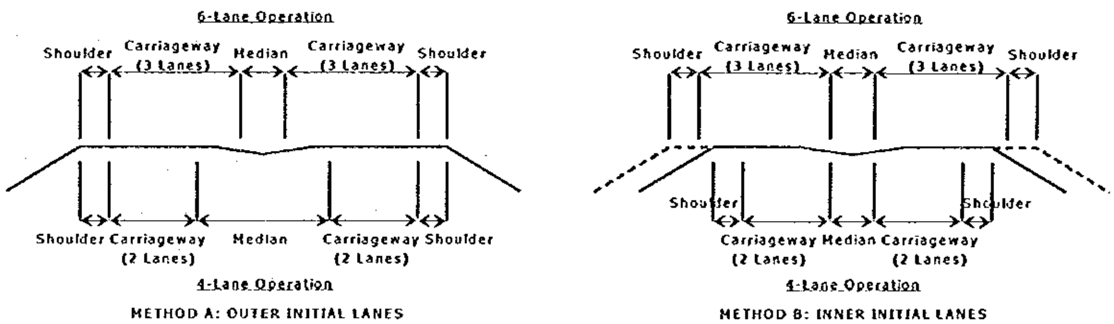
9.4.3 Stage Construction Methodology

Stage construction is a scheme of initially constructing smaller number of lanes appropriate for immediate traffic demand, and additionally constructing ultimately planned number of lanes when traffic demand grows later time in order to minimize the initial cost. This scheme is most effective when the initial traffic demand is small but it is expected to grow rapidly in the future. A simple summation of construction costs of the initial stage plus the ultimate stage will be generally larger than the normal scheme of constructing the ultimate number of lanes at the initial stage. In order to apply a stage construction scheme, therefore, the value of the total (discounted) benefit over the total (discounted) cost for stage construction should be larger than that of the normal scheme.

Due to the traffic characteristics it is expected that a stage construction scheme is considered very effective for K-G and G-M Expressways. The designated staging scheme will be initially 6 lanes and ultimately 8 lanes for the JUNCTION - Ghaziabad IC section, and initially 4 lanes and ultimately 6 lanes for the other sections. The stage construction for 4 to 6 lanes have basically 2 methods as shown in Figure 9.4.1. The stage construction from 6 to 8 lanes is basically the same.

Figure 9.4.1: Typical Methods of Stage Construction



Method A is more appropriate when the growth of traffic is expected in near future. The additional construction is easier since the embankment is substantially completed at the initial stage, however, the initial cost can not be reduced substantially. In this case bridges are usually constructed for ultimate lanes due to the difficulty of the additional construction.

Method B is simply better when the timing of additional construction is expected in far future or uncertain in foreseeable future since the initial cost can be lower than Method A. When the additional construction for the ultimate stage actually happens, however, it will be more costly since additional embankment will be necessary.

The expected timing for widening for ultimate lanes is around year 2021 - 2026 as discussed in the previous section. This means that the period of operation with the initial lanes is more than 20 years. The policy on stage construction, therefore, should focus on minimizing the initial construction cost, rather than minimizing the additional cost at the time of widening.

With this policy the construction method should be Method B: Inner Initial Lane Method. The width of initial bridges could be for ultimate lane width, and it could be better for small bridges, however, the width of major bridges should be for the initial lanes to minimize the initial construction cost. This will be discussed more in detail in the section for construction planning.

9.5 Preliminary Engineering Design

9.5.1 Preliminary Geometric Design

(1) Horizontal Alignment

The horizontal alignment of the proposed optimum route was refined against major control points within an accuracy of the available information including site observation and investigation. The topographic survey was performed based on the designated alignment, and preliminary design was performed on the surveyed topographic sheets.

The station (chainage) was set forth from Kundli IC (STA0+600) to Ghaziabad North JCT (STA41+400) for K-G Expressway, and from Ghaziabad IC (STA00-200) to Meerut IC (STA39+750) for G-M Expressway.

A summary of design features for horizontal alignment for the designed routes are shown in Table 9.5.1. A set of drawings for preliminary design of K-G and G-M Expressways are shown in the separate volume. The design was performed in the scale of 1: 2,500, and the sets of design drawings are prepared for A1 size (S=1: 2,500) and A3 size (S=1:5,000).

Table 9.5.1: Summary of Design Features of Horizontal Alignment of the Projects

Item	Unit	K-G Expressway (Kundli IC - JCT)	G-M Expressway (Ghaziabad IC-Meerut IC)
Design Speed	km/h	120	120
Expressway Length	km	41.2 (including JCT)	40.0
Minimum Radius	m	1,500 (K-G Ramp)	2,000
Minimum Curve Length	m	485 (K-G Ramp)	1,694 (STA1+867 - 3+561)
Maximum Curve Length	m	6,000 (STA18+650 - 24+622)	6,300 (STA26+887 - 33+187)
Maximum Tangent Length	m	2,940 (STA10+570 - 13+510)	2,403 (STA14+071 - 16+474)
Minimum Tangent Length between Opposite Curves	m	2,450 (STA10+570 - 13+510)	1,175 (STA7+107 - 8+282)
Minimum Tangent Length between Same-directional Curves	m	1,140 (STA5+000 - 6+140)	N.A.
Maximum Superelevation	%	4 (K-G Ramp)	3

Source: JICA Study Team

(2) Vertical Alignment

The existing crossing facilities such as roads, rivers, distributary canals and drains, and railway lines are principal controls for vertical alignment design. At the same time, both of the expressway stretches are all on embankment structures except bridge and culvert sections, and it is critical to keep the height of the embankment low to save the construction cost. Also, the minimum level of embankment height for the flood prone area should be maintained.

With these considerations, the embankment height at the western side of Yamuna River is kept to be 5 to 6 m to avoid the influence of floods. The eastern side of Yamuna River and other area is kept to have an embankment height of 2 to 3 m to save the amount of earthworks. To keep necessary clearance over the vertical control points, the vertical alignment will be elevated for the necessary clearance with a reasonable approach grades. A minimum grade of 0.3 % was maintained where the vertical alignment can be completely flat to provide minimum drainage gradient.

A summary of design features for vertical alignment is shown in Table 9.5.2.

Table 9.5.2: Summary of Design Features of Vertical Alignment of the Projects

Item	Unit	K-G Expressway (Kundli IC - JCT)	G-M Expressway (Ghaziabad IC-Meerut IC)
Design Speed	km/h	120	120
Expressway Length	km	41.2 (including JCT)	40.0
Maximum Gradient	%	2 %	2 %
Minimum Vertical Curve Length (crest)	m	300	300
Minimum Vertical Curve Radius (crest)	m	15,800	16,700
Minimum Vertical Curve Length (sag)	m	200	200
Minimum Vertical Curve Radius (sag)	m	9,500	8,300

Source: JICA Study Team

9.5.2 Preliminary Design of Interchanges, Toll Plaza and Rest Facilities

(1) Interchanges

The five interchanges of Kundli, Khekra, Meerut, Modinagar, Ghaziabad, and Ghaziabad North Junction are designed based on the result of discussion in Section 9.3.3.

Ghaziabad IC is necessary for FNG Expressway, and has been already designed as a partial-cloverleaf type interchange by the FNG Expressway Study. However, as is discussed in Section 9.3.3, an alternative recommendation is to change this interchange to a double-trumpet type to avoid throughway toll plazas. The designed Ghaziabad IC, therefore, is an alternative proposal against the FNG Expressway Study, the cost of which is not included in the K-G or G-M Expressway Projects.

The base case is assuming that FNG will construct Ghaziabad IC by the cloverleaf type, and K-G and G-M Expressway will provide a throughway toll plaza between Ghaziabad IC and Ghaziabad North Junction, which will be the boundary toll gates for the expressways.

The designed number of toll gates at each interchange and toll plaza is computed by the following method indicated in Design Guideline-C.

$$N = V \times Sm \ / 3600$$

where, N: Required number of toll gate lanes
V: Total number of vehicles using toll gates (vehicle/hour)
Sm: Average transaction time per vehicle (seconds)

(1) Exit Ramp
$Sm = (6.0 \times Ve + 8.8 \times Vp + 12.0 \times Ve) / V$
Where, Ve: Estimated number of passenger vehicles with exact change
Vp: Estimated number of passenger vehicles without exact change
Vc: Number of trucks and buses

(2) Entrance Ramp
Sm = 6.0 sec.

The designed number of toll gates are shown in Table 9.5.3 for year 2026 and 2016.

Table 9.5.3: Required Number of Toll Gate Lanes (Year 2026/2016)

Toll Gate Location			ADT	DHV	Ve	Vp	Vc	V	Sm	N	
			pcu/day	pcu/hr	vehicles	vehicles	vehicles	vehicles	sec	lanes	
Year 2026	Kundli IC	Exit	69,900	5,243	916	1,831	1,389	4,136	9.25	10.63	11
		Entrance	69,900	5,243				4,012	6.00	6.69	7
	Khekra IC	Exit	24,300	1,823	318	637	483	1,438	9.25	3.70	4
		Entrance	24,300	1,823				1,395	6.00	2.32	3
	Merrut IC	Exit	33,840	2,538	443	887	673	2,002	9.25	5.15	6
		Entrance	33,840	2,538				1,942	6.00	3.24	4
	Modinagar IC	Exit	23,880	1,791	313	626	475	1,413	9.25	3.63	4
		Entrance	23,880	1,791				1,371	6.00	2.28	3
	Ghaziabad IC	Exit	71,580	5,369	938	1,875	1,423	4,236	9.25	10.89	11
		Entrance	71,580	5,369				4,109	6.00	6.85	7
Year 2016	Kundli IC	Exit	47,040	3,528	616	1,232	935	2,784	9.25	7.16	8
		Entrance	47,040	3,528				2,700	6.00	4.50	5
	Khekra IC	Exit	14,940	1,121	196	391	297	884	9.25	2.27	3
		Entrance	14,940	1,121				858	6.00	1.43	2
	Merrut IC	Exit	18,420	1,382	241	483	366	1,090	9.25	2.80	3
		Entrance	18,420	1,382				1,057	6.00	1.76	2
	Modinagar IC	Exit	8,640	648	113	226	172	511	9.25	1.31	2
		Entrance	8,640	648				496	6.00	0.83	1
	Ghaziabad IC	Exit	42,840	3,213	561	1,122	851	2,535	9.25	6.52	7
		Entrance	42,840	3,213				2,459	6.00	4.10	5

Note: 1) Ghaziabad IC is optional against Ghaziabad Toll Plaza
2) Vehicle Composition: Car (52.4%), Mini Bus (3.0%), Large Bus (9.3%), LCV (13.4%), 2-Axle Truck (19.8%), Multi-Axle Truck (9.2%)
3) K=7.5%, D=60%

Source: JICA Study Team

The design layout and the features for the interchanges are summarized in Figure 9.5.1 (1)~(5), and the same for the junction are summarized in Figure 9.5.2.

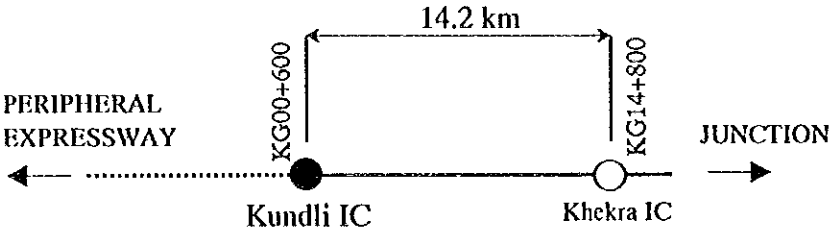
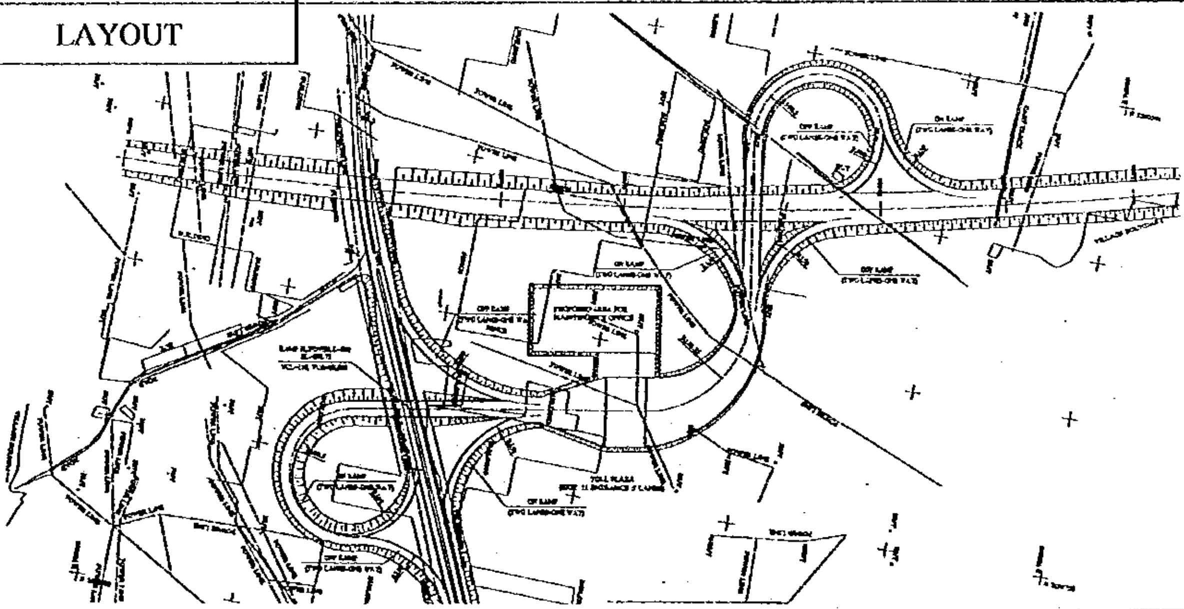
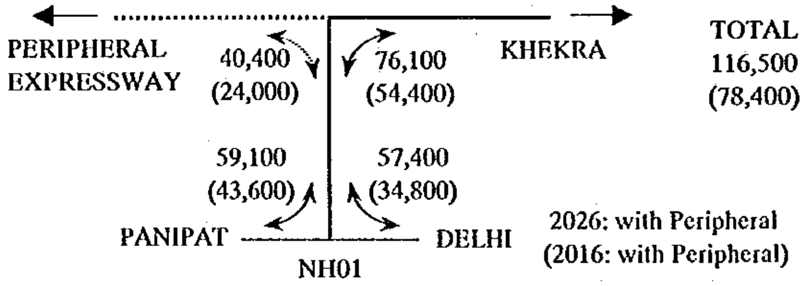
<table>
<tr><td>NAME</td><td colspan="2">KUNDLI INTERCHANGE</td></tr>
<tr><td>LOCATION</td><td colspan="2">
</td></tr>
<tr><td>LAYOUT</td><td colspan="2"></td></tr>
<tr><td rowspan="2">ACCESS ROAD</td><td>NAME</td><td>NATIONAL HIGHWAY NO. 1</td></tr>
<tr><td>NO. LANES</td><td>4 LANES DIVIDED</td></tr>
<tr><td>ON/OFF TRAFFIC IN 2026 (2016) (PCU/DAY)</td><td colspan="2">
</td></tr>
<tr><td>NO. OF TOLL GATE LANES FOR 2026 (2016)</td><td colspan="2">ON : 7 (5) OFF : 11 (8) TOTAL : 18 (13)</td></tr>
<tr><td>TYPE AND CHARACTERISTICS</td><td colspan="2">Double Trumpet Type (B-type on the Expressway side)
- Busy interchange between major national highway (NO1) and the K-G Expressway.
- Since it is a terminal interchange, the ramps are paved only for K-G Expressway, and the ramps for Peripheral Expressway will not be paved. (Pavement will be done by Peripheral Expressway Project)
- All ramps are 2 lanes.</td></tr>
</table>

Figure 9.5.1: Interchange Layout (1)

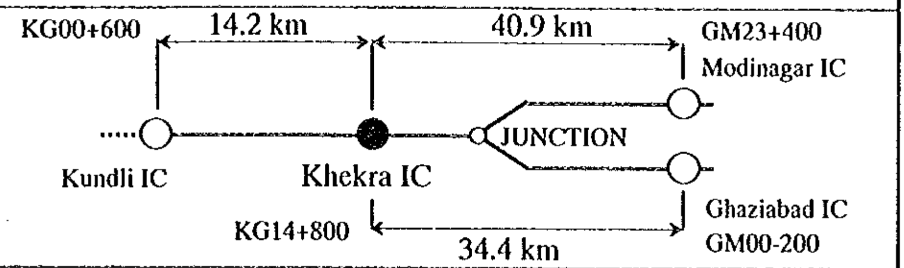
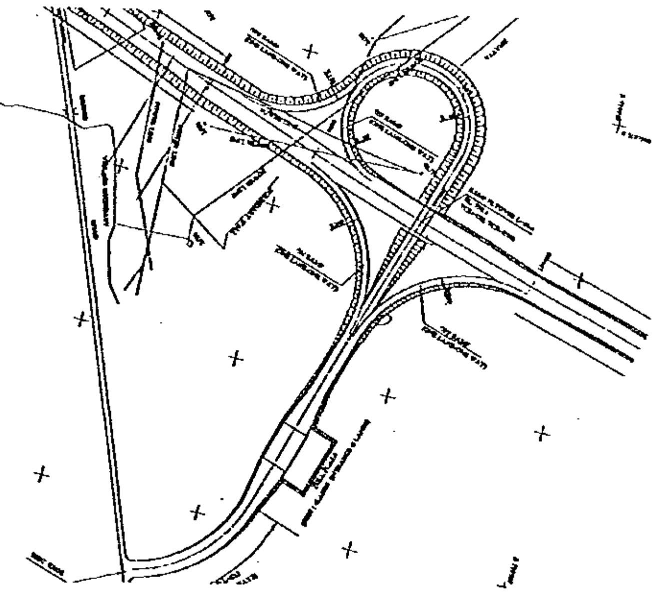
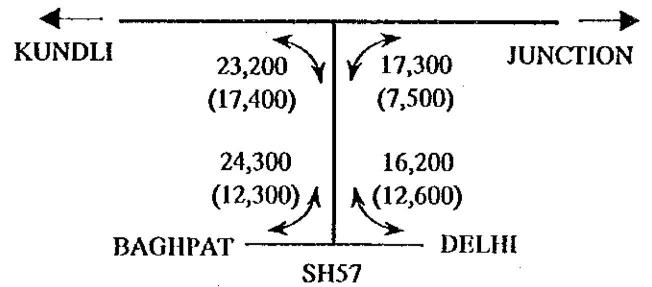
<table>
<tr><td>NAME</td><td colspan="2">KHEKRA INTERCHANGE</td></tr>
<tr><td>LOCATION</td><td colspan="2">
</td></tr>
<tr><td>LAYOUT</td><td colspan="2"></td></tr>
<tr><td rowspan="2">ACCESS ROAD</td><td>NAME</td><td>STATE HIGHWAY NO. 57</td></tr>
<tr><td>NO. LANES</td><td>2 LANES UNDIVIDED</td></tr>
<tr><td>ON/OFF TRAFFIC IN 2026 (2016) (PCU/DAY)</td><td colspan="2">
</td></tr>
<tr><td>NO. OF TOLL GATE LANES FOR 2026 (2016)</td><td colspan="2">ON : 3 (2) OFF : 4 (3) TOTAL : 7 (5)</td></tr>
<tr><td>TYPE AND CHARACTERISTICS</td><td colspan="2">Trumpet Type (A)
- Local interchange for Khekra, Baghpat and Tronica Industrial City.
- Since main direction is for Kundli (Expressway side), A-type is recommended
- All ramps are 1 lane.</td></tr>
</table>

Figure 9.5.1: Interchange Layout (2)

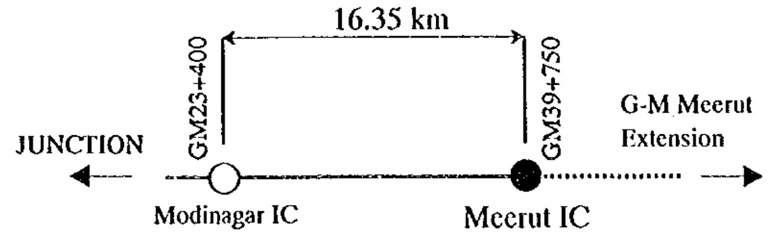
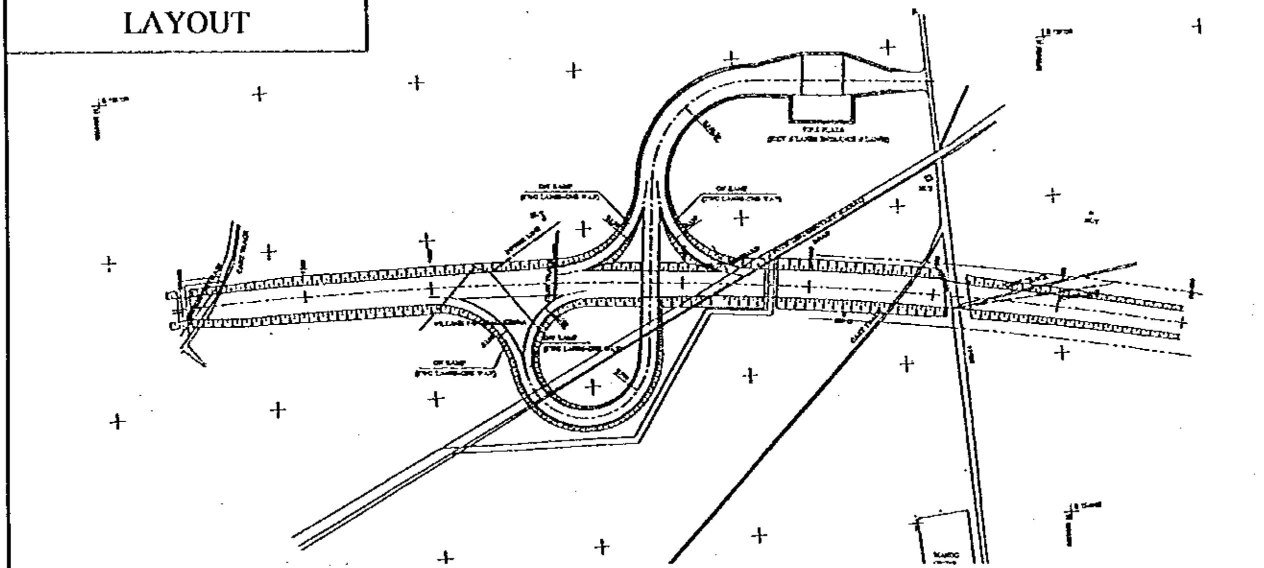
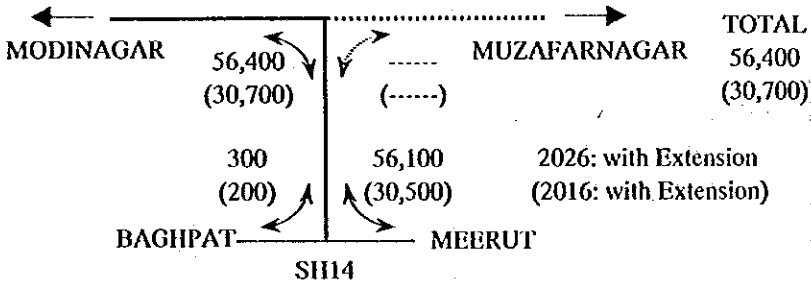
NAME		MEERUT INTERCHANGE
LOCATION		
LAYOUT		
ACCESS ROAD	NAME	STATE HIGHWAY NO. 14
	NO. LANES	2 LANES UNDIVIDED
ON/OFF TRAFFIC IN 2026 (2016) (PCU/DAY)		
NO. OF TOLL GATE LANES FOR 2026 (2016)		ON : 4 (2) OFF : 6 (3) TOTAL : 10 (5)
TYPE AND CHARACTERISTICS		**Trumpet Type (B)** - Terminal interchange of G-M Expressway until the Meerut Extension will be implemented. - Since it is a terminal interchange, the ramps are paved only for G-M Expressway, and the ramps for Meerut Extension will not be paved. (Pavement will be done by Meerut Extension Project) - Since SH14 side traffic is strongly biased to Meerut direction, no grade separation will be necessary.(at-grade intersection) - All ramps are 2 lanes.

Figure 9.5.1: Interchange Layout (3)

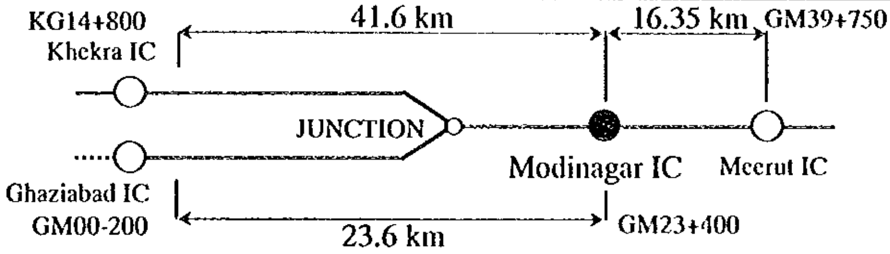
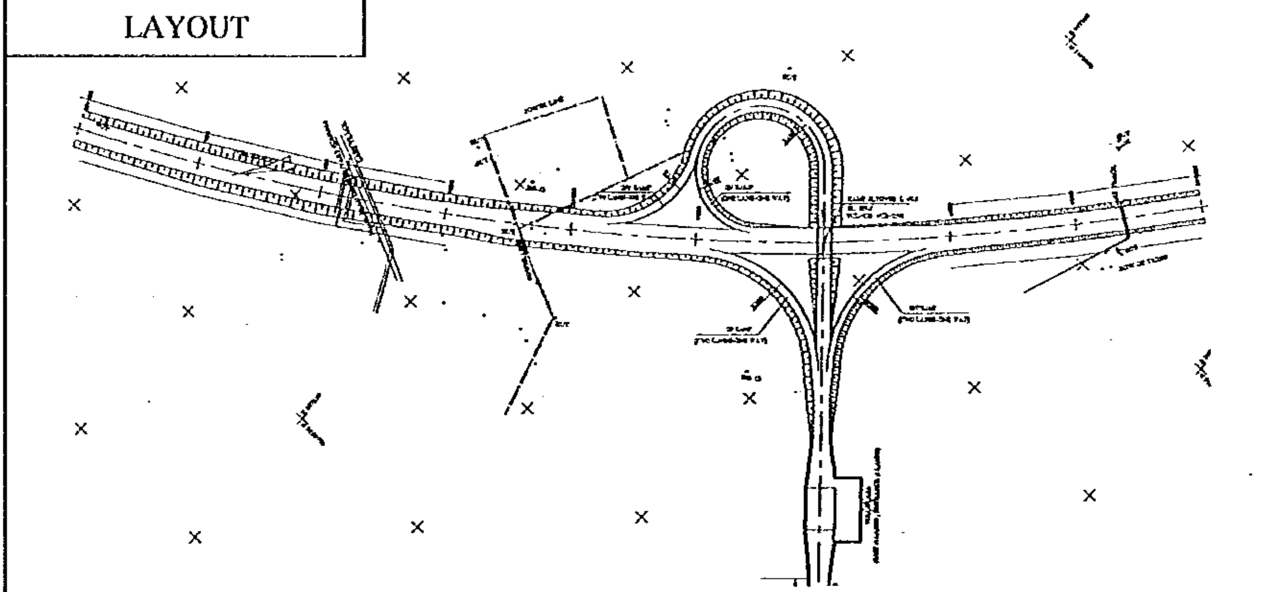
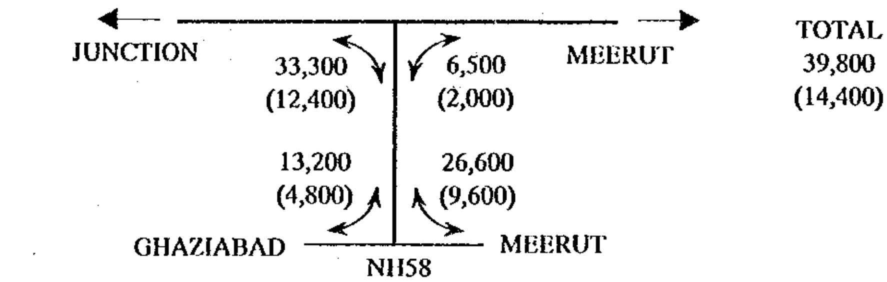
NAME	MODINAGAR INTERCHANGE	
LOCATION		
LAYOUT		
ACCESS ROAD	NAME	NATIONAL HIGHWAY NO. 58
	NO. LANES	4 LANES DIVIDED
ON/OFF TRAFFIC IN 2026 (2016) (PCU/DAY)		
NO. OF TOLL GATE LANES FOR 2026 (2016)	ON : 3 (1) OFF : 4 (2) TOTAL : 7 (3)	
TYPE AND CHARACTERISTICS	**Trumpet Type (A)** - Local interchange for Modinagar. - Since main direction is for Junction (Expressway side), A-type is recommended - Ramps for Junction (ON/OFF) will be 2 lanes, and other ramps will be 1 lane. - The intersection at NH58 will be at-grade.	

Figure 9.5.1: Interchange Layout (4)

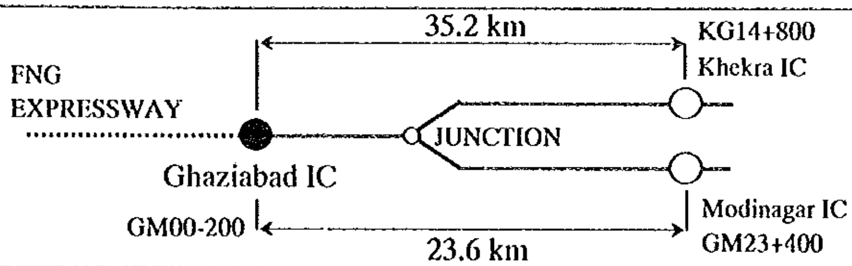
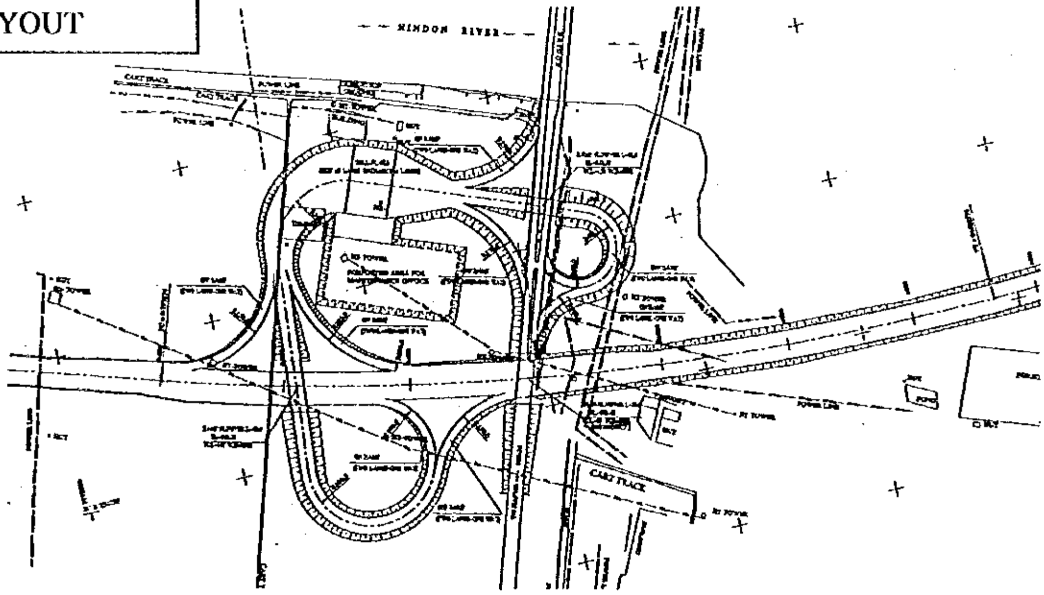
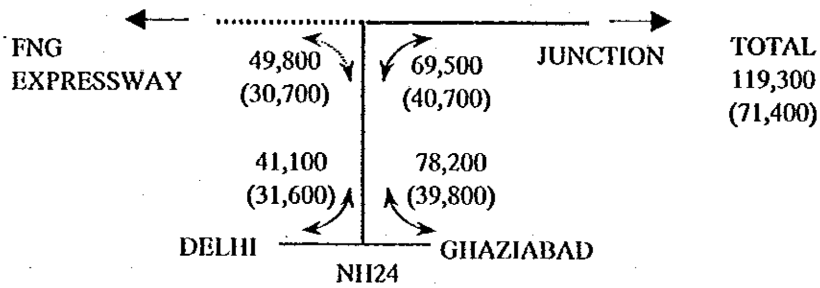
<table>
<tr><td>NAME</td><td colspan="2">GHAZIABAD INTERCHANGE (OPTIONAL DESIGN)</td></tr>
<tr><td>LOCATION</td><td colspan="2">
</td></tr>
<tr><td>LAYOUT</td><td colspan="2"></td></tr>
<tr><td rowspan="2">ACCESS ROAD</td><td>NAME</td><td>NATIONAL HIGHWAY NO. 24</td></tr>
<tr><td>NO. LANES</td><td>4 LANES DIVIDED</td></tr>
<tr><td>ON/OFF TRAFFIC IN 2026 (2016) (PCU/DAY)</td><td colspan="2">
</td></tr>
<tr><td>NO. OF TOLL GATE LANES FOR 2026 (2016)</td><td colspan="2">ON : 7 (5) OFF : 11 (7) TOTAL : 18 (12)</td></tr>
<tr><td>TYPE AND CHARACTERISTICS</td><td colspan="2">Double Trumpet Type (A-type on the Expressway side)
- Alternative design against FNG proposal (partial-cloverleaf).
- Busy interchange between major national highway (NH24) and G-M / FNG Expressway.
- All ramps are 2 lanes.</td></tr>
</table>

Figure 9.5.1: Interchange Layout (5)

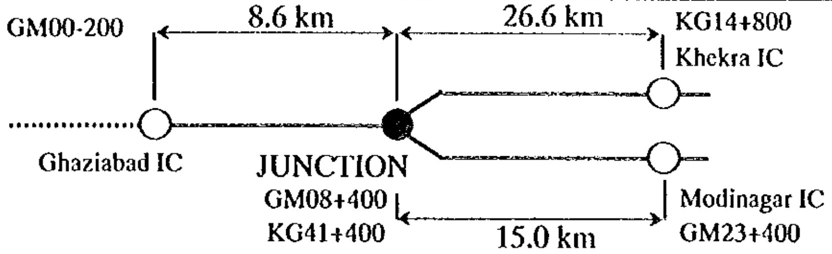
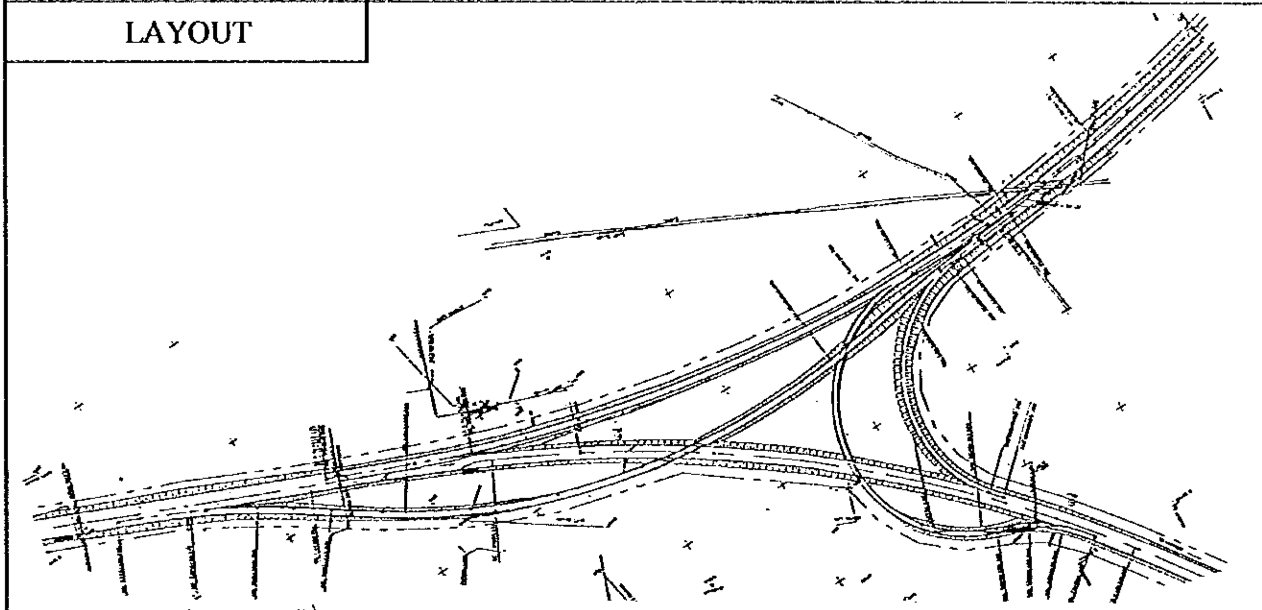
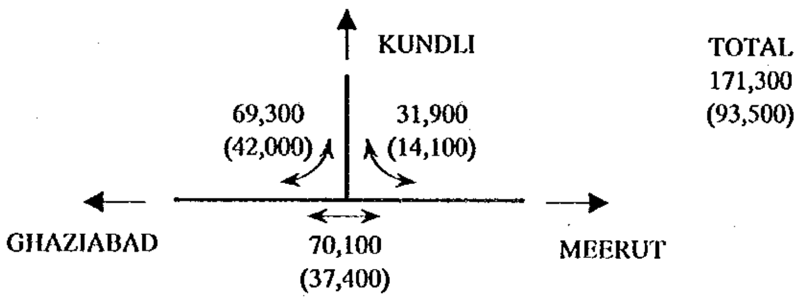
NAME	GHAZIABAD NORTH JUNCTION	
LOCATION		
LAYOUT		
ACCESS ROAD	NAME	NOT APPLICABLE
	NO. LANES	NOT APPLICABLE
ON/OFF TRAFFIC IN 2026 (2016) (PCU/DAY)		
NO. OF TOLL GATE LANES FOR 2026 (2016)	NOT APPLICABLE	
TYPE AND CHARACTERISTICS	**Y (Direct-Fastening) Type** - Major directions are Ghaziabad - Meerut and Ghaziabad - Kundli, and all the ramps for these connections will be 2 lanes. - Kundli - Meerut is a minor direction, and the ramps are both 1 lane. - Junction is designed that K-G is connected to G-M throughway. - Major direction ramps are designed to satisfy the throughway geometric design standard.	

Figure 9.5.2: Junction Layout

(2) Toll Plaza

The term of Toll Plaza is being used in this study to mean toll gates on the throughway. The toll plaza should be avoided wherever possible on expressways to create a traffic bottleneck at peak hours, and the interchanges were designed with trumpet type to provide the toll gates off the throughway. If FNG Expressway adopts the partial cloverleaf design for Ghaziabad IC with NH24, however, a toll plaza (Ghaziabad Toll Plaza) should be provided as a boundary toll gate with FNG. For the purpose of identifying the area, facility and cost, a typical plan drawing is prepared for the toll plaza design. A recommended location would be around GM6+700, however, the exact location is not indicated on the plan and profile drawings.

The Ghaziabad Toll Plaza is designed to have the following number of gates. The computation method is as same as in the interchange toll gate design.

Table 9.5.4: Required Number of Toll Plaza Lanes (Year 2026/2016)

Toll Gate Location			ADT	DHV	Ve	Vp	Vc	V	Sm	N	
			pcu/day	pcu/hr	vehicles	vehicles	vehicles	vehicles	sec	lanes	
2026	Ghaziabad	Throughway	132,300	5,954	1,040	2,080	1,578	4,687	9.25	12.08	13
	Toll Plaza	Throughway	132,300	5,954	1,040	2,080	1,578	4,687	9.25	12.08	13
2016	Ghaziabad	Throughway	74,400	3,348	585	1,170	887	2,642	9.25	6.79	7
	Toll Plaza	Throughway	74,400	3,348	585	1,170	887	2,642	9.25	6.79	7

Note: 1) The computation process is the same as in Table 9.5.3.
2) Vehicle Composition: Car (52.4%), Mini Bus (3.0%), Large Bus (9.3%), LCV (13.4%), 2-Axle Truck (19.8%), Multi-Axle Truck (9.2%)
3) K=7.5%, D=60%

Source: JICA Study Team

(3) Rest Facility

There are different terminology in different countries for exclusive rest facility on expressway. Guideline-C, however, recommend two types of facilities for Indian expressways, which are a) Rest Areas, and b) Service Areas. The rest area is recommended to have about 10,000 m^2 area with facilities of benches, tables, shelters, drinking fountains, telephones and toilets. The service area is a larger in size (about 60,000 to 100,000 m^2) and more service facilities of fuel station, service station, work shop, restaurant, rest facilities (as above), snack bars, dormitory, motel, telephones and tourist information center.

For K-G and G-M Expressways, it is recommended that a rest area be provided on both of the expressways. Due to the balance of kilometrage, one should be located between Khekra IC and Junction (Rataul Rest Area) on K-G Expressway, and the other should be located between Modinagar IC and Junction (Muradnagar Rest Area) on G-M Expressway. For the purpose of identifying the area, facility and cost, a typical plan drawing is prepared for the rest area design. Recommended locations would be around KG29+000 (Rataul RA) and GM17+500 (Muradnagar RA), however, the exact location is not indicated on the plan and profile drawings.

By Guideline-C, the necessary parking lots are computed as follows:

$$NPS = (AADT \times DDF \times SF \times VR \times RF) / R$$

where,
- NPS: Number of parking spaces
- AADT: Annual average daily traffic (vehicles/day)
- DDF: Directional distribution factor (60%)
- SF: Seasonal factor (1.25)
- R: Rotation rate
- VR: Visitation rate, number of visiting vehicles to traffic volume
- RF: Rush factor, number of visiting vehicles to traffic volume

The computation for parking requirements are shown in Table 9.5.5.

Table 9.5.5: Parking Lot Numbers for Rest Area (Year 2026/2016)

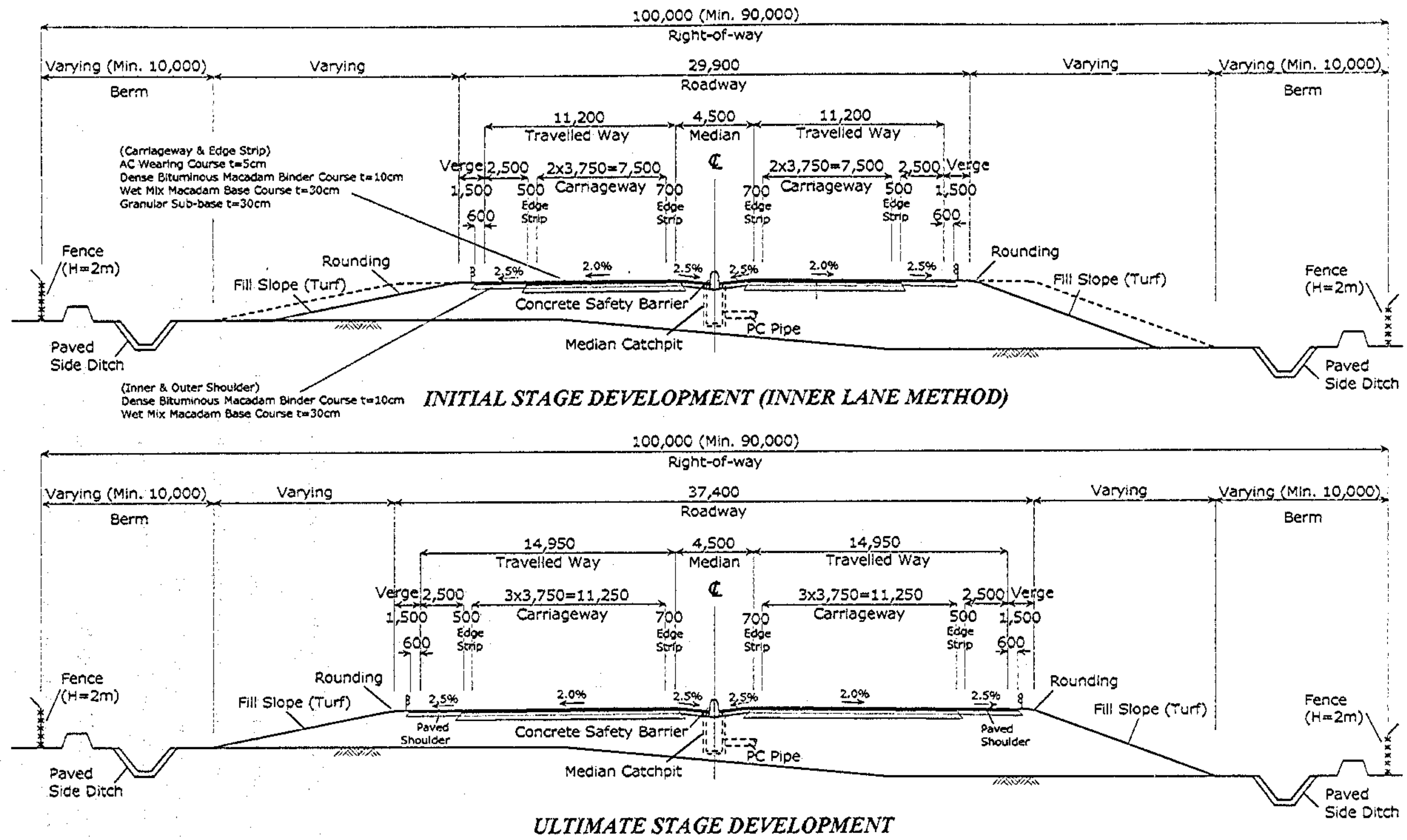
Name	Year	Vehicle	AADT		VR	RF	R	NPS
			Total pcu	veh/day				
Rataul	2026	Car	98,100	53,030	0.05	0.100	4	50
		Bus		4,660	0.05	0.125	4	6
		Goods Vehicle		19,760	0.06	0.100	3	30
	2016	Car	52,900	29,400	0.05	0.100	4	28
		Bus		2,580	0.05	0.125	4	4
		Goods Vehicle		10,960	0.06	0.100	3	17
Muradnagar	2026	Car	101,300	53,450	0.05	0.100	4	51
		Bus		4,690	0.05	0.125	4	6
		Goods Vehicle		19,920	0.06	0.100	3	30
	2016	Car	50,700	26,780	0.05	0.100	4	26
		Bus		2,350	0.05	0.125	4	3
		Goods Vehicle		9,980	0.06	0.100	3	15

Source: JICA Study Team

9.5.3 Typical Cross Sections and Right-of-way

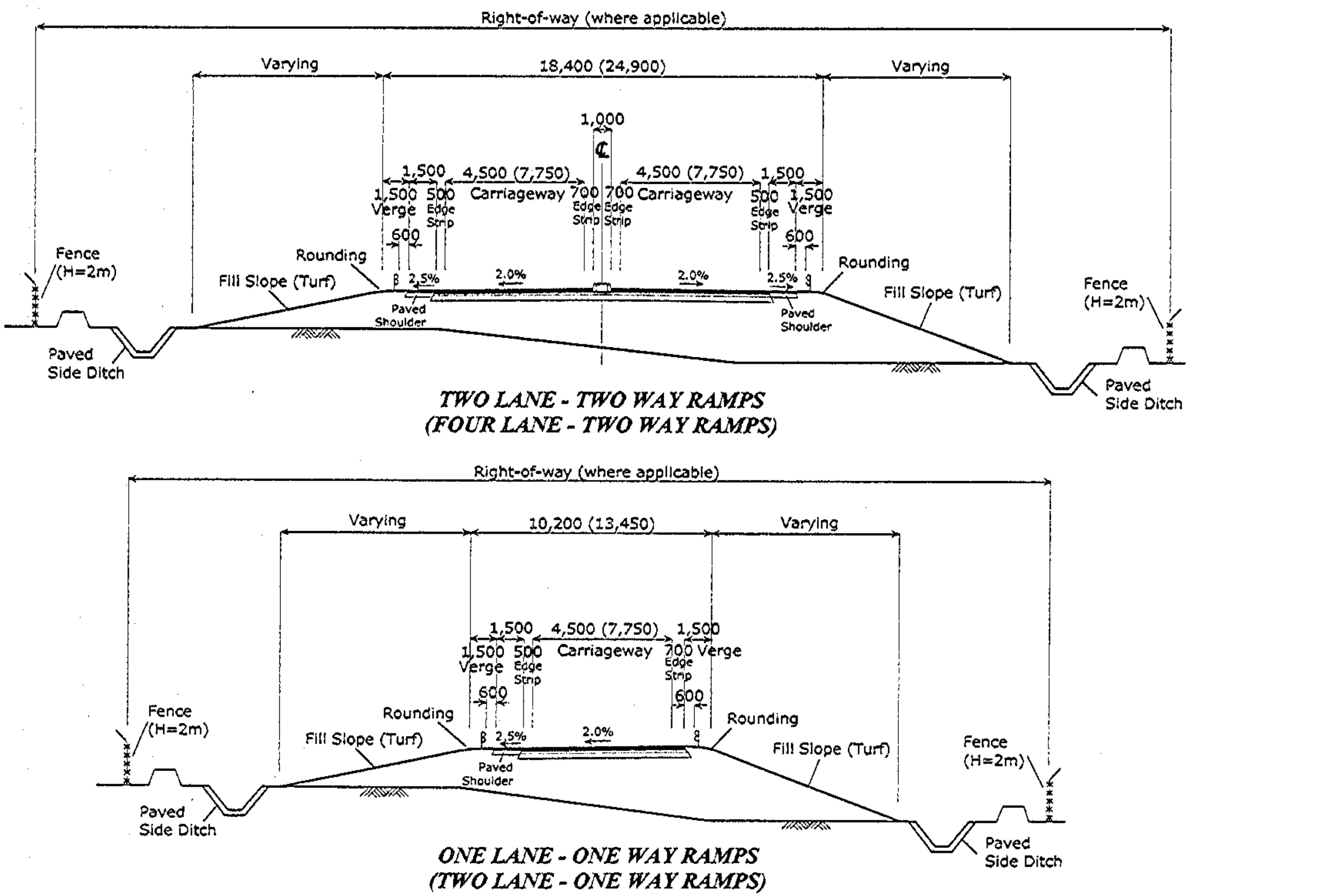
Recommended typical cross sections of the Expressways are shown in Figure 9.4.2, including typical cross sections for interchange ramps. The typical cross section was prepared for initial inner lane method (Figure 9.5.3 (1)) for stage construction. The typical cross sections for interchange ramps are shown in Figure 9.5.3 (2).

The lane width will be 3.75 m with a paved outer shoulder of 2.5 m plus a verge. The fill slopes will have varying grade depending on the height of the embankment.



Note : 1. All dimensions are in millimeter.
2. Fill slopes will be: 0-2m 6 : 1
2-4m 3 : 1
4m< 2 : 1

Figure 9.5.3 (1) : Typical Cross Sections of Throughway (Inner Initial Lane Method)



Note : 1. All dimensions are in millimeter.
2. Fill slopes will be: 0-2m 6 : 1
2-4m 3 : 1
4m< 2 : 1

Figure 9.5.3 (2) : Typical Cross Sections of Ramps

The side ditches will be provided for drainage, and the berm will be at least 10 m width.

It is recommended that the right-of-way be 100 m for normal section of the entire expressway corridor, with a minimum width of 90 m in special cases.

9.5.4 Preliminary Earthwork Design

(1) Borrow Pit Materials

The major portion of K-G and G-M Expressways will be in embankment structure. The necessary earthwork volume will be 12 million m^3. To cover this amount of embankment material, possible borrow areas have been investigated along the routes of the both expressway. The location of the proposed borrow areas is shown in Table 9.5.6. The location map is also shown in Appendix 9.1.

Table 9.5.6: Location of Borrow Materials

Name	Location	Depth (m)	Position
K-G expressway			
KGBA-1/1	2 km from Kundli IC	1	Left
KGBA-1/2		2	Left
KGBA-2/1	10 km from Kundli IC	1	Left
KGBA-2/2		2	Left
KGBA-3/1	14 km from Kundli IC	1	Right
KGBA-3/2		2	Right
KGBA-4/1	28 km from Kundli IC	1	Center
KGBA-4/2		2	Center
KGBA-5/1	34 km from Kundli IC	1	Center
KGBA-5/2		2	Center
G-M expressway			
GMBA-6/1	2 km from Ghaziabad IC	1	Left
GMBA-6/2		2	Left
GMBA-7/1	10 km from Ghaziabad IC	1	Left
GMBA-7/2		2	Left
GMBA-8/1	14 km from Ghaziabad IC	1	Right
GMBA-8/2		2	Right

Source: JICA Study Team

Laboratory tests for these borrow materials have been conducted to confirm the quality of the materials. These tests includes specific gravity tests, density tests, grain size analysis, compaction tests and California bearing ratio tests. A summary of these test results are shown in Table 9.5.7.

Table 9.5.7: Summary of Test Results for Borrow Materials

	Description	Density ton/m3	Compaction MDD	Compaction OMC	CBR %
K-G Expressway					
KGBA-1/1	Silty clay	1.67	2.01	11	12
KGBA-1/2	Silty sand		1.73	12	27
KGBA-2/1	Silty clay	1.90	1.88	13	8
KGBA-2/2	Silty clay		1.88	13	4
KGBA-3/1	Silty clay	1.90	1.88	13	8
KGBA-3/2	Silty clay		1.99	14	4
KGBA-4/1	Silty clay	1.90	1.99	11	9
KGBA-4/2	Silty clay		1.78	14	10
KGBA-5/1	Silty sand	1.89	2.05	8	16
KGBA-5/2	Silty sand		1.94	12	12
G-M Expressway					
GMBA-6/1	Silty clay	1.90	1.88	13	8
GMBA-6/2	Silty clay		1.99	14	4
GMBA-7/1	Silty clay	1.90	1.99	11	9
GMBA-7/2	Silty clay		1.78	14	10
GMBA-8/1	Silty clay	1.89	2.05	8	16
GMBA-8/2	Silty clay		1.94	12	12

Source: JICA Study Team

The test results show that the borrow area soils are mostly silty but reasonably in good quality, and no major construction problem is expected.

(2) Embankment Stability

The necessary height of expressway embankment are from 2 m to 11 m. The lowest height of 2 m will happen where no crossing facility is necessary. The highest height of 11 m will happen at the edge of major grade separation bridge abutments. To confirm the stability of these embankment structures, a stability analysis was performed for the embankment height of 5, 7, 9, 11 m. The slope of the embankment is set to be 1:2 (1 vertical to 2 horizontal). The width of embankment is 37 m. The stability was examined for the embankment stability and the existing ground stability.

The physical properties of embankment and layers are estimated based on the performed soil investigation data because direct shearing tests were not carried out at this stage. The estimated physical properties are shown in Table 9.5.8.

Table 9.5.8: Value of soil layers for analyzing embankment stability

	Thickness of layer (m)	Unit weight (tonf/m3)	Angle of internal friction (degree)	Cohesion (tonf/m2)	Ground water level
Embankment	5, 7, 9, 11	1.9	25	2.0	
Layer-1	5	1.8	20	2.0	-2 m from top
Layer-2	10	1.9	30	2.0	

Source: JICA Study Team

A typical slope failure and ground failure are shown in figure 9.5.4.

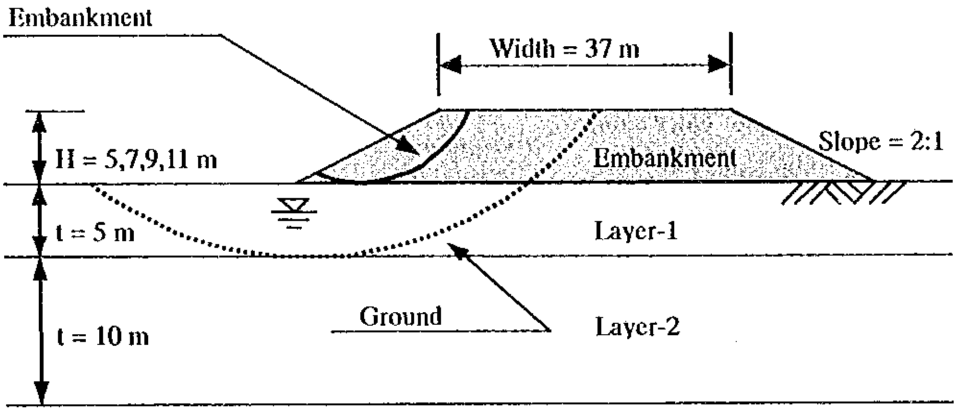


Figure 9.5.4: A Typical Slope Failure and Ground Failure

The result of embankment stability calculation are shown in Appendix 9.2. Minimum safety factor is 1.676 in the case of 11 m height of ground failure. The computed safety factors are shown in Table 9.5.9.

Table 9.5.9: Safety Factors

Embankment height	Minimum safety factor	
	Embankment failure	Ground failure
5	2.987	2.582
7	2.456	2.097
9	2.168	1.836
11	1.977	1.676

Source: JICA Study Team

The result shows that the embankment structure will not have a major problem in stability with the designed height.

9.5.5 Preliminary Design of Bridges and Culverts

By frequent site surveys, observations and interviews with State and National Government officials, contractors and consultants, the followings are the assessment on the conditions of road bridges in the study area in general.

- The superstructure of road bridges are almost all PC or RC girders or PC or RC box girders. As far as the Study Team has investigated, there is no steel bridge in the study area.
- The foundation of road bridges are almost all caisson type.
- Yamuna River flows have been shifted partially during the last 30 years.
- Erosion is observed at many riverside locations both along Yamuna and Hindan Rivers.

The basic policies for bridge type selection are as follows:

1) the selected bridge type should be reasonably economical,
2) the materials for constructing the selected type of bridge can be easily procured near the site,
3) the construction method should be reasonably easy and safe.

The superstructure is recommended to be prestressed concrete composite girder type for medium span (L = 20m~50m) bridges, and reinforced concrete slab girder type for shorter span (L = 20m or less) bridges. Steel bridges are more costly, the comparison of which against PC girder bridges would be obviously in favor of PC girder bridges in the study area.

The foundation should be piles or caissons for all the bridges, except box culverts, due to the characteristics of the alluvial soil at all over the study area. The foundation for river bridges is recommended to be a caisson type. This is because caisson type is historically the only accepted foundation for river bridges in the study area. There is a possibility that pile foundations will be economically competitive against caisson type, however, they are not usually accepted because of their lower reliability against local scoring. The foundation for grade separation bridges is recommended to be a reverse circulation type cast-in-situ piles.

The pier type is recommended to be wall type or single column type since these types are most common, most economical and most effective against erosion. The reverse T type is recommended for abutment for the same reason.

For the typical width of the bridges, the longer bridges (L = 100m or more) are designed to have no outer shoulder width (2.5m) to save the cost. The shorter bridges (L = less than 100m) are designed to have the same width as that of the embankment section.

The planned bridges are categorized as in Table 9.5.10. The list of the bridges are shown in Appendix 9.3.

Table 9.5.10: The Number of Bridges and Culverts by Category

Category	K-G Expressway	G-M Expressway
Major River Bridge	2	---
Canal/Drain Overpass Bridge	6	9
Highway Overpass Bridge	2	1
Railway Overpass Bridge	1	---
Village Road Overpass Bridge	11	10
Canal/Drain Box Culvert	3	2
Cart Track Box Culvert	36	30

Source: JICA Study Team

The design considerations are described as follows:

(1) Major River Bridges (Yamuna and Hindan River Bridges)

The two major river bridges are the longest bridges on the expressway routes. Though the total width of Yamuna River is about 2 km, other existing Yamuna River bridges are all about 600 m. The planned Yamuna River Bridge, therefore, is designed to have 600 m length as same as other bridges with 100-year return period.

Hindan River Bridge is also designed with 100-year return period, and it is designed to be 240 m length to accommodate the flood level of the 100-year return period.

The foundation is designated to be a caisson type. The result of the Hydrological Survey reveals that no scouring is observed at existing Yamuna and Hindan bridge foundations, the observed tendency is rather sedimentary. Therefore, the top of the caisson is designed to be 1 m below the low water levels in the river bed, and 1 m below the ground level in the no-running water area.

(2) Canal/Drain Overpass Bridges

There are a number of irrigation canals, drains and distributaries along the expressways, and overpassing bridges were to be designed. The major canals are tried not to be detoured, and the existing flow lines are maintained as much as possible.

(3) Overpass Bridges for Existing Major Highways

The major grade separation bridges are National Highway No. 1 at Kundli and State Highway No. 57 near Khekra on K-G Expressway, and State Highway No. 14 on G-M Expressway. The bridge lengths are designed to consider possible future widening of the existing highways.

(4) Railway Overpass Bridge

There is one railway flyover near Khekra with the Northern Railway. Although the future plan for double tracking is unknown, the overpass bridge is designed so that it can accommodate either side of double tracking in the future. The bridge type is prestressed concrete composite girder, and the bridge length is 40 m.

(5) Village Roads Overpass Bridge

The number of bridges overpassing existing village roads are the highest number among the categories. For local services and their future functions, these bridges are designed to have a 3.75 m lane with 2×1.875 m shoulder, which can also accommodate future two-lane roads (2×3.75 m). The bridge type is prestressed concrete slab type with the all-staging method.

(6) Cart Track Overpass

The cart track is defined as a local service road mostly for non-motorized vehicles and walking people. The location of these existing cart tracks was identified by the topographic survey and interviews with local people. To secure the transportation, 3 m×3 m box culvert is designed for the crossing facility of this type of road.

9.5.6 Preliminary Design of Pavement

(1) Pavement Type Analysis

Flexible pavement (asphalt or bituminous pavement) has been widely used for road pavement in India. Today most of urban or inter-urban highways are paved by asphalt pavement. In recent years, however, there have been efforts to develop rigid pavement (cement concrete pavement) for major highways in the country. One recent major example around Delhi area is the National Highway No. 2 upgrading project in Faridabad District in the State of Haryana. It is an ADB loan assistance project, and adopted 44 km of cement concrete pavement, which was completed in May 1997. Another major example is the on-going Mumbai-Pune Expressway Project in the State of Maharashtra, which adopts cement concrete pavement for the entire corridor of about 100 km. It is therefore considered necessary to rationally analyze the pavement type between flexible and rigid pavement to recommend which is more appropriate for these projects.

Selection of pavement type is generally a controversial issue. Major characteristics in selecting the pavement type on expressways can be discussed as follows:

Table 9.5.11: Comparison of Characteristics of Flexible and Rigid Pavements

Item	Flexible Pavement	Rigid Pavement
Design Life	Target design period of 10 years. The life will be extended by proper rehabilitation.	Target design period of 20 years.
Resistance against Rutting & Wear	Deformed rutting is likely.	Deformation or rutting is unlikely. Wear resistance is large.
Noise & Vibration	Less than rigid pavement.	Noise due to joints and vibration due to rough surface sometimes cause public nuisance
Brightness	Surface reflection is weak and inferior.	Brighter in darkness.
Surface Smoothness	Better than rigid pavement and provide more comfortable riding condition.	Need more sensitive quality control to achieve acceptable level of surface smoothness.
Characteristics in Construction	Less constraints in construction. Constructing speed is faster.	The following constraints should be taken into account for continuous construction since equipment fleet is generally larger than that of flexible pavement. 1) Subgrade is prepared in smooth condition. 2) Less bridge/viaduct structures.
Maintenance	Frequent maintenance is required but the method is simple.	Once damage occurs, heavier and longer repair is required.
Construction Economy	Initial stage construction cost is lower than rigid pavement. More frequent rehabilitation is necessary.	Initial construction cost is higher than flexible pavement due to longer life. The cost of repair is higher.

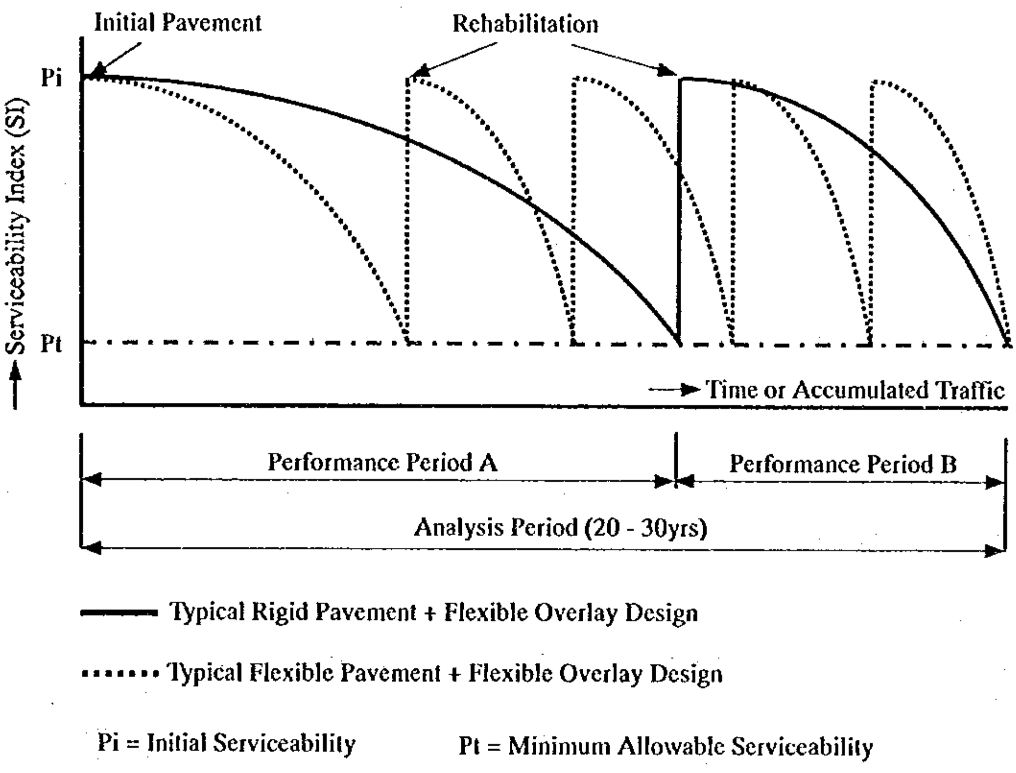
Source: JICA Study Team

Pavement should be analyzed by a life cycle cost analysis to evaluate the performance of total analysis period. AASHTO design guideline[3] suggests a design method for a life cycle cost analysis, and it is a recommended design guideline for this purpose. The following two important terms should be defined for life cycle cost analysis.

- **Analysis Period:** the length of time for which an economic analysis is made.
- **Performance (Design) Period:** the period of time that an initial or rehabilitated pavement structure will last before reaching its terminal serviceability.

This means that an analysis period is a combination of single or multiple performance periods. This relationship is shown in Figure 9.5.5.

Figure 9.5.5: Pavement Life Cycle



The analysis period is designated to be 30 years considering the expected concession period. The performance period combination will be analyzed by design comparison. A reasonable comparison between flexible and rigid pavements can be done by performing optimum pavement design for the entire analysis period for both pavement types, and comparing the net present value of such optimum design combinations.

[3] AASHTO Guide for Design of Pavement Structures 1993, American Association of State Highway and Transportation Officials, Washington, D.C., U.S.A.

The comparative design is summarized as follows.

Axle Load Model

The Load Equivalency Factor (ESAL Factor) for 18 kips is computed as in Table 9.5.12 based on the result of the Axle Load Survey data conducted in February 1999.

Table 9.5.12: Load Equivalency Factors by Axle Load Survey

Vehicle	Average Maximum Axle Load		ESAL Factor	
	ton	kips	Asphalt 2)	Concrete 3)
Large Bus	7.53	16.6	0.63	0.61
LCV 1)	5.27	11.6	0.19	0.18
2-axle Truck	9.85	21.7	2.18	2.34
Multi-axle Truck	10.60	23.4	0.26	0.44

Note: 1) Light Commercial Vehicle
2) Pt=2.5, SN=5 (in)
3) Pt=2.5, D=9 (in)

Source: JICA Study Team

Cumulative 18-kip ESAL

The18-kip equivalent single axle load is computed for the four kinds of vehicles with the ESAL Factors in Table 9.5.12 based on the traffic demand forecast result. The computation result is summarized in Appendix 9.4. The result shows that 2-axle trucks are dominant by their volume and their heavy average axle load.

Flexible Pavement Design Computation

Flexible pavement input data, computed SN and the pavement layer design are summarized as follows:

<u>Initial Pavement Layer Design</u>:

$R=0.95$, $S_0=0.45$, $M_R=10500$, $\Delta PSI=2.1$, $W_{18}=49.0\times10^6 \rightarrow$ $SN_0=5.5$

D1=	15cm:	AC Wearing Course + Dense Bituminous Macadam Binder Course	($a_1=0.176$)
D2=	30cm:	Wet Mix Macadam Base Course	($a_2=0.055$)
D3=	30cm:	Granular Sub-base	($a_3=0.043$)
Total Pavement Thickness = 75 cm			($SN_0=5.58$)

<u>Bituminous Overlay Design</u>: ($SN_{OL} = SN_y - F_{RL}\times SN_{xeff}$)

$R=0.95$, $F_{RL}=0.575$, $SN_{xeff}=C_X\times SN_0=0.85\times5.58$, $W_{18}=42.0\times10^6 \rightarrow$ $SN_{OL}=2.6$

D1=	15cm:	AC Wearing Course + Dense Bituminous Macadam Binder Course	($a_1=0.176$)
Total Overlay Thickness = 15 cm			($SN_{OL}=2.64$)

By the computed cumulative ESAL (W_{18}), the optimum overlay plan is expected as follows:

the 1st Overlay: 11th year,
the 2nd Overlay: 17th year,
the 3rd Overlay: 21st year,
the 4th Overlay: 25th year,
the 5th Overlay: 28th year

The 30year analysis period will consist of seven performance periods. The compound reliability for this design will be:

$$R_{OVERALL} = (0.95)^6 = 0.735$$

Rigid Pavement Design Computation

Rigid pavement input data, computed D_0, SN for overlay and the pavement layer design are summarized as follows:

Initial Pavement Layer Design:

R=0.80, S_0=0.35, k=900(Cement-treated Sub-base), Δ PSI=2.0, $E_C=3.6\times10^6$, S'c=640, J=3.1, Cd=1.15, $W_{18}=135.0\times10^6$ → **D_0=11.8 in → 30cm**

D1= 30cm: Pavement Quality Concrete (PQC)
D2= 15cm: Dry Lean Concrete Sub-base (DLC)

Total Pavement Thickness = 45 cm

Bituminous Overlay Design: ($SN_{OL} = SN_y - F_{RL}\times(a_{2r}D_0+SN_{xeff\text{-}rp})$)

R=0.92, F_{RL}=0.575, a_{2r}=0.54, $SN_{xeff\text{-}rp}$=0.84, $W_{18}=108.0\times10^6$ → **SN_{OL}=1.76**

D1= 10cm: AC Wearing Course (a_1=0.176)

Total Overlay Thickness = 10 cm (SN_{OL}=1.76)

By the computed cumulative ESAL (W_{18}), the optimum overlay plan is expected as follows:

the 1st Overlay: 21st year,

The 30year analysis period will consist of two performance periods. The compound reliability for this design will be:

$$R_{OVERALL} = 0.80\times0.92 = 0.736$$

Economic Analysis and Pavement Type Selection

Unit prices for each pavement layer were collected from the NH No. 2 Upgrading Project, Faridabad as a recent example, and used in this analysis. The pavement costs are as follows:

		(Rs./m^2)
Flexible Pavement:	05 cm AC Wearing Course	152
	10 cm DBM Binder Course	251
	30 cm WMM Base course	300
	30 cm Granular Sub-base	122
	Total	825
Bituminous Overlay:	15 cm AC W.C.	455

		(Rs./m^2)
Rigid Pavement:	30 cm PQC	1,365
	15 cm DLC	288
	Total	1,653
Bituminous Overlay:	10 cm AC W.C.	303

The net present values for each design combination are computed by the discount rate of 12.0% as follows:

NPV (Flexible Pavement):	**Rs.1,110/m^2**
NPV (Rigid Pavement):	**Rs.1,681/m^2**

The economic analysis shows that the flexible pavement has a distinct economical advantage against the rigid pavement with this level of discount rate. This is because the high discount rate makes the initial pavement predominant compared with the future rehabilitation frequency and costs. A sensitivity analysis shows that the rigid pavement would be economical only if the discount rate were 4.5% or less.

It is therefore recommended that the pavement type for K-G and G-M Expressway Projects be a flexible pavement. The economic analysis shows an economical advantage of flexible pavement against rigid pavement at higher discount rate. It should also be considered that flexible pavement has smooth surface for high speed traffic, and is easier to be rehabilitated, which are both important factors for expressway pavement.

Flexible Pavement Design ---- Summary

The flexible pavement layer design is the same as designed in the pavement type analysis, which is as follows:

AC Wearing Course	5.0 cm
Dense Bituminous Macadam Binder Course	10.0 cm
Wet Mix Macadam Base Course	30.0 cm
Granular Sub-base	30.0 cm

Total Pavement Thickness	75.0 cm

Pavement Design for Shoulders

Empirical data in Japanese inter-urban expressway operation suggest that SN=3.5 (in) or more is recommendable for shoulder pavement design. Based on that data, the following layer design is recommended for the inner and outer shoulder pavement:

Dense Bituminous Macadam Binder Course	10.0 cm
Wet Mix Macadam Base Course	30.0 cm
Total Pavement Thickness	40.0 cm

It is recommended that the wearing course not be provided to save the cost, and also to restrain shoulder driving by setting a rounded gap between the carriageway and the shoulder.

9.6 Construction Planning

9.6.1 Basic Conditions for Construction Planning

(1) Construction Segments

The Expressway corridors will be mostly an embankment structure except river bridges and grade separation structures of bridges, culverts and underpasses. There are two major river bridges on K-G Expressway, Yamuna River Bridge (L = 600 m) and Hindan River Bridge (L = 240 m). On G-M Expressway a major river bridge of Upper Ganga Canal Bridge (L = 90 m) will be necessary.

For the purpose of construction planning, the Expressways are divided into five construction segments shown in Table 9.6.1. The previous engineering analysis and design considered that Kundli IC - Ghaziabad N. Junction was designated to be K-G Expressway, and Ghaziabad IC - Meerut IC was to be G-M Expressway including the stationing due to engineering reasons and convenience. The construction segmentation, however, have considered the Junction - Ghaziabad IC section to be an independent section so that it can be included either expressway project. This is because there is an opinion that the Junction - Ghaziabad IC section is more desirable to be constructed as a part of the circumferential network consisting of FNG Expressway and K-G Expressway.

Table 9.6.1: Construction Segments for Preliminary Construction Planning

Expressway	No.	Segment	Length	Remarks
K-G Expressway	Segment 1	Kundli IC (KG00+600) - Yamuna Br. (KG12+900)	12.30 km	include Yamuna Br.
	Segment 2	Yamuna Br. (KG12+900) - Ghaziabad N. JCT (KG39+800)	28.50 km	include Hindan Br.
G-M Expressway	Segment 3	Ghaziabad IC (GM00-200) - Ghaziabad N. JCT (GM8+000)	8.20 km	
	Segment 4	Ghaziabad N. JCT- Modinagar IC (GM8+000) - (GM23+600)	15.60 km	include Modinagar IC & Junction
	Segment 5	Modinagar IC (GM23+600) - Meerut IC (GM39+750)	16.15 km	
Sub-total	Total		**80.75 km**	

Source: JICA Study Team

(2) Stage Construction

As discussed in Section 9.4 a stage construction scheme should be introduced for K-G and G-M Expressway projects. The stage construction methodology should be as follows:

Initial Stage: The sections of Kundli IC - Ghaziabad North JCT and Ghaziabad North JCT - Meerut IC will be constructed as a 2 + 2 = 4 lane expressway. The section of Ghaziabad IC - Ghaziabad North JCT will be constructed as a 3 + 3 = 6 lane expressway. Initial opening year is estimated to be year 2006.

Ultimate Stage: To accommodate the increasing traffic demand the sections of Kundli IC - Ghaziabad North JCT and Ghaziabad North JCT - Meerut IC will be widened to 3 + 3 = 6 lanes, and the section of Ghaziabad IC - Ghaziabad North JCT will be widened to 4 + 4 = 8 lanes. The expected time of the widening is year 2021 - 2026.

The embankment structure should be the initial inner lane method as discussed in Section 9.4.3. The bridges should also be constructed for the initial number of lanes for the initial stage, and should be widened to the ultimate number of lanes at the time of widening. This will be achieved by the following method:

Initial Stage: constructing the substructures of the bridges for the ultimate lanes, and the superstructure will be for the initial lanes.

Ultimate Stage: constructing the remaining additional outer lane superstructure on the existing substructure.

The right-of-way will be acquired for the ultimate structure, that is, 100 m width for the throughway.

9.6.2 Construction Features, Methods and Procedures

The construction works will include hauling, laying and compaction of a large quantity of embankment, pavement, bridge and other concrete structure works, and construction and installation of required architectural, mechanical, and electrical facilities for tollway operation.

The existing vertical alignment is quite flat. The embankment height is designated as 3 - 4 m above the ground level, and raised to be 10 - 11 m in maximum at grade separation for crossing facilities in accordance with the necessary clearance. The required earthwork volume will be approximately 12 million m^3. To minimize the hauling of borrow materials, a partial supply of the embankment should be from the side borrow excavation of about 50 cm - 1 m depth within the right-of-way. The rest of the borrow materials for embankment is assumed to come from shallow excavation of local borrow pits reasonably close to the embankment site along the roadway within 5 - 10 km hauling distance as shown in Table 9.5.6.

For construction of major river bridge foundations, an open caisson will be used. For other bridge foundations, cast-in-situ piles will be used if necessary. The river bridge foundations will be constructed by providing temporary islands in the river during dry season from October to June, which is roughly 9 months. It is anticipated that the major river bridge construction will be the critical path for construction schedule, and it is recommended that the jack down method for forcing the caisson body to sink down be adopted to minimize the construction time of the foundations. The prestressed concrete girders will be precast on stable throughway embankment areas. For the erection of precast prestressed concrete beams the steel erection girder will be used.

Fine and coarse aggregates for concrete and paving works will be supplied from the quarry sites. The available quarry sites are mostly located at the south of Delhi from where the hauling distance to the site will be approximately 100 km. These sites are shown in Appendix 9.5.

9.6.3 Construction Time Schedule

The climate of the study area is basically divided into two seasons, which are a dry season (October to June) and a rainy season (July to September). In accordance with available rainfall data the efficiency of construction works in the study area is estimated as in Table 9.6.2.

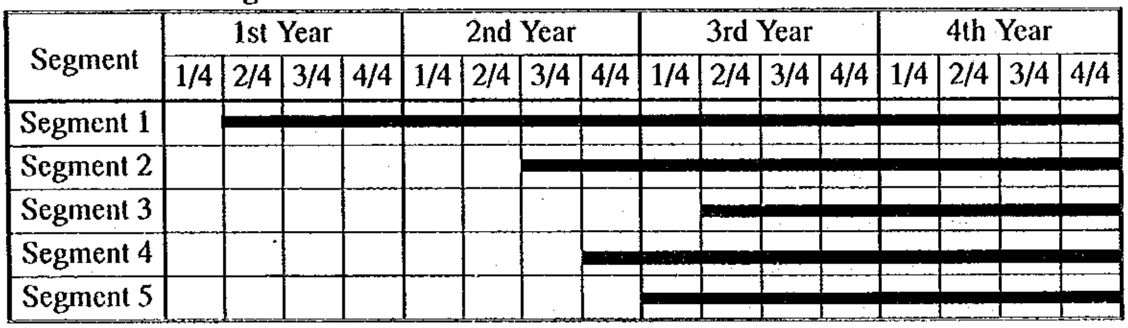
Table 9.6.2: Estimated Working Efficiency for Construction in the Study Area

Item	Dry Season Oct-Jun (9 months)	Rainy Season Jul-Sep (3 months)	Annual Figure
1. No. of Rainy Days	3 days/month	13 days/month	66 days
2. Working Efficiency on a Rainy Day	80 %	40 %	70 %
3. No. of Holidays	6.0 days/month	5.0 days/month	69 days
4. No. of Working Days	23.4 days/month	17.2 days/month	262 days
5. Working Efficiency	78 %	57 %	72 %

Source: JICA Study Team

For toll road construction, for which the most of the cost is covered by loan or other forms of money bearing interests, the most desirable schedule is to commence the construction as late as possible to complete the total segments at the same time (the opening) to minimize the interests during construction. Based on the above assumptions the construction time schedule for each segment is estimated as follows:

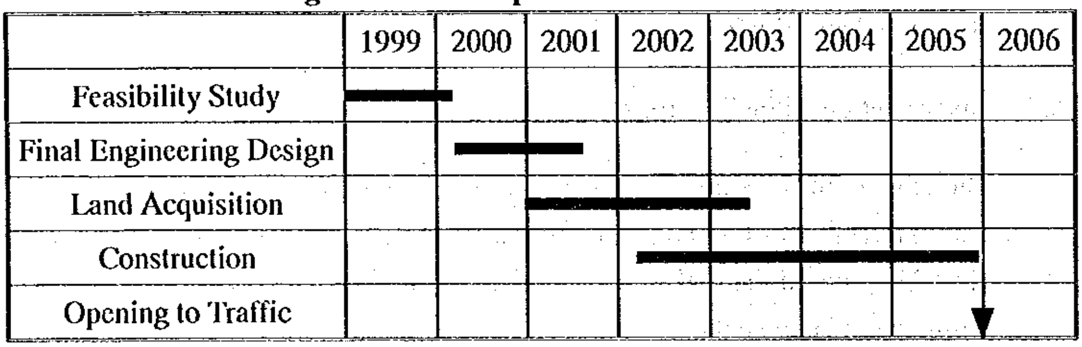
Figure 9.6.1: Overall Construction Time Schedule



9.6.4 Implementation Schedule

The total implementation schedule including the above construction time schedule in the earliest case is presented in Figure 9.6.2.

Figure 9.6.2: Implementation Schedule



9.7 Project Cost Estimate

9.7.1 Basic Conditions for Project Cost Estimate

The estimate of the project cost is based on the results of the preliminary engineering design and quantity take-off of each work item, a study on construction methods described in the preceding chapters.

The project cost discussed here consists of the following items (operation and maintenance cost of the project will be discussed separately with operation and maintenance plan in the later stage).

(1) Initial Investment Cost
- Construction Cost
- Land Acquisition and Compensation Cost
- Administration Cost
- Engineering Cost
- Contingency

(2) Additional Investment Cost
- Pavement Rehabilitation (Overlay) Cost
- Widening Cost

The basic premises in estimating the project cost is as follows:

1) All the construction works will be executed by contractors to be employed by the toll road development corporation of the expressway projects, whichever form of the corporation is going to be formed.
2) The unit price of each cost component was determined based on the economic conditions prevailing in August 1999.
3) Contractor's profit and overhead are assumed to be 15 % of the direct cost.
4) For the construction works, the Indian sales tax (5 %) is imposed on the contractor.
5) Engineering cost, consisting of final engineering design and construction supervision, is assumed to be 10 % of the construction cost.
6) Administration cost is assumed to be 5 % of the construction cost.
7) Physical contingency is estimated to be 10 % of the total of the construction cost, the land acquisition and compensation costs, the administration cost and the engineering cost.

9.7.2 Boundary Conditions

Since K-G and G-M Expressways are a part of the NCR Expressway Network, the boundary conditions for construction should be defined to determine the project construction cost. The following is the boundary conditions of each terminal interchange of the expressway.

(1) Kundli IC

Peripheral Expressway Project is expected to be implemented later than K-G Expressway. The embankment and pavement of the throughway, therefore, is up to the edge of the interchange bridge located at KG00+600. The interchange bridge will not be constructed by K-G Expressway side. The on/off ramps for K-G Expressway will be constructed, however, the on/off ramps for Peripheral Expressway will not be necessary. The embankment of these Peripheral Expressway ramps will be substantially constructed for the embankment balance. The westward portion of the throughway from KG00+600 including NH No. 1 flyover bridge will not be constructed by K-G Expressway either. (A reference should be made to Figure 9.3.2 (1): Kundli IC: Alternative 2)

(2) Meerut IC

The Extension of G-M Expressway after Meerut IC is expected to be implemented later than G-M Expressway. The embankment and pavement of the throughway, therefore, is up to the edge of the interchange bridge located at GM39+750. The interchange bridge will not be constructed by G-M Expressway side. The on/off ramps for G-M Expressway will be constructed, however, the on/off ramps for the Meerut Extension will not be necessary. The embankment of these Meerut Extension ramps will be substantially constructed for the embankment balance. The northward portion of the throughway from GM39+750 will not be constructed by G-M Expressway either. (A reference should be made to Figure 9.3.2 (2): Meerut IC: Alternative 1)

(3) Ghaziabad IC

Since FNG Expressway is expected to be constructed earlier than K-G and G-M Expressways, Ghaziabad IC will be constructed by FNG Expressway side. For construction cost estimate, Ghaziabad boundary is set to be at NH No. 24, and the throughway cost only is included. If FNG Expressway constructs the Ghaziabad IC with the partial cloverleaf design, K-G and G-M Expressways will need a throughway tall plaza between Ghaziabad IC and Ghaziabad North JCT, which will not be necessary if FNG Expressway adopts the double trumpet design recommended by us. The boundary condition of Ghaziabad IC, therefore, is to consider the throughway from NH No. 24 with the throughway toll plaza. The cost of the optional double trumpet interchange is independently estimated for the recommendation.

9.7.3 Estimated Construction Cost

(1) Initial Construction Cost

The estimated initial stage construction cost is Rs.7,322 million for the total segments as shown in Table 9.7.1. In the construction cost, pavement (27.0 %), bridge/flyover construction (27.2 %) and embankment (18.2 %) constitute the dominant portions.

(2) Widening and Overlay Cost

The project expressway will be widened from 4-lane at the initial stage (6-lane for Ghaziabad IC - Junction) to 6-lane at the ultimate stage development (8-lane for Ghaziabad IC - Junction) presumed between year 2021 and year 2026 in accordance with the results of the traffic demand forcast.

For pavement overlay, it is assumed that overlays will be executed five times as follows in the 30-year concession period of the project as discussed in Section 9.5.6.

the 1st Overlay: 11th year (2016; for initial number of lanes),
the 2nd Overlay: 17th year (2022; for initial number of lanes),
the 3rd Overlay: 21st year (2026; for ultimate number of lanes),
the 4th Overlay: 25th year (2030; for ultimate number of lanes),
the 5th Overlay: 28th year (2033; for ultimate number of lanes).

The estimated construction cost for the widening and overlay is shown in Table 9.7.2.

9.7.4 Land Acquisition and Compensation Cost

Based on the result of the environmental and social surveys, the land acquisition cost in the project area is estimated to be Rs.962,000 per ha on average. The required land area for the right-of-way is 916 ha, of which 572 ha is village area, 186 ha is agriculture area, and 158 ha is vacant land. An additional 30 % of the cost is added for solatium.

The compensation costs for private properties, such as buildings, brick kilms and orchards, and relocation of temples or schools are estimated as follows:

Table 9.7.1: Construction Cost (Initial Stage Construction)

Item	Unit	Unit Price (Rs.)	Segment 1 (L=12.30km)		Segment 2 (L=28.50km)		Segment 3 (L=8.20km)		Segment 4 (L=15.60km)		Segment 5 (L=16.15km)		TOTAL (L=80.75km)	
			Qty	Amount	Qty	Amount	Qty	Amount	Qty	Amount	Qty	Amount	Qty	Amount
1. Preparatory Works	LS		1	80,000,000	1	96,000,000	1	27,000,000	1	61,000,000	1	50,000,000	1	314,000,000
2. Earthwork														
Cleaning & Grubbing	Ha	5,100	157	800,700	280	1,428,000	82	418,200	211	1,076,100	187	953,700	917	4,676,700
Excavation-Unclassified	m3	50	0	0	139,000	6,950,000	1,600	80,000	8,400	420,000	0	0	149,000	7,450,000
Embankment-Borrow	m3	110	2,480,300	272,833,000	3,957,800	435,358,000	1,319,000	145,090,000	2,074,400	228,184,000	2,307,100	253,781,000	12,138,600	1,335,246,000
Slope Protection, Turfing	m2	10	239,700	2,397,000	488,100	4,881,000	103,700	1,037,000	454,900	4,549,000	337,500	3,375,000	1,623,900	16,239,000
Slope Protection, Rip-rap	m2	300	54,500	16,350,000	50,900	15,270,000	5,100	1,530,000	0	0	0	0	110,500	33,150,000
SUB-TOTAL				292,380,700		463,887,000		148,155,200		234,229,100		258,109,700		1,396,761,700
3. Pavement														
Bituminous Concrete (t=50mm)	m3	3,120	10,700	33,384,000	23,400	73,008,000	10,200	31,824,000	11,740	36,628,800	14,000	43,680,000	70,040	218,524,800
Dense Bituminous Macadam (t=100mm)	m3	3,100	31,470	97,557,000	71,710	222,301,000	28,200	87,420,000	36,310	112,561,000	43,300	134,230,000	210,990	654,069,000
Wet Mix Macadam Base (t=300mm)	m3	1,050	94,410	99,130,500	215,140	225,897,000	84,620	88,851,000	108,940	114,387,000	129,920	136,416,000	633,030	664,681,500
Granular Sub-base (t=300mm)	m3	1,000	61,070	61,070,000	139,160	139,160,000	61,250	61,250,000	70,470	70,470,000	84,000	84,000,000	415,950	415,950,000
Sub-grade Preparation	m2	15	203,500	3,052,500	463,800	6,957,000	204,100	3,061,500	234,900	3,523,500	280,100	4,201,500	1,386,400	20,796,000
SUB-TOTAL				294,194,000		667,323,000		272,406,500		337,570,300		402,527,500		1,974,021,300
4. Major Bridges														
Superstructure	m2	23,330	10,440	243,565,200	4,176	97,426,080		0		0		0	14,616	340,991,280
Substructure	m3	7,340	14,940	109,659,600	5,976	43,863,840		0		0		0	20,916	153,523,440
Foundation	Ea	10,804,000	32	345,728,000	14	151,256,000		0		0		0	46	496,984,000
Guide Bunds (Up & Downstream)	m	34,760	2,000	69,520,000	800	27,808,000		0		0		0	2,800	97,328,000
SUB-TOTAL				768,472,800		320,353,920		0		0		0		1,088,826,720
5. Minor Bridges														
Superstructure	m2	20,420	2,308	47,129,360	6,452	131,749,840	1,316	26,872,720	4,346	88,745,320	4,188	85,518,960	18,610	380,016,200
Substructure & Foundation	m2	21,000	3,080	64,680,000	8,612	180,852,000	1,646	34,566,000	5,800	121,800,000	5,592	117,432,000	24,730	519,330,000
SUB-TOTAL				111,809,360		312,601,840		61,438,720		210,545,320		202,950,960		899,346,200
6. Ditches and Culverts														
Box Culvert - 3.0m×3.0m	Lm	48,100	640	30,784,000	1,286	61,856,600	269	12,938,900	501	24,098,100	816	39,249,600	3,512	168,927,200
Pipe Culvert - D=1.0m	Lm	5,000	0	0	108	540,000	65	325,000	0	0	616	3,080,000	789	3,945,000
Side Ditch	Lm	350	25,600	8,960,000	52,300	18,305,000	15,700	5,495,000	46,400	16,240,000	33,600	11,760,000	173,600	60,760,000
Median Drainage	Ea	10,500	47	493,500	103	1,081,500	33	346,500	63	661,500	65	682,500	311	3,265,500
SUB-TOTAL				40,237,500		81,783,100		19,105,400		40,999,600		54,772,100	0	236,897,700
7. Interchange / Junction														
Earthwork	m3	110	585,000	64,350,000	202,000	22,220,000		0	1,246,000	137,060,000	351,000	38,610,000	2,384,000	262,240,000
Grade Separation Structures	m2	46,640		0	720	33,580,800		0	882	41,136,480		0	1,602	74,717,280
Box Culvert - 7.5m×5.0m	Lm	143,650		0		0		0	85	12,210,250		0		12,210,250
Box Culvert - 10.5m×5.0m	Lm	214,900		0		0		0	90	19,341,000		0		19,341,000
Pavement	m2	1,095	81,500	89,242,500	38,300	41,938,500		0	151,700	166,111,500	48,000	52,560,000	319,500	349,852,500
Toll Gate	LS	2,250,000	1	2,250,000	1	2,250,000		0	1	2,250,000	1	2,250,000	4	9,000,000
SUB-TOTAL				155,842,500		99,989,300		0		378,109,230		93,420,000		727,361,030
8. Rest Area	Ea	19,447,600	0	0	2	38,895,200	0	0	2	38,895,200	0	0	4	77,790,400
9. Toll Plaza	Ea	46,927,300	0	0	0	0	1	46,927,300	0	0	0	0	1	46,927,300
10. Relocation of Road / Drain / Canal														
Relocation ofVillage Road	km	2,067,500	1.1	2,274,250	1.7	3,514,750	0	0	0.8	1,654,000	0	0	3.6	7,443,000
Relocation of Cart Track	km	802,000	1.6	1,283,200	4.9	3,929,800	0.3	240,600	2.7	2,165,400	2.7	2,165,400	12.2	9,784,400
Relocation of Drain / Canal	km	1,050,000	0.2	210,000	1.0	1,050,000	0.3	315,000	0.9	945,000	2.5	2,625,000	4.9	5,145,000
SUB-TOTAL				3,767,450		8,494,550		555,600		4,764,400		4,790,400		22,372,400
11. Utility Relocation														
Relocation of High Power Line	Ea	1,200,000	1	1,200,000	1	1,200,000	0	0	2	2,400,000	0	0	4	4,800,000
Relocation of Power Line	Ea	100,000	23	2,300,000	66	6,600,000	12	1,200,000	8	800,000	11	1,100,000	120	12,000,000
SUB-TOTAL				3,500,000		7,800,000		1,200,000		3,200,000		1,100,000		16,800,000
12. Road Appurtenances														
Guard Rail	Lm	3,020	27,900	84,258,000	24,390	73,657,800	8,600	25,972,000	24,970	75,409,400	15,640	47,232,800	101,500	306,530,000
Concrete Safety Barrier	Lm	490	11,700	5,733,000	26,600	13,034,000	8,200	4,018,000	15,600	7,644,000	16,100	7,889,000	78,200	38,318,000
ROW Fance	Lm	1,030	22,200	22,866,000	50,900	52,427,000	16,400	16,892,000	27,900	28,737,000	34,500	35,535,000	151,900	156,457,000
Road Signs	km	110,000	12	1,353,000	27	2,959,000	8	880,000	22	2,409,000	16	1,760,000	85	9,361,000
Road Markings	km	15,000	74	1,104,000	141	2,112,000	49	738,000	105	1,567,500	87	1,299,000	455	6,820,500
SUB-TOTAL				115,314,000		144,189,800		48,500,000		115,766,900		93,715,800		517,486,500
13. Landscaping	km	25,000	24.6	615,000	53.8	1,344,000	16.0	399,000	31.2	779,000	32.3	806,500	157.9	3,943,500
TOTAL CONSTRUCTION COST				1,866,132,000		2,242,661,000		625,687,000		1,425,859,000		1,162,192,000	0	7,322,531,000

Source: JICA Study Team

Table 9.7.2 (1): Widening and Overlay Costs (K-G Expressway; Segment 1, 2, 3)

Item	Unit	Unit Price (Rs.)	Winening in 2022		Overlay (Initial Width) (2016 & 2022)		Overlay (Ultimate Width) (2026, 2030 & 2033)	
			Qty	Amount	Qty	Amount	Qty	Amount
1. Preparatory Works	LS		1	52,000,000	1	16,000,000	1	23,000,000
2. Earthwork								
Excavation-Unclassified	m3	50	337,500	16,875,000	-----	-----	-----	-----
Embankment-Borrow	m3	110	1,939,200	213,312,000	-----	-----	-----	-----
Slope Protection, Turfing	m2	10	831,600	8,316,000	-----	-----	-----	-----
Slope Protection, Rip-rap	m2	300	110,600	33,180,000	-----	-----	-----	-----
SUB-TOTAL				271,683,000	-----	-----	-----	-----
3. Major Bridges								
Superstructure	m2	25,663	6,300	161,676,900	-----	-----	-----	-----
SUB-TOTAL				161,676,900	-----	-----	-----	-----
4. Minor Bridges								
Superstructure	m2	22,462	3,262	73,271,044	-----	-----	-----	-----
SUB-TOTAL				73,271,044	-----	-----	-----	-----
5. Pavement								
Binuminous Concrete	m3	3,120	17,770	55,442,400	43,580	135,969,600	61,040	190,444,800
Dense Bituminous Macadam	m3	3,100	59,250	183,675,000	87,160	270,196,000	122,080	378,448,000
Wet Mix Macadam	m3	1,050	177,750	186,637,500	-----	-----	-----	-----
Granular Sub-base	m3	1,000	106,650	106,650,000	-----	-----	-----	-----
Subgrade Preparation	m2	15	355,500	5,332,500	-----	-----	-----	-----
SUB-TOTAL				537,737,400		406,165,600		568,892,800
6. Toll Plaza								
Embankment-Borrow	m3	110	60,600	6,666,000	-----	-----	-----	-----
Pavement	m2	1,095	60,600	66,357,000	-----	-----	-----	-----
SUB-TOTAL				73,023,000	-----	-----	-----	-----
7. Miscellaneous								
Guard Rail	Lm	3,020	56,400	170,328,000	-----	-----	-----	-----
Road Markings	km	15,000	142	2,130,000	245	3,675,000	287	4,305,000
SUB-TOTAL				172,458,000		3,675,000		4,305,000
TOTAL CONSTRUCTION COST				1,341,849,000		425,840,000		596,197,000

Source: JICA Study Team

Table 9.7.2 (2): Widening and Overlay Costs (G-M Expressway; Segment 4, 5)

Item	Unit	Unit Price (Rs.)	Winening in 2022		Overlay (Initial Width) (2016 & 2022)		Overlay (Ultimate Width) (2026, 2030 & 2033)	
			Qty	Amount	Qty	Amount	Qty	Amount
1. Preparatory Works	LS		1	25,000,000	1	15,000,000	1	0
2. Earthwork								
Excavation-Unclassified	m3	50	214,600	10,730,000	-----	-----	-----	-----
Embankment-Borrow	m3	110	1,095,400	120,494,000	-----	-----	-----	-----
Slope Protection, Turfing	m2	10	623,300	6,233,000	-----	-----	-----	-----
Slope Protection, Rip-rap	m2	300	0	0	-----	-----	-----	-----
SUB-TOTAL				137,457,000		-----	-----	-----
3. Major Bridges								
Superstructure	m2	25,663	-----	-----	-----	-----	-----	-----
SUB-TOTAL			-----	-----		-----	-----	-----
4. Minor Bridges								
Superstructure	m2	22,462	2,858	64,196,396	-----	-----	-----	-----
SUB-TOTAL				64,196,396	-----	-----	-----	-----
5. Pavement								
Binuminous Concrete	m3	3,120	11,100	34,632,000	29,980	93,537,600	41,080	128,169,600
Dense Bituminous Macadam	m3	3,100	37,000	114,700,000	59,960	185,876,000	82,160	254,696,000
Wet Mix Macadam	m3	1,050	111,000	116,550,000	-----	-----	-----	-----
Granular Sub-base	m3	1,000	66,600	66,600,000	-----	-----	-----	-----
Subgrade Preparation	m2	15	222,000	3,330,000	-----	-----	-----	-----
SUB-TOTAL				335,812,000		279,413,600		382,865,600
6. Toll Plaza								
Embankment-Borrow	m3	110	-----	-----	-----	-----	-----	-----
Pavement	m2	1,095	-----	-----	-----	-----	-----	-----
SUB-TOTAL			-----	-----	-----	-----	-----	-----
7. Miscellaneous								
Guard Rail	Lm	3,020	29,400	88,788,000	-----	-----	-----	-----
Road Markings	km	15,000	88	1,320,000	168	2,520,000	198	2,970,000
SUB-TOTAL				90,108,000		2,520,000		2,970,000
TOTAL CONSTRUCTION COST				652,573,000		296,933,000		385,835,000

Source: JICA Study Team

Compensation Cost for	Buildings:	Rs.417,825,000
	Brick Kilms:	Rs.38,045,000
	Orchards:	Rs.27,320,000
Relocation Cost for Temples and Schools:		Rs.99,225,000
	Total	Rs.582,415,000

9.7.5 Estimated Project Cost

Based on the result of the construction cost estimate, the initial investment cost for K-G and G-M Expressways, widening and overlay costs are estimated as in Table 9.7.3.

Table 9.7.3: Summary of Investment Costs

Item	K-G Expressway (Segment 1, 2, 3)		G-M Expressway (Segment 4, 5)		TOTAL
	Local Portion	Foreign Portion	Local Portion	Foreign Portion	
1. Initial Construction Cost	4,413,090,000	321,390,000	2,432,769,000	155,282,000	7,322,531,000
2. Land Acquisition and Compensation Cost	1,199,911,000	0	449,502,000	0	1,649,413,000
3. Engineering Cost ((1.+2.) x 10%)	474,749,000	118,686,000	243,003,000	60,750,000	897,188,000
4. Administration Cost ((1.+2.) x 5%)	296,718,000	0	151,877,000	0	448,595,000
5. Contingency ((1.+2.+3.+4.) x 10%)	638,532,000	43,924,000	327,849,000	20,968,000	1,031,273,000
TOTAL INITIAL INVESTMENT COST	7,023,000,000	484,000,000	3,605,000,000	237,000,000	11,349,000,000
5. Widening Construction Cost	1,234,501,000	107,348,000	613,418,000	39,155,000	1,994,422,000
6. Engineering Cost (5. x 10%)	107,347,000	26,838,000	52,205,000	13,052,000	199,442,000
7. Contingency ((5.+6.) x 10%)	134,152,000	12,814,000	66,377,000	4,793,000	218,136,000
TOTAL WIDENING COST	1,476,000,000	147,000,000	732,000,000	57,000,000	2,412,000,000
8. Overlay Construction Cost (Initial Width)	383,256,000	42,584,000	267,239,000	29,694,000	722,773,000
9. Contingency (10 %)	38,744,000	3,416,000	26,761,000	2,306,000	71,227,000
TOTAL OVERLAY (Initial Width) COST	422,000,000	46,000,000	294,000,000	32,000,000	794,000,000
10. Overlay Construction Cost (Ultimate Width)	536,577,000	59,620,000	347,251,000	38,584,000	982,032,000
11. Contingency (10 %)	53,423,000	5,380,000	34,749,000	4,416,000	97,968,000
TOTAL OVERLAY (Ultimate Width) COST	590,000,000	65,000,000	381,000,000	42,000,000	1,080,000,000

Source: JICA Study Team

9.7.6 Yearly Cash Flow of the Project Cost

The yearly cash flow of the project is estimated as shown in Table 9.7.4, assuming the implementation schedule as shown in Figure 9.6.2.

Table 9.7.4: Yearly Cash Flow of the Project

Item	Initial Investment							Overlay	Overlay	Widening	Overlay	Overlay	Overlay
	2000	2001	2002	2003	2004	2005	Total	2016	2022	2022	2026	2030	2033
Construction Cost			373,226	1,104,596	2,877,662	2,967,047	7,322,531	722,773	722,773	1,994,422	982,032	982,032	982,032
Land Acquisition & Compensation		659,765	659,765	329,883			1,649,413	0	0	199,442	0	0	0
Engineering with Supervision	149,531	149,531	149,531	149,531	149,531	149,533	897,188	0	0	0	0	0	0
Administration		89,719	89,719	89,719	89,719	89,719	448,595	0	0	0	0	0	0
SUB-TOTAL	149,531	899,015	1,272,241	1,673,729	3,116,912	3,206,299	10,317,727	722,773	722,773	2,193,864	982,032	982,032	982,032
Contingency	14,953	89,901	127,223	167,372	311,690	320,631	1,031,770	71,227	71,227	218,136	97,968	97,968	97,968
CASH OUT FLOW TOTAL	164,484	988,916	1,399,464	1,841,101	3,428,602	3,526,930	11,349,497	794,000	794,000	2,412,000	1,080,000	1,080,000	1,080,000

Year	2000～2005 (Project Preparation and Construction)	2006	2016	2022	2026	2030	2033
ANNUAL CASH INFLOW (not accummulated)	N.A.	899,300	1,813,300	2,428,000	2,961,000	3,622,200	4,221,800

Source: JICA Study Team

Unit: Rs.x1,000

CHAPTER 10:

EXPRESSWAY OPERATION AND MAINTENANCE PLAN

10.1 Expressway Operation and Maintenance Works

10.1.1 Scope of Operation and Maintenance Works

The scope of Expressway operation and maintenance works is broadly divided into three major components; (1) Expressway Maintenance, (2) Traffic Management, and (3) Toll Collection.

(1) Expressway Maintenance

The basic objectives of expressway maintenance are to secure traffic safety, smooth traffic flow and user comfort. The activities for maintenance can be categorized as routine maintenance, periodic maintenance and incidental maintenance by their frequency and characteristics.

Routine maintenance is based on routine (daily) inspection of the pavement conditions, embankment slope conditions, drainage, bridges and other structures and facilities to monitor any defects and damages on them. The results of routine inspection will be promptly reported to the operation and maintenance office for follow-up maintenance works as required.

Periodic maintenance is based on detailed inspection to be performed at certain time intervals of weekly, monthly or yearly depending on the type of facilities, including checking and testing of the conditions of structures and facilities. Defects and damages will be reported for repairs or remedies. Periodic maintenance also covers such works as cleaning of pavement, guardrail and sign boards, mowing and trimming of landscape plantation, and repair of road marking and painting.

Incidental maintenance is basically the works to be carried out to restore the expressway and the related facilities to their normal operating conditions after they are substantially damaged by road accidents or natural causes.

Major maintenance works except inspection will be either performed by the expressway operator, or performed on contract basis. On contract basis of maintenance works, the necessary work package will be contracted to contractors by small tender or appointments depending on the scale of the works. This is because it is often economically more reasonable than possessing own performing units by their frequency. Work items can be categorized as follows:

a) Cleaning of pavement
b) Mowing and trimming of plantation
c) Cleaning of ditches and culverts
d) Pavement repair as patching and resurfacing
e) Repair of expansion joints of bridges and viaducts
f) Repair of embankment slopes
g) Repair of damages on facilities caused by traffic accidents
h) Pavement overlay, road markings and kerb stone repairs.

(2) Traffic Management

Traffic management includes activities of traffic control, towing of disabled cars involved in accidents, and furnishing users with expressway and traffic information. Highway patrol will be performed to find damages on road facilities, traffic accident, illegal parking, disabled cars and other extraordinary conditions which disturb traffic safety. Information and report will be dispatched to the operation and maintenance office through radio communication equipped on patrol cars. Services as rescue, ambulance and emergency treatment to the injured by accidents, towing of disabled cars will also be executed.

Traffic control includes general control of speed, overloading and emergency lane use under unusual conditions of accidents, abnormal weather and maintenance work performance. Control and omission of illegally overloaded trucks will be conducted in cooperation with traffic police. Axle load meters will be installed at entries of interchanges for weighing, so that such illegal overloaded trucks can be prevented from entering the expressway.

Traffic surveillance including information collection and dissemination is also an important part of traffic management especially when the traffic volume is approaching the expressway capacity. Installation of such facilities as CCTV, radio broadcast, variable message signs and emergency telephone should be programmed in the future for better service for users. These higher level of traffic information services than ordinary highway is required for toll expressway since the users are charged for using the facility, and will expect to obtain better services.

(3) Toll Collection

Toll levy system can be either flat toll system or proportional toll system from the system viewpoint. The result of the toll levy system for K-G and G-M Expressways, however, is more in favor of proportional (distance-based) toll system.

The number of tollgates will depend heavily on whether they are throughway tollgates at toll plazas or access tollgates at interchanges. The necessary number of tollgates will generally depend on traffic amount that the tollgates will manage. Since the toll collectors (booth attendants) will handle a large amount of cash on daily basis, security system for the collector, and for the cash will be critical.

10.1.2 Maintenance of Roadway, Structures and Facilities

(1) Inspection System

Inspection of road facilities is to recognize and evaluate the physical conditions of the roadway facilities by observations so that the roadway will be maintained in appropriate conditions for traffic flows, and maintained harmless to general public. The inspection is a main part of maintenance activities as well as repair works which will be done if the inspection finds it necessary. As same as the maintenance categorization, inspection activities are categorized as follows:

Routine (Daily) Inspection: Daily inspection of road conditions and usage by driving observation.

Periodic Inspection: General inspection of structures in the designated area including details of structures which cannot be done in routine inspection.

Incidental Inspection: Special inspection when an evaluation is difficult by routine and periodic inspections, when an abnormal weather condition is expected, when the roadway has or expected to have any abnormal conditions.

Table 10.1.1 shows the scope of inspection works for each category of the inspection system. It is recommended that the periodic inspection be broken down into three different levels for different level of details.

Table 10.1.1: The Scope of Inspection Works

Inspection Category		Routine	Periodic (Class A)	Periodic (Class B)	Periodic (Class C)	Incidental	Remarks
Frequency		Once/day	Once/year	Once/1 - 3years	Once/1 - 5years	Upon necessity	
Items	Definition	Daily inspection mainly by driving observations	General overall Inspection for all bridges & culverts	More particular inspection for bridges & culverts	Detailed inspection for selected part of bridges & culverts	Supplemental inspection upon particular necessity	
Roadway	Pavement	●				Necessary Items	
	Kerb	●					
Slope	Cut Slope	● *	●	●	●		* within driving observation
	Special Cut Slope	● *	●	●	●		
	Embankment Slope		●	●	● **		** Specified location only
	Special Embankment Slope		●	●	● **		
Drainage	Shoulder Drainage	● *	●	●			
	Median Drainage	● *		●			
	Slope Drainage		●	●	●		
	Bridge Drainage		●	●	●		
	ROW Boundary Drainage		●	●			
Bridge	Concrete Superstructure		●	●	●		
	Concrete Substructure		●	●	●		
	Bearings		●	●	●		
	Joints	●	●	●	●		
	Rails	● *	●	●	●		
Culverts	Box Culverts		●	●	●		
	Pipe Culverts		●	●	●		
Traffic Control Devices	Traffic Signs	●	●	●	●		
	Road Markings	●					
	Delineators	●					
Others	Fences		●				

Source: "Construction Supervision on Expressways; Maintenance Version" Japan Highway Public Corporation, Modified by JICA Study Team

(2) Repair Works

The inspection system does not conclude by itself, but continues to the next step of further investigation, continuing observation or repair works depending on the necessity. Particularly the decision of repair works is an important engineering decision to be made by the operation and maintenance office.

Figure 10.1.1 shows a flowchart for summarizing a decision making process on repair works and other alternatives following the inspection result.

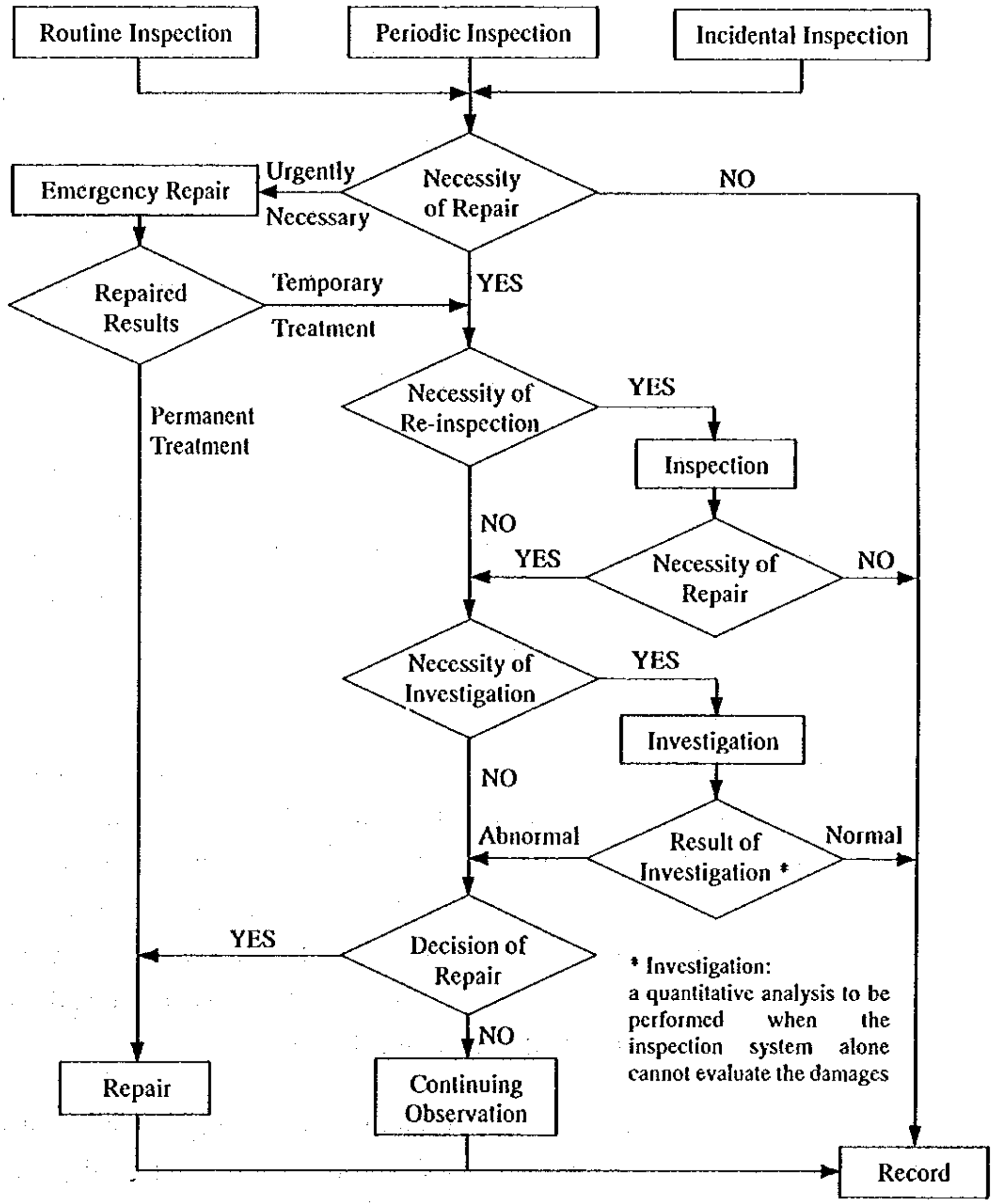


Figure 10.1.1: Flowchart for Inspection and Repair Works

10.1.3 Traffic Management and Accident Measures

Traffic management on expressways needs a more sophisticated system than that on arterial roads. An expressway is an access-controlled, thus a segregated space from at-grade road network. Once an accident occurs, it may take longer time for ambulance or police to reach the site than at-grade roads; even the information of such accidents may not be transmitted immediately without a systematic traffic management system. Yet expressway users expect higher level of service in traffic management, as well as the physical quality of the facility, because they are paying money for using the facility.

That is why an expressway operation requires a centralized traffic management system. Figure 10.1.2 shows a diagram for centralized traffic management and accident measures on expressway. A centralized traffic management system is to collect all of traffic information including accident information to the Traffic Control Center, and the Traffic Control Center will make all the necessary decisions to cope with the traffic situations on all over the expressway sections they are responsible. In the normal operational conditions, information on expressway is collected through traffic patrol cars provided by the tollway operator itself, police patrol cars, engineering patrol cars for facility inspections, toll gate patrol and roadway cleaning operators. These people are supposed to have a radio communication device to report any conditions at the site to the traffic control center. The traffic control center also collect information on weather conditions through meteorological observation units, and information on current traffic volume through automatic traffic counter, both of which are to be furnished on the roadway.

When an traffic accident occurs, the accident party or general road users should be able to inform the situation to the Traffic Control Center by emergency telephones along the roadway. The emergency telephone is furnished at the road side by a certain interval, ideally by about 1 km each, so that the users can immediately access to one of them when necessary. The accident information is also supposed be reported by patrol cars and other parties on duty on the expressway. The information can also be transmitted from the Traffic Control Center to the traffic and police patrol so that they can be dispatched to the site immediately.

As soon as the Traffic Control Center has known the accident situation, it will make decisions on to what extent the accident should be managed. It will dispatch traffic police and maintenance clues to the site, request ambulance for injured persons or fire station to dispatch their forces, and request for towing services for the damaged

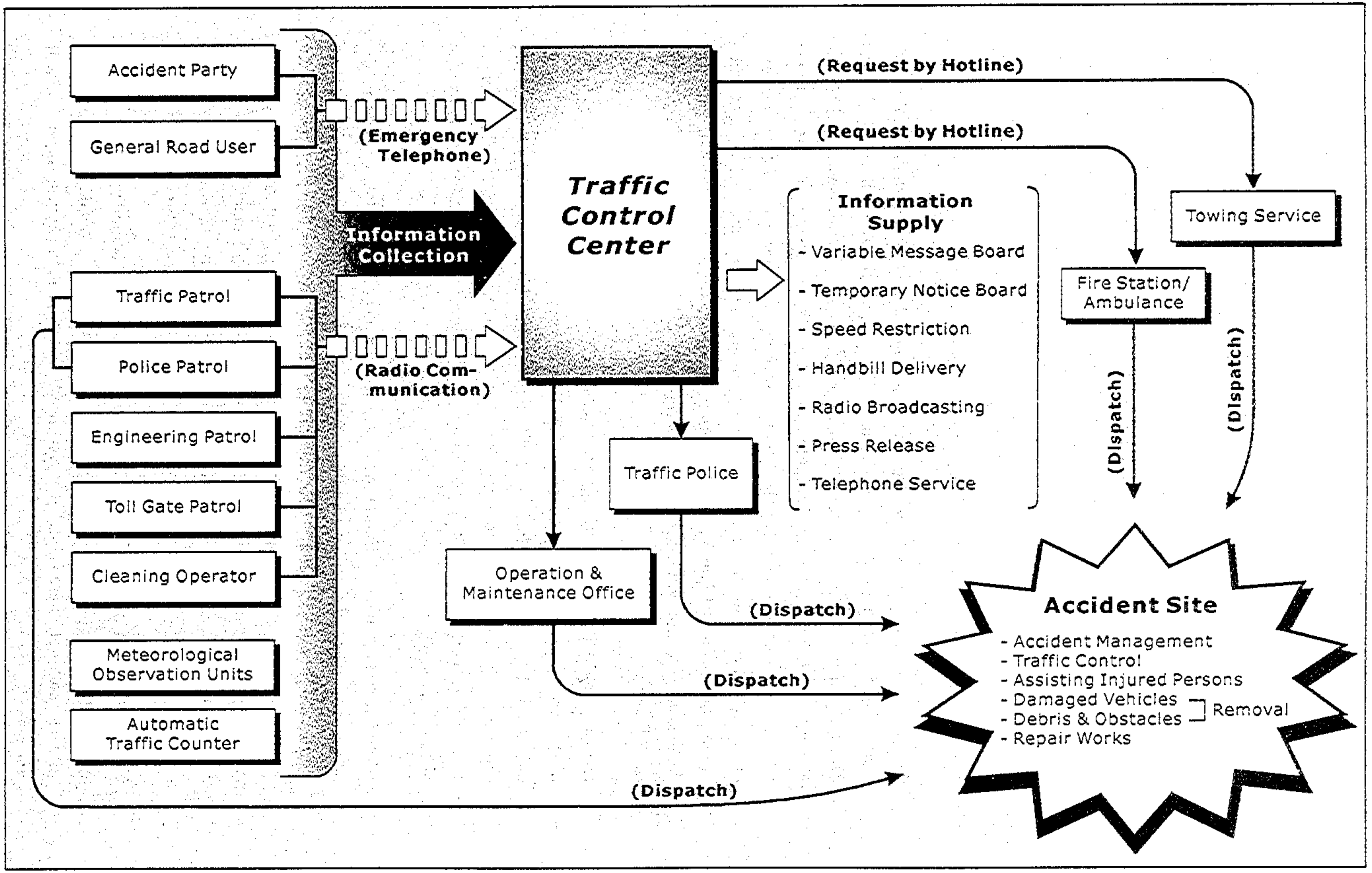


Figure 10.1.2: Diagram for Centralized Traffic Management & Accident Measures

vehicles. The center will also be responsible for the supply of the accident information to other expressway users, and general public, depending on the necessity.

The facility for the centralized traffic management system may vary depending on the length of the responsible expressway, and the level of service the operator will plan. The idea of centralized control, however, should be realized on every access controlled expressway system.

10.1.4 Toll Collection System

(1) Flat Toll System versus Distance-based Toll System

The decision on whether the toll expressway adopts the Flat Toll System or Distance-based Toll System will affect the road user's usage patterns and toll revenue. Flat Toll System is effective and convenient to users for urban expressways, where the average trip distance is relatively shorter and the average frequency of usage per user is higher. Urban expressways are usually crowded, many users often enter and exit on daily basis, and the operator handles many similar short trips. In such circumstances, a flat toll system is preferable because the operator can save the collection cost, shorten the service time at payment, and the user can easily remember the toll amount.

Distance-based Toll System, on the other hand, is effective and fair to users for inter-urban expressways, where the average trip distance is longer, and frequency of usage per user is less. If the difference in distance between longer trip users and shorter trip users become large, the distance-based toll creates unfairness. The longer service time, normally less than ten seconds, is not a major problem when the average distance is longer.

Although K-G and G-M Expressways are located near the capital region and the neighborhood is expected to rapidly urbanized in the future, the nature of the two expressways are both inter-urban expressways. The average interchange interval will be 24 km, and the interchange interval varies depending on each section. According to our traffic demand forecast, the average trip distance will be 38 km. The nature of the network is multi-directional with a junction, which necessitates complete "issuing at entrance and collecting at exit" type of collection system.

Considering such nature of the expressway system, it is recommended that the toll system on K-G and G-M Expressways be Distance-based. By adopting the access tollgate system at interchanges, the system can avoid throughway toll plaza. It will enhance the less-crowded, barrier-free toll road system.

(2) Computerized Toll Collection System

Since K-G and G-M Expressways are not a single road stretch but constitute part of a network, a computerized toll collection system is recommended. A single and simple toll road stretch can be operated by a simple system of issuing a small piece of paper at the entrance and collecting the necessary toll at the exit. In a network, however, it needs to identify all of the vehicles on the system. The system will need a reliable cash management which enables the complete matching between registered or computed toll data and actually collected cash amount. Also the system should be able to acquire complete data of traffic volume and revenue, origin-destination (OD) data, peak-hour, weekly, monthly and seasonal traffic volume fluctuations for better traffic management system.

Figure 10.1.3 shows a schematic diagram for computerized distance-based toll collection system. When a vehicle entering the expressway receives a ticket, the ticket should have information such as the serial number, vehicle type, entrance IC number, date and time of entrance, and the booth attendant's number, etc. This information will be used when the vehicle exits the expressway; the toll price will be computed, payment will be confirmed and the statistical data will be registered. The number of vehicle passing the gate is also confirmed by automatic vehicle sensors located in front of the entrance and exit tollbooth. This confirms the complete matching of registered toll data and actually collected cash amount. Those toll collecting data will be all registered in the central computer, which enables a reliable revenue & cash management, and is an interest of not only the operator, but also the investors to the operating corporation.

The computerized toll collection system has optional functions, which should not necessarily be adopted at the initial opening stage, but can be future integrated services. These optional functions are:

1) Prepaid Card system for quicker payment at the exit gate,

2) Permanent Plate for frequent users for deferred payment, and

3) Automatic Toll Collection (ETC) system (a system automatically identifying a vehicle at a gate and the toll amount, and deducting the amount from the user's bank account without stopping the vehicle at the gate).

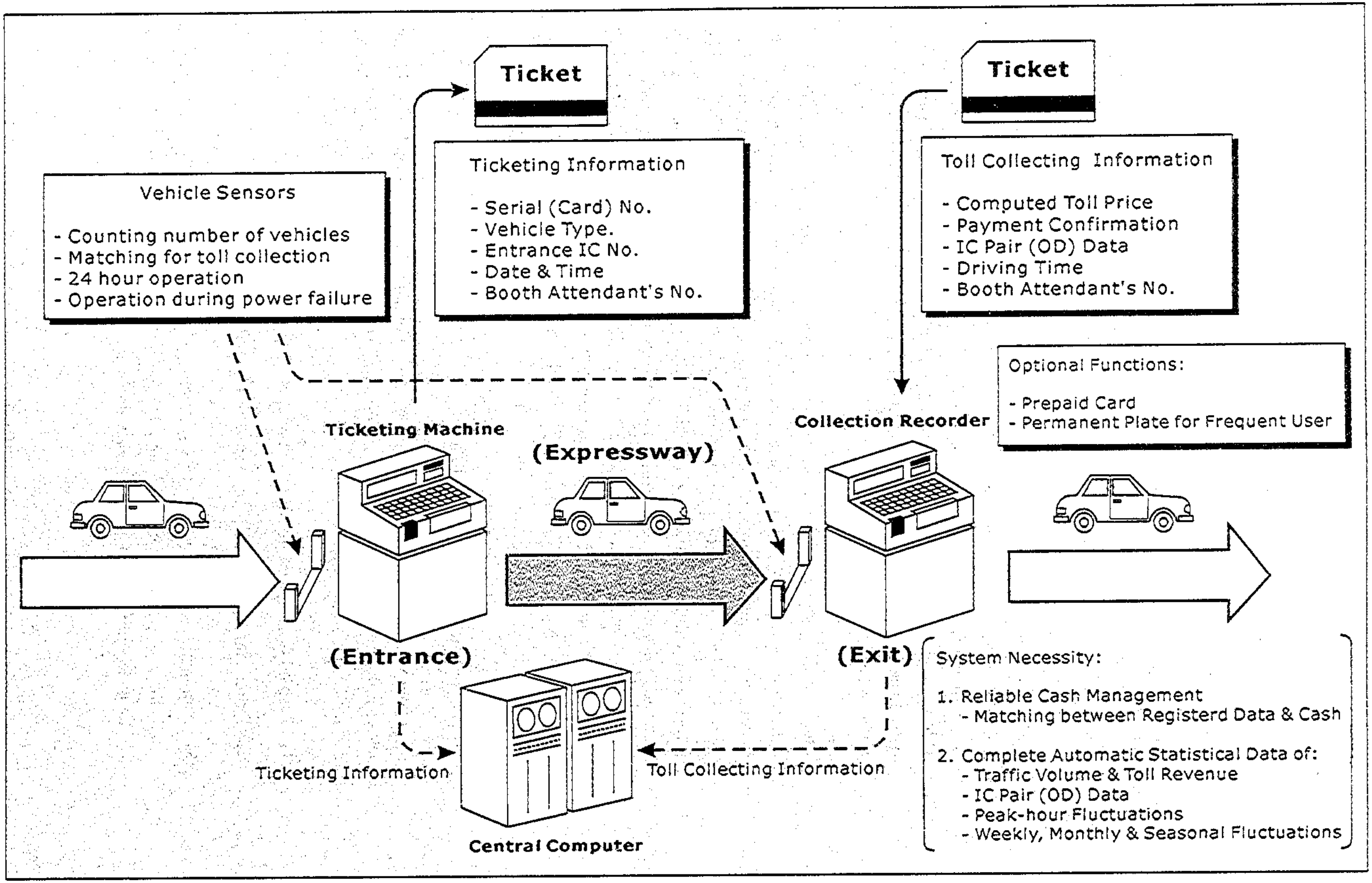


Figure 10.1.3: Distance-based Toll Collection System

10.2 Organization for Expressway Operation and Maintenance

10.2.1 Basic Organization Hierarchy

For the assumed expressway operation period, the organization for operation and maintenance should be self-sufficient. The basic organization structure will be composed of a head office, an operation and maintenance (O&M) office and tollgate offices. Figure 10.2.1 shows an example of organization charts for the head office and the O&M office.

The head office will be directed by a board of directors of the corporation to operate the tollway. It will be responsible for overall management of the organization including decision making related to basic policies on operation and maintenance of the expressway, budgetary control, short-term financing, etc. The function of the traffic control center should also directly belong to the head office because of its importance in decision making, although it should be located at the O&M office for better communication. The head office generally has the functions of technical, administration, operation and accounting. The head office should be able to ensure smooth and easy access to the related government agencies, financial institutions and business opportunities.

The O&M office will be responsible for the actual execution of operation and maintenance works for the expressway including the supervision of contracted maintenance works. The total length of Ghaziabad - Meerut and Kundli - Ghaziabad Expressways will be about 80 km. This can be operated by one O&M office if the two projects are operated by a single expressway corporation. If the expressways are divided into two different projects, it is natural to set up each regional O&M office for each project by each entity. For the maintenance activities, however, it can be performed by a single O&M office through entrustment of the maintenance of the one project to the other since this is economically a better solution for both entities.

The tollgate offices will be provided at every interchange and toll plaza location. The tollgate offices will be operated for 24 hours, 365 days a year. The toll collector (booth attendant) will work, in common practice, in three shifts. The tollgate offices will be responsible for the control of the number of open tollgates depending on the fluctuation of the traffic volume. When the amount of traffic is small, it is better to operate fewer number of tollgates to save the operation cost. On the other hand, it will create a congestion if the amount of traffic is too large compared with the number of tollgates.

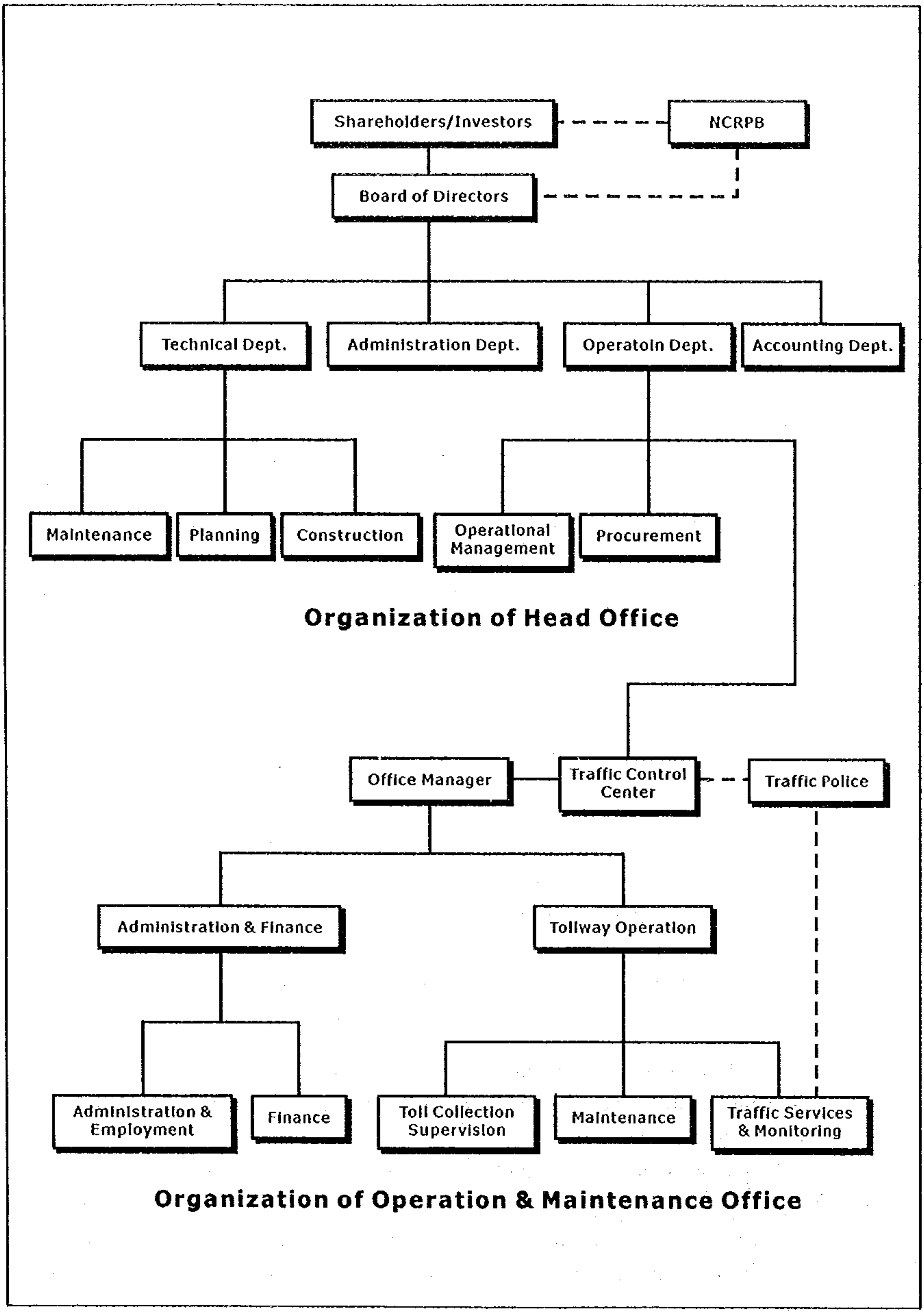


Figure 10.2.1: Organization Chart of Head Office and Operation & Maintenance Office

10.2.2 Office Location Plan

The location of the head office depends on several conditions beyond the scope of the study for K-G and G-M Expressways only. If the expressway corporation is formed for implementing K-G and G-M Expressways only, for example, it is recommended that the head office be located together with the O&M office in one of the interchange areas. This is because the responsible portion of the expressway is the same between the head office and the O&M office. On the other hand, if the expressway corporation is formed for FNG Expressway and K-G, G-M Expressways altogether, it might be better to locate the head office in the city of Delhi seeking smoother and easier access to the related government agencies, financial institutions and business opportunities, especially if FNG Expressway and K-G/G-M Expressways has independent O&M offices.

The location of the O&M office should be in one of the interchange areas since it can utilize the acquired land area for the operation, and it can have an easy access both to the expressway and other urban functions outside of the expressway area. It is desirable to reach the farthest point of the expressway approximately within 30 minutes from the office. For K-G and G-M Expressways, it is recommended that the O&M office be located in the interchange of Ghaziabad. This is because among the possible five interchanges where the operation and maintenance office can be located, Khekra IC and Modinagar IC are small and do not have a good access to urban area. Kundli IC is too far from G-M Expressway, and Meerut IC is too far from K-G Expressway at the time of emergency. The O&M office in Ghaziabad could also function for FNG Expressway if the corporate condition allows because of its ideal midway location for entire FNG, K-G and G-M Expressway system.

The tollgate offices should be located at each of the five interchanges at the side of tollgates. The tollgate offices will manage a lot of cash everyday, and the security for carrying the cash is strictly important. Hence, the physical distance between the tollgates and the office should be as short as possible. The tollgate office of Ghaziabad IC can share the space with the O&M office if it is located in the same interchange area.

10.3 Facilities and Equipment for Operation and Maintenance

10.3.1 Operation and Maintenance Office

The facilities of the O&M office should basically consist of the office space, parking lot, electrical rooms and others. The required office area is approximately around 10,000 to 20,000 m^2. The office space includes the spaces for office manager and other staff, meeting rooms and other necessary facilities. The parking lot space should be able to accommodate all the necessary vehicles for maintenance. The electrical rooms includes a computer room, a power supply and generator room, a telecommunication control room, and other storage spaces.

The necessary equipment for maintenance activities are ordinary sedans and vans, light and heavy trucks, lift trucks, water trucks, backhoes, portable generators, chain saws, electric welders, air compressors, tampers, concrete mixers, concrete vibrators, and other hand tools, etc. Introducing special types of vehicles such as a road cleaner should be considered upon necessity.

10.3.2 Tollgate Offices

The tollgate office facilities should basically consist of the tollbooths, islands and their roofs, the office space including a cash calculation room, ticket storage, electrical rooms, and others. Since the office is operated on 24-hour basis, the office facilities should equip a minimum accommodations for resting and temporary sleeping facilities for booth attendants and other employees. The required office area is approximately around 3,000 to 5,000 m^2. The tollgate office that is located in the interchange where the O&M office is also located, the two offices can share a space in the interchange.

The tollgate office should be able to observe the gate area well, and if the interchange design allows, it is desirable to be located at the exit gate side of the tollgate area. This is to minimize the distance for carrying cash. On K-G and G-M Expressways, Khekra IC, Modinagar IC can achieve this design; however, Kundli IC, Meerut IC and Ghaziabad IC locate the tollgate office at the entrance side due to the ramp design reasons. It would be better, if it is deemed necessary, to provide a direct underground walking tunnel for carrying cash from the booths to the office.

The tollgates should be equipped with barricades to be able to close all of the gates when necessary. Normally these are used when some of the booths are closed, but they can be used when the operator need to control the number of vehicles entering the expressway on emergency or abnormal traffic saturation, etc.

10.4 Operation and Maintenance Cost

The operation and maintenance cost consists of roadway maintenance materials cost, maintenance equipment and fuel costs, facility and utility running cost, and manpower cost. The maintenance materials are for incidental pavement repairs, replacement of broken facilities and their parts. The equipment consists of the machines and tools mentioned in Section 10.3.1. For estimating the necessary cost, it is assumed that the equipment necessary for routine and periodic maintenance activities will be owned by the expressway operator. The facility and utility running cost is for office buildings, toll plaza and rest area facilities including lighting and other utilities. The manpower cost includes all of the necessary personnel for the head office, O&M office, and tollgate offices.

The estimated operation and maintenance cost (1999 prices) for all of K-G and G-M Expressways (Total O&M Length = 80.75 km) is as follows:

Table 10.4.1: Annual Operation and Maintenance Cost

No.	Item	Annual Cost
1.	Maintenance Material Cost	Rs. 6,000,000
2.	Maintenance Equipment & Fuel Costs	Rs. 6,500,000
3.	Facility and Utility Cost	Rs. 5,700,000
4.	Manpower Cost	Rs. 14,800,000
Total Annual Cost		Rs. 33,000,000

Source: JICA Study Team

Note: Annual equipment cost is computed based on the assumption that all machines and tools will be purchased and depreciated (used up) in ten years.

For a summary, all of "non-initial project costs," that means the costs arising after the initial construction is completed and the expressways are open to traffic, are summarized in Table 10.4.2. These are also all 1999 prices.

Table 10.4.2: Summary of "Non-initial Project Costs" of the Expressways

Item		Cost
Operation and Routine/Periodic Maintenance Cost		Rs. 33,000,000 /year
Pavement Rehabilitation Cost	(For Initial Number of Lanes)	Rs. 792,000,000 /each
	(For Ultimate Number of Lanes)	Rs. 1,078,000,000 /each
Expressway Widening Cost		Rs. 2,412,000,000

Source: JICA Study Team

CHAPTER 11:

ECONOMIC ANALYSIS

11.1 Vehicle Operating Cost and Time Cost

11.1.1 Vehicle Operating Cost(VOC)

(1) Vehicles for the estimation of VOC

When the project is implemented, vehicle speeds will tend to increase, consequently, all vehicles are able to enjoy benefit of the saving in vehicle operating costs. Figure 11.1.1 shows 6 kinds of vehicles selected for calculation of VOC; 1) passenger car, 2) small size bus, 3) large size bus, 4) small size truck, 5) large size truck, and 6) motorcycle.

These 6 kinds of vehicles are grouped into 4 categories in the stage of economic evaluation to match the estimated traffic volume. Slow moving vehicles such as auto rickshaw, agriculture tractors/trailers, cycles and cycle-rickshaw are excluded from the calculation.

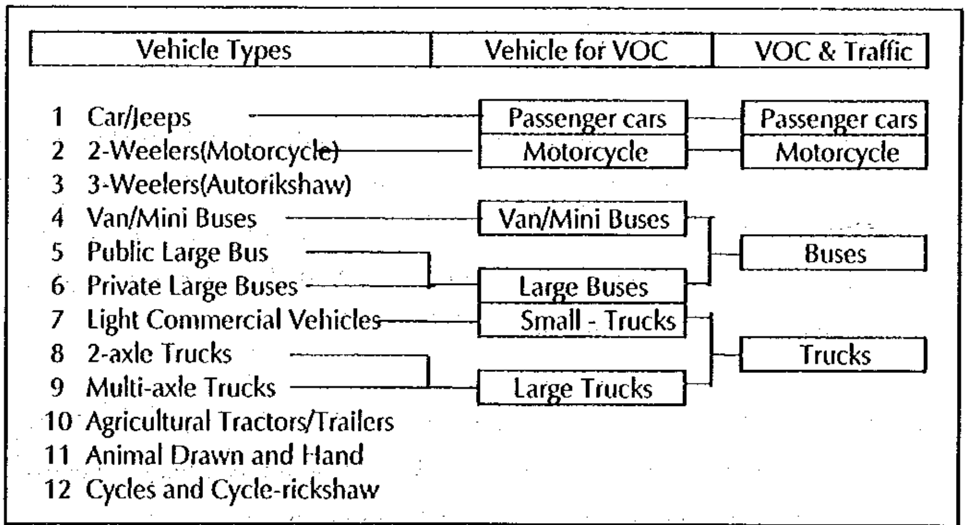


Figure 11.1.1 Vehicle Classification for Vehicle Operating

(2) Component of Vehicle Operating Cost

Vehicle operation cost (VOC) can be divided into two major components; 1) running cost and 2) fixed cost. Vehicle running cost changes in proportion to vehicle running conditions and vehicle usage conditions. Fixed cost accrues in the purchase of a vehicle while running cost accrues by driving vehicles. Figure 11.1.2 shows running cost consisting of 5 items and fixed cost consisting of 4 items.

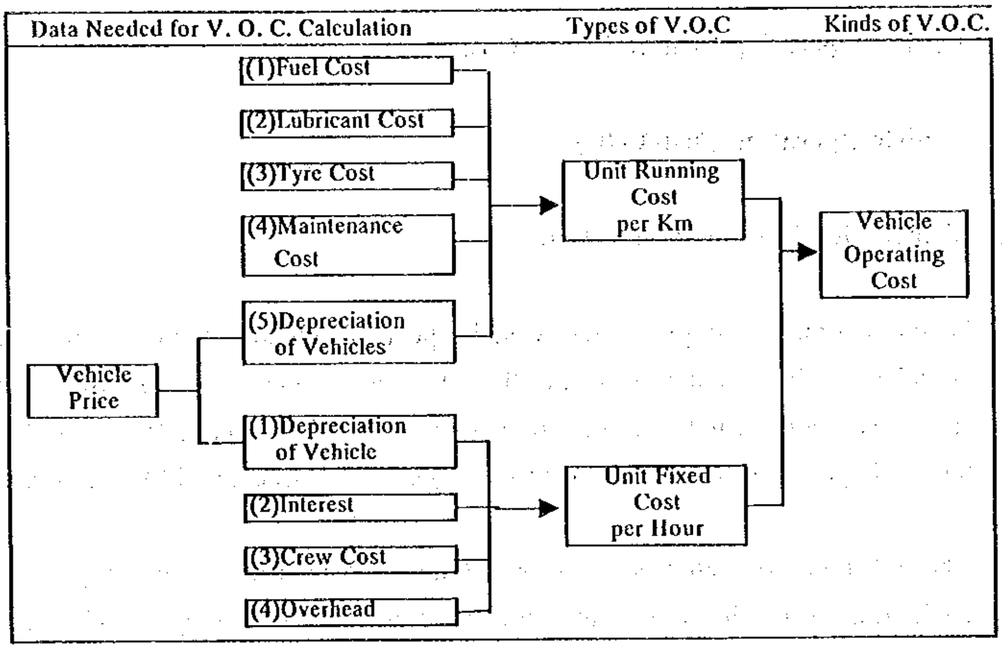


Figure 11.1.2 Diagram of Vehicle Operating Cost Estimation Procedure

(3) Economic Price of Vehicles

The price of the vehicle affects VOC greatly. Table 11.1.1 shows the calculation of financial cost and economic cost of a passenger car. The selected car is the product of MARUTI UDYOG TD, which occupies 80% to 85% of market share. The average retail price of the car is estimated at 182,775 Rs. And the economic cost is found to be 140,550Rs, deducting 23% for tax and duties.

For other vehicles refer to 1) Appendix Table 11.1.1 for small bus, 2) Appendix Table 11.1.2, for large bus, 3) Appendix Table 11.1.3 for small truck, Appendix Table 11.1.4 for large size truck, and Appendix 11.1.5 for motorcycle.

Table 11.1.1 Calculation of Financial /Economic Price of Vehicles

- The Case of Passenger Car -

Item	Calculation	Economic Cost	Tax/duty	Financial Cost
		Cost		Cumulative
a) CKD & Assembly Costs		135,586		135,586
b) Excise Duty(Include Cess)	14.31%		22,642	158,228
c) Whole sale price				158,228
d) Dealer Commission	3.04%	4,964		4,964
e) Retail price				163,192
f)Sales Tax	8%		13,055	176,248
g) Registration Tax	4% of Item(e)		6,528	182,775
On the road price(Financial Cost)		140,550	42,226	182,775
Cost Component %		77 %	23 %	100 %

Note: CKD: Complete Knock Down

Source: Association of India Automobile Manufactures

(4) Prices of Input Items for Vehicle Operating Cost Estimation

Table 11.1.2 shows cost by items by vehicle types. Cost data of items in the table are obtained through various trade organizations. The items are 1) vehicle price, 2) fuel price/litter, 3) tyre unit price, 4) lubricant price/litter, 5) maintenance labor cost, 6) overhead cost, and 7) crew unit cost. Diesel oil price of fuel for vehicles increased from 9.94 Rs/Litter to 11.67 Rs/Litter in October 1999 thus affecting running cost and VOC.

Other items in the table are taken from data of IBRD and AASHTO with consideration to actual data obtained in study area. Data are also based on the ADB financed "Study for Updating Road User Cost Data" prepared by Dr.L.R.Kadiyali and Associates.

Table 11.1.2 Input Data for Unit Vehicle Operating Cost at Base Speed

Unit : Rupee

Items	Passenger Car	Small Bus	Large Bus	Small Truck	Large Truck	Motor-cycle
1) Vehicle Price(Excl.Tyres)Fin-Rs.	182,775	350,328	449,967	332,512	572,633	38,376
Vehicle Price(excl.Tyres)Econ-Rs.	140,550	227,722	343,103	246,119	436,736	28,507
Vehicle Life(Years)	8	9	8	8	8	6
Vehicle Life Km	104,000	382,500	320,000	224,000	322,500	90,000
Vehicle Annual Km	13,000	45,000	40,000	28,000	43,000	15,000
Vehicle Life Operating Hours	4,000	12,750	12,800	9,600	11,250	3,600
Vehicle Annual Operating Hours	500	1,500	1,600	1,200	1,500	600
2) Fuel Price (Fin-Rs./Liter)	25.86	13.91	13.91	13.91	13.91	13.91
Fuel Price (Econ-Rs./Liter)	21.72	11.68	11.68	11.68	11.68	11.68
Fuel Consumption (Liter/Km)	0.13	0.18	0.25	0.27	0.30	0.03
3) Tyre Unit Price (Fin-Rs./Piece)	1,550	4,800	10,020	10,020	12,000	480
Tyre Unit Price (Econ-Rs./Piece)	1,054	3,264	6,814	6,814	8,160	326
Number of Tyres	4	4	6	6	10	2
Tyre Life -Km	40,000	30,000	40,000	40,000	40,000	30,000
4) Lubricants Price(Fin-Rs./Liter)	75.00	75.00	75.00	75.00	75.00	75.00
Lubricants Price(Econ-Rs./Liter)	63.00	63.00	63.00	63.00	63.00	63.00
Lubri.OilConsumpt.(Liter/100km)	1.2	2.0	2.2	3.0	3.4	0.2
5) Maintenance Spares/Year (%)	7	8	10	8	8	3
MaintenanceLabor(Hour/1000km)	3	15	15	12	15	2
Maintenance LaborCost(Fin-Rs/h)	23.88	23.88	23.88	23.88	23.88	23.88
Maintenance LaborCost(Econ-Rs.	23.67	23.67	23.67	23.67	23.67	23.67
6) Depreciation.Distance Related(%)	60	80	85	70	70	60
Depreciation.Time Related(%)	40	20	15	30	30	40
7) Real Rate of Interest of Capital (%	13.5	13.5	13.5	13.5	13.5	8.5
Opportunity Cost of Capital(%)	12	12	12	12	12	12
8) Overhead cost(Annum Fin-Rs.)	0	38,095	38,095	38,095	38,095	0
Overhead cost(Annum Econ-Rs.)	0	38,095	38,095	38,095	38,095	0
9) Crew-Number(Driver)	0	1	1	1	1	0
Crew-Number(Assistant)	0	1	1	1	1	0
Crew Unit Cost (Fin-Rs./Hour)	0	23.88	23.88	23.88	23.88	0
Crew Unit Cost(Econ-Rs./Hour)	0	23.67	23.67	23.67	23.67	0

(5) Estimation Procedure

Vehicle operating costs by vehicle types are estimated by the following formula by using the input data of Table 11.1.2 namely:

1) Fuel cost/km: Fuel price/litter x fuel consumption /km by speed
2) Lubricant cost/km: lubricant price/litter x lubricant consumption/100km
3) Tyre cost/km: Tyre unit price / tyre life km
4) Maintenance

   Spares portion/km: Vehicle price / vehicle life km x % of maintenance spare cost /year as % of vehicle price

   Labor portion/km: (working hour/1000km x labor cost/hour) 1000

5) Depreciation

Distance related/km: Vehicle price / vehicle life km x distance Ratio (60%)

Time related/km: Vehicle price / vehicle life hour x time related ratio (40%)

6) Overhead cost/km: Annual labor cost x annual working hour

7) Crew cost/km: Annual crew cost x time cost/hour

(6) Result of Calculation of Running Cost

Running cost of vehicles contain five factors such as 1) fuel cost, 2) lubricant cost, 3) tyre cost, 4) maintenance cost, and 5) depreciation cost related to running distance. Table 11.1.3 shows the result of the calculation. The share between large and small bus and truck is taken from traffic survey.

Table 11.1.3 Summary of Running Cost Per km by Base Speed (Economic Price)

Unit: Rupees/km

Items	Pass. Car	Bus		Truck		M.Cycle
		Small Bus	Large Bus	Small Truck	Large Truck	
Fuel Costs	2.82	2.10	2.92	3.15	3.50	0.35
Lubricant Costs	0.08	0.13	0.14	0.19	0.21	0.01
Tyre Costs	0.11	0.44	1.02	1.02	2.04	0.02
Maintenance Spares Costs	0.09	0.05	0.11	0.09	0.11	0.01
Maintenance Labor Costs	0.07	0.36	0.36	0.28	0.36	0.05
Depreciation Costs	0.81	0.48	0.91	0.77	0.95	0.19
Total Running Costs/vehicle-km	3.98	3.54	5.45	5.51	7.17	0.63
Vehicle Component	100%	33%	67%	48%	52%	100%
Weighted	3.98	1.17	3.65	2.64	3.73	0.63
Running Costs/vehicle-km	3.98	4.82		6.37		0.63

The relationship between running speed and running cost by vehicle types is expressed in following formulas where Y is running cost, and X is running speed on city road.

1) Passenger car $Y = 0.000902x^2 - 0.139788x + 8.440934$
2) Bus $Y = 0.000984x^2 - 0.123030x + 8.166583$
3) Truck $Y = 0.001804x^2 - 0.235464x + 12.901529$
4) Motorcycle $Y = 0.000179x^2 - 0.016251x + 0.996781$

(7) Fixed Cost

There are 5 items in the fixed cost such as 1) depreciation cost related to time consumed, 2) interest cost, 3) overhead cost, 4) crew cost, and 5) Usage cost that is accruing from car utilization. Details of unit VOC by item is presented in Table 11.1.4.

Table 11.1.4 Summary of Fixed Costs per Km at Base Speed (Economic Price)

Unit: Rupees/km

Items	Pass. Car	Bus		Truck		M.Cycle
		Small Bus	Large Bus	Small Truck	Large Truck	
Capital Costs(Dep-Time Relation)	14.06	3.57	4.02	7.69	11.65	3.17
Opportunity Cost of Capital	33.73	18.22	25.73	24.61	34.94	5.70
Overhead Cost	0.00	25.40	23.81	31.75	25.40	0.00
Crew Costs	0.00	47.34	47.34	47.34	47.34	0.00
Fixed Costs, All	47.79	94.53	100.90	111.39	119.32	8.87
Factor (%)	0.30	0.65	0.65	0.70	0.70	0.30
Total Fixed Costs/Vehicle-hour	14.34	61.44	65.59	77.97	83.53	2.66
Total Fixed Costs/Vehicle-km	0.32	1.37	1.64	1.95	2.09	0.07
Vehicle Composition	100%	33%	67%	48%	52%	100%
Weighted	0.32	0.45	1.10	0.94	1.09	0.07
Fixed Costs/Vehicle-km	0.32	1.55		2.02		0.07

(8) Summary of Unit VOC

As shown in Table 5.1.3 and 5.1.4, following is the unit VOC at basic speed, which ranges from 50km/h for passenger car to 40km/h for other vehicles.

Vehicles:	Running Cost	Fixed Cost
Passenger car	3.98 Rs./km	0.32 Rs./km
Bus	4.82 Rs/km	1.55 Rs/km
Truck	6.37 Rs/km	2.02 Rs/km
Motorcycle	0.63 Rs/km	0.07 Rs/km

11.1.2 Travel Time Cost

(1) Wage Rate Approach

Traveling hours saving of persons as a result of the project is considered as an economic benefit of the expressway. Estimation of travel time cost was done on the basis of wage rate approach. The wage rate and trip purpose is function of the passenger time value. Therefore, time value is obtained by the following procedures:

1) Estimation of income per worker by income level;
2) Estimation of working time value by vehicle user; and
3) Estimation of travel time value of passenger by vehicle type.

(2) Income Level

Data of Gross Regional Domestic Product (GRDP), population, employee are based on the socio-economic analysis in Chapter 5. Table 11.1.5 shows the income distribution by income level. Detail is shown in Appendix Table 11.1.6.

As shown in the table the number of employee in the study area is 7,577,000 in 1999 and the annual average income per employee is 83,962 Rupee for the same year

Table 11.1.5 Distribution of Annual Income by Groups of Study Area in 1999

Items	Lowest	Second	Third	Fourth	Highest	Ave.or Total
Distribution of Employee by Income Level	20.04%	39.43%	18.38%	10.75%	11.40%	100%
Number of Employee Year 1999(1000)	1,518	2,987	1,393	814	864	7,577
Distribution of Income by Income Level	3.84%	11.46%	19.52%	28.18%	37.01%	100%
Amount of Income Year 1999(Rs)	24,406	72,895	124,191	179,266	235,422	636,180
Annual Income per Employee(Rs)	16,073	24,401	89,162	220,120	272,518	83,962

Source: JICA Study Team and Statistical Outline of India 1998-99, P214

(3) Working Time Value

Working time value for workers should differ by the level of income. As shown in the Table 11.1.6, the annual income level of the lowest class, which amounts to 20% of the total workers, is 6.70 Rs /h. Conversely, that of the highest class, approximately 11% of total workers, is 84.22 Rs/h., which is about 14 times higher than the lowest income level.

Table 11.1.6 Unit Working Time Value by Income Level (Economic)

Unit: Rupee

Level of Income by Group	Lowest	Second	Third	Fourth	Highest
Annual Income per Employee	16,073	24,401	89,162	220,120	272,518
Tax Liability	0	0	3,300	29,150	70,400
Annual Income after Tax	16,073	24,401	85,862	190,970	202,118
Working Hour /Year	2,400	2,400	2,400	2,400	2,400
Working Time Value/Hour	6.70	10.17	35.78	79.57	84.22

Source: 1)Statistical Outline of India 1998-99, P214

(4) Time Value by Vehicles

It is assumed that the income group lowest and the second lowest income group use bus, the second and third groups use motorcycle, whilst the fourth and the highest income groups use passenger car. Occupancy rate of vehicles is adjusted by non-employment ratio. Table 11.1.7 shows the working time value by vehicle type.

Table 11.1.7 Working Time Value by Type of Vehicle Users

Grouping by Vehicle	Bus Passenger	M.cycle	Passenger Car
No. of Passengers	45.0	1.4	1.60
Adjustment by Non-Employment Ratio (7%)	31.5	0.98	1.04
Time Value /Vehicle.Hour (Rs.)	265.61	22.51	85.17
Time Value /Vehicle.Minute	4.43	0.38	1.42

Source: Occupancy rate of vehicles & Income level of M.cycle by Interview Survey ,JICA Study Team

(5) Summary of Travel Time Cost

There is a difference between the working time value and the transportation (trip) time value. Trips from origin to destination by using project expressway or by using ordinary streets are not always made for productive purposes. According to the results of the traffic survey, about 20% of trips are for leisure purpose, which is not included in time value calculation. Business trips are valued at 100% of wage while non-work related trips are valued at around 50%.

Table 11.1.8 Travel Time Value by the Type of Vehicle User

Unit : Rupee

Usage of Vehicle	Trip Purpose			Time Productivity				TimeValue/minute	
Types by Passenger	Work	NonLeisure	Leisure	Work	Non-Leisure	Leisure	Total	Working	Trip
	A	B	C	D	E=Bx0.50	F	G=D+E	H	I=GxH
Passenger Car	35%	45%	20%	35%	23%	0%	58%	1.42	**0.82**
Motorcycle	35%	45%	20%	35%	23%	0%	58%	0.38	**0.22**
Bus	20%	55%	25%	20%	28%	0%	48%	4.43	**2.10**

Source: Interview Survey by JICA Study Team

As Table 11.1.8 shows, the time value estimated by working income is 1.42 Rs/minute in the case of passenger car, but the time value adjusted by non-employment ratio and trip purpose is 0.82 Rs /minute.

The following travel time value will be used for the time saving benefit calculation of the project as follows:

Time value per minute ....Passenger car .... 0.82 Rs.
Time value per minute ....Bus ....2.10 Rs.
Time value per minute ....Motorcycle .... 0.22Rs.

The increase in time value as a result of the growth of GRDP is not considered because all cost and benefit are compared at present value by constant price for the calculation of Internal Rate of Return.

11.2 Network and Cost

11.2.1 Project Network and Cost Components

(1) Network for Evaluation

A total length of the project expressway network, 80.75 km, is defined to be the following groups for economic evaluation namely:

1) Whole Expressway Network	80.75km
2) Section of Kundli – Ghaziabad Expressway	49.00km
2) Section of Ghaziabad – Meerut Expressway	39.95 km

Each group is evaluated separately to determine 1) scale of investment, 2) timing of investment , and 3) priority of investment using economic analysis.

The three alternatives are considered to be constructed initially as 4 lanes with 6 lanes for the section between Ghaziabad I.C and Ghaziabad junction. Alternatives of widening to 6 lanes are considered when traffic demand reaches the capacity in year 2022, 17 years after the opening. The upgrading of parallel national highways is not considered as an alternative.

(2) Project Cost

Table 11.2.1 shows initial investment cost for each section. The cost figures in the table are based on the calculation in Chapter 9. Total investment cost of the whole network, K-G and G-M, is 11,350 million Rs.

Table 11.2.1 Component of Construction Cost of Sections

Unit: Million Rs.

Items	K-G Section	G-M Section	(K-G)+(M-G)
Length (km)	49.00km	39.55km	80.75km
Construction	5,445	3,696	8,422
Land Acquisition	1,384	1,071	1,902
Engineering Services	678	473	1,025
Total	7,507	5,240	11,350

The investment cost includes physical contingency but does not include price contingency. The price is shown in 1999 prices. More details of initial investment cost by segment are shown in Appendix Table 11.2.1. The cost of maintenance and cost of widening are shown in Appendix 11.2.2.

11.2.2 Estimation of Economic Costs

In the economic analysis of the project, the financial cost, which is estimated in market price, was converted to an economic price. Economic cost expresses the real value of expressway investment cost in monetary unit. This economic cost is compared with the economic benefit to justify the project. The following 6 items estimated by market price are converted into economic cost.

(1) Foreign and Local Portion

Economic cost of the project is estimated separately for, 1) construction cost, 2) engineering cost and 3) land acquisition cost. Cost components of foreign and local portion are as follows:

	1) Foreign portion	2) Local portion.
1) Construction cost	6%	94%
2) Engineering cost	19%	81%
3) Land acquisition cost	0%	100%

The local portion is further divided into following 5 items; 1) tradable goods, 2) non-tradable goods, 3) skilled labor, 4) non-skilled labor, and 5) tax.

(2) Economic Price of Foreign and Tradable Goods

Economic prices of foreign and tradable goods are the same with market price. The price of those goods shows the real value by the free competitive international market.

(3) Economic Price of Non-Tradable Goods

Non-tradable goods used in the project are considered not to show their real value because of piece distortion. The shadow (real value) exchange coefficient are calculated by the following formula by using data in Table 11.2.2 namely:

$$\frac{(\text{Import} + \text{Import Tax}) + (\text{Export} - \text{Export Tax} + \text{Subsidy})}{\text{Import} + \text{Export}}$$

= 1.07

Shadow exchange coefficient is calculated as 1.07, which means the price of non-tradable goods is separated from the international market price as a result of high import duties.

Table 11.2.2 Shadow Exchange Coefficient for Non-Tradable Goods

Unit: Million Rs.

	1993-94	1994-95	1995-96	1996-97	1997-98	Average
Import (CIF)	731,010	899,710	1,465,420	1,737,530	1,902,670	1,347,268
Import Tax	2,265	27,145	36,066	370,164	400,389	167,206
Export (FOB)	696,558	826,740	1,084,810	1,211,940	1,295,160	1,023,042
Export Tax	660	850	1,080	1,172	1,410	1,034
Subsidy	Na.	Na.	Na.	Na.	20	20

Source:1)Statistical Outline of India 1998-99,p114

2) Statistical abstract India 1997, p255,p490

3) Data by Internet, Ministry of Finance

(4) Economic Price of Right of Way

The total cost of land acquisition is estimated at 1,900 million Rs in market price for required land of 916 ha. Regardless, the land belongs to the government or even if the government finances total land acquisition cost, the cost should be included in the economic project cost. Economic cost of right of way is estimated by the productivity of the land.

The area produces mainly wheat, rice, cotton, repseed, bajra, gram and sugarcane. Those productions are estimated by area, by volume, and by amount of production. The amount of productivity of average agriculture land is obtained at 688,842 Rs. per hectare in 1999 price under the assumption of market interest rate of 10%. Details are shown in Appendix Table 11.2.3, Land Productivity of the Study Area.

The right of way consists of 1) village land, 2) agriculture land, and 3) vacant land. As shown in Table 11.2.3, for the amount of land productivity 2 times is applied to village land and only 10% for vacancy land against agriculture land to get economic price. Shadow rate, which is the conversion factor for economic price is obtained as follows:

Shadow rate of right of way: 927 Million Rs / 1,332 Million Rs = 69.6%

Table 11.2.3 Economic Price of Right of Way of the Expressway

Unit:1000Rs.

Kinds of Land for Land Acquisition	Required Area (ha)	Market Price		Economic Price		
		Total Cost	Adjusted Cost	PresentValueof Productivity		Shadow Rate
			Solatium(-30%)	688,842/ha	Adjustment	
Village Area	572	1,187,954	831,568	394,018	788,035	
Agriculture Area	186	386,293	270,405	128,125	128,125	
Vacant land	158	328,141	229,699	108,837	10,884	
Total	916	1,902,388	1,331,672	630,979	927,043	69.6%

(5) Economic Price of Labor

Economic price of skilled labor and unskilled labor are different. Skilled labor is assumed the same with market price and economic price, assuming free competitive condition.

Economic price of unskilled labor is calculated by the comparison between number of workable unskilled labor and number of unemployment. Based on the socio-economic data, the shadow wage rate is estimated at 72% in this analysis

(6) Tax and Duties

Amount of tax included assumed to be 10% in financial cost though there are many kinds and different levels of taxes. The tax is assumed, as the cost needed for the Government to operate as country. The figure of 10% is used in normal feasibility studies. These taxes and duties are removed from financial cost for they are not real costs of the economy, but are only transfer of payments.

(7) Summary of Economic Cost of the Project

The following overall conversion factors are applied to the financial cost to estimate the economic cost namely:

1)	Construction cost	90.5%
2)	Engineering cost	88.9%
3)	Land acquisition cost	69.6%
4)	Routine maintenance cost	75.3%
5)	Periodic maintenance cost	83.1%

Table 11.2.4 shows economic costs converted from financial cost of initial investment. Calculation in details is found in Appendix Tables 11.2.4, 11.2.5, and 11.2.6. Economic cost of routine works and widening are shown in Appendix Table 11.2.2.

Table 11.2.4 Summary of Conversion from Financial Costs to Economic Cost

Unit: 1000 Rs.

Classification	K-G&G-M 80.75km		K-G Section 49.00km		G-M Section 39.55km	
	Financial	Economic	Financial	Economic	Financial	Economic
Construction	8,421,751	7,620,656	5,444,845	4,926,920	3,696,084	3,344,505
Engineering	1,025,358	911,168	678,238	602,705	473,340	420,626
Land Acquisition	1,902,388	1,324,348	1,383,913	963,411	1,071,145	745,678
Total	11,349,497	9,856,172	7,506,996	6,493,036	5,240,569	4,510,808

(8) Yearly Allocation of the Project Cost

It reacquires 6 years for the construction at the earliest. Table 11.2.5 shows yearly allocation of investment cost by sections. The yearly investment ratio on average is as follows:

1%	for the 1st year
9 ~ 10%	for the 2nd year
10~15%	for the 3rd year
10~ 20%	for the 4th year
27~33%	for the 5th year
28~35%	for the 6th year

Table 11.2.5 Yearly Allocation of Investment Cost (Economic Cost)

Unit: 1000 Rs.

Year	K-G &G-M 80.75km			K-G Section 49.00km			G - M Section 39.55km		
	Financial	%	Economic	Financial	%	Economic	Financial	%	Economic
2000	164,484	1%	142,842	108,795	1%	94,100	75,949	1%	65,373
2001	988,916	9%	858,798	702,033	9%	607,210	530,283	10%	456,440
2002	1,399,464	12%	1,215,328	1,112,581	15%	962,306	530,284	10%	456,441
2003	1,841,101	16%	1,598,856	1,478,838	20%	1,279,093	500,175	10%	430,525
2004	3,428,602	30%	2,977,479	2,003,208	27%	1,732,637	1,752,777	33%	1,508,699
2005	3,526,930	31%	3,062,870	2,101,541	28%	1,817,689	1,851,101	35%	1,593,331
Total	11,349,497	100%	9,856,172	7,506,996	100%	6,493,036	5,240,569	100%	4,510,808

11.3 Estimation of Benefit

11.3.1 Users Benefit and Toll Level

(1) Economic Benefit and Users Benefit

Economic benefit which is used for project evaluation consists of two groups; (1) benefit from direct user of expressway by using expressway + city road, (2) benefit from non-users of expressway by using only city street. Toll is related only to the direct users benefit of expressway.

(2) Users Benefit and Users Surplus

In the traffic analysis, it is clear that the toll level of 1.5 Rs /PCU-km makes the highest toll revenue. The highest revenue is the key factor to cover the high cost and quick completion of expressway by user charge. Therefore, following three items should be clear when 1.5Rs/PCU-km is charged to users:

1) Amount of users benefit
2) Level of benefit users obtained
3) Ratio between toll fee and users surplus

(3) Users Benefit

Table 11.3.1 shows the result of the calculation of financial (not economic) user benefit by 42,600-vehicle per day on the expressway in 2006. Result can be summarized as follows:

Total users' vehicle operating cost saving	3,414,000 Rs
Total time cost saving	2,884,000 Rs
Total	6,298,000 Rs

Table 11.3.1 Amount of Financial Users Benefits in 2006

Items		Unit	Passenger Car	Bus	Truck	Total
VOC	Without	1000Rs	33,548	1,519	17,010	52,077
	With	1000Rs	31,207	1,451	16,006	48,663
	Users Saving Benefit	1000Rs	**2,341**	**68**	**1,004**	**3,414**
Travel Time Cost	Without	1000Hr	282	9	71	362
	With	1000Hr	185	7	57	249
	Travel Hour Saving	1000Hr	97.0	2.0	14.0	113.0
	Time value/hour	Rs	61.2	126.0	0.0	---
	Users Saving Benefit	1000Rs	**5,936**	**252**	**0**	**6,188**
Total Users Benefit		1000Rs	**8,277**	**320**	**1,004**	**9,602**

(4) Toll Charge and Surplus

Table 11.3.2 shows relationship between financial users' benefit and toll fee, 1.5 Rs per PCU-km. The convert rate of PCU-km to vehicle-km for passenger car is1.0, bus is 2.7, and for truck is 1.9. Therefore, when 1.5 Rs per PCU-km is applied to vehicle types, passenger car is 1.5 Rs/km, bus is 4.0 Rs/km, and truck is 2.8 Rs/km. The result can be summarized as follows:

1) The level of toll, 1.5 Rs./pcu-km represents a Toll Charge Ratio of 32 % of users' benefit on average.
2) Users can get 68 % of surplus benefit by using the expressway on average.
3) Amount of surplus benefit by vehicle types is passenger car; 77 %, bus; 41 % and truck; 2 %. A lower surplus of trucks accrued from the negligence of such time values of cargoes in the user benefit calculation.

Level of toll must be less than road users' benefit. Even the case where only vehicle operating cost saving is considered as the benefit, toll of 1.5 Rs/pcu-km account for 90 % of the benefit, but users still receive 10 % of surplus benefit on average.

Table 11.3.2 Level of Toll and Users Surplus in 2006

Item	Passenger Car	Bus	Truck	Total
Total User Benefit	**8,277**	**320**	**1,004**	**9,602**
Total PCU-km(1000)	1,260	126	658	2,044
Users Benefit/PCU-km	6.57	2.54	1.53	4.7
Toll 1.5Rs/PCU-km	1.5	1.5	1.5	1.5
Total Vehicle-km(1000)	1,260	47	356	1,663
Users Benefit/Vehicle-km	6.57	6.81	2.82	5.8
PCU/Vehicle Covert Ratio	1.0	2.7	1.9	---
Toll /Vehicle-km	1.5	4.0	2.8	
Toll Charge Ratio	**23%**	**59%**	**98%**	**32%**
Users Surplus to 1.5Rs	**77%**	**41%**	**2%**	**68%**

11.3.2 Estimation of Economic Benefit

(1) Kinds of Benefit

Table 11.3.3 shows the kinds of benefits derived from the construction of expressway.

(2) Benefit Used for Economic Evaluation

The following three major direct users' benefits are selected and measured for economic evaluation of the project:

1) Benefits of Driving Cost Saving (or Vehicle Operating Cost Saving);
2) Benefits of Driving Time Saving (or Time Cost Saving); and
3) Decrease of Traffic Accident

Increase of land productivity and utilization especially in the area located near the interchanges of the project, is benefit from the project. The quick movement of commodities ensures smaller inventory costs and results in economic operations. Also there is an investment cost saving of the parallel highway by the construction of the Expressway. There are other measurable benefits as listed in the table, such as decrease of spoiling loss of agricultural products.

Table 11.3.3 Kinds of Benefit of Expressway Project

1) Benefits of Traveling Cost Saving (or Vehicle Operating Cost Saving)
2) Benefits of Traveling Time Saving (or Time Cost Saving)
3) Decrease of Traffic Accident
4) Other Indirect Benefits

   1) Benefits from Increase of Land Productivity
   2) Time and Interest Saving by Quick Movement of Commodities
   3) Decrease of Spoiling Loss of Agricultural Products
   4) Investment Cost Saving of Parallel Highway
   5) Enhancement of Urban Development
   6) Strengthening the Function as the Capital City
   7) Decrease of Social Cost by Improvement of Environments
   8) Enhancement of Social Development
   9) Integration of the Region

But this amount is relatively small compared with benefits mentioned above and often there are many uncertain factors. Therefore, they are not included in the main calculation as benefit but will be considered in sensitivity analysis.

(3) Estimation of VOC Saving Benefit

Vehicle operating cost saving benefit is estimated to 1) passenger car, 2) bus, 3) truck, and 4) motorcycle. Benefits to motorcycle are included, though they are not allowed on the expressway but motorcycles still obtain benefit as indirect beneficiaries. The number of trips, trip distance, travel speed and VOC of 4 kinds of vehicles are compared with and without project from the year 2006, opening year, to the year 2033.

Table 11.3.4 shows calculated result of benefit of the vehicle operating cost saving. Appendix 11.3.1 shows more details.

Table 11.3.4 Benefit of the Vehicle Operating Cost Saving by Vehicle Types

Unit: 1000 Rs/Day

Target Year	Passenger Car	Bus	Truck	Motorcycle	Total (1000Rs/yer)
2006	1,155	-22	148	414	508,243
2016	3,347	5	922	3,560	2,350,192
2026	10,947	299	7,879	6,596	7,716037

Total VOC saving benefit of bus is calculated at –22,000Rs in year 2006, because of the number of bus-km with project is estimate higher than the case of without project namely:

Without project: 982,000veh-km x 8.0Rs/veh-km(Unit VOC) = 7,846,000Rs/day
With project: 1,004,000veh-km x 7.8 Rs/veh-km(Unit VOC) = 7,868,000Rs/day
Without – with = -22,000Rs/day

(4) Estimation of Time Cost Saving Benefit

The benefit of time cost saving is calculated by the difference of running speed between the existing city road and the project road. Beneficiaries of time cost saving are users of passenger cars, buses and motorcycles. The time saving benefit of trucks is not included here because it is calculated in running cost benefit as fixed cost saving.

Time benefit is estimated by using the same data used in VOC except the data of unit time value. Following unit time value is used as presented in the previous section namely:

1) Passenger car 0.82 Rs/minute 49.2 Rs/hour
2) Bus 2.10 Rs/minute 126.0 Rs/hour
3) Motorcycle 0.22 Rs/minute 13.2 Rs/hour

Tables 11.3.5 shows the result of estimation of time cost saving benefit. Details are in Appendix Table 11.3.2.

Table 11.3.5 Time Cost Saving Benefit of the Project

Unit: Million Rs/year

Target Year	Passenger car	Bus	Motorcycle	Total
2006	1,742	189	1,267	3,198
2016	4,649	454	2,934	8,037
2026	8,782	869	6,332	15,984

The amount of benefit from time cost saving is higher than the VOC saving. The main reason is the project is located in the city and the big effect comes from the time saving of indirect beneficiaries.

(5) Benefit of Traffic Accident Saving

1) Accident Rate of Expressway

Accidents include death, injury, damage of vehicles and others. Around 60,000 people die of road accidents a year recently in India, but there is no data of accident rate in relation with vehicle kilometer. A comparison of various accident rates on expressways and on all roads in Japan shows that the death accident rate on expressway is about $1/7^{th}$ of the total road. . Appendix Table 11.3.3 shows the statistical data in the case of Japan. The decrease of accidents as a result of the expressway is considered as a monetary benefit by applying the data of Japan.

2) Cost of Fatal Road Accident

Decrease of fatal road accident is counted as project benefit. Decrease of injury, loss of property and of damage of vehicles are not included here since those data are hard to obtain. The Road User Cost Study in India, financed by Asian Development Bank undertaken in 1990 estimated the fatal accident cost for 1978,1981 and 1990. Data of average income of the victim in this study was taken from result of insurance companies. Table 11.3.6 shows the result of the study.

Table 11.3.6 Estimation of the Cost of A Fatal Road Accident

Unit: Rs

Items	1978	1981	1990
Average age of the fatal victim (years)		31	31
Average life expectancy (years)	54	59	59
Curtailment of the earning (years)		28	28
Average income of the victim (Rs/year)	4,200	15,720	
Present value of the loss of output of the victim	39,220	157,200	171,820
Additional cost of hospital, lawyer and police, etc	10,584	39,300	38,734
Total	49,804	196,500	210,554

Source: RUDS(Study for Updating Road User Cost Data),financed by ADB in 1990.

Based on the study, the fatal accident cost is estimated at 250,000 Rs in 1999 price, under the following assumptions:

1) Average age of the fatal victim — 31 years old
2) Average life expectancy — 60 yeas old
3) Curtailment of the earning — 29 years
4) Average income of the victim — 20,000 Rs per year
5) Present value of the loss of output after victim — 200,000 Rs
(Discounted future income rate at 10%)
6) Additional cost of hospital fee, legal expense and, police expense, etc (+ 25%) — 50,000 Rs
7) Total — 250,000Rs

3) Benefit of Fatal Accident

Table 11.3.7 shows the benefit of fatal accident saving by expressway. By applying the data taken from the case of Japan, total saving of person's life is estimated at 540 in year 2006, which is estimated at 125 million Rs in monetary term. Details are shown in Appendix Table 11.3.4.

Table 11.3.7 Fatal Road Accident Saving of the Project

Target Year	Without(Person)	With(Person)	Saving(Person)	Million Rs
2006	617	77	540	125
2016	1,243	155	1,088	253
2026	1,824	228	1,596	371

11.4 Economic Evaluation of Project

11.4.1 Base and Alternative Network Studies

(1) Cost Benefit Comparison

Table 11.4.1 includes the following costs and benefits comparison of the project namely:

1) Project life: 2000 –2033 34 years
2) Construction period: 6 years
3) Cost component: capital cost, routine maintenance and operation cost, periodic maintenance cost and widening cost.
4) Salvage value: 270 million Rs is deducted year 2033 as salvage value of widening cost which is taken at 48.5% of the widening cost with 30 years depreciation period.

Table 11.4.1 Cost Benefit Analysis for Investment Justification

K-G &G-M Section 80.75km

Unit: Million Rs

No.	year	Economic Cost			Economic Benefits				Present Worth		
		Capital Periodic	Routine & Operation	Total	Passenger Time Saving	Vehicle VOC Saving	Traffic Accident	Total	Discount Factor	Cost	Benefit
1	2000	143		143					0.79	113	
2	2001	859	0	859					0.63	538	
3	2002	1,215	0	1,215					0.50	602	
4	2003	1,599	0	1,599					0.39	627	
5	2004	2,977	0	2,977					0.31	924	
6	2005	3,063	0	3,063					0.25	752	
7	2006	0	25	25	1,599	508	125	2,233	0.19	5	434
8	2007	0	25	25	1,762	672	135	2,569	0.15	4	395
9	2008	0	25	25	1,940	844	144	2,928	0.12	3	356
10	2009	0	25	25	2,133	1,020	155	3,307	0.10	2	318
11	2010	0	25	25	2,342	1,200	166	3,708	0.08	2	282
12	2011	0	25	25	2,568	1,384	178	4,130	0.06	1	249
13	2012	0	25	25	2,814	1,571	191	4,576	0.05	1	218
14	2013	0	25	25	3,080	1,761	205	5,047	0.04	1	191
15	2014	0	25	25	3,369	1,955	220	5,543	0.03	1	166
16	2015	0	25	25	3,681	2,151	236	6,068	0.02	1	143
17	2016	660	25	685	4,019	2,350	253	6,622	0.02	13	124
18	2017	0	25	25	4,324	2,709	262	7,295	0.01	0	108
19	2018	0	25	25	4,647	3,098	271	8,017	0.01	0	94
20	2019	0	25	25	4,989	3,521	282	8,791	0.01	0	82
21	2020	0	25	25	5,350	3,980	292	9,622	0.01	0	71
22	2021	0	25	25	5,732	4,478	303	10,514	0.01	0	61
23	2022	2,840	25	2,865	6,136	5,021	315	11,472	0.00	13	53
24	2023	0	25	25	6,562	5,611	328	12,501	0.00	0	45
25	2024	0	25	25	7,013	6,253	342	13,607	0.00	0	39
26	2025	0	25	25	7,489	6,953	356	14,798	0.00	0	34
27	2026	898	25	923	7,992	7,716	371	16,079	0.00	2	29
28	2027	0	25	25	8,523	8,549	387	17,458	0.00	0	25
29	2028	0	25	25	9,083	9,458	404	18,945	0.00	0	21
30	2029	0	25	25	9,674	10,452	422	20,548	0.00	0	18
31	2030	898	25	923	10,298	11,538	442	22,278	0.00	1	16
32	2031	0	25	25	10,957	12,727	463	24,146	0.00	0	13
33	2032	0	25	25	11,651	14,029	485	26,165	0.00	0	12
34	2033	228	25	253	12,384	15,455	508	28,347	0.00	0	10
0	0	15,380	696	16,075	162,110	146,963	8,241	317,315	26.37%	3,607	3,607

1) Passenger time cost saving: 50% to the total is used as benefit.
2) Total economic benefit: of which time saving is 51%, VOC saving 46%, and accident saving 3%.

(2) Result of Economic Analysis

Total present value of cost and benefit (million Rs.) become equal when discounted at 26.37%, which means economic internal rate of return (EIRR) is 26.37%.

When the Net present value (NPV) and benefit cost ratio (BC ratio) is calculated, discounted at 12% of the opportunity cost of capital the result is as follows:

1) Net Present Values (NPV):
Benefit 24,549 million Rs – Cost 6,414 million Rs = 18,134 million Rs.
2) Cost Benefit Ratio (B/C):
Benefit 24,549 million Rs / Cost 6,414 million Rs = 3.85

Economic analysis will be made to ensure the level of investment scale, investment of timing and investment priority of alternatives optimize use of national resources.

EIRR is the discounted rate in which total discounted present value of benefits equals to the total discounted present value of costs. The higher the internal rate of return is, the higher is the priority of project. If the internal rate of return turns out higher than the opportunity cost of capitals, that is 12% in the economic analysis, investment is proved to be feasible.

26.37% of EIRR is much higher than the opportunity cost of capital. Therefore project is judged feasible and proves economically feasible from the national point of view.

(3) Economic Analysis of K-G and G-M Section

Analysis is made for Kundli – Ghaziabad section and for Gaziabad – Meerut section separately. Following are the results of the analysis:

Kundli – Ghaziabad section	EIRR 27.06% ; and
Gaziabad – Meerut section	EIRR 25.29%

EIRR of both sections are over 12% of opportunity cost of capital, which means both are economically feasible. Since the degree of EIRR is similar, project implementation does not need to be conducted by stage. Details are given in Appendix 11.4.1 and 2.

11.4.2 Sensitivity Analysis of Base Case

(1) Cost increase and Benefit Decrease

Table 11.4.2 shows possible change of EIRR due to future uncertainty in cost increase and benefit decrease of the project for the base case. Followings are the results of the sensitivity analysis.

1) Project is feasible even if the cost increases around 20%;
2) Project is feasible even if the benefit decreases around 20%; and
3) Project is feasible even if benefit decreases 20% and cost increases 20%.

Table 11.4.2 Sensitivity Analysis of the Project

Conditions		Investment Cost Increase			
		0	10%	15%	20%
Benefit Decrease	0	26.37%	25.07%	24.49%	23.93%
	-10%	24.93%	23.68%	23.14%	22.62%
	-15%	24.15%	22.97%	22.42%	21.91%
	-20%	23.38%	22.21%	21.69%	21.20%

(2) Effect of Time Cost

Percentage of time saving benefit in the total benefits is relatively high. It amounts to 51% of the total benefit. The economic viability of transport project is sometimes analyzed excluding time saving costs. In this case the benefits are as follows:

Not including time saving benefit EIRR is 15.97%

EIRR, not including time cost saving benefit is 15.97% which is much less comparable with the case of the base case, 26.37%. But the project is still economically feasible.

(3) Effect of FNG

Faridabad – Noida – Ghaziabad expressway (FNG) is considered to be completed by year 2006 in the base case analysis. The case where the FNG is not completed by 2006 is analyzed, and resulted as follows:

The number of traffic using the project will decrease marginally from 42,497 to 41,823 in 2006. This implies whether FNG exist or not does not affect the feasibility of the KG GM Expressway.

(4) Conclusion

Results of the sensitivity analysis proves the project is economically feasible from national viewpoint, because EIRR is found to be more than the opportunity cost of capital in spite of many uncertain conditions. These uncertain conditions are namely:

1) Cost increase;
2) Benefit decrease due to toll system and to toll level;
3) Possible improvement of running condition on roads;
4) Change of time cost during project life; and
5) Traffic increase reaching to the capacity earlier than estimation.

There are many other benefits which will contribute to an increase in EIRR such as:

1) Benefits from increase of land productivity, especially utilization near the interchange area.
2) Enhancement of urban development.
3) Strengthening of the function as the capital city.
4) Decrease of social costs such as noise and vibration

Those benefits are not included here for EIRR calculation. EIRR is found to be more than 12 %, calculating only measurable benefits. If other benefits are included, EIRR will be higher. Therefore, it is concluded that this project is economically feasible and needs to be implemented as soon as possible.