirement even upon successful improvement of berth operation. The construction of four oil berths at Qasim Port is estimated to cost approximately 1.4 billion Rupees, which is more than the estimated cost of the buoy berth and related facilities of equivalent capacity.

Table 4-3 Estimated Demand for Liquid Berths Excluding the First One at Port Qasim

Year	Import/Export(1000t)	Number of Vessels per Year	Number of Vessels per Day
1988 / 89	670	26	0.07
1989 / 90	1,437	56	0.15
1990 / 91	2,252	87	0.24
1991 / 92	3,118	120	0.33
1992 / 93	4,039	156	0.43
1993 / 94	5,018	193	0.53
1994 / 95	6,059	234	0.64
1995 / 96	7,165	276	0.76
1996 / 97	8,341	321	0.88
1997 / 98	9,591	369	1.01
1998 / 99	10,920	420	1.15
1999 / 00	12,295	473	1.30

Source: Study Team
Note: (1) A constant annual average growth rate is assumed to project the intermediate years.
(2) The average load per vessel is assumed to be 26,000t.

(3) Mini-Port at Gwadar

The construction of a mini-port in Gwadar was studied by JICA in 1980 and the following benefits were identified:

1) The availability of a modern fishing port will improve the fishing productivity in the region and increase the protein supply in the region as well as Pakistan.
2) The export of a large quantity of high-grade shrimp will become possible, contributing to securing more foreign currencies.
3) 150-ton class coastal steamers will become able to berth at the proposed mini-port, accelerating the use of coastal shipping.
4) After the development of mini-port, larger barges may be used, reducing the cargo-handling time and the anchorage days of coastal trade vessels.
5) The project is expected to play an important role for the development of Baluchistan Province and in particular Gwadar City.

Quantifying the first four effects, the cost benefit analysis can be concluded with the internal rate of return of 3.8%. This appears to be a rather low return. Upon implementation of the project, therefore, the expansion of Gwadar based fishery activities in an efficient manner will have to be most encouraged. At the same time, the indirect effects of the project including the last one in the above list are to be taken into consideration.

(4) Others

By the conventional fertilizer unloading system of 1,750-ton daily handling rate, the berth occupancy of a vessel with the average load of 13,000 tons is more than eight days. Without the proposed fertilizer terminal development at Qasim Port, the required number of berths to keep up with the estimated volume of incoming fertilizer and phosphate/sulpher of 1.5 million tons in 1987/88 and 3.1 million tons in 1999/2000 are about four and seven, respectively. The proposed development of equipments, whose cost is almost equivalent to the construction cost of 1.5 berth, is expected to enable one terminal of 279 m long to handle the demand for 1999/2000.

The major aim of wheat terminal development at Qasim Port is to clear the apron occupancy of bulk wheat by the conventional handling way. Although the project is not necessarily requisite from a point of view of berth congestions (ρ of one berth for wheat products in 1999/2000 = 0.5), an early implementation is favored from a point of view of berth apron management.

The small boat harbor basin is presently occupied during peak hours by 300 to 400 small boats, which are of many and still-increasing motor launches offering access to the public, approximately 50 sail boats stationed in the basin and roughly 200 launches belonging to KPT, Navy, Coast Guard and oil companies. As stated in KPT Act (V-30), Karachi Port is to provide such public landing facilities free of charge. The existing facilities which were built in 1920 and are becoming deteriorated need to be rebuilt before too late.