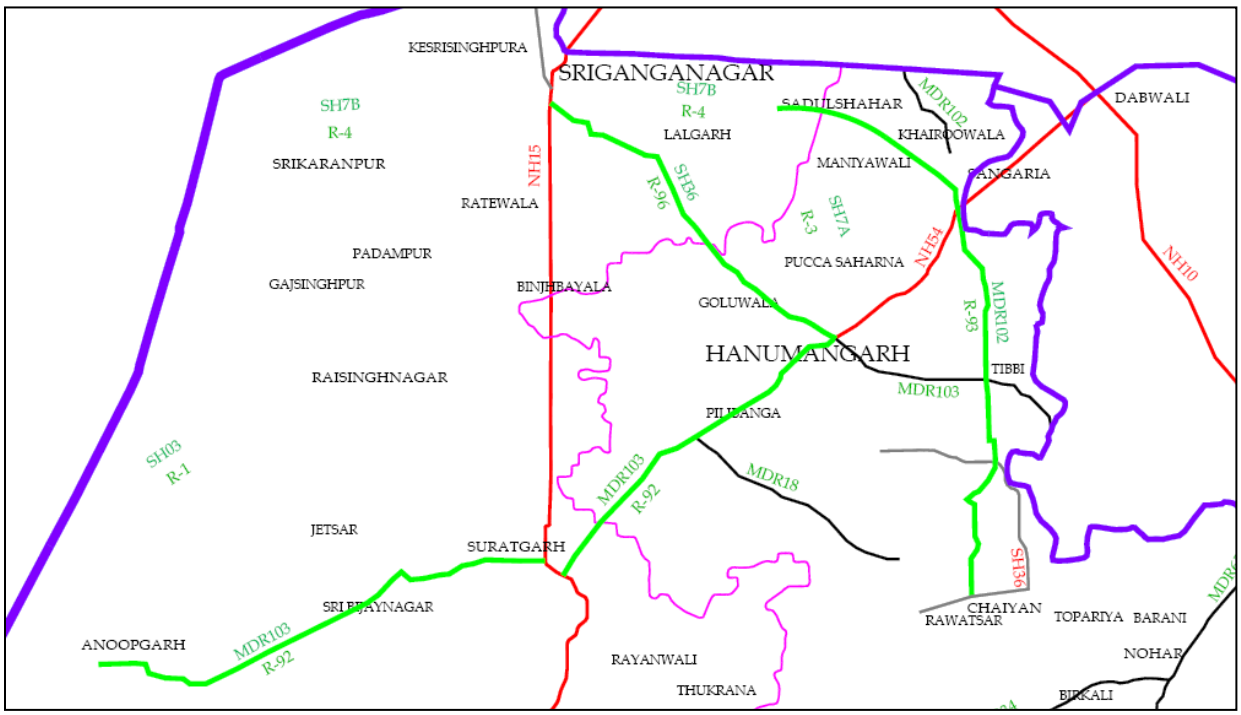
PUBLIC WORKS DEPARTMENT
GOVERNENT OF RAJASTHAN

Consultancy Services for Preparation of Feasibility Report of Two-Laning with Paved Shoulder of Km. 0.00 to Km. 41.00 of SH-36 comprising the section from Sri Ganganagar to Pacca

FEASIBILITY REPORT
(MAIN REPORT)



September 2016

- **CENTRO DE ESTUDIOS DE MATERIALS Y CONTROL DE OBRA,S.A.**
- **AVANZA ENGINEERING PVT.LTD.**
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ABBREVIATIONS

Abbreviation	Description
2-AT	Two Axle Truck
2-Lane/2L	Two lane
3-AT	Three Axle Truck
4L-DCW	Four Lane Divided Carriageway
AACGR	Annual Average Compounded Growth Rate
AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
BBD	Benkelman Beam Deflection
BOQ	Bill of Quantities
CBR	California Bearing Ratio
CC	Cement Concrete
CSA	Cumulative Standard Axles expressed in terms of MSA
CW	Carriageway
DSV	Design Service Volume
ES	Granular Shoulder
ESA	Equivalent Single Axle Load
FP	Foot Path
FV	Farm Vehicles
GDP	Gross Domestic Product of India
GOI	Government of India
GOR	Government of Rajasthan
GQ	Golden Quadrilateral
GSDP	Gross State Domestic Product
GV	Goods Vehicles
HCM	Heavy Commercial Vehicle / Heavy Construction Machine
IL	Intermediate Lane
IRC	Indian Roads Congress
LCV	Light Commercial Vehicle
LOS-B	Level of Service -B
MAV	Multi-axle Vehicle (used to mean a vehicle with 4 axles to 6 axles)
Mini LCV	Tata Ace and Mahindra Small Commercial Vehicle
MORTH	Ministry of Road Transport and Highways
MSA	Traffic Loading in terms of Million Standard Axles of 8.2 Tonnes
NHAI	National Highways Authority of India
NMV	Non- Motorised Vehicles
NSDP	Net State Domestic Product

Abbreviation	Description
O-D	Origin – Destination
OSV	Over-sized Vehicles
PCI	Per Capita Income
PCU	Passenger Car Unit
PIA	Project Influence Area
PPP	Private Public Partnership
PS	Paved Shoulder
PUP	Pedestrian Underpass
PV	Passenger Vehicles
RIICO	Rajasthan Industrial Investment Corporation
ROW	Right of Way
RSI	Road Side Interview
RUB/ROB	Road Under Bridge / Road Over Bridge
SCF	Seasonal Correction Factor
SL	Single Lane
SOR/SR	Schedule of Rates
TCS	Typical Cross-Sections
TMC	Intersection Turning Movement Count
TOR	Terms of Reference
TP	Toll Plaza
TPC	Total Project Cost
TS Loc	Traffic Survey Location
TVC/CTVC	Classified Traffic Volume Count
VDF	Vehicle Damage Factor
VGF	Viability Gap Funding
VUP	Vehicular Underpass
WBM	Water Bound Macadam
WPI /CPI	Wholesale Price Index / Consumer Price Index
ZIF	Zone Influence Factor

Executive Summary

A. Introduction

A.1 Project Background

Govt. of Rajasthan has announced development of 20000 kms highways during next 5 years. Projects and schemes are being identified for implementation of the announcement. Planning commission, New Delhi was also approached for selected projects to get 20% VGF from GoI. Several rounds of meetings held at Planning Commission for identification of road stretches, working out packages, finalization of various documents and working out timeline etc.

This Feasibility Report details the approach, methodology and work plan for carrying out feasibility study of the following road grouped under package-21

Project Road Considered for Study

During the initial stages of the study, the scope of the project road was from Sri Ganganagar to Hanumangarh from Km 0.0 to Km 55.0. Later on after the submission of supplementary inception report, the project road length has been revised to 41.0 Km and starts from Km 0.0 at Sri Ganganagar and ends at Km 41.0 near Pacca Saharana.

S No	Description of Road	Length (Km)
1	Sri Ganganagar to Pacca Saharana	41.0

A.2 The Study

The Study consists of the following:

- feasibility study including survey and investigation
- preliminary project designs
- preparation of bidding documents

B. Socio-Economic Profile in the Project Influence Area (PIA)

Rajasthan, the largest State in the country in terms of geographical area, is located in the north-western part of the country. It has a geographical area of 3,42,239 sq.km, which constitute 10.41 per cent area of the country and 5.67 per cent of national population (Census of India, 2011). It shares international border with Pakistan in the west. Physiographically, the State can be divided into 4 major regions, namely the western desert: with barren hills, rocky plains and sandy plains, the Aravalli hills: running south-west to north-east starting from Gujarat and ending in Delhi, the eastern plains: with rich alluvial soils and south-eastern plateau. Mahi, Chambal and Banas are the three major rivers of the State. The State has varied climatic conditions ranging from semi-arid to arid. It is administratively divided into 7 divisions and 33 districts.

The advance estimates of Gross State Domestic Product at current prices is estimated to be Rs 5,74,549 crore for the year 2014-15 as compared to Rs 5,74,549 crore during the year 2013-14 (quick estimates), showing an increase of 11.00 per cent over the previous year. As per the advance estimates, Gross State Domestic Product at constant (2004-05) prices, in the year

2014-15 is likely to attain a level of Rs 2,72,227 crore, as against the estimates of GSDP for the year 2013-14 (quick estimates) of Rs 2,57,432 crore, registering an increase of 5.75 per cent over the preceding year.

The advance estimates of Net State Domestic Product at current prices is worked out to be Rs 5,16,462 crore for the year 2014-15 as compared to Rs 4,65,504 crore during the year 2013-14 (quick estimates) showing an increase of 10.95 per cent over the previous year. As per the advance estimates, the Net State Domestic Product at constant (2004-05) prices, in the year 2014-15 has been estimated at Rs 2,37,530 crore as against Rs 2,24,632 crore in the year 2013-14 (quick estimates) showing an increase of 5.74 per cent over the previous year.

The per capita income for the year 2014-15 at current prices works out to be Rs 72,156 as against Rs 65,974 during the year 2013-14 (quick estimates) registering an increase of 9.37 per cent over the previous year. The per capita income at 2004-05 constant prices during 2014-15, is likely to be Rs 33,186 as compared to Rs 31,836 in the year 2013-14 (quick estimates), registering an increase of 4.24 per cent over the previous year.

In 2011, Ganganagar had population of 1,969,168 of which male and female were 1,043,340 and 925,828 respectively. In 2001 census, Ganganagar had a population of 1,789,423 of which males were 955,378 and remaining 834,045 were females. There was change of 10.04 percent in the population compared to population as per 2001. In the previous census of India 2001, Ganganagar District recorded increase of 26.17 percent to its population compared to 1991. The initial provisional data released by census India 2011, shows that density of Ganganagar district for 2011 is 179 people per sq. km. In 2001, Ganganagar district density was at 163 people per sq. km. Ganganagar district administers 10,978 square kilometers of areas.

C. Traffic Studies and Analysis

The traffic data were collected on the study corridor and relevant information obtained on traffic flow characteristics including classified traffic volume, hourly and daily traffic variation and travel pattern and vehicle load characteristics. The following primary surveys were conducted to assess the present traffic scenario:

- Classified Traffic Volume Counts
- Axle Load Survey

C.1 Present Traffic Scenario

Project road sections witness annual average daily traffic (AADT) in the range of 4,197 – 5,593 vehicles (5,719 – 6,965 PCUs). Composition of cars is in the range of 30-40percent, mini buses and buses is in the range of 5-7percent. Among commercial vehicles, mini LCVs and LCVs is in the range of 4-7percent and all categories of trucks together constitute about 4-8percent in total traffic.

The AADT so obtained at all the traffic survey locations are projected at a uniform growth rate of 5% for all categories of vehicles as mentioned in the TOR. The year in which the project road reaches its design service volume at LOS-B is worked out for 2-lane and 2-lane with paved shoulder configuration. The results are tabulated ***Table E-1***.

Table E-1: Year of Achieving DSV (PCUs/day)

Loc No.	Location	Design Ch.	Traffic (PCUs/Day) Y-2014	2-Lane	2-Lane + PS
				LOS-B	LOS-B
				DSV-15000	DSV-18000
1	Km-10	Km-10	6965	2029	2033
2	Km-29	Km-29	5719	2033	2037
	Average		6342	2031	2035

LOS-B: Level of Service-B, DSV-Design Service Volume

To estimate the Equivalent Standard Axle Load of traffic, axle load surveys were carried out at one location at Km 29.0 near Morajare Khera. Based on the Spectrum of Axle loads and analysis of axle load data, the resulting VDFs are as given in ***Table E-2***.

Table E-2: Vehicle Damage Factors

Location	Direction	LCV	Buses	2-AT	3-AT	MAV
Sri Ganganagar to Hanumangarh Km 29, Morjare Khera	Lalgarh Jattan To Pacca Sharana	0.01	0.68	0.22	4.11	0.42
	Pacca Sharana To Lalgarh Jattan	0.01	0.62	2.56	6.12	16.47
	Both Directions	0.01	0.64	1.66	4.91	10.63
Adopted for the project road		**1.00**	**1.00**	**2.50**	**5.00**	**10.50**

The major commodity types being carried along the Project Road comprise machinery, agricultural products chemical and pharmaceuticals, iron, steel and manufacturing goods.

D. Engineering Surveys and Investigations

The Consultants have carried out engineering surveys and investigations along the Project Road. These include: topographic surveys, road inventory and condition survey, alignment study, pavement investigations, Benkelman beam deflection, pavement surface roughness, hydrological study, environmental study, axle load survey, condition surveys for bridges and structures and exploration and selection of construction materials.

D.1 Road Alignment

The alignment has been studied, based on physical features and other constraints at site viz. Land acquisition, Utilities, Construction activities, presence of religious structures etc. It has been observed that Optical Fiber Cable (O.F.C.) is running along the road alignment. Symmetrical widening has been proposed and through built-up area except at locations of sharp horizontal curves.

D.2 Existing Road: Inventory

D.2.1 Land use and Terrain

The terrain along the highway is plain. The predominant landuse along this part of the Project Road is agricultural. There is ribbon development with a mix of commercial / residential and industrial activities.

D.2.2 Horizontal Alignment

The majority of the existing curves have radii as per SH standards except a few which would require improvement.

D.2.3 Vertical Profile

Topographic survey data reveals that majority of longitudinal gradients is less than 2 percent and maximum gradient at some over bridge approaches is around 2.5 per cent.

D.2.4 Carriageway, Shoulder and Roadway width

Existing road has 5.8-6.0m dual carriageway with 0.7m wide median for a length of 4.0Km in the initial section and 2lane wide carriageway with 0.5m to 2.0m granular shoulder exists in the rest of the length. The roadway width varies from 10 to 12 m. The land use along the project road is predominantly agriculture intersperse with built-up section. Available width of road land along the project corridor varies between 22m and 40m.

D.2.5 Roadside Drains

There are no channelized regular longitudinal drains in most part of the project section.

D.2.6 Roadside Features

The development along the road has been uncontrolled. Therefore, at certain locations encroachment within ROW has been observed in the form of shops, hotels and various other commercial establishments.

D.2.7 Utilities

Low-tension overhead electrical lines are running along the highway and cross the highway at certain locations. While widening the road, the utility lines located on the new carriageway or widening portion would need shifting. At intersections of the cross-roads and locations of traffic facilities, there may be a need for relocation of a few electric and telephone poles during execution stage.

D.3 Pavement Condition

Detailed pavement condition surveys bring out the following salient aspects:

Pavement condition survey by visual method was carried out on the Project Road to assess the condition of existing pavement in serving the present traffic needs. Entire project road is of bituminous pavement surface. The % distress is compared with criteria for classification of pavement sections as per IRC: 81-1997.

Entire length of the road has bituminous surface. 98% of project road length is in good condition and 2% in fair condition except isolated patches of failed sections (40.7-40.8km). About 40% of shoulder is fair and 60% of length in poor condition with uneven surface and corrugation, lack of compaction and good quality shoulder material.

Pavement Composition: The existing pavement consists of bituminous layers, WBM and granular sub base. The minimum existing thickness excluding subgrade is about 480 mm. The composition of various layers of the pavement in above reaches is summarised here under:

Pavement layer	Thickness
Bituminous courses	70 to 170 mm
WBM	210 to 390 mm
Sub Base	200 to 250 mm

Pavement Deflection and sub grade strength: The BBD values vary between 0.43 mm to 0.62mm along the project road.

The CBR value at sub grade level is 6.1-6.5% at various locations along the project road.

E. Improvement Proposals

The design standards have been formulated for as per IRC:SP:73:2015. At few curve locations, design speed is reduced further to minimize land acquisition. In built-up sections the existing geometric will be improved without any social impacts. The paved shoulder widths of 1.5 m and granular shoulder of 2m have been proposed. Camber of 2.5 percent has been adopted for the carriageway and paved shoulder and 3.0% for earth shoulders. Super-elevation adopted is restricted to 7 per cent.

Initial 8.2 Km section of project road shall have 4-lane divided carriageway (7.0m dual carriageway) with 2.5m median and 1.5m interlocking paver block shoulder and rest of the length shall have 7m carriageway, 1.5m paved shoulder and 2.0m granular shoulder.

E.1 Pavement Design

E.1.1 Main Carriageway

The design inputs i.e. CBR value (effective CBR of 7% is considered for design) for the proposed subgrade material, Traffic loading in terms of cumulative standard axles in million (MSA) considered for pavement design have been summarized in ***Table E-3***. Pavement layers have been designed for 15 years with minimum 20msa as per requirement of IRC:SP:73:2015.

Table E-3: Design Inputs for Flexible pavement

Design Parameter	Entire Project Road length
Design life Years	15
Lane Distribution factor	0.5
Directional Split	50:50
CBR (Effective)	7%
Traffic Loading (MSA) for 15 years	20 (actual 13.47)

The pavement composition and layer thicknesses as per IRC: 37 –2012 considering the above design parameters are presented in ***Table E-4***.

Table E-4: Pavement Layer Thicknesses (mm)

Pavement Composition	New Construction
Bituminous Concrete (BC)	40
Dense Bituminous Macadam (DBM)	90
Wet Mix Macadam (WMM)	250
Granular Sub base (GSB)	230
Subgrade (Effective CBR=7%)	500

The thickness of DBM & BC overlay have been designed considering the subgrade strength, total required thickness and available thickness of existing pavement.

Project road sections with poor condition shall have two layers of GSB (total=230mm) with first layer for the entire width of formation and two layers of WMM (total=250mm) for the entire carriageway width and surface layers were recommended over WMM layer.

The proposed pavement composition and layer thicknesses considering the above design parameters are presented in ***Table E-5*** for various category of pavement surface conditions (good/fair, poor) recorded and for new construction.

Table E-5: Proposed Pavement Layer Thicknesses (mm)

Pavement Composition	Reconstruction Sections				New Construction
	Good/Fair		Poor		
	Widening Portion	Central portion	Widening Portion	Central portion	
Bituminous Concrete (BC)	40	40	40	40	40
Dense Bituminous Macadam (DBM)	90	90	90	90	90
Wet Mix Macadam (WMM)	250	250	250	250	250
Granular Sub base (GSB)	230	-	230	230	230
Subgrade (Effective CBR=7%)	500	-	500	-	500

E.1.2 Shoulders

Shoulder has been designed as a single unit with main carriageway with 1.5m as paved shoulder and 2.0m as granular shoulder.

E.2 Bridges and Culverts

The engineering studies included inventory and condition survey of the existing bridges and cross drainage structures, development of scheme for widening of bridges and cross drainage structures and design of new bridges, if any.

No major bridges were observed along the project road

There were 49nos RC slab culvert; 2nos pipe culverts and 4nos minor bridges across irrigation canals. Majority of the culverts have also been inspected and found to be structurally functional. Some additional culverts are proposed for efficient cross drainage.

The slab and pipe culverts details are presented in the following ***Table E-6*** with their improvement proposal.

Table E-6: Details of Culverts

STRUCTURES TYPES	Total No's	Reconstruction	Retained	Widening
RC Slab Culverts	49	3	-	46
Hume Pipe Culvert	2	1	-	1

The details of structures provided across the irrigation canals are provided in the following ***Table E-7*** along with the suggested improvement.

Table E-7: Details of Minor Bridges across Canals

STRUCTURES TYPES	Total No's	Span	Span	New construction	Retained	Widening
Irrigation Canal Structures		< 4 m	> 4m			
	4	0	4	1	-	3

E.3 Road bridges over Railway lines

No RUB, ROB and at-grade railway level crossing were observed along the project road.

E.4 Toll Plaza

Two toll plazas (2+2 lanes) are proposed along the entire project road length of 41.0 Km. Tentative sections for tolling (proposed toll plazas) purposes are presented in ***Table E-8***.

Table E-8: Tentative Tolling Sections

Section	Toll Plaza	Length km	Toll Plaza Location Chainage
Sri Ganganagar to Lalgarh Jattan	TP-1 (Km 0.0 – Km 19.0)	19.0	Km 10.364
Lalgarh Jattan to Pacca Saharana	TP-2 (Km 19.0- Km 22.0)	22.0	Km 34.970

F. Wayside Amenities

Wayside amenity is not envisaged as part of the project proposal.

G. Cost Estimate

The cost estimates have been worked out based on the unit rates as per BSR 2016 of PWD NH Circle, Bikaner, Rajasthan.

- The estimated total construction cost of the Project is Rs**. 80.88 Cr.**
- **Total Project Cost is Rs 101.10 Cr.**

H. Financial Analysis

Project is financially viable for the VGF less than 40%.

I. Social and Environmental Impact Assessment

Social and environmental impact assessments for the project road are enclosed separately.

1. Project Description

1.1. Background

Govt. of Rajasthan has announced development of 20,000 kms highways during next 5 years. Projects and schemes are being identified for implementation of the announcement. Planning commission, New Delhi was also approached for selected projects to get 20% VGF from GoI. Several rounds of meetings held at Planning Commission for identification of road stretches, working out packages, finalization of various documents and working out timeline etc.

For time bound implementation of PPP projects GoR has shown commitment by introducing a first ever comprehensive 'Raj. State Highways Bill-2014'. The bill has been passed by Rajasthan State Legislative Assembly on 09-04-2015.

The Governor of Rajasthan acting through the Chief Engineer (Roads), Public Works Department, Government of Rajasthan (the "Authority") is engaged in the development of state highways and as part of this endeavour, the Authority has decided to undertake package wise shortlisted road sections (the "Project") through Public Private Partnership (the "PPP") on Design, Build, Finance, Operate and Transfer (the "DBFOT") basis.

Authority has decided to conduct feasibility studies for determining the technical feasibility and financial viability of all Highways comprising the Project. If found technically feasible and financially viable, the Highways under the Project may be awarded on DBFOT basis to a private entity (the "Concessionaire") selected through a competitive bidding process. The Project would be implemented in accordance with the terms and conditions stated in the concession agreement to be entered into between the Authority and the Concessionaire (the "Concession Agreement").

In pursuance of the above, the Authority has decided to carry out the process for selection of a Technical Consultant, a Financial Consultant and a Legal Adviser for preparing the Feasibility Report and bid documents. The Financial Consultant will develop the revenue model and assist the Authority in the bidding process. The Legal Adviser will review the draft concession agreement based on the Model Concession Agreement for State Highways through Public Private Partnership (the "MCA") read with the Manual of Standards and Specifications. The Technical Consultant shall prepare the Feasibility Report in accordance with the Terms of Reference specified ("TOR").

1.2. Project Road Details

The shortlisted roads were grouped under various packages for carrying out feasibility studies. Further to the bidding process, package-21 consisting of five roads as mentioned below were assigned to technical consultant M/s CEMOSA,,AVANZA & PCPL for carrying out feasibility study on individual road basis, vide LOI dated 10-SEP-2014

Package-21 Road Details

S No	Description of Road	Length (Km)
1	Suratgarh to Anupgarh	71
2	Sadulshahahar – Sangaria - Chaiya	94
3	Bidasar – Sri Dungargarh - Kalu	82

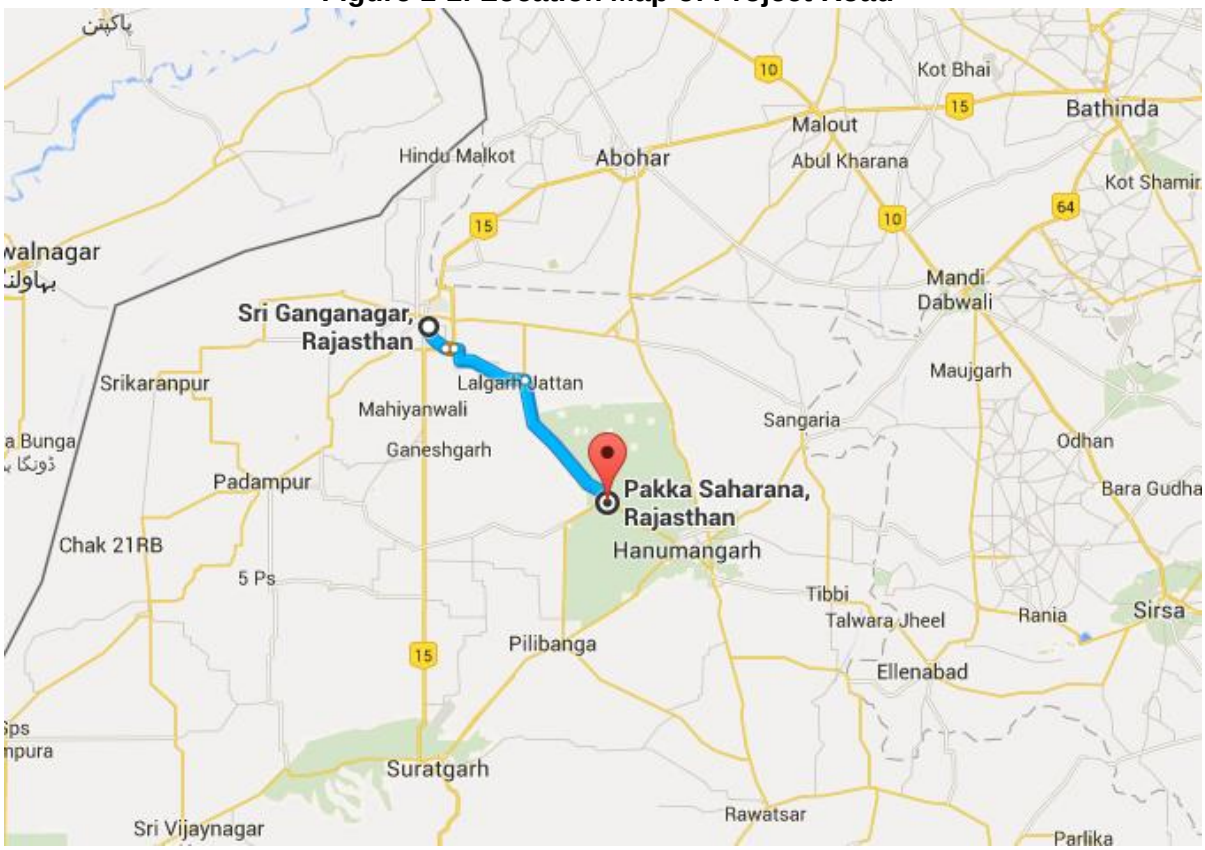
4	Jodhpur – Balesar - Shergarh	117
5	Sri Ganganagar to Pacca Saharana	41.0

This Feasibility Report details the approach, methodology and work plan for carrying out feasibility study of the following road grouped under package-21

Project Road Considered for Study

S No	Description of Road	Length (Km)
1	Sri Ganganagar to Pacca Saharana	41.0

Figure 1-1: Location Map of Project Road



1.3. Objectives of the Feasibility Study

The main objective of the Consultancy services is to establish the technical and financial viability for the selected project roads.

The objective of this consultancy is to undertake feasibility studies and prepare road specific feasibility Reports for all highways comprising the project for the purpose of firming up the Authority's requirements in respect of development and construction of the project and project facilities and enabling the prospective bidders to assess the Authority's requirements in a clear and predictable manner with a view to ensuring:

(i) enhanced safety and level of service for the road users;
(ii) superior operation and maintenance enabling enhanced operational efficiency of the Project;
(iii) minimal adverse impact on the local population and road users due to road construction;
(iv) minimal adverse impact on environment;
(v) minimal additional acquisition of land; and
(vi) phased development of the Project for improving its financial viability consistent with the need to minimise frequent inconvenience to traffic that may be caused if additional works are undertaken within a period of seven years from the commencement of construction of the Project.

1.4. Scope of Work

Scope of Services According to the Terms of Reference of the Study, the consultancy is to cover the following

- Feasibility Study;
- Bidding documents on commercial format

1.4.1. Feasibility Study

Following surveys, investigations and design activities are envisaged during the of the feasibility study

- Traffic surveys
- Axle load survey
- Pavement Invesigations
- Sub-soil investigation along the alignment for the road as well as the bridge.
- Detailed soil and material survey for the purpose of pavement design and for ascertaining the suitability of road construction material.
- Preliminary designs and cost estimates for different alternatives
- Environmental and Social impact assessment of all alternatives.
- Selection of best alternative for the pavement as well as the bridge
- Economic analysis and financial viability of the project on commercial format

1.4.2. Bidding documents on commercial format (PPP)

Following activities are envisaged during the of the Bidding Docs finalisation

- Preparation of indicative BOQ, rate analysis & cost estimates.
- Preparation of Schedules A, B, C, D and H of Concession Agreement

1.5. Report

This Feasibility Report highlights road network, inventory and condition survey details of road and CD structures and proposed locations for carrying out traffic surveys. The next section provides a summary of the Progress to Date. Section 3 presents the detailed methodology for the Feasibility Report Preparation.

1.6. Progress to-Date

This section summarises the work that has been carried out to-date. Analysis of the data already collected is in hand and it is not considered relevant to this Feasibility Report to provide details of this analysis since this report focuses on the detailed methodology and work programme for the study. However where the data collected is relevant to the detailed methodology the information is presented in the following section.

1.7. Staff Mobilization

Following the Agreement dated 08/10/2014, the mobilization of Key Personnel is shown in the Staffing Schedule in Table 1-1.

Table 1-1: Mobilization Dates of Key Personnel

Name	Position	Mobilisation Date
Aditya Ashwin	Team Leader	15/10/2014
K.C.Prakash	Traffic Cum Transport Engineer	15/10/2014
Arvind Salecha	Bridge Engineer	15/10/2014
Yaqub	Surveyor	15/10/2014
R.C.Agarwal	Fiancial Expert	21/10/2014
Devendra Goyal	Environmental Expert	21/10/2014
	Highway Design Engineer	21/10/2014
	Bridge Engineer	21/10/2014
	Pavement cum Material Engineer	21/10/2014
	Geo-technical Expert	21/10/2014
	Hydrologist	21/10/2014
	Environment analyst	21/10/2014
	Social Analyst	21/10/2014
	Quantity Engineer	21/10/2014
	Surveyor1	21/10/2014
	Surveyor2	21/10/2014
	Surveyor3	21/10/2014
	CAD Draughtman 1	21/10/2014
	CAD Draughtman 2	21/10/2014

1.8. Mobilization Meeting

A meeting was held in 3rd week of October 2014 between the Nodal officer and Consultant team to discuss the proposed methodology that is likely to be adopted for the project roads feasibility study analysis. The issues of suitable pavement treatment options and realistic unit costs to be adopted for analysis were discussed.

1.9. Feasibility Report Structure

Executive Summary

1. Project Background
2. Socio-Economic Profile
3. Design Standards

4. Inventory and Condition Surveys
5. Traffic Surveys
6. Engineering Surveys and Investigations
7. Preliminary Road Design
8. Preliminary Design of Structures
9. Cost Estimates
10. Economic and Financial Analysis
11. Discussions and Conclusions

1.10. Client Meeting

A meeting was held in 3rd week of October 2014 between the Nodal officer and Consultant team to discuss the proposed methodology that is likely to be adopted for the project roads feasibility study analysis. The issues of suitable pavement treatment options and realistic unit costs to be adopted for analysis were discussed.

2. Socio-Economic Profile

2.1. Introduction

Rajasthan, the largest State in the country in terms of geographical area, is located in the north-western part of the country. It has a geographical area of 3,42,239 sq.km, which constitute 10.41 per cent area of the country and 5.67 per cent of national population (Census, 2011 Provisional data). It shares international border with Pakistan in the west. Physiographically, the State can be divided into 4 major regions, namely the western desert: with barren hills, rocky plains and sandy plains, the Aravalli hills: running south-west to north-east starting from Gujarat and ending in Delhi, the eastern plains: with rich alluvial soils and south-eastern plateau. Mahi, Chambal and Banas are the three major rivers of the State. The State has varied climatic conditions ranging from semi-arid to arid. It is administratively divided into 7 divisions and 33 districts.

2.2. Socio-Economic Profile of Rajasthan

2.2.1. The profile of Population in Census 2011

The fifteenth census has been conducted in 2011 and the provisional results have been released. According to the provisional results of census 2011, the population of Rajasthan is 6.86 crore. The decadal growth rate of the population is 21.44 per cent during 2001-2011 compared to 28.41 per cent in the previous decennial period of 1991-2001. The pace of growth has slowed down, but still it is higher than the all India level. The population density in the State has increased from 165 per sq.km in Census 2001 to 201 in Census 2011. The overall sex-ratio of the population of Rajasthan in terms of number of females per thousand males is 926 compared to 940 of all India. The literacy rate of Rajasthan is 67.06 per cent in total and 80.51 per cent and 52.66 per cent for males and females respectively.

2.2.2. Profile of Rajasthan

The salient features of the State vis-a-vis India are given in the table below:

S. No.	Indicators	Year	Unit	Rajasthan	India
1.	Geographical Area	2011	Lakh Sq. Km.	3.42	32.87
2.	Population	2011*	Crore	6.86	121.02
3.	Decadal Growth Rate	2011*	Percentage	21.44	17.64
4.	Density of Population	2011*	Population Per Sq. Km.	201	382
5.	Urban Population to total Population	2011*	Percentage	24.89	31.16
6.	Sex Ratio	2011*	Females Per 1,000 Males	926	940
7.	Total Literacy Rate	2011*	Percentage	67.06	74.04
	Female Literacy Rate	2011*	Percentage	52.66	65.46
	Male Literacy Rate	2011*	Percentage	80.51	82.14

S. No.	Indicators	Year	Unit	Rajasthan	India
8.	Birth Rate	2010**	Per 1,000 Mid-year population	26.7	22.1
9.	Death Rate	2010**	Per 1,000 Mid-year population	6.7	7.2
10.	Infant Mortality Rate	2010**	Per 1,000 live births	55	47
11.	Maternal Mortality Ratio	2007-09**	Per lakh live births	212	318
12.	Life expectancy at Birth	2002-06**	Years	62.0	63.5

*Census 2011 (provisional) **SRS

2.2.3. Rajasthan's Economy

The economy of the state is primarily agricultural and pastoral. The state has nine agro-climatic zones & variety of soils that support cultivation of various crops. Rajasthan has been in the forefront of economic reforms. The State is committed in catalyzing investments, accelerating economic growth & creating large scale employment opportunities for the people. The main industries in the state are mineral, agricultural and textile based. It is the second largest producer of Polyester fiber and cement in India. The state is famous for its marble quarries, copper, zinc mines and salt deposits.

The Gross State Domestic Product (GSDP) is a measurement of the economic health of the state. It is defined as a measure, in monetary terms, of the volume of all the final goods and services produced within the boundaries of the state during a year accounted without duplication.

The estimates of Gross and Net State Domestic Product (GSDP & NSDP) and Per-Capita Income (PCI) have been prepared both at current and constant (2004-05) prices. The year-wise estimates of Gross & Net State Domestic Product and Per-Capita Income from the year 2010-11 at current prices are given below:

GSDP and NSDP at Current Prices (Crore)

Year	GSDP	NSDP
2010 - 11	338348	300907
2011 - 12	414179	374090
2012 - 13 P	470178	422982
2013 - 14 Q	517615	465504
2014 - 15 A	574549	516462

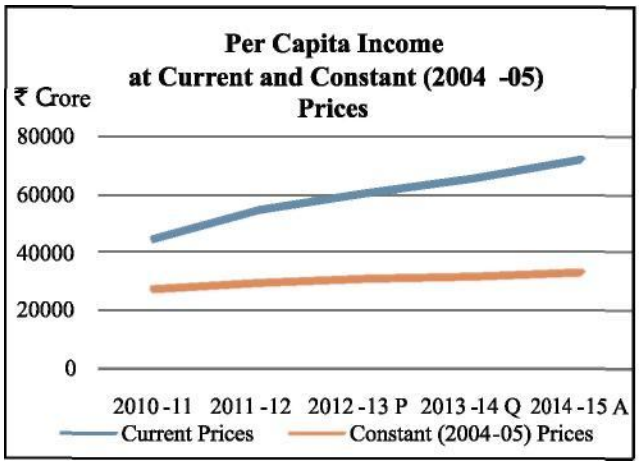
P-Provisional, Q-Quick, A-Advance

GSDP and NSDP at Constant Prices (2004-05) (Crore)

Year	GSDP	NSDP
2010- 11	213079	185366
2011 - 12	230859	202749
2012- 13 P	245666	214391
2013- 14 Q	257432	224632
2014- 15 A	272227	237530

Per Capita Income at Current and Constant (2004-05) Prices

Year	At Current Prices	At Constant (2004-05) Prices
2010-11	44644	27502
2011 - 12	54637	29612
2012- 13 P	60844	30839
2013 - 14 Q	65974	31836
2014- 15 A	72156	33186



The advance estimates of Gross State Domestic Product at current prices is estimated to be Rs 5,74,549 crore for the year 2014-15 as compared to Rs 5,74,549 crore during the year 2013-14 (quick estimates), showing an increase of 11.00 per cent over the previous year. As per the advance estimates, Gross State Domestic Product at constant (2004-05) prices, in the year 2014-15 is likely to attain a level of Rs 2,72,227 crore, as against the estimates of GSDP for the year 2013-14 (quick estimates) of Rs 2,57,432 crore, registering an increase of 5.75 per cent over the preceding year.

The advance estimates of Net State Domestic Product at current prices is worked out to be Rs 5,16,462 crore for the year 2014-15 as compared to Rs 4,65,504 crore during the year 2013-14 (quick estimates) showing an increase of 10.95 per cent over the previous year. As per the advance estimates, the Net State Domestic Product at constant (2004-05) prices, in the year 2014-15 has been estimated at Rs 2,37,530 crore as against Rs 2,24,632 crore in

the year 2013-14 (quick estimates) showing an increase of 5.74 per cent over the previous year.

The per capita income for the year 2014-15 at current prices works out to be Rs 72,156 as against Rs 65,974 during the year 2013-14 (quick estimates) registering an increase of 9.37 per cent over the previous year. The per capita income at 2004-05 constant prices during 2014-15, is likely to be Rs 33,186 as compared to Rs 31,836 in the year 2013-14 (quick estimates), registering an increase of 4.24 per cent over the previous year.

2.2.4 Wholesale and Consumer Price Index

Changes in the level of wholesale and retail prices at specific intervals are measured and expressed through Wholesale and Consumer Price Index. The General Index of Wholesale Price of the State during the year 2014 stood at 266.82 as against 257.55 in the year 2013, which shows an increase of 3.60 per cent over the previous year.

The Index of Primary Articles Group registered an increase of 1.53 per cent, 'Fuel, Power, Light and Lubricants' Group by 8.68 per cent and Manufactured Product's Group increased by 2.72 per cent. While at All India level, the General Index of Wholesale Price increased by 3.85 per cent.

A continuous rising trend has also been observed in Consumer Price Index during the year 2014.General Index of Consumer Price for the year 2014 recorded an increase of 3.48 per cent at Jaipur centre, 3.00 per cent at Ajmer centre and 3.81 per cent at Bhilwara centre over the previous year.

2.2.5 Banking

The state has an extensive network of Banking & Financial system. As on Sept., 2014 there are total no. of 5,915 bank offices in the state, out of which 2,487 are of Nationalized Banks, 1,375 of SBI & its Associate banks, 1,262 of Regional Rural Banks, 784 of Private Sector Banks and 7 of Foreign Banks.

The deposits have increased by 12.71 per cent in Rajasthan in September, 2014 over September, 2013, while at all India level deposits increased by 12.29 per cent during the same period. The credit deposit ratio for all scheduled commercial banks is 85.87 per cent in Rajasthan and 75.89 per cent at all India level as on September, 2014, whereas it was 91.52 per cent in Rajasthan and 77.83 per cent at all India level in September, 2013. The total credit percentage increased by 5.76 per cent in Rajasthan upto September, 2014 over corresponding period of 2013, while it has increased by 9.49 per cent at all India level.

2.2.6 Agriculture

During 2014-15, the food grain production in the state is expected to be 201.66 lakh tones as compared to 206.89 lakh tones in the agricultural year 2013-14, which shows a decrease of 2.53 per cent.

Under National 1 horticulture Mission, orchards of fruits and spices have been established in 9,628.67 hectare and 1,980 hectare respectively, under National Mission for Sustainable Agriculture, drips and sprinkles have been installed in 9,880.12 hectares and 4,671 hectare respectively.

Agricultural Marketing Board has incurred 7185.33 crore on construction of Mandi Yards, roads and its repairing, cold storage and deposit wot*sduringlheyear2014-15till December, 2014.

For breed improvement 3.20 lakh castrations and 17.72 lakh artificial insemination have been executed during the year 2014-15 till Dcccmbcr,2014.

278 new dairy co-operative societies have been opened and 528 dairy co-operative societies have been revived during the year 2014-15 till December, 2014. 6,382 lakh kg milk have been procured by Rajasthan Co-operative Dairy Federation.

During 2014-15 short term co-operative loans of 713,941.87 crore, medium term co-operative loans of 7241*46 crore and long term co-operative loans of 7166.75 crore have been disbursed till December* 2014.

2.2.7 Irrigation

During 2014-15, an expenditure of 7517.21 crore is incurred on various irrigation projects. During the same period, 8,990 hectare additional Irrigation facilities have been provided and 2 minor irrigation projects have been completed. Work on Gang canal modernization project is under process, an amount of 740.59 crore has been incurred on this project and 179 hectare Culturablc Command Area has been created during the year 2014-15 UllDecember,20I4.

Total 393 Sub projects were identified in the Rajasthan Minor Irrigation Improvement project costing 7612.29 crore with the financial assistance from Japanese International Co-operation Agency (JICA), out of these 272 sub projects have been completed.

2.2.8 Industries

The department of Industries is working for the development of industries and handicrafts in the State and providing necessary guidance, assistance and facilities for industrial activities. At present, 36 District Industries Centres and 7 sub-centres are working for providing inputs and other facilities to entrepreneurs. The Bureau of Investment Promotion (BIP) has been providing investment facilitation services, mainly for large projects by acting as an interface between investors and the government for speedy clearances and redressal of issues.

Industries Department has extended the Cooperation agreement with "International Finance Corporation, a member of the World Bank group, for a 3 year Knowledge Partnership (KP) to attract more investments and policy related regulations in various schemes.

Enactment of Raj asthan Enterprises Single Window Enabling and Clearance Act, 2011 led to attract 485 investment proposals involving an investment of 31,177.51 crore till December 2014, out of which 194 proposals involving an investment of 10,3 84.71 crore have been cleared.

Special and exclusive parks like Agro food parks, Japanese Park at Neemrana etc, have been developed by RIICO, all of them are very innovative and effective measures to attract the investors.

RIICO has allotted 610 acres land at Bhiwadi Industrial Area for establishment of Honda Siel Car project with an investment of 6,144 crore similarly an investment of 1,989.06 crore has been made in Mahindra World City (Jaipur) in the year 2014-15 upto December, 2014.

Till December 2014, 15,221 Micro, Small and Medium Enterprises have been registered for attracting an Investment of 1,863.36 crore and generating a direct employment for 76,403 persons. Rajasthan Financial Corporation (RFC) has sanctioned loans amounting to 147 crore, disbursed 78 crore and has recovered loans of 184 crore during 2014-15 upto Dec, 2014. Rajasthan State Industrial Development and Industrial Corporation has acquired 2,114.99 acre of land & developed 553.78 acre of land during the year 2014-15 up to December, 2014.

2.2.9 Mines and Minerals

There are 3,403 mining leases for major minerals and 11,861 minor leases and 18,249 quarry licenses in the State.

During 2014-15, a revenue target of 3,860 crore has been earmarked, out of which 2,100 crore has been achieved till December, 2014.

2.2.10 Oil and Gas

Rajasthan has huge potential of hydrocarbons under 4 Petroliferous Basins, 3 Petroliferous Basins of Rajasthan has been upgraded into Category-I i.e. equivalent to Bombay High, Assam and Gujarat. After explorations by various companies 25-30 billion cubic meter of Natural gas reserve has been found in Jaisalmer Basin. Heavy Oil resource of 25.00 million tonnes and Bitumen reserves of 53.00 million tonnes have been proved in place by an agreement entered between Oil India and Venezuelan Company PD VSA for exploitation.

By the end of December 2014, Cairn Energy has drilled a total of 481 wells, similarly Focus Energy has drilled 50 wells in district Jaisalmer. 3.7- 4.1 billion barrels of Oil reserves (i.e. 480-500 million tons) have been found alone in Barmer-Sanchore basin, one of the biggest discoveries in last three decades in the country.

Reputed companies have shown their interest to Petroleum & Natural Gas Regulatory Board to develop infrastructure for City Gas Distribution in major cities/towns of Rajasthan.

2.2.11 Power

The main sources of energy generation in the State are Kota and Suratgarh Thermal Projects, Dholpur Gas Thermal Project, Mahi Hydel, Wind farms, Biomass, Captive Power Plants, Bhakra, Vyas, Chambal, Satpura Inter-State Partnership Projects and Rajasthan Atomic Power Project Singroli, Rihand, Dadri, Anta, Auriya, Dadri Gas plants, Unchahar thermal, and Tanakpur, Salal, Chamera and Urihydel projects from Central Sector

The installed capacity of the State as on March, 2014 was 14,371.61 MW. The total increase in installed capacity during year 2014-15 (Upto December, 2014) is 1,370.61 MW. As such, the installed capacity as on December, 2014 was 15,742.22 MW..

2.2.12 Transport

2.2.12.1 Railways

The length of railway routes in the State March, 2012 was 5,822.28 km which has increased to 5,871.65 km at the end of March, 2013. Out of it, 4,801.18 km was covered under broad gauge, 983.71km under meter gauge and 86.76 km under narrow gauge.

2.2.12.2 Roads

As on December 2014, state has a total road length of 2,05,003 km, out of these 7,310 km are National Highways, 11,881 km are State Highways, 9,540 km are major District roads,

29,216 km are other district roads and 147,056 km are village roads. The road density in the state is 59.90 km per 100 sq. km against the national average of 148 km.

4,459 km Black Top roads have been constructed under various programmes / projects like National Bank for Agriculture and Rural Development (NABARD), Pradhan Mantri Gram Sadak Yojana (PMGSY), Rajasthan Road Sector Modernization Projects (RRSMP) etc.

The distribution of road network in Rajasthan State is as per table below:

Table 2-1: Distribution of road network in Rajasthan State

Sr No.	Classification	Length (s.)	Percentage
	Total Roads (As on 31.12.2014)		
1.1	National Highways	7310	3.57
1.2	State Highways	11881	5.80
1.3	Major District Roads	9540	4.65
1.4	Other District Roads	29216	14.25
1.5	Village Roads	147056	71.73
	Total	205003	100.00

The total road length which was just 13,553 km in 1949 increased to 2,05,003 km upto December, 2014. The road density in the state is 59.90 km per 100 sq. km at the end of 31.12.2014, which is much below the national average of 148 km. It speaks of the need to further enhance the road network in the state. The total classified road length is given in table below.

Road Length (km) in the State as on 31.12.2014 (Tentative)

Classification	BT	MR	GR	FW	TOTAL
National Highways	7279.58	0.00	0.00	30.10	7309.68
State Highways	11825.77	4.20	5.00	45.70	11880.67
Major District Roads	9374.87	11.00	79.60	74.95	9540.42
Other District Roads	27239.17	903.80	997.24	75.96	29216.17
Village Roads	107452.58	1139.78	35643.92	2820.19	147056.47
GRAND TOTAL	163171.97	2058.78	36725.76	3046.90	205003.41

(BT- Black Top, MR- Metal Road, GR- Graveled Road, FW-Fair Weather)

There are 39,753 villages in the state. The connectivity of villages by BT road in different population groups at the end of 2013-14 and likely 2014-15 is shown in table below.

Road connectivity of Villages

S.No.	Population Group	Total number of villages	Villages connected as on 3/14	Villages connected as on 3/15 (Likely)	Per cent of Villages connected
1	1000 & Above	14198	14180	14180	99.87
2	500-1000	11058	10957	10957	99.08
3	250-500	7713	6150	6700	86.87
4	100-250	3852	1597	1697	44.06
5	Below-100	2932	864	864	29.47
	Total	39753	33748	34398	86.53

During the year 2014-15, the important achievements up to December, 2014 under road development are given below:

- 4,459 km BT roads have been constructed under National Bank for Agriculture and Rural Development (NABARD)-Rural Infrastructure Development Fund (RIDF) - XVII, XVIII, XIX, Pradhan Mantri Gram Sadak Yojana (PMGSY), Rajasthan Road Sector Modernization Project (RRSMP) and Rural Roads.
- 5 villages having population 250 and above and 725 habitations (Dhani/Majara) have been connected by 2,318 km BT road with an expenditure of 618.00 crore under PMGSY.
- 89 villages having population 250 to 499 have been connected by BT road under National Bank for Agriculture and Rural Development (NABARD)-Rural Infrastructure Development Fund (RIDF)-XVIII/XIX.
- 425 villages having population 250 to 499 has been connected by 1,004 km BT road with an expenditure of 449.28 crore in Rajasthan Road Sector Modernization Project (RRSMP).
- 236 km missing links have been constructed under NABARD-XVII andXVIII.
- Construction of 13 Railway under Bridges (RUB's) has been completed. Work of Rail over bridge at Bharatpur-Mathura road has been completed.
- Sanctions of 2,119 Gramin Gaurav Path (GGP) roads in 2,154 Panchayat headquarters, amounting to 1,113 crore has issued.

Built Operate and Transfer (BOT)/PPP/ Annuity Project

Public Private Partnership (PPP) -PWD

Development work of 20,000 km State Highways on Public Private Partnership (PPP) mode is to be executed in next 5 years. In the first phase, 8,910 km length of State Highways and Major District Roads has been identified. It includes 132 roads in 29 packages. For Detailed Project Report (DPR) of all these roads, work order has been issued. In this phase development work of East-West corridor (1,012 km) has also been included.

Road Infrastructure Development Company of Rajasthan (RIDCOR)

For development of Jaipur-Bhilwara (State Highway) and Chomu-Mahela costing 7416.00 crore on PPP basis, work is under progress and is likely to be completed by March, 2015 and June, 2015 respectively.

Work on Mathura-Bhadoti (185.50 km) and Rawatsar-Nohar-Bhadara (118.00 km) road are under progress.

Rajasthan State Road Development Corporation (RSRDC)

17 projects had been taken up under BOT and Annuity pattern for development of State Highways and Major District Roads having length of 1,532.00 km and costing 73,342.00 crore by RSRDC. Work has been completed on 13 projects and work is under progress on4projects.

Widening and strengthening work on 6 State Highway/Major District roads having length 451.87 km and costing to 71,313 crore has been started on BOT/Annuity basis by RSRDC. Work has been completed on one project and work is under progress on 5 projects.

Built Operate and Transfer (BOT) - State

During 2014-15, one project i.e. Chechat, Modak, Ramganj Mandi-Udawa upto Madhya Pradesh border (28.20 km), has been completed with cost of 789.48 crore on BOT basis.

16 Mega Highways with a length of 2,631 km has to be developed at a cost of 73,590 crore. These Mega Highways include 28 road stretches. Out of this, 20 works completed and 8 road works are under progress.

Public Private Partnership (PPP-NH) PWD

Six projects amounting 72,756.05 crore to develop 859 km National Highway length on BOT basis is under progress.

Two Projects amounting to 7566.00 crore to develop 185 km length of National Highways to 2-lane/2 lane with paved shoulder under World Bank funded National Highway Inter-connectivity Improvement Programme (NHIIP Phase-I) scheme is under progress.

Three Projects under Engineering Procurement Construction (EPC) funded by Ministry of Road Transport Highway (MoRTH) are under implementation by PWD for 7745.38 crore for development of 193.05 km length of National Highway. Agreements have been singed in all 3-projects.

National Highway Authority of India (NHAI)

- Six lane work of Jaipur-Gurgaon NH-8 of 71,897.00 crore having length of 225.60 km is under progress in which length under Rajasthan State is 161.30 Km 81 per cent work has been completed by December, 2014.
- Six lane work of Kishangarh-Ajmer-Beawar NH-8 of 7795.00 crore having length of 92 km is under progress. 92 per cent work has been completed by December, 2014.
- Four lane work of Jaipur-Deoli-Kota NH-12 of 71,431.24 crore having length of 232.40 km is under progress. 97 per cent work (227.15 km) has been completed by December, 2014.
- Four lane work of Jaipur-Reengus-Sikar NH-11 of 7687.51 crore having length 95.72 km is under progress. Work in 91.70 km (95.80 per cent) completed by December, 2014.
- Four lane work of Beawar-Pali-Pindwara NH-14 of 72,388.00 crore having length of 244

km is under progress. 97 per cent work has beencompleted by December, 2014.

- Four lane work of Gomati Chauraha-Udaipur NH-8 of 914.50 crore having length of 79.31 km. is under progress. Work in 48.85 km (59.89 per cent) has been completed by December, 2014.
- Two lane work of Karauli-Dholpur NH-1 IB of ^261.00 crore having length of 100.90 km started in September 2014 and is under progress.
- Two lane work of State Border-Fatehnagar-Salasar NH-65 of 530.07 crore having length of 154.14 km is under progress. Work in 10.61 km (18.32 per cent) has been completed.
- Two lane work of Jhalawar-Biaora NH-12 of 227.36 crore having length of 62.16 km is under progress. Work in 48.73 km (78.39 per cent) has been completed.
- Two lane work of Bhim-Parasoli NH-148D of 80.36 crore having length of 33 km is under progress. Work in 12.74 km (38.6 per cent) has been completed.
- Two lane work of Parasoli-Gulabpura NH-148D of ^87.18 crore having length of 36.26 km is under progress. Work in 19.81 km (54.62 per cent) has been completed.
- Two lane work of Ladnun-Degana-Merta cityNH-458 of 273.78 crore having length of 139.90 km is under progress. Work in 14.50 km (10.36 per cent) has been completed.
- Two lane work of Bhilwara-Ladpura NH-758 of 353.42 crore having length of 67.75 km is under progress

2.2.12.3 Motor Vehicles

Rajasthan State Road Transport Corporation (RSRTC) was established on October 1, 1964 under the Road Transport Corporation Act. 1950. Presently Rajasthan State Road Transport Corporation (RSRTC) is operating to run a total of 4,729 own and on contract Private buses. The vehicles are operated on 2,506 routes in the States, plying 17.25 lakh km and carrying 9.80 lakh passengers per day.

In the Transport sector, against a target of 2,950 crore, 1,798.5 crore revenue has been collected in the year 2014-15, till December, 2014.

The total number of motor vehicles registered with transport department increased by **8.21 percent** from 111.84 lakh in 2013-14 to 121.02 lakh in December, 2014.

The number of motor vehicles registered in the State at the end of December, 2014 is 51.52 per cent higher, as compared to the year 2010-11 revealing fairly good growth.

The numbers of vehicles are increasing daily in the State. The detailed information is presented in table below:

Vehicles Registered in Rajasthan

S No	Type of Vehicle	Cumulative Numbers by the end of Year				
		2010-11	2011-12	2012-13	2013-14	2014-15*
1	Motorised Rickshaws	90	90	90	90	90
2	Two Wheelers	5859719	6629743	7465863	8331142	9060869
3	Auto Rickshaws	102967	110456	117990	125638	131487
4	Tempo carrying goods	46159	49812	53418	56668	59535

5	Tempo carrying passengers	20361	23889	27432	31031	33784
6	Car	520385	591069	659542	733916	790821
7	Jeep	227910	254840	288056	319490	346214
8	Tractor	644305	699881	768645	841290	894307
9	Trailer	70525	71665	73732	74568	75226
10	Taxies	77317	89053	103690	114615	120385
11	Buses and Mini Buses	77980	83345	88616	93892	97001
12	Trucks	323273	362028	401983	434379	462464
13	Other	16364	19697	22978	27711	30040
	Total	7987355	8985568	10072035	11184430	12102223

2.2.12.4 Aviation Industry

Rajasthan is easily accessible from anywhere in India and the rest of the world. The place has many airports that cater to both international as well as domestic flights. There is one major international airport of Rajasthan. Rests of the airports in Rajasthan are domestic and cater to flights from all over India. Read about Rajasthan airports in this section.

Bikaner Domestic Airport

Known as Nal Airport, this domestic airport of Bikaner is located approximately at a distance of 9 kilometers from the main city.

Jaipur International Airport

Located at a distance of around 10 kilometers from the city, the airport at Jaipur is the only international airport in this state. It is situated in a place called Sanganer and caters to many international as well as domestic flights.

Jaisalmer Domestic Airport

The airport at Jaisalmer is not open throughout the year. It becomes operational during the peak travel season, i.e., from 1st October to 31st March. It is located at a distance of around 9 kilometres from the main city centre.

Jodhpur Domestic Airport

The Jodhpur airport is approximately 5 kilometres from the center of the city. It has domestic flights daily from Mumbai, Udaipur, Delhi and Jaipur.

Kota Domestic Airport

There is another airport at Kota district. This is also a domestic airport and is located at a distance of around 10 kilometers from the heart of Kota.

Udaipur Domestic Airport

The domestic airport at Udaipur is known as Maharana Pratap Airport. It is at a distance of 22 kilometers from the city center

2.2.13 Tourism

Forts, Palaces & Havelies, Fairs & Festivals, Handicrafts, Heritage Hotels, Adventure Tourism, Rural and Eco Tourism, Religious Tourism and Temple Architecture, Folk music and classical music, dance etc. are the most popular tourist attraction points of the State along with world class Luxury trains (Palace-on-Wheels & Rajasthan Royal on Wheels) for comfortable journey of tourists.

In the calendar year 2014, the number of tourist arrival in Rajasthan was 346.02 lakh (330.76 lakh domestic and 15.26 lakh foreign) and recorded an increase of 9.17 per cent in domestic tourist and 6.15 per cent in foreign tourist arrivals. Within the same period 36 fairs and festivals have been organized by Tourism Department.

73 new projects of tourism units having an investment of 398 crore have been approved by the State Government.

Department has launched 40 Virtual tour for prominent tourist places, fairs and festivals of Rajasthan out of which 15 have been displayed on departmental website..

2.2.14 Urban Infrastructure Development

Rajasthan Housing Board has taken up construction of 2,42,949 dwelling units, out of which 2,30,678 units have been completed, 2,33,962 units have been allotted and 2,15,533 units have been handed over to applicants till December, 2014.

Out of 184 municipal towns, 182 municipal towns Master plans have been prepared and got approved by the Government.

Jaipur Metro Rail Project is being implemented in two phases, phase-I of the project is divided in two parts: Phase-1A from Mansaro var to Chandpole and Phase-IB from Chandpole to Badi Chaupar and Phase-II of the project is from Ambabari to Sitapura. The work of Phase IA is in its last stage of completion, Research Design & Standards Organization, Lucknow issued speed certificates with maximum speed of 80 km per hour for Jaipur Metro on the basis of speed trials and safety certification is under process for Phase IA.

The Phase-IB of this proj ect is funded by the Asian Development Bank (ADB). The total project cost is 1,126 crore in which 969 crore is ADB loan portion and 157 crore will be provided by the State Government. Preliminary works like soil testing, pre-building condition survey, construction of casting yard, procurement of two Tunnel Bowring Machines etc. have been completed. Work of Chhoti and Bari Chauper underground stations has already commenced. Since inception, an expenditure of 68.47 crore has been incurred under the project. During year 2014-15, an outlay of 162.00 crore was earmarked against which 37.01 crore have been utilized till December, 2014.

2.3 Socio-Economic Influence of the Project Road

2.3.1 Sri Ganganagar & Hanumangarh

Sri Ganganagar is a northern most city of Rajasthan State of western India. Sri Ganganagar District is located between Latitude 28.4 to 30.6 and Longitude 72.2 to 75.3. The total area of Sri Ganganagar is 11,154.66 km² or 1,115,466 hectares. It is surrounded on the east by Hanumangarh District, (Hanumangarh district was carved out of it on July 12, 1994) on the south by Bikaner District, and on the west by Bahawalnagar district of the Pakistani Punjab and on the north by the Punjab. Sri Ganganagar is situated at the point where the Satluj Waters enter Rajasthan.

Hanumangarh district situated at 29°5' to 30°6' North and 74°3' to 75º3' east, shares its boundaries with Haryana state in the east, Sriganganagar district in the west, Punjab state in the North and Churu district in the South. The geographical area of the district is 9656.09 Sq. Km. The climate of the district is semi-dry, extremely hot during the summer and extremely cold during winter. The maximum average temperature remains 18° to 48° and minimum average is 2° to 28° celcius. The average rainfall during the year is 225 to 300 mm.

2.3.2 Topography

Ganga canal irrigates northern-western area of the district; photo taken near Ganganagar city from Ganganagar-Hanumangarh road. Irrigation has made Ganganagar greener but sandy dunes can still be seen. A photo taken in Gharsana tehsil.

The Anupgarh branch of the IGNP canal is the main source of irrigation in southern tehsils; photo taken inGharsana Tehsil. Although Ganganagar District lies in the great Thar desert, irrigation via the Gang canal and Ignp canal has changed the flora and fauna. The district can be classified into five geographical regions. The region irrigated by the Gang canal and the Bhakhra canal tributaries: the northern region, which is 3/4 of the district, resembles the fertile plains of Punjab, but some areas, like the area between the towns of Raisinghnagar and Vijaynagar, have desert like conditions.

Area irrigated by the Suratgarh branch of the IGNP canal. Area irrigated by Anupgarh branch of IGNP canal: it comprises Anupgarh and Gharsana tehsils. It is the southernmost region of the district, of which much has been converted into plains, but sandy dunes can still be seen.

The Naali belt: this is a narrow basin of the Ghaggar River. It is the only major river of the district. It is a seasonal river, which flows in the rainy season. It enters the district near Suratgarh and then flows in areas of Jaitsar, Vijaynagar, Anupgarh and then crosses the Indo-Pakistani border.

The 'Uncha Tibba' (high sandy dunes) area of Suratgarh tehsil: large sandy dunes and lack of water predominate here. This area can be said to be a 'real desert'. People of this area face harsh conditions in the desert.

2.3.3 Economy

The economy of Sri Ganganagar District is dependent on agriculture. Major crops of the region are wheat, cotton, mustard, guar, grams, and sugarcane. Horticulture is also becoming popular among farmers. Kinnow (a citrus family fruit) is a popular horticultural product; other fruits of the citrus family are also grown.

Industries in Sri Ganganagar District are based on agriculture. Major industries are cotton ginning and pressing factories, mustard oil mills, wheat flour mills, sugar mills, and cotton spinning and textile factories. Most of the factories are located in and around Sri Ganganagar City.

3 Design Standards

3.1 General

The general planning aspects laid out in the IRC:SP:73:2015 (the Manual) shall be applicable for development of the project highway. The Scope of the work shall be as defined in the Concession Agreement. The Standards and Technical Specifications applicable for the design and construction of project components shall be in accordance with the Codes, Standards, and Guidelines as published by IRC, MoRTH and BIS as referred in the Manual.

3.2 Terrain Classification

The following terrain classification recommended by IRC-73 is adopted:

Terrain Classification	Percentage Slope of the Country
Plain	0 – 10

The proposed alignment follows the plain terrain as per the above classification and thus geometric designs are prepared based on IRC: 73-1980 for plain terrain.

3.3 Topographical Survey

Topographical survey is the backbone of any highway design. Accuracy of the information collected during this survey has a direct bearing on all the design activities involved in project preparation.

For the purpose of highway design, a topographical survey is divided into the following activities:

- Setting up permanent bench marks and control stations;
- Establishment of horizontal control;
- Establishment of vertical control to have the elevation coordinate hooked to nearest GTS stations along the Project Road;
- Collection of Digital Terrain Model data containing the existing highway, rivers, streams and other topographical features to form the basis for the new designs; and
- Preparation of base plans containing the entire natural and manmade features like buildings, fences, walls, utilities, temples and other religious structures etc. That would govern the finalization of horizontal alignment.

The following paragraphs describe the methodology followed in carrying out the above-said activities in topographical survey.

3.3.1 Horizontal Control Stations

Permanent Ground Markers (PGMs) were established at every 2 km intervals. These PGMs are concrete pillars constructed with a punched steel rod at the centre and established on ground in pairs. Horizontal control was ascribed to all PGMs using the Global Positioning System (GPS). Reference pillars of size 15 cm x 15 cm x 45 cm are cast in RCC of grade M 20 with a nail fixed in the center of the top surface. These are embedded in concrete upto a depth of 30 cm with CC M15 (5 cm wide all around) at site at 2 km intervals to form control stations along the proposed alignment.

The intermediate secondary traverse stations (TS) were fixed and are connected from one PGM pair to another using total station to maintain a high degree of accuracy. Double Tertiary (DT) levelling was carried out to fix temporary benchmarks from one GTS benchmark (Survey of India control point) to another as well as establishing vertical control to all PGMs and TS along the way.

The vertical control stations (Bench Marks) along the proposed alignment are established by leveling using Auto Level. Control Stations that have been set up for horizontal control are also used to serve as Benchmarks and Reduced Levels (RLs) of these Control Points are established. They are linked with respect to GTS Benchmarks located in the vicinity of the Project Road. Besides control stations, due consideration is given to install as many additional Benchmarks as possible.A loop system is adopted to ensure the accuracy of RLs within the permissible limits. The ultimate error is found to be within the permissible limit of 12, where K is the length in km and the error in mm.

3.4 Environmental and Social Assessments

Based on the detailed report on environmental and social assessment of potential critical impacts, complying with the environmental requirements, environmental design for enhancement of areas within the ROW, which would likely to have environmental degradation as a result of the proposed highway improvement, is prepared.

4 Inventory & Condition Surveys

4.1 Road Network

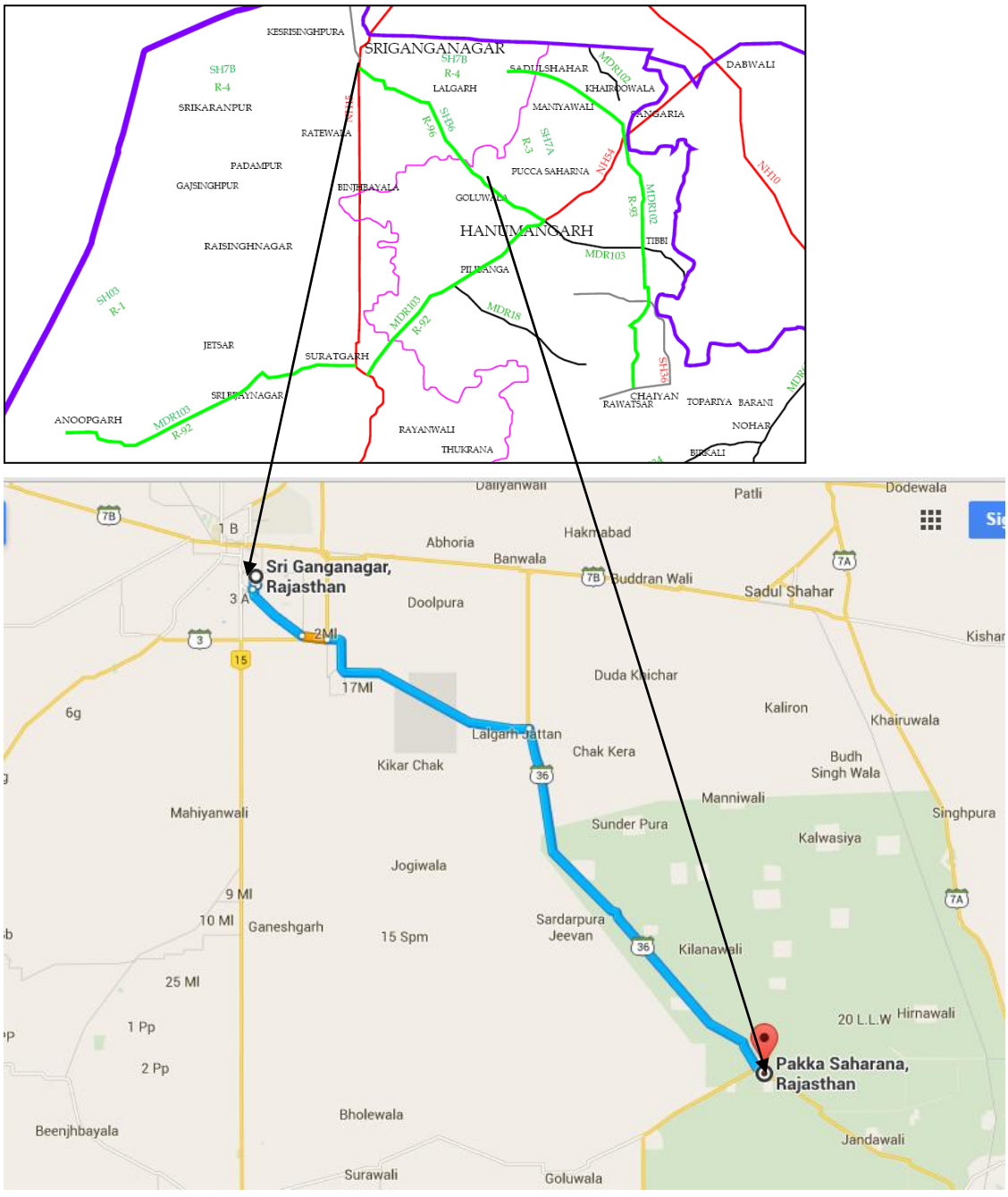
This Feasibility Report details the approach, methodology and work plan for carrying out feasibility study of the following road (**Table 4-1**) grouped under package-21.

Table 4-1: Project Road under Study

S No	Description of Road	Length (Km)
1	Sri Ganganagar to Pacca Saharana	41.0

The project road mainly traverses in Sri Ganganagar and Hanumangarh Districts.

Figure 4-1: Project Road Alignment



4.2 Road Inventory and Pavement Condition Survey

Road inventory and pavement condition survey of the project road were carried out on 31st of October, 2014. Project road traverses through plain terrain. Land use being predominantly agriculture in some locations and interspersed with built-up sections. The salient details are discussed in the following paragraphs.

4.3 Start and End of the Project Road

The distance between Sri Ganganagar to Pacca Saharana is 41.0 km. The project road start at Shiv circle in Sri Ganganagar with start chainage 0+00 and ends at Ch. 41+00 near Pacca Saharana. The project road is a part of SH-36. The 'Northing' and 'Easting' at start, end and at control points of alignment change are given in **Table 4-2**. These are referenced from 'Google Earth'.


Start @ Shiv Circle

Table 4-2: Northing and Easting along Project Road

S No	Chainage	Northing	Easting
1	0+000	29°54'44.52"N	73°52'33.44"E
2	4+000	29°53'18.47"N	73°54'30.26"E
3	7+500	29°53'11.00"N	73°55'46.81"E
4	9+000	29°52'16.77"N	73°55'51.85"E
5	10+100	29°52'14.66"N	73°57'2.82"E
6	17+000	29°50'40.35"N	74° 1'55.08"E
7	39+000	29°40'58.09"N	74° 9'21.83"E
8	40+500	29°40'40.90"N	74° 9'39.96"E

4.4 ROW Characteristics

The land use along the project road is predominantly agriculture intersperse with built-up section. Available width of road land along the project corridor varies between 22m and 40m. The details of road length available under various categories are presented in **Table 4-3**. The km-wise available road land width is given in **Annexure-1.**

Table 4-3: Length under Available Road Land Width

S No	Category	20-25	25-30	>30	Total
1	Rural	23.0Km	-	-	23.0Km
2	Built-up	13.0Km	5.0Km	-	18.0Km

4.5 Distribution of Roads by Category and Surface Type

Existing road has 5.8-6.0m divided carriageway with median for a length of 4.0Km in the initial section and 2lane wide carriageway with 0.5m to 2.0m granular shoulder exists in the rest of the length. Based on the road category and surface type, the project road length is categorized as per the following **Table 4-4**.

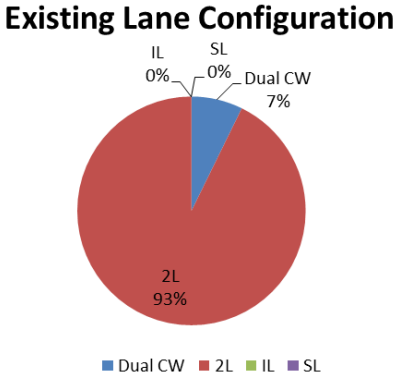


Table 4-4: Road Length under Various Road Category and Surface Type

S No.	Classification	Black Top	Cement Concrete	TOTAL
1	SH-36	40.025 Km	0.975 Km	41.0 Km

4.6 Visual Road Condition

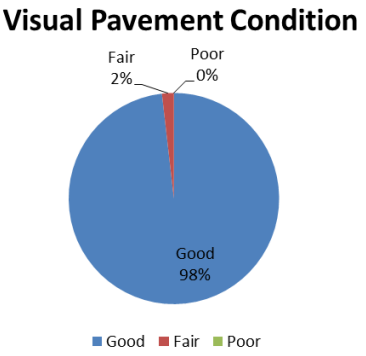
Pavement condition survey by visual method was carried out on the Project Road to assess the condition of existing pavement in serving the present traffic needs. Entire project road is of bituminous pavement surface. The % distress is compared with criteria for classification of pavement sections as per IRC: 81-1997. The maintenance standard levels as specified by IRC are shown in the below **Table 4-5**.

Table 4-5: Pavement distress Indices (IRC)

Sl. No	Serviceability Indicator	Good	Fair	Poor
1	Cracking	-	<5% (No Cracking or confined to single cracking in w. path)	>5-20% (Extensive Cracking * (up to 20% of area))
2	Rutting (20 mm depth max)	1%	1-1.5%	1.5-2.5%
3	Raveling	-	<10%	>10%
4	Pothole in numbers of 0.1 sq. m area	-	2-3	4-8

*Failed Sections - Cracking exceeding 20 per cent.

Predominant length (40.025 Km) of the road has bituminous surface and 0.975 Km (Km 17.375 – Km 18.350) has CC pavement. 98% of project road length is in good condition and 2% in fair condition except isolated patches of failed sections (40.7-40.8km). About 40% of shoulder is fair and 60% of length in poor condition with uneven surface and corrugation, lack of compaction and good quality shoulder material.



Summary of pavement surface condition is given in **Table 4-6.** Detailed road inventory and pavement condition survey details of project road are presented in **Annexure 1 & 2.**

Table 4-6: Summary of the Pavement Surface Condition

SL. No	Chainage, km		Length km	Overall Pavement Surface Condition
	From	To		
1	0.0	5.0	5	Good
2	5.0	6.0	1	Fair
3	6.0	41.0	35	Good*

*Localised failed section at 40.7-40.8Km

Good Condition @ km 6.5

Fair Condition @ km 5.3

Failed Sections @ km 40.7

4.7 At-grade Important Junctions

The important at-grade junctions along the project road and their chainages are presented in **Table 4-7**.

Table 4-7: List of Important Junctions

S No	Chainage	Junction Type	Remarks
1	@ Km 0.0	4 –Legged	Start of the project
2	@ Km 4.85	4 –Legged	Junction of Bypass
3	@ Km 8.010	3-Legged	RIICO Road
4	@ Km 18.400	3legged (Y-junction)	Lalgarh Jattan
5	@ Km 40.990	3legged (T-junction)	Pacca Sahrana village

4.8 Important Habitation along Project Road

The important habitation along the project road are presented in **Table 4-8.**

Table 4-8: List of Built-up Sections

START AND END CHAINAGE OF VILLAGE		NAME OF VILLAGE/TOWN	NAME OF BLOCK	NAME OF DISTRICT	TOTAL LENGTH (IN DISTRICT)	TYPE OF ROAD
0.0		SHIVA CIRCLE	Sri Ganganagar	Sri Ganganagar	Approx. 30.2 Km	SH-36
0.0	6.0	Ganganagar Town				
10.0	11.0	SIHAGAN WALI				
16.0	17.0	LALGARH JATTAN				
17.0	18.0	LALGARH JATTAN				
18.0	19.0	LALGARH JATTAN				
26.0	27.0	MAMARKHERA				
28.0	29.0	MORJANDAN				
40.8	41.0	PACCA SAHARANA	Hanumangarh	Hanumangarh	10.8 Km	

4.9 Existing and Proposed Drain Locations

The existing drain details along the project road are presented in **Table 4-9.**

Table 4-9: Existing Drain Locations

Sl No.	Chainage in Km		Village Name	Side		Remarks
	From	To		LHS	RHS	
1	0.0	1.0	-	0.20	0.00	Lined Drain
2	4.0	5.0	-	0.20	0.00	Kutcha Drain
3	5.0	6.0	-	0.30	0.20	Kutcha Drain
4	7.0	8.0	-	0.10	0.10	Lined Drain
5	9.0	10.0	-	0.03	0.00	Lined Drain on LHS
6	9.0	10.0	-	0.05	0.05	Kutcha Drain
7	16.0	19.0	LALGARH JATTAN	0.70	0.70	BM Drain
Total Length in Km				**1.580**	**1.050**	

The new lined drains are proposed and presented in **Table 4-10**.

Table 4-10: Proposed Drain Locations

Sl No.	Chainage in Km		Village Name	Side	
	From	To		LHS	RHS
1	0.000	4.000	Sri Ganganagar	4.000	4.000
2	4.000	8.300	Industrial area	4.300	4.300
3	10.100	10.350	Sihagan Wali	0.250	0.250
4	16.800	18.900	Lalgarh Jattan	2.100	2.100
5	26.200	26.300	Mamarkhera	0.100	0.100
6	28.700	28.900	Morjdana	0.200	0.200
7	40.800	41.000	Pacca Saharana	0.200	0.200
			Total Length in Km	**11.150**	**11.150**

4.10 Utilities along the Project Road

Electric poles along the road at some intermittent stretches and crossing of HT lines were observed and noted. Length of sections where electric poles were observed is presented in **Table 4-11**.

Table 4-11: Utilities Details

Sl No	Chainage		Rural / Built-up	Length of Section (Km)	
	LHS	RHS		LHS	RHS
1	1	1.8	Sri Ganganagar	0.8	0.8
2	1.8	4		-	2.2
3	4	4.2		0.2	-
4	4.2	4.9		-	0.7
5	10.5	-	Rural	High Tension line crossing over the Road	
6	11	14	Rural	-	3
7	13.3	-	Rural	High Tension line crossing over the Road at near to 'SPEAR HEADS WE LEAD'	
8	14	15	Rural	1	-
9	15	16	Rural	1	1
10	16	16.5	Rural	0.5	0.5
11	40.8	41	PACCA SAHARANA	1	1

4.11 Inventory and Condition Survey of Structures

The Inventory and condition survey of cross drainage structures are carried out along with the road inventory. The details of CD structures observed along the project road, their condition and the suggested improvement proposal are discussed in the following paragraphs. The inventory details are presented in **Annexure 3 & 4.**

4.12 Major Bridges

No major bridges were observed along the project road

4.13 Minor Bridges

The details of minor bridges provided across the irrigation canals are provided in the following **Table 4-12** along with the suggested improvement.

Table 4-12: Details of Culverts across Canals

STRUCTURES TYPES	Total No's	Span	Span	New construction	Retained	Widening
Irrigation Canal Structures		< 4 m	> 4m			
	4	-	4	1	-	3

4.14 Culverts

The slab and pipe culverts details are presented in the following **Table 4-13** with their improvement proposal.

Table 4-13: Details of Culverts

STRUCTURES TYPES	Total No's	Reconstruction	Retained	Extension
RC Slab Culverts	49	3	-	46
Hume Pipe Culvert	2	1	-	1

4.15 RUB/ROB/Railway Crossing

No RUB, ROB and at-grade railway level crossing were observed along the project road.

5 Traffic Study

5.1 General

Traffic assessment for the project corridor for the base and horizon years is an essential aspect as part of the feasibility studies and as a part of it; traffic surveys were commissioned and detailed traffic assessment were carried out during the period of November 2014.

This Report (Traffic Assessment Report) presents details on:

- ◊ Base traffic (ADT and AADT), capacity augmentation and tollable traffic estimates,
- ◊ Axle load surveys and tentative pavement design
- ◊ Preliminary project construction cost estimates
- ◊ Toll revenue estimates and financial viability analysis
- ◊ Findings and recommendations

5.2 Project Road

The Site of the Two-Lane Project Highway comprises the sections of SH-36, commencing from Sri Ganganagar to Pacca Saharana.

The length of the project stretch is 41.0 km from Sri Ganganagar to Pacca Saharna.

Mostly the project corridor has a two lane carriageway. In general the terrain is plain. There are sections of roads having carriageway width of single and intermediate lane configuration. In some built-up sections, higher road widths were observed. The land use pattern is mainly agricultural, commercial and built-up area. Existing road has 0.5m to 2.0m granular shoulder exists.

5.3 Traffic Surveys

Traffic surveys were carried out on the project road from Sri Ganganagar to Hanumangarh as per the original scope. Estimation of traffic over the project corridor is an essential step in project preparation. This includes conducting field traffic surveys, data analysis estimation of traffic (ADT & AADT) and estimating commercial vehicles loading (CSA) for pavement design.

The present traffic surveys have been planned in a way to obtain all the necessary information and data deemed necessary for the detailed project preparation. In order to identify traffic survey locations, the project road is divided into homogeneous sections based traffic flow pattern as given **Table 5-1**.

Table 5-1: Homogeneous Sections

Section	From	En-route	To	Length
Section-1	Sri Ganganagar	Sihagan Wali	Lalgarh Jattan	19.0 Km
Section-2	Lalgarh Jattan	Sardarpura Jeevan	Pacca Saharana	22.0 Km
			Total =	**41.0 Km**

To establish the traffic flow characteristics and travel pattern on the corridor and to evaluate the viability of the project road on PPP mode, the following surveys were conducted on the identified locations along the project road sections.

- ◊ 7-days Classified Traffic Volume Count (CTVC) Surveys
- ◊ 1-day 24 hr. Axle Load Surveys

5.3.1 Traffic Survey Locations

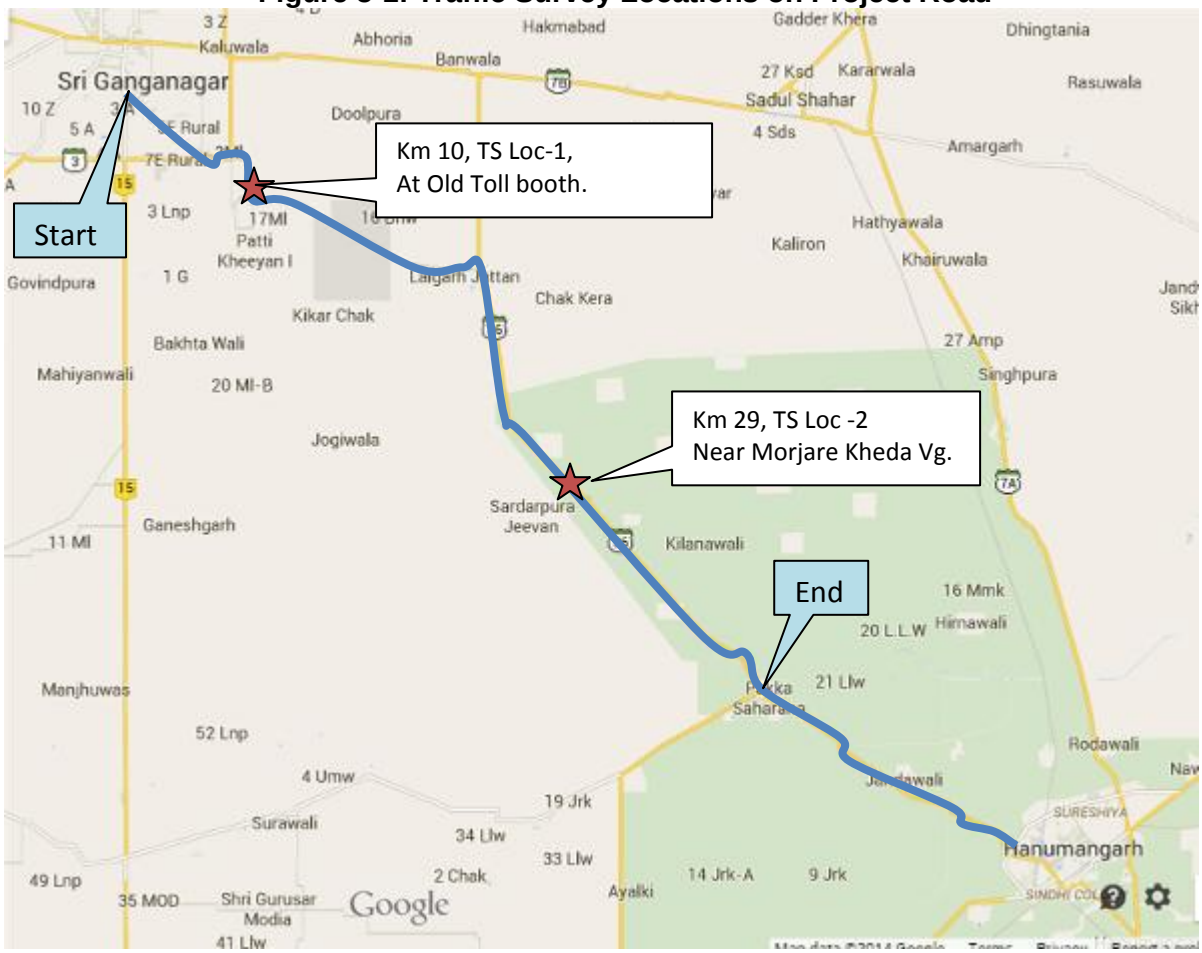
Location for carrying out traffic surveys were selected so as to coincide with the proposed toll plaza locations based on site reconnaissance and was finalized in-consultation with the client. The traffic survey locations on project road along with survey schedule are presented in **Table 5.2** and shown in **Figure 5.2**.

The surveys were undertaken during the period 19th to 25th November 2014.

Table 5-2: Traffic Survey Location

S No	Traffic Survey Details	Section	Location Details, PWD & Design Ch.	Start date	End date
A	**Traffic Volume Count**				
1	Sri Ganganagar to Lalgarh Jattan	Section-1	Km 10, TS Loc-1, At Existing Toll booth.	19/11/2014	25/11/2014
2	Lalgarh Jattan to Pacca Saharana	Section-2	Km 29, TS Loc -2 Near Morjare Kheda Vg.	19/11/2014	25/11/2014
B	**Axle Load Survey**				
1	Lalgarh Jattan to Pacca Saharana	Section-2	Km 29, TS Loc -2 Near Morjare Kheda Vg.	25/11/2014	26/11/2014

Figure 5-1: Traffic Survey Locations on Project Road



5.3.2 Methodology for Traffic Surveys

For carrying out these surveys, the vehicles were grouped into the following categories.

Table 5-3: Vehicle Classification System

Motorized Traffic	
Two Wheeler	Motor cycle & Scooter
Three Wheeler	Auto Rickshaws
Car / Jeep / Van	Private
	Taxi
Bus	Mini Bus
	Government Bus
	Private Bus
	School Bus
Commercial Vehicles (Trucks)	Mini Light Commercial Vehicle
	Light Commercial Vehicle (LCV) – 4
	Light Commercial Vehicle (LCV) – 6
	2-Axle Rigid Chassis Truck (2AT)
	3-Axle Rigid Chassis Truck (3AT)
	Multi Axle Truck (MAV) – 4 to 6 axles
	Multi Axle Truck (MAV) – >6 axles
Farm Vehicle	Agricultural Tractor (AgT)
	Agricultural Tractor & Trailer (AgTT)
Non-motorized Vehicles	Pedal Cycle
	Hand Cart
	Animal Drawn

5.3.2.1 Mid-block Classified Traffic Volume Count

The CTVC surveys were conducted for 7 days for both directions separately using manual counting method on project road sections. The count data was recorded with 15-minute interval using hand tallies.

5.3.2.2 Axle Load Surveys

Traffic loading on highway pavements is a heterogeneous combination of different types of vehicles, carrying a wide spectrum of wheel loads. It is very much essential to convert this heterogeneous traffic to an equivalent homogenous traffic in terms of a chosen standard vehicle. One means of achieving this objective is the use of Equivalent Standard Axle Load (ESAL) factors. Axle load surveys of commercial vehicles were carried out for 1-day 24 hour durations, to establish Vehicle Damage Factor for use in pavement design. Since, lighter vehicles have a very small equivalent standard axle load value and less damaging effect, these vehicle types were excluded in the present axle load survey.

5.4 Traffic Volume Count Data Analysis

This section describes the baseline traffic and travel characteristics in the Project Influence Area (PIA) based on the analysis of primary data. The findings from the analysis of classified traffic volume observed at various count locations is given in this section. Analysis has been carried out for:

- ADT (Average Daily Traffic)
- Traffic composition
- Hourly variation
- Directional Distribution
- Seasonal Variation
- AADT (Annual Average Daily Traffic)

In the absence of regular count data in the PIA, monthly fuel sales (both petrol and diesel) have been used as proxy for seasonal variation in traffic.

5.4.1 Passenger Car Equivalents

Different vehicle types having different size and characteristics were converted into equivalent passenger car units. The Passenger Car Unit values (PCU) suggested by the Indian Roads Congress in IRC: 64-1990 "Guidelines for Capacity of Roads in Rural Areas" have been adopted and the same are given in **Table 5.4**.

Table 5-4: Values of PCU Factors Adopted for the Study

Vehicle Type	PCU	Vehicle Type	PCU
Car/Jeep/Taxi	1.0	Auto Rickshaw	1.0
Mini Bus/ LCV	1.5	Agricultural Tractor	1.5
Standard Bus	3.0	Agricultural Tractor & Trailer	4.5
2/3 Axle Truck	3.0	Animal Drawn Vehicle	6.0
MAV	4.5	Cycle	0.5
Two Wheeler	0.5	Hand Cart	3.0

Source: IRC: 64-1990: Guidelines for capacity of Roads in Rural Areas

5.4.2 Average Daily Traffic and Traffic Composition

The hourly traffic data collected at respective count station for each day was totaled to obtain the daily traffic volumes. The seven-day traffic volumes were then averaged out to obtain the Average Daily Traffic (ADT) at respective survey stations**.** A summary of Average Daily Traffic (ADT) on project road sections is presented in **Table 5.5.** TVC locations on project road sections witness average daily traffic (ADT) in the range of 3,924 – 5,279 vehicles (5,247 – 6,449 PCUs).

Composition of cars is in the range of 30-40percent, mini buses and buses is in the range of 5-7percent. Among commercial vehicles, mini LCVs and LCVs is in the range of 4-7percent and all categories of trucks together constitute about 4-8percent in total traffic. Mode wise composition is presented in **Table 5.6**.

A summary of daily traffic at respective count locations on project road are presented in **Table 5.7** and **5.8.** The day/hour wise traffic data is provided in **Annexure 5.**

Table 5-5: Summary ADT (Y-2014)

Vehicle Category	Average Daily Traffic (ADT)	
	TVC Location	
	Km 10	Km 29
2 Wheeler	1910	1209
3 Wheeler	105	60
Car / Jeep /Van	2002	1534
Mini Bus	1	2
School Bus	18	13
Govt Bus	191	189
Private Bus	76	64
Mini LCV	197	213
LCV	74	67
2 Axle Truck	130	84
3 Axle Truck	158	153
MAV	25	100
MAV (more than 6 Axles)	0	0
Tractor	20	25
Tractor + Trailer	230	130
Pedal Cycle	70	38
Hand Cart	0	1
Animal Drawn	1	13
Toll Exempted - Car	22	16
Toll Exempted - Bus	7	3
Toll Exempted - LCV	5	0
Toll Exempted - Truck	33	9
Vehicles (Nos)	5279	3924
Vehicles (PCUs)	6449	5247

Project road is 41 Km in length. Normally, one toll plaza is proposed for a length of 50-60 km as per toll policy.

Project road is divided into two homogeneous sections

1. Sriganganagar to Lalgarh = approx. 19.0 Km
2. Lalhgarh to PakkaSaharana = approx.22.0 Km

It is observed that approximately about 500 nos of car traffic are getting diverted at Lalgarh. This is mainly attributed to local trips and multiple trips too. Major volume of second section traffic is mainly considered as through trips. Thus, second section has resulted in slightly lower car traffic.

Commercial vehicles traffic volume (about 120 vehicles) especially that of 3-AT and MAVs has increased in the second section between Lalgarh and PakkaSaharana compared to the first section. This may be due to additional traffic generated from Banawala and north of Lalgarh and Pilibanga and south of Pakka Saharana. Higher commercial traffic volume will be more advantageous from tolling point of view.

If one toll plaza is proposed in 1st section, the additional traffic generated and getting diverted in the second section and making use of 21.5Km (predominant) length of the project road will not get captured and this will result in a loss in the additional toll revenue generated.

In order to maximise the toll revenue, second toll plaza is proposed in the second location at Km 35 (which is 5 km before Pacca Saharana @ Km 41).

Considering traffic at Km 10 and Km 35, the toll revenue is maximized by capturing local traffic between Sriganganagar and Lalgarh and additional traffic generated in the second section in addition to the through traffic between Sri Ganganagar to Pacca Saharana.

Table 5-6: Composition of Traffic (%)

Location	2W	3W	Car/ van	Bus	M. Bus	Mini LCV	LCV	2-AT	3-AT	MAV	FV	NMV	Total
Km 10	37.9	7.1	33.7	4.9	0.0	3.2	1.3	3.7	2.6	0.4	4.1	1.1	100
Km 29	30.8	1.5	39.5	6.8	0.1	5.4	1.7	2.4	3.9	2.5	4.0	1.3	100

Hourly variation will be useful in deriving the capacity of the Road. Hourly traffic variations at traffic count locations are presented in **Table 5.7.**

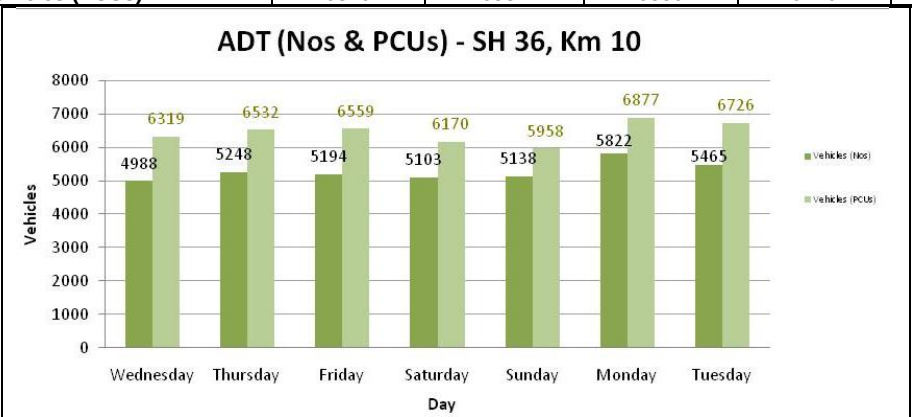
Table 5-7: Hourly traffic Variations at Km 10.0 and Km 29.0

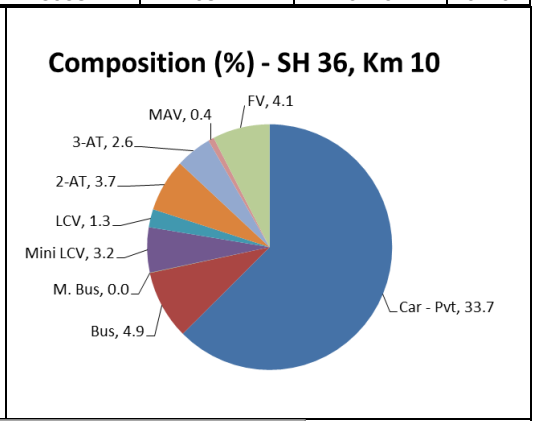
Time	Km 10.0			Km 29.0		
	Passenger Vehs (PV)	Goods Vehs (GV)	All Vehicles	Passenger Vehs (PV)	Goods Vehs (GV)	All Vehicles
8 - 9	274	44	338	114	28	156
9 - 10	388	31	446	181	29	223
10 - 11	369	32	424	249	33	293
11 - 12	410	35	466	282	31	328
12 - 13	389	39	450	261	33	305
13 - 14	376	44	438	234	37	285
14 - 15	397	46	462	234	34	283
15 - 16	445	43	513	266	36	319
16 - 17	465	43	540	282	35	335
17 - 18	429	37	498	280	40	339
18 - 19	346	35	404	223	34	277
19 - 20	248	42	303	139	33	184
20 - 21	128	30	165	78	29	113
21 - 22	89	30	121	54	26	84
22 - 23	44	23	69	26	18	46
23 - 24	17	15	33	13	17	31
0 - 1	14	12	27	9	17	26
1 - 2	11	12	25	5	9	15
2 - 3	9	13	24	5	13	19
3 - 4	13	13	29	4	10	15
4 - 5	15	11	28	11	16	28
5 - 6	43	14	59	32	21	55
6 - 7	73	17	97	39	18	61
7 - 8	146	27	188	69	30	105

The peak-hour traffic observed at Km 10.0 and Km 29.0 were 540 and 339 vehicles respectively. The peak-hour was observed between 16:00-17:00 and 17:00-18:00 at both the count stations. From the figure (**Table 5.8** and **5.9**) it can be seen that the night traffic of goods vehicles on the project road is less and the hourly variation is nearly uniform. No tidal flows were observed.

Table 5-8: Traffic Volume at Km 10, SH-36

Vehicle Category	Wednesday 19-11-2014	Thursday 20-11-2014	Friday 21-11-2014	Saturday 22-11-2014	Sunday 23-11-2014	Monday 24-11-2014	Tuesday 25-11-2014	ADT
2 Wheeler	1754	1844	1811	1894	1820	2257	1988	1910
3 Wheeler	103	111	101	100	85	116	115	105
Car / Jeep /Van	1862	1953	1972	1855	2279	2123	1973	2002
Mini Bus	0	1	2	2	2	1	2	1
School Bus	26	25	20	3	4	24	22	18
Govt Bus	196	186	191	193	186	186	198	191
Private Bus	76	74	72	73	73	79	84	76
Mini LCV	142	212	255	186	156	208	218	197
LCV	97	69	65	81	68	65	75	74
2 Axle Truck	148	141	141	122	95	127	133	130
3 Axle Truck	135	140	173	158	170	169	159	158
MAV	28	16	28	24	32	31	17	25
MAV (more than 6 Axles)	0	0	0	0	0	0	0	0
Tractor	24	19	15	26	18	28	13	20
Tractor + Trailer	223	274	269	213	148	225	255	230
Pedal Cycle	57	88	51	54	58	73	109	70
Hand Cart	0	0	0	0	0	0	0	0
Animal Drawn	0	0	0	0	0	0	4	1
Toll Exempted - Car	22	26	20	35	14	19	16	22
Toll Exempted - Bus	12	5	3	7	8	6	8	7
Toll Exempted - LCV	2	2	0	9	1	8	11	5
Toll Exempted - Truck	42	33	30	29	17	39	38	33
Vehicles (Nos)	**4988**	**5248**	**5194**	**5103**	**5138**	**5822**	**5465**	**5279**
Vehicles (PCUs)	**6319**	**6532**	**6559**	**6170**	**5958**	**6877**	**6726**	**6449**





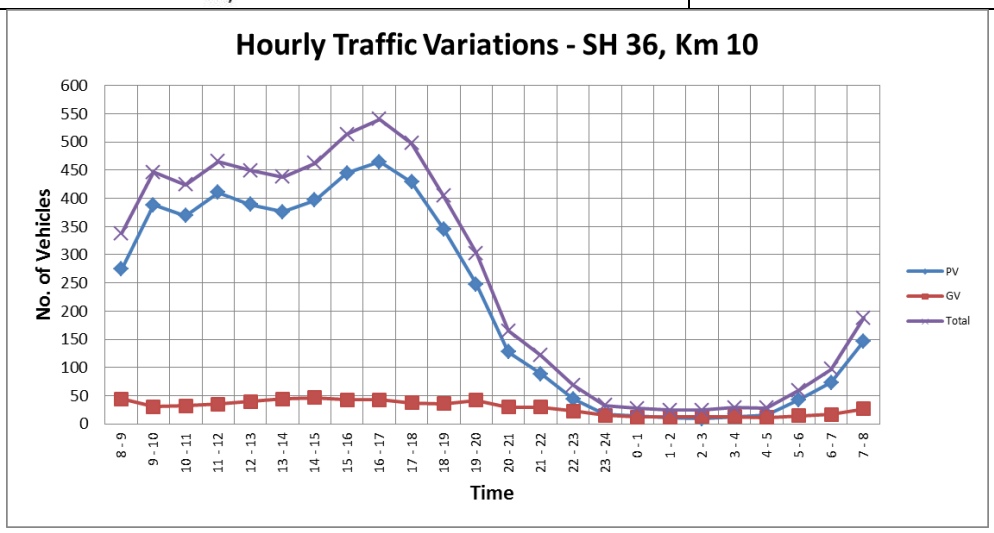
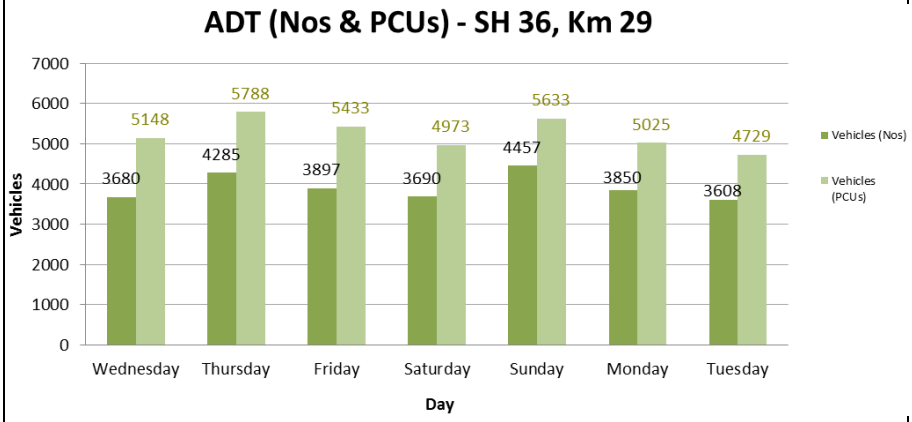
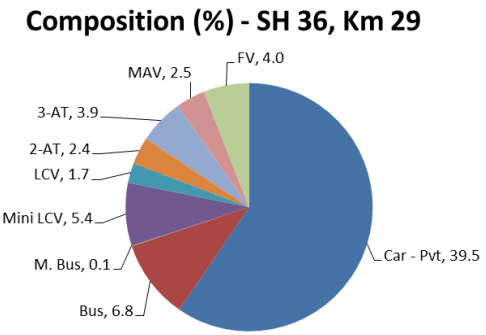
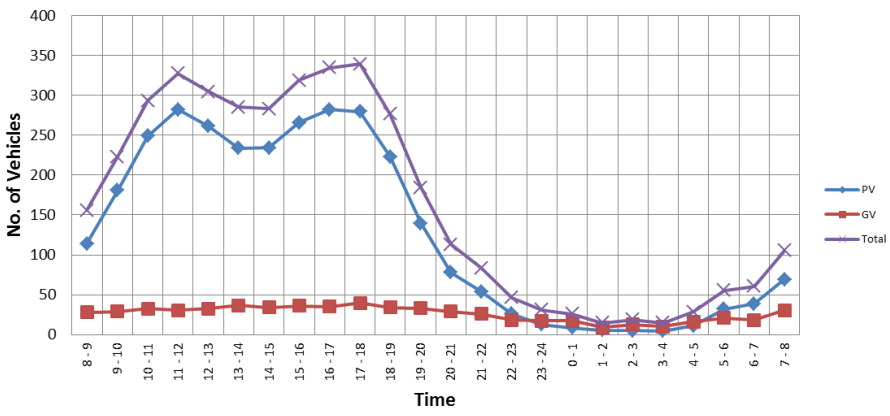


Table 5-9: Traffic Volume at Km 29, SH-36

Vehicle Category	Wednesday 19-11-2014	Thursday 20-11-2014	Friday 21-11-2014	Saturday 22-11-2014	Sunday 23-11-2014	Monday 24-11-2014	Tuesday 25-11-2014	ADT
2 Wheeler	1053	1423	1163	1170	1315	1253	1089	**1209**
3 Wheeler	59	111	48	51	51	41	62	**60**
Car / Jeep /Van	1446	1505	1459	1399	2048	1460	1423	**1534**
Mini Bus	0	0	1	1	1	9	3	**2**
School Bus	13	19	19	11	2	9	16	**13**
Govt Bus	192	189	189	190	181	194	189	**189**
Private Bus	62	64	70	64	64	62	63	**64**
Mini LCV	198	249	225	202	195	200	225	**213**
LCV	86	75	75	66	52	66	47	**67**
2 Axle Truck	55	95	105	80	80	95	80	**84**
3 Axle Truck	142	175	182	119	168	162	123	**153**
MAV	109	92	98	117	115	83	84	**100**
MAV (more than 6 Axles)	0	0	0	0	0	0	0	**0**
Tractor	38	28	22	36	24	11	19	**25**
Tractor + Trailer	146	170	151	116	105	116	105	**130**
Pedal Cycle	25	35	39	29	31	60	46	**38**
Hand Cart	0	3	1	0	0	0	4	**1**
Animal Drawn	18	27	10	11	8	8	8	**13**
Toll Exempted - Car	21	6	23	12	12	15	21	**16**
Toll Exempted - Bus	1	4	6	5	1	1	0	**3**
Toll Exempted - LCV	0	0	0	0	0	3	0	**0**
Toll Exempted - Truck	16	15	11	11	4	2	1	**9**
Vehicles (Nos)	**3680**	**4285**	**3897**	**3690**	**4457**	**3850**	**3608**	**3924**
Vehicles (PCUs)	**5148**	**5788**	**5433**	**4973**	**5633**	**5025**	**4729**	**5247**







5.4.3 Seasonal Correction and Annual Average Daily Traffic (AADT)

To convert ADT to AADT the traffic in the month(s) of the year in which survey is conducted is compared with the annual traffic to obtain the factor. This factor, termed as seasonality correction factor, is applied to the ADT to obtain the Annual Average Daily Traffic (AADT).

Estimation of seasonality correction factor is based on the sale of monthly Petrol and Diesel along the project corridor (**Table 5.10**). Because of non-availability of regular counts, for the project influence area fuel (petrol and diesel) sales data was collected by the consultants in the present study for the year 2013-14. All the petrol driven vehicles were converted into AADT by applying seasonal correction factor determined from the motor spirit (MS) data (0.99 for Nov), whereas for all diesel driven vehicles, seasonality factor was calculated from High Speed Diesel (HSD) sales data (1.14 for Nov). Variations in monthly fuel sales with respect to average sales are presented in **Figure 5.2.**

Table 5-10: Fuel Sales Data and Seasonal Factors

Month	Total Monthly Sales (Litres)		Average Daily Sales (Litres)			Seasonal Correction Factors (Multiplication Factor)		
	Diesel	MS	Diesel	MS	Combined	Diesel	MS	Combined
April	318000	80000	10600	2667	13267	1.00	1.18	1.04
May	365000	98000	11774	3161	14935	0.90	0.99	0.92
June	342000	76000	11400	2533	13933	0.93	1.24	0.99
July	378000	92000	12194	2968	15161	0.87	1.06	0.91
August	410000	102000	13226	3290	16516	0.80	0.95	0.83
September	345000	108000	11500	3600	15100	0.92	0.87	0.91
October	326000	112000	10516	3613	14129	1.01	0.87	0.97
November	280000	95000	9333	3167	12500	1.14	0.99	1.10
December	245000	88000	7903	2839	10742	1.34	1.11	1.28
January	260000	97000	8387	3129	11516	1.27	1.00	1.19
February	295000	94000	10536	3357	13893	1.01	0.93	0.99
March	310000	103000	10000	3323	13323	1.06	0.94	1.03

Figure 5-2: Average Sales Variations (ASV) in Fuel Sales Data

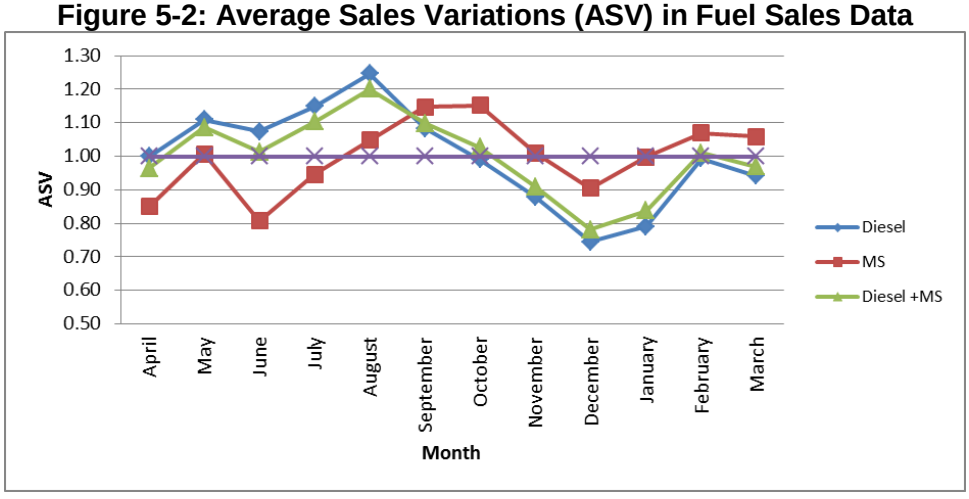


Figure 5-3: Location wise (AADT) Comparison

A summary of Annual Average Daily Traffic (AADT) on project road sections is presented in **Table 5.11** and depicted in **Figure 5-3.** Project road sections witness annual average daily traffic (AADT) in the range of 4,197 – 5,593 vehicles (5,719 – 6,965 PCUs).

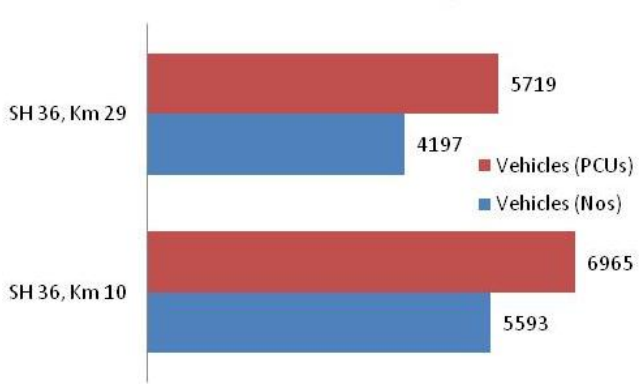


Table 5-11: Summary AADT (Y-2014)

Vehicle Category	Annual Average Daily Traffic (AADT)		
	TVC Location		Average
	Km 10.0	Km 29.0	
2 Wheeler	1892	1198	1545
3 Wheeler	115	66	91
Car / Jeep /Van	2203	1688	1945
Mini Bus	2	2	2
School Bus	20	14	17
Govt Bus	217	215	216
Private Bus	86	73	80
Mini LCV	224	243	233
LCV	84	76	80
2 Axle Truck	147	96	122
3 Axle Truck	179	174	177
MAV	29	113	71
MAV (more than 6 Axles)	0	0	0
Tractor	20	25	23
Tractor + Trailer	230	130	180
Pedal Cycle	70	38	54
Hand Cart	0	1	1
Animal Drawn	1	13	7
Toll Exempted - Car	24	17	21
Toll Exempted - Bus	8	3	5
Toll Exempted - LCV	5	0	3
Toll Exempted - Truck	37	10	23
Vehicles (Nos) – Y 2014	**5593**	**4197**	**4895**
Vehicles (PCUs) – Y 2014	**6965**	**5719**	**6342**
AADT during year 2015 at 5% growth			
Vehicles (Nos) – Y 2015	**5873**	**4407**	**5140**
Vehicles (PCUs) – Y 2015	**7313**	**6005**	**6659**

5.5 Traffic Forecasting

Adopting the transport demand elasticity method, which is a proven technique worldwide and is the preferred technique in India, we have carried out the traffic forecast for the project road. As the past traffic data on time series basis could not be collected, we have made efforts to build time series past data on vehicle population available for Rajasthan State from the available sources, as a proxy variable to the project road traffic. This past traffic data has been obtained from the available state government sources. Similar time series past data on economic and demographic variables for Rajasthan State such as population, state income (NSDP) at constant prices and per capita income at constant prices has been developed.

5.5.1 Vehicle Population Growth

Time series data collected from the secondary sources and used for the analysis including the periodical growth rates achieved for Rajasthan State is presented in ***Table 5.12***.

Table 5-12: Summary of AACGR of Vehicles (%) in Rajasthan State

Year	Two Wheeler	cars	Mini Bus	Buses	Trucks
2,005	30,16,763	2,34,297	10,583	58,092	1,91,207
2,006	33,93,916	2,69,861	11,797	60,979	2,06,381
2,007	38,33,746	3,10,101	12,683	63,320	2,32,007
2,008	42,61,695	3,55,122	13,311	65,605	2,52,109
2,009	47,15,835	4,02,239	13,945	69,298	2,66,048
2,010	52,30,454	4,55,924	17,054	73,257	2,89,925
2,011	58,59,719	5,20,385	20,361	77,980	3,23,273
2,012	66,29,743	5,91,069	23,889	83,345	3,62,028
2,013	74,65,863	6,59,542	27,432	88,616	4,01,983
2,014	83,31,142	7,33,916	31,031	93,892	4,34,379
AACGR (%) (2005-2014)	**11.95**	**13.53**	**12.70**	**5.48**	**9.55**

Source:

1. Statistical Abstract 2014, Transport Department, Govt. of Rajasthan

2.Compiled from different publications from the Directorate of Economics & Statistics, Govt. of Rajasthan

5.5.2 Economic Indicators

The past performance of the economic indicators for the project influence area (PIA) are also collected for the same period (2005-2014), with the objective of establishing elasticity of traffic demand to the different economic indicators. The economic indicators considered for the analysis include:

- Net State Domestic Product (NSDP)
- Population
- Per Capita Income (PCI)

Collected data used for the analysis with respect to Rajasthan State is given in ***Table 5.13***.

Table 5-13: Summary of Economic and Demographic Indicators in Rajasthan State

Year	NSDP at Constant Price (Rs. In Cr.)	PCI (Rs.)	Population (in lakhs)
2,005	1,12,636	18,565	607
2,006	1,20,202	19,445	618
2,007	1,34,350	21,342	630
2,008	1,40,472	21,922	641
2,009	1,52,284	23,356	652
2,010	1,61,159	24,304	663
2,011	1,85,366	27,502	674
2,012	1,94,651	28,429	685
2,013	2,03,296	29,244	695
2,014	2,12,523	30,120	706
AACGR (%) (2005-2014)	**7.31**	**5.52**	**1.69**

Source:

1. Department of Economics & Statistics, Govt. of Rajasthan

2. Statistical Hand Book 2013-14, Reserve Bank of India

5.5.3 Elasticity

In line with this philosophy, first, the elasticity of traffic demand for car, bus, 2-W and truck are estimated with respect to past traffic growth. Considering the time series data on category wise registered vehicles and the economic variables (NSDP), by regression analysis elasticity values is estimated as shown in ***Table 5-14***.

Table 5-14: Results of the Regression Analysis - Vehicle Registration Data

Sl. No.	Vehicle Type	Economic / Demographic Variable	R2	Elasticity
1	Car	NSDP	0.99	0.58
2	Two Wheeler	NSDP	0.99	0.66
3	Mini Bus	NSDP	0.95	0.58
4	Bus	NSDP	0.97	1.35
5	Truck	NSDP	0.98	0.80

Passenger traffic demand is a function of growth of population and per capita income. State income growth or its sectoral income, mostly govern freight traffic growth. However, considering the level of moderations required for the elasticity values based on population growth and PCI growth as well the available recommendation on elasticity values for different vehicle categories for future traffic projections (refer ***Table 5-15***), NSDP based elasticity values that are derived are considered for passenger and goods traffic respectively for the present analysis (***Table 5-16***).

Table 5-15: Projected Transport Demand Elasticity (with respect to NSDP)

Year	Two Wheeler	Auto Rickshaw	Car [1]	Bus	Truck/ Lorries [1]	MAV/ Trailer [1]	Tractor
2014-2015	1.8	1.2	1.5	1.2	1.2	1.2	0.5
2016-2020	1.7	1.1	1.4	1.1	1.1	1.1	0.4
2021-2025	1.6	1.1	1.3	0.9	1	1	0.4
2026-2030	1.5	1	1.3	0.9	1	1	0.4

Note: 1. Adopted from IRC (Road Development Plan: Vision 2021)

2. Others are estimated from Cars and trucks

Table 5-16: Elasticity Value for Project Road Traffic

Vehicle Type	NSDP
Car	0.58
Two Wheeler	0.66
Mini Bus	0.58
Bus	1.35
Truck	0.80

In the next stage, considering the various factors such as likely future orientation of the economy, modal shift, user preference, development in vehicle technology, market driven forces, available guidelines on future elasticity's and finally the past performance, the elasticity values are penetrated and projected during the analysis period. The resultant projected elasticity values are presented in ***Table 5-17.***

Table 5-17: Recommended Elasticity

Vehicle Type	Elasticity for 2005-2014 (Present Study)	Economic variable considered	Recommended Elasticity		
			2014-2019	2020-2025	2026 and beyond
Car	0.6	NSDP	1.5	1.4	1.3
Two Wheeler	0.7	NSDP	1.2	1.0	0.9
Mini Bus	0.6	NSDP	0.9	0.8	0.6
Bus	1.3	NSDP	1.2	1.1	0.9
Truck	0.8	NSDP	1.2	1.1	1.0

Note: Considering the recent growth pattern in different vehicle categories and the potential of the state economy to absorb the growth along with the recommended elasticity values by IRC, the elasticity for future were estimated.

[1] **IRC - Road Development Plan Vision Extract Table**

TABLE 6.5. SUGGESTED ELASTICITY VALUES

Vehicle type	Period			
	2001-2006	2006-2011	2011-2016	2016-2021
Car	1.7	1.6	1.5	1.4
Bus	1.4	1.3	1.2	1.1
Truck	1.5	1.4	1.2	1.1

These figures would also give for the year 2021 a fleet strength of 5-7 times the fleet strength of 2001. This would imply the need for provision of additional capacity by way of widening existing roads and expressways.

5.5.4 Future economy prospects

Ongoing economic liberalization measures, introduced in the nineties, make the national economy with the strong competitive base, leading to open economy system. But unfortunately, this system makes Indian economy to depend more on the global fluctuations. With the strengths and weakness of the present system, equipped with adequate safeguards, Indian economy had performed fairly well during the liberalization period, as well as before, though the targets mostly never achieved.

Recent economic performance of the nation, in terms of net domestic product, was found to be in the range of 7 to 9 percent growth. The Ninth Five Year Plan Documents (1997-2002) set 7% target for economic growth for the Nation which was further increased to during the subsequent Five Year Plans.

Future traffic growth rates were projected based on the i) transport demand elasticity values discussed above and ii) the periodical projected economic growth pattern (NSDP/PCI/Population) specific to the region.

However, the recent global economic crisis had its impact on the Indian economy also and this had drastically changed the economic growth projections downwards. At national level, the achieved growth rate of 9% (2007-08) was projected to reduce to 6.2% (2011-12).

The results of professional forecasters' survey conducted by the Reserve Bank in December 2014[2] suggested further moderation in economic activity for 2014 on the whole and the national GDP is estimated to reduce to 5.5% during 2014.

During the recent revival of economic recession the estimates and achievements of GDP at national level had improved considerably to around 6%. The Indian economy is expected to grow at 5.5 per cent in the current fiscal (2013-14) and 6 per cent in the next fiscal (2014-15) as per the revised survey of professional forecasters released by the Reserve Bank of India (RBI)[3]. The survey has revised India's real GDP growth to 5.5 percent from the 5.8 per cent projected in the last survey (2013-14), on the basis of increased private final consumption expenditure growth, stronger industrial activity in the first quarter and further contribution of services in the subsequent quarters, RBI said. For the next five years (2013-14 to 2017-18) and the next ten years (2013-14 to 2022-23), are expected to be 6.5 per cent and 7.25 per cent, respectively[4]. This national projections bound affect all the states, including all PIA states.

Independent evaluations by different agencies put the nation's economic growth during the partly completed Eleventh Plan period, in the range of 7 - 9 percent. It may vary to 6 – 7 percent during the Twelfth Plan Period as indicated by RBI Forecast. The individual state's economy performances and their targets may slightly vary to the national level. In the absence

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[2] *Reserve Bank of India, Macroeconomic and Monetary Developments: Third Quarter Review 2008-09*

[3] *http://www.domain-b.com/finance/banks/RBI/20100805_survey.html*

[4] *Average real GDP growth for the next five years (2013-14 to 2017-18) and the next ten years (2013-14 to 2022-23), are expected to be 6.5 per cent and 7.25 per cent, respectively. Over the next five years, inflation based on CPI-Combined and WPI is expected to be 7.25 per cent and 5.5 per cent, respectively. Over the next ten years, inflation based on CPI-Combined and WPI is expected to be around 7.0 per cent and 5.5 per cent, respectively.* ***(Annex Table A.8)****. - Results of the Survey of Professional Forecasters on Macroeconomic Indicators – 27th Round (Q4:2013-14), Reserve Bank of India*

of adequate data for the future economy proposals and achievements during this period, the national economy trend is considered for the present study.

Considering the following factors such as past performance of the economy against their set targets, recent developments in economic liberalization measures, shift in between sectors, opportunities available in local and global markets etc., future economic growth scenario is formulated for the following time periods.

- 2014 – 2016
- 2016 – 2021
- 2021 and beyond

We feel, any projection beyond 10-15 years will have little relevance, and no further projection is attempted. Hence, the entire period beyond 2021 has been kept as one slab.

Based on the likely future orientation of the economy growth prospects, its population changes and the resultant per capita income growth trend in the project influence area, as discussed above, the following three growth scenarios [5] are worked out and presented in ***Table 5.18*** below.

- Normal scenario – realistic scenario.
- Optimistic scenario – 1% addition to normal scenario
- Pessimistic scenario – 1% less to normal scenario

Table 5-18: Projected growth rates of Economic variables

Details	NSDP			Population			PCI		
	2014-2019	2020-2025	2026 and beyond	2014-2019	2020-2025	2026 and beyond	2014-2019	2020-2025	2026 and beyond
Rajasthan									
Optimistic	7.21	7.71	7.21	1.37	1.23	1.11	5.84	6.48	6.10
Pessimistic	5.21	5.71	5.21	1.51	1.36	1.22	3.71	4.36	3.99
Normal	6.21	6.52	6.20	1.52	1.37	1.23	4.69	5.15	4.96

Note: 1. For NSDP, the estimated National GDP growth projection and the existing growth ratio of individual state(s) to the national GDP were used for estimation.

5.5.5 Traffic growth rates

Based on the moderated elasticity values and the projected economic/demographic indicators and with the given model as follows, the future average annual compound traffic growth rates by vehicle type are estimated.

A. Passenger Vehicles

[5] For sensitivity purpose, the projected economic variables are penetrated as follows for pessimistic and optimistic scenarios, with the assumption that their growth rates will vary between these ranges only. Here the assumption is under optimistic scenario, NSDP will grow than normal scenario and population growth will less than normal scenario. In the pessimistic scenario it will be vice versa.
NSDP : Pessimistic Scenario = Normal growth – 1%; Optimistic Scenario = Normal growth + 1%
Population : Pessimistic Scenario = Normal growth + 1%; Optimistic Scenario = Normal growth - 1%
PCI: NSDP Growth – Population growth
Using the estimated economic parameters estimated under three scenarios (normal, pessimistic and optimistic scenarios) and the elasticity values, traffic growth under three different scenarios are estimated.

Tgr = [(1+rp) (1+ rpci x Em) – 1]

Where,

rp= Population Growth

rpci= Per capita Income Growth

Em= Elasticity

B. Goods Vehicles

Growth Rate for Goods Vehicles = Elasticity Value * NSDP Growth Rate
The resultant traffic growth scenarios are presented in ***Table 5.19***.

Table 5-19: Projected Traffic Growth Rates (%)

Details	Car			Bus			Two wheelers			Truck			Mini Bus		
	2014-2019	2020-2025	2026 and beyond	2014-2019	2020-2025	2026 and beyond	2014-2019	2020-2025	2026 and beyond	2014-2019	2020-2025	2026 and beyond	2014-2019	2020-2025	2026 and beyond
Project Road (Weighted)															
Optimistic	10.3	10.4	9.1	8.5	8.4	6.7	8.6	8.1	6.6	8.7	8.5	7.2	6.6	6.2	5.1
Pessimistic	7.1	7.5	6.5	6.0	6.2	4.9	6.1	6.0	4.8	6.3	6.3	5.2	4.9	4.7	3.8
Normal	8.7	8.7	7.8	7.2	7.1	5.8	7.4	6.8	5.7	7.5	7.2	6.2	5.8	5.3	4.5

Source: Consultant estimates

5.5.6 Suggested Growth Rates

The traffic growth rates, as estimated and presented in ***Table 5.19*** is recommended for further planning purpose, as it represent the most likely scenario of future traffic growth for the project road.

Growth rates estimated for the base category vehicles were further moderated for other category vehicles like MAV, LCV etc to represent the recent changes in the vehicle technology related market demand impact. Results of the further moderated vehicle growth rates are presented in ***Table 5.20 to 5.22*** below.

Table 5-20: Traffic Growth Rates (Pessimistic Approach)

Sl. No	Vehicle Type	Projected Anuual Traffic Growth Rate (%) - Pessimistic Approach		
		2014-2019	2020-2025	2026 and beyond
1	Car	7.1	7.5	6.5
2	LCV	6.9	6.9	5.7
3	2-Axle Truck	4.7	4.7	3.9
4	3-Axle Truck	6.3	6.3	5.2
5	Multi-Axle Truck	6.9	6.9	5.7
6	Bus	6.0	6.2	4.9
7	Mini Bus	4.9	4.7	3.8

Table 5-21: Traffic Growth Rates (Normal Approach)

Sl. No	Vehicle Type	Projected Anuual Traffic Growth Rate (%) - Normal Approach		
		2014-2019	2020-2025	2026 and beyond
1	Car	8.7	8.7	7.8
2	LCV	8.2	7.9	6.8
3	2-Axle Truck	5.6	5.4	4.6
4	3-Axle Truck	7.5	7.2	6.2
5	Multi-Axle Truck	8.2	7.9	6.8
6	Bus	7.2	7.1	5.8
7	Mini Bus	5.8	5.3	4.5

Table 5-22: Traffic Growth Rates (Optimistic Approach)

Sl. No	Vehicle Type	Projected Anuual Traffic Growth Rate (%) - Optimistic Approach		
		2014-2019	2020-2025	2026 and beyond
1	Car	10.3	10.4	9.1
2	LCV	9.5	9.3	7.9
3	2-Axle Truck	6.5	6.4	5.4
4	3-Axle Truck	8.7	8.5	7.2
5	Multi-Axle Truck	9.5	9.3	7.9
6	Bus	8.5	8.4	6.7
7	Mini Bus	6.6	6.2	5.1

By considering the pessimistic and normal approach and further moderating the derived values especially for LCV, bus and truck categories suggested growth rates for the pavement design is presented in ***Table 5.23*** below.

Table 5-23: Suggested Traffic Growth Rates for Pavement Design

Growth Period	LCV	2-AT	3-AT	MAV	Bus
2014-2019	6.5%	5.0%	7.5%	7.5%	6.0%
2020-2025	6.5%	5.0%	7.5%	7.5%	6.0%
2026 and beyond	6.5%	5.0%	7.5%	7.5%	6.0%

5.5.7 Traffic Projection and Capacity

The AADT so obtained at all the traffic survey locations are projected at a uniform growth rate of 5% for all categories of vehicles as mentioned in the TOR. The year in which the project road reaches its design service volume at LOS-B (Level of Service-B) is worked out for 2-lane with paved shoulder configuration. The results are tabulated **Table 5.24.**

Table 5-24: Year of Achieving DSV (PCUs/day)

Loc No.	Location	Traffic (PCUs/Day) Y-2014	2-Lane + PS
			LOS-B
			DSV-18000
1	Km-10	6965	2033
2	Km-29	5719	2037
	Average	6342	2035

The year-wise projection of traffic at 5% growth rate and year of reaching DSV (PCUs/day) of the intermediate, 2-lane and 2-lane with paved shoulder at LOS-B is presented and highlighted in **Table 5.25.**

Table 5-25: Projection of AADT (PCUs/day) at 5% Growth Rate

Year		Km 10	Km 29	Average	Remarks
Base Year	**2014**	**6965**	**5719**	**6342**	
1	2015	7313	6005	6659	
2	2016	7679	6305	6992	
3	2017	8063	6620	7341	Likely Commencement
4	2018	8466	6951	7709	2nd Year
5	2019	8889	7299	8094	3rd Year
6	2020	9334	7664	8499	4th Year
7	2021	9800	8047	8924	5 th Year
8	2022	10290	8449	9370	6 th Year
9	2023	10805	8872	9838	7 th Year
10	2024	11345	9315	10330	8 th Year
11	2025	11912	9781	10847	9 th Year
12	2026	12508	10270	11389	10 th Year
13	2027	13133	10784	11958	11 th Year
14	2028	13790	11323	12556	12 th Year
15	2029	14480	11889	13184	13 th Year
16	2030	15204	12483	13843	14 th Year
17	2031	15964	13108	14536	15 th Year
18	2032	16762	13763	15262	16 th Year
19	2033	17600	14451	16026	17 th Year
20	2034	18480	15174	16827	18 th Year
21	2035	19404	15932	17668	19 th Year
22	2036	20374	16729	18552	20 th Year
23	2037	21393	17565	19479	21 st Year
24	2038	22463	18444	20453	22nd Year
25	2039	23586	19366	21476	23 rd Year
26	2040	24765	20334	22550	24 th Year
27	2041	26003	21351	23677	25 th Year
28	2042	27303	22418	24861	26 th Year
29	2043	28669	23539	26104	27 th Year
30	2044	30102	24716	27409	28 th Year

5.5.8 Tollable Traffic

The tollable traffic (PCUs/day) details during the year 2014 and 2015 at respective count stations are presented in **Table 5.26.**

Table 5-26: Tollable Traffic Volume

Year	Count Station	Car / Jeep /Van	Buses	LCV	2AT	3AT	MAV	Ag. Tractor Trolley
2014	Km 10	2426	323	86	147	179	29	230
	Km 29	1931	302	78	96	174	113	130
	Average	**2178**	**313**	**82**	**122**	**177**	**71**	**180**
2015	Km 10	2548	340	90	155	188	30	241
	Km 29	2027	318	82	101	183	119	136
	Average	**2287**	**329**	**86**	**128**	**186**	**75**	**189**

The details of tollable, non-tollable, motorized and non-motorized traffic are presented in following **Table 5.27**.

Table 5-27: Tollable and Non-Tollable Traffic Details

Year	Count Station	Total		Total Tollable		Total Non-tollable		Motorized Vehicles		Non-Motorized Vehicles	
		Vehs	PCUs	Vehs	PCUs	Vehs	PCUs	Vehs	PCUs	Vehs	PCUs
2014	Km 10	5593	6965	3421	5668	2172	1297	6439	6926	71	921
	Km 29	4197	5719	2825	4860	1372	859	4145	5619	52	100
	Average	**4895**	**6342**	**3123**	**5264**	**1772**	**1078**	**5292**	**6273**	**61**	**510**
2015	Km 10	5873	7313	3592	5951	2281	1362	6761	7273	74	967
	Km 29	4407	6005	2966	5103	1441	902	4352	5900	54	104
	Average	**5140**	**6659**	**3279**	**5527**	**1861**	**1132**	**5557**	**6587**	**64**	**536**

6 Engineering Surveys and Investigations

6.1 Axle Load Surveys

Traffic loading on highway pavements is a heterogeneous combination of different types of vehicles, carrying a wide spectrum of wheel loads. It is very much essential to convert this heterogeneous traffic to an equivalent homogenous traffic in terms of a chosen standard vehicle. One means of achieving this objective is the use of Equivalent Standard Axle Load (ESAL) factors. Axle load surveys of commercial vehicles were carried out to establish Vehicle Damage Factor for use in pavement design. Since, lighter vehicles have a very small equivalent standard axle load value and less damaging effect, these vehicle types were excluded in the present axle load survey.

6.1.1 Locations of Survey Station

To estimate the Equivalent Standard Axle Load of traffic, axle load surveys were carried out at one location at Km 29.0 near Morajare Khera as indicated in **Table 1.2**.

6.1.2 Measurements of Axle Loads in the Field

At the selected survey location, arrangements were made for the installation of the portable weighing pads by placing it at the edge of the uniform and level pavement surface available. The portable and pre-calibrated wheel-weighing pads were used for the measurement of wheel loads. The size of the weighing unit permitted only one single or dual tyre assembly to be weighed at a time. Each vehicle to be weighed was aligned so that both the front axle and rear axle's wheels on one (outer) side of the vehicle were in line with the weighing unit. The vehicle was then driven slowly on to the unit and stationed with the wheel being weighed at the center of the top plate of the weighing pad. The vehicle was stopped long enough for the reading on the display unit to stabilize. The same procedure was repeated with the next axle.

Assuming the load on each axle is evenly distributed the axle load is taken to be twice the wheel load. Axle loads were weighed for all the fast commercial modes (LCV, 2-Axle Trucks, 3 Axle Trucks, Multi-Axle Vehicles and Buses) on a sample basis for 24 hours. While the vehicles were being weighed, information about the axle-type was also recorded.

6.1.3 Computation of Vehicle Damage Factor (VDF) using Field Data

The Vehicle Damage Factor (VDF) is a multiplier to convert the number of commercial vehicles of different axle loads and axle configuration into the number of repetitions of standard axle load of magnitude 80 kN (8.2 Tonnes). It is defined as equivalent number of standard axles per commercial vehicle. The VDF varies with the vehicle axle configuration and axle loading.

The spectrum of axle load in terms of axle weights of single, tandem, tridem and multi-axle have been determined and compiled under various classes with class intervals of 10 kN, such as 10 kN, 20 kN and 30 kN for single, tandem and tridem axles respectively.

The equations for computing equivalency factors for single, tandem and tridem axles given below have been used for converting different axle load repetitions into equivalent standard axle load repetitions.

- Single axle with single wheel on either side, ESA = (axle load in kN/65)^4
- Single axle with dual wheels on either side, ESA = (axle load in kN/80)^4
- Tandem axle with dual wheels on either side, ESA = (axle load in kN/148)^4
- Tridem axles with dual wheels on either side, ESA = (axle load in kN/224)^4

Summation of all ESA gives the total damaging effect for that location. By knowing the number of vehicles weighed and number of axles weighed and total damaging effect, VDF and Axle Equivalency were computed.

VDF = Total ESA / No. of vehicles weighed

Axle Equivalency = Total ESA / No. of axles weighed

For the purpose of structural design of pavement, only the number of commercial vehicles with laden weight of 30 kN or more and their axle loading pattern has been considered.

The vehicle damage factor is a multiplier for converting the number of commercial vehicles of different axle loads to the number of standard axle load repetitions. Design of new pavement for additional lane or strengthening of existing pavement is based upon the cumulative number of 80 kN (8.16 tonne) equivalent standard axles (ESA) that will pass over during the design period. The classes of traffic which lead to significant axle loads (or damage) to the pavement and accordingly considered for design are: LCVs, Buses, two / three axle and multi axle trucks. Vehicle damage factors (VDF) are calculated in accordance with the guidelines provided in IRC: 37 – 2012. Based on the Spectrum of Axle loads and analysis of axle load data, the resulting VDFs are as given in **Table 6-1**.

Table 6-1: Vehicle Damage Factors

Location	Direction	LCV	Buses	2-AT	3-AT	MAV
Sri Ganganagar to Hanumangarh Km 29, Morjare Khera	Lalgarh Jattan To Pacca Sharana	0.01	0.68	0.22	4.11	0.42
	Pacca Sharana To Lalgarh Jattan	0.01	0.62	2.56	6.12	16.47
	Both Directions	0.01	0.64	1.66	4.91	10.63
Adopted value for the project road		**1.00**	**1.00**	**2.50**	**5.00**	**10.50**

6.2 TOPOGRAPHICAL SURVEY

6.2.1 DGPS Pillar Construction

At every 5 kilometres a pair is marked as GPS pillars using Dual Frequency. The exposed surface of these markings has been painted in yellow. Submission of co-ordinates shall be converted to scale factor (universal transit method (UTM) Co-ordinates).

6.2.2 Total station Traverse

In every stretch, closed traversing in loop has been completed prior to detailed survey. A closed loop traverse was run from point to point. Maximum length of each loop was not more than 5 km. While traversing, stations (Reference Pillars / TBM) were established 200 to 250m apart; these points were further used for detailed survey. The traversing survey measurement is of two rounds of angle measurements, to be taken on left and right face in both clockwise and anticlockwise directions. The angle spread between the observed round was not to be more than 1 second. The minimum accuracy of this survey was 1:10000.

All computations have been complied with Traverse adjustment by Bowditch method.

6.2.3 Leveling

A closed circuit levelling (double territory) was run along the entire route. Maximum length of each loop was not more than 4 km. The levelling survey has been done with respect to the GTS benchmark. During the course of levelling all the temporary benchmarks (TBMs / Reference

Pillars) as established above at intervals of 200 to 250 m will be connected with GTS benchmark. Apart from these, reference benchmarks are also left on permanent structure like buildings, bridges & culverts etc., available on route.

The accuracy of levelling is of the order of +/- 6√k mm where k is the loop length in km. Precision auto level / digital level will be used for the leveling purpose.

6.2.4 Detailed surveys

The detailed survey involves picking up of all existing features of the project road width of 60m or as instructed by engineer-in-charge, on either side of the existing center line. In urban / built-up areas the corridor width surveyed was between building lines. The survey covers all major important features, if any, within the ROW.

At sharp curves (R<1200 m) the survey was extended up to 100m on either side. At important road junctions and railway crossings, small streams and nallahs survey was extended up to a maximum distance as per IRC specifications. For the purpose of Blow up Surveys of water bodies and junctions, total station instrument was used. Collection of Digital Terrain Model [DTM] data begins from two known station points and closed station but not the backside station point. In Topographical survey, the following points were essentially covered:

- Electrical Poles, Telephone Poles, Lamp Poles and any other Private/Unauthorized utility Poles with their routing network.
- All Utility lines, both overhead and underground within the ROW as instructed by the Survey Engineer
- Trees with girth more than or equal to 0.3m - while surveying the trees, care has been taken to exactly classify the trees according to its girth.
- Building lines indicating the type of buildings (shops or houses), Right of Way boundary if available at site by presence of boundary stones.
- Road center points, edge points and shoulder points have been taken to define the existing layout of the roadway.
- Approach road details for 50 m length on either side of the road. But, important junctions have been surveyed up to a minimum length of 100m.
- Location of bus bays / bus stops, truck - parking areas, taper length, and roadway widths.
- Special emphasis has been laid in identifying graveyards and all religious places - temples, mosque, church; their locations, boundary lines and clear dimensions of compound walls and entrances.
- Locations of roadside drain clearly identifying the type (Built-up / Granular, Rectangular / Trapezoidal etc., whether Open / Closed) and width of drain (waterway width and wall width in case of built-up drain) including the beginning and end of drain. While surveying the existing drains, care had been taken to take the top and bottom points of the drain to get the true contour and shape of the drain. All water features such as ponds, tanks, lakes, streams, canals and wells etc have been mapped.
- Roadside cultivation viz., agricultural and residential, commercial, shops and business established areas etc. have been marked.
- Identification of all bridges and culverts along the project road - including location (Chainage) reference number, width of bridge / culvert (width of slab or diameter of pipe, no of pipes/spans), course of water path, skew of bridge / culvert, span arrangement and Bridge/culvert cross - section.

- Any other Structures / Utilities found at site have been recorded.

6.2.4.1 Longitudinal – sections

Plotting of longitudinal centreline points was 25 m apart in straight section. On the vertical and horizontal curves it was 10 m to 20 m apart depending on the nature of curve i.e. degree of sharpness of curve. Apart from this, in case of vertical curves and causeway the points were captured in such a fashion by which the crest and bottom most points of the curve and the extent of causeways should not be missed. Centreline profile was continued for at least 200m beyond the limits of the curve portions to ensure proper connecting grades at both ends.

6.2.4.2 Cross – Sections

All cross-sectional details were taken with reference to the centre line, extended normally up to the proposed ROW limits or between building lines, whichever is more, with levels at every 1 to 2m intervals and at all breaks in the profile. While taking cross - section of existing road apart from the proposed center lines and edges of the existing pavement, mid point of each traffic lane in each direction, paved shoulder demarcation (if any), shoulder drop, edges of formation, toe lines and points on existing ditches have been taken.

Wherever ditches are encountered, point(s) are taken to indicate the depth of the ditches. Points on the natural surface were taken 10 m apart within the proposed ROW or between building lines, whichever is more. Also cross – sections were taken at points of beginning and end of spiral transition curves, at the beginning, middle and end of circular curves, and at other critical locations. Total station was used for this purpose. Cross sectional details are collected at 50 m interval for straight section. For isolated curve and hilly stretches, the cross section interval was reduced to 10 to 20 m.

6.2.4.3 Minor Intersections

At small intersections (the intersections with MDR and the road below this category), survey was extended up to 100m on either side of the crossroad. The cross width covered along the crossroad was at least 60m.

6.2.4.4 Major Intersections

At Major road intersections (i.e. intersection with SHs, NHs) survey were extended up to 750m on either side on the crossroad. The cross width covered along the crossroad is at least 150m.

6.2.4.5 Minor Bridges

There are 4nos of Minor Bridges found along the stretch of project road.

6.2.4.6 Major Bridges

There are no any Major Bridges found along the stretch of project road.

6.3 Pavement Investigations

6.3.1 Pavement Structural Evaluation – BBD Studies

Benkelman Beam deflection studies were carried out on the project road in both the directions. The Benkelman Beam Deflection measurements were carried out on the project road with the frequency of one set of ten readings in 250 m for every three km of the project road as per TOR. BBD survey is depicted in **Figure 6-1**.

The evaluation of structural strength of existing flexible pavement was carried out using a Benkelman Beam in accordance with the procedure given in IRC 81-1997. Performance of

flexible pavement is closely related to the elastic deflection of pavement under the wheel load. The deformation or elastic deflection under a given load depends upon subgrade soil type, its moisture content and compaction, thickness and quality of pavement courses, drainage condition, pavement surface temperature etc.

For measuring pavement deflection, the C.G.R.A procedure that is based on testing under static load was adopted. Benkelman beam deflection survey is carried out for measuring the pavement deflection. Benkelman beam that consists of a slender beam 3.66 m long pivoted at a distance of 2.44 m from the tip, dial gauge is fitted to the beam to know the pavement deflection. The beam was calibrated using metal plates of known thickness prior to testing. A standard truck having a rear axle weighing 8170kg fitted with dual tire inflated to a pressure of 5.60 kg/sq.cm was used for loading the pavement. A point on the pavement is selected at 90 cm from the edge of the pavement both on LHS and RHS of carriageway. The dual wheels of the truck are centered above the selected point. In the selected point readings were taken at intervals of 0.0m, 2.7m and 11.7m. The maximum attention was given to record the dial gauge readings (deflection) and the same were recorded on data sheets.

The deflection test has been carried out along the project corridor at an interval of 100m staggered both on LHS and RHS of Carriageway. Pavement temperature was recorded at every km of testing inserting a thermometer in a hole (approximately 5 cm deep and 10 mm diameter) drilled in the pavement and filled with glycerol. For deviation of the pavement temperature from the standard temperature of 35^0C, correction has been applied to the deflection measured in accordance with the procedure described in IRC: 81-1997. Seasonal correction was carried out using the moisture correction factors given in Figure 2 to Figure 7 in IRC: 81-1997. The Plasticity Index and Field Moisture Content of the subgrade were established from test pit excavations carried out simultaneously along with the Benkelman Beam tests.

Figure 6-1: Photographs showing BBD Tests in Progress

The data obtained was analyzed to determine the structural strength of the existing pavement and determine the overlay design to cope up with the projected traffic. Overlay thickness of the project corridor is based on the statistical analysis of deflection value in the section corrected for temperature and seasonal variations. This involves calculation of mean deflection, standard

deviation and characteristics deflection. The formulae used for calculation of characteristics deflection are as follows

Characteristic deflection, $D_C = X + 2\sigma$

X = Individual deflection, mm

σ = Standard deviation, mm

D_C = Characteristic deflection

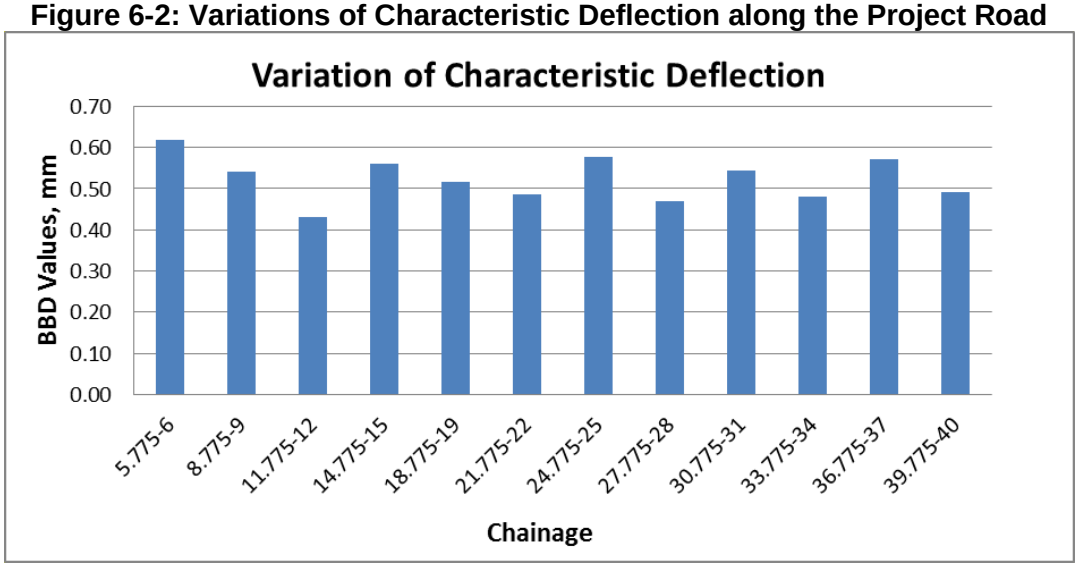
The summary of the Characteristic deflection for the project road section are presented in **Table 6-2** and the variation is represented graphically in **Figure 6-2**. The detailed data and analysis of BBD studies is presented in **Annexure 6**

The BBD values vary between 0.43 mm to 0.62 mm along the project road. The average value is 0.52mm for the project road.

Table 6-2: Summary of Characteristic Deflection

Chainage (km)		Characteristic Deflection (mm)
From	To	
5.775	6.000	0.62
8.775	9.000	0.54
11.775	12.000	0.43
14.775	15.000	0.56
18.775	19.000	0.52
21.775	22.000	0.49
24.775	25.000	0.58
27.775	28.000	0.47
30.775	31.000	0.54
33.775	34.000	0.48
36.775	37.000	0.57
39.775	40.000	0.49

Figure 6-2: Variations of Characteristic Deflection along the Project Road



6.3.2 Subgrade Soil Investigations

6.3.2.1 Trial Pits

Soil investigations along the existing road pavement were carried out at all the test sections considered. To study the characteristics of the existing soil, two samples from every five km of the Project or closer where change in soil type is encountered. The determination of subgrade CBR (soaked) every three km of the Project or closer where change in soil type is encountered. The investigations include several operations viz., field and laboratory testing as described below along with the approach and methodology adopted in this project. Trial pits of size 0.60m x 0.60m were excavated manually staggered left and right side of the existing road pavement and pavement-shoulder interface, extending through the pavement layers and to the level of subgrade and 500 mm below soil subgrade. Field Tests were also conducted at soil subgrade level and bulk soil samples were collected for conducting laboratory investigations.

The existing pavement layers type, crest thicknesses, visual classification of soil subgrade and existing embankment soil classification, water table found if any were recorded and field tests such as In-situ density by Core Cutter Method were also conducted. About 30 kgs of existing bulk soil sample and Soil below subgrade was also collected and packed in polythene bags, labeled, numbered and send to laboratory for conducting necessary laboratory testing.

6.3.2.2 Field Tests – In-situ density and moisture Content of subgrade Soil

In-situ density tests were carried out using core cutter method as per IS 2720 part XXVIII. Soil from density hole was immediately transferred to the Rapid Moisture Tester and the field moisture content was determined.

6.3.2.3 Existing Pavement Layer Crust Thicknesses

During Trial Pit Excavation, the existing pavement layers thicknesses and visual classification of soil subgrade and existing embankment, water table found if any were recorded. The details of existing pavement layer thicknesses and sub grade soil type is tabulated in **Table 6-3.** Existing subgrade thickness varies from 300-500mm.

Table 6-3: Existing Pavement Layer Details

Sr. No.	Chainage	Side	BT mm (BC/DBM)	Granular Base (WBM/WMM)	Sub Base (GSB/Boulder)	Subgrade type
1	6	LHS	70+100 =170	80+130=210	240 sand	sand
2	8	RHS	90+130=210	120+180=300	200 sand	sand
3	10	LHS	80+90=170	140+130=270	210 sand	sand
4	13	RHS	40+110=150	90+160=250	sand	sand
5	15	LHS	30+110=140	120+240=360	sand	sand
6	17	RHS	40+80=120	90+130=220	sand	sand
7	20	LHS	40+110=150	70+250=320	sand	sand
8	23	RHS	30+40=70	60+270=330	sand	sand
9	25	LHS	45+130=175	55+230 Bricks=285	sand	sand
10	28	RHS	35+100135	90+250 Bricks=340	sand	sand
11	30	LHS	40+80=120	70+280 Bricks=350	sand	sand
12	32	RHS	35+90=125	70+280 Bricks=350	sand	sand
13	35	LHS	50+110=160	90+300 Bricks=390	sand	sand
14	38	RHS	40+80=120	100+290=390	sand	sand
15	40	LHS	50+100=150	70 (Bricks 240)=310	sand	sand

6.3.2.4 Laboratory Testing

The following Laboratory tests were conducted on collected bulk sub grade soil as per IS SP 36-Part-2

- Grain size Analysis – by Wet sieving (24 hours soaked)
- Atterberg's limits (LL, PL & PI)
- Differential Free Swelling Index
- Compaction Tests (MDD & OMC) heavy compaction
- CBR (under 4 days soaked condition at 97% of MDD) heavy compaction
- Soil classification as per IS, HRB & AASHTO

Grain size Analysis - Wet Sieve Analysis (24 hours Soaked)

Wet Sieve Analysis as per IS 2720 part 4 – 1985 was carried out to find the percentages of gravels, sand, silt and clay for the soil samples collected.

Hydrometer Analysis – By Sedimentation Method

Hydrometer analysis was carried out on all the collected BC soil samples to know percentage of Silt and percentage of Clay fractions.

Atterberg's Limits - Casagrande and Cone Penetrometer Method

The Liquid Limit and Plastic Limit tests were conducted as per IS 2720 part 5 - 1985, IS 2720 part 2 - 1973 to evaluate the plasticity characteristics of the Subgrade Soil Samples. The Plasticity Index has been calculated is the numerical difference between the Liquid Limit and Plastic Limit for the plastic soils. The Plasticity Index shall be designated as Non Plastic (NP) for purely frictional soils (cohesion less soil) such as pure gravel, pure sand and combination thereof.

Soil classification - IS, HRB and AASHTO Soil Classifications

IS, HRB and AASHTO Classifications of sub grade and embankment Soil Samples was carried out based on the Grain Size analysis data, plasticity characteristics and swelling characteristics. The following symbols were used to designate the type of soils.

G	-	Gravels	W	-	Well graded
S	-	Sand	P	-	Poorly graded
M	-	Silt	B	-	Clay Binder
C	-	Clay	Pt	-	Peat
I	-	Inorganic	O	-	Organic
L	-	Low Plasticity	W	-	Well Graded
H	-	High Plasticity	SP	-	Poorly graded sand
SM	-	Silty Sand	GW	-	Well graded Gravels
SW	-	Well Graded Sand	SC	-	Sandy Clay
CL	-	Clay with low compressibility	CH	-	Clay with high compressibility
ML	-	Silt with low compressibility	MH	-	Silt with high compressibility
GC	-	Gravelly Clay	CI	-	Inorganic Clay
MI	-	Inorganic Silt	GM	-	Gravelly Silt

HRB classifications are also called AASHTO classification of revised Public Roads Administration (PRA) soil classification system. In this classifications, the soils are subdivided in to seven groups A-1 to A-7 based on Grainsize analysis, Atterberg Limits and percentage fines.

A-1, A-2, A-3 soils are granular soils, percentage fines passing 0.075 mm sieve being less than 35. A-4, A-5, A-6 and A-7 soils are fine grained or silty clay soils, passing 0.075 mm sieve being greater than 35 %.

Compaction Test (Heavy compaction Method)

The Dry Density and Moisture Content relationship has been established by conducting Heavy Compaction Test by compaction of soil sample using 4.89 kg rammer falling at a height of 45 cm in 5 layers by giving 25 Blows for each layer. The Maximum Dry Density and Optimum Moisture Content are determined from Dry Density Vs Moisture Content Plot.

Differential Free Swelling Index Tests

The differential free swelling Index Tests were conducted on selected soil subgrade and embankment soil passing 425 microns sieve by 24 hours soaking in both kerosene and distilled water as per IS 2720 part 40.

California Bearing Ratio Tests (4 days Soaked) - Heavy Compaction Method

Soil Samples were compacted in to the CBR mould at the 97% of optimum moisture content and maximum dry density obtained by compaction Test at Energy Level 3 by Heavy Compaction with 4.89 kg rammer falling at a height of 45 cm in five layers by giving 55 Blows for each layer. After the compaction the specimen with surcharge load was soaked for 4 days. The CBR tests were carried out for the penetration up to 12.5mm.

6.3.2.5 Analysis of Existing Sub grade Soil

Existing sub-grade soil laboratory test results are presented in **Table 6-4**.

Based on the laboratory test results, the existing sub grade soil is classified as Silty Sand (SM). The MDD is varying from 1.42 to 1.45 gm/cc. The soaked soil sub grade CBR strength is varying from 6.1% to 6.5%. Test results are enclosed in **Annexure 7**.

Table 6-4: Lab Results of Existing Sub-grade Soil

Sl. No.	Chainage	Side	Grain Size Analysis			LL	PL	PI	IS Class	FSI	Bulk Density	In-situ mc	CBR Tests (4 days Soaked)		
			Gravel	Sand	Silt + Clay								Heavy Compaction		
													MDD	OMC	CBR
	Km		%	%	%	%	%	%	IS	%	g/cc	%	g/cc	%	%
1	6.00	LHS	5.6	17.7	76.7	24.5	19.2	5.3	SM	2	1.72	5.1	1.43	6.2	**6.5**
2	8.00	RHS	5.8	16.2	78.0	25.2	18.7	6.5	SM	2	1.79	5.3	1.45	6.5	**6.4**
3	10.00	LHS	5.4	17.1	77.5	24.7	18.5	6.2	SM	2	1.74	5.1	1.43	6.3	**6.2**
4	13.00	RHS	5.6	17.3	77.1	24.8	19.4	5.4	SM	2	1.71	4.8	1.42	6.1	**6.1**
5	15.00	LHS	5.2	17.1	77.7	24.3	19.1	5.2	SM	2	2.17	4.9	1.44	6.3	**6.2**
6	17.00	RHS	5.1	17	77.9	24.7	19.2	5.5	SM	2	2.02	5.2	1.43	6.4	**6.2**
7	20.00	LHS	5.6	17.8	76.6	24.9	18.7	6.2	SM	2	1.73	5.0	1.45	6.1	**6.3**
8	23.00	RHS	5.4	17.7	76.9	24.5	18.6	5.9	SM	2	1.69	4.9	1.43	6.2	**6.2**
9	25.00	LHS	5.1	17	77.9	25.6	18.8	6.8	SM	2	1.60	4.7	1.44	6.4	**6.3**
10	28.00	RHS	5.5	17.7	76.8	25.3	18.5	6.8	SM	2	1.58	4.9	1.42	6.2	**6.2**
11	30.00	LHS	5.3	17.5	77.2	24.7	18.9	5.8	SM	2	1.69	5.3	1.42	6.3	**6.1**
12	32.00	RHS	5.2	17.6	77.2	24.9	18.5	6.4	SM	2	1.71	5.4	1.44	6.3	**6.4**
13	35.00	LHS	5.0	17.1	77.9	24.5	18.3	6.2	SM	2	1.70	5.1	1.45	6.4	**6.5**
14	38.00	RHS	5.6	17.7	76.7	25.2	18.1	7.1	SM	2	1.69	5.0	1.44	6.2	**6.2**

Sl. No.	Chainage	Side	Grain Size Analysis			LL	PL	PI	IS Class	FSI	Bulk Density	In-situ mc	CBR Tests (4 days Soaked)		
			Gravel	Sand	Silt + Clay								Heavy Compaction		
													MDD	OMC	CBR
	Km		%	%	%	%	%	%	IS	%	g/cc	%	g/cc	%	%
15	40.00	LHS	5.3	17.5	77.2	24.8	18.0	6.8	SM	2	1.68	5.1	1.43	6.3	**6.4**

6.4 Quarry and Materials Investigations

The information about existing stone Quarries, Murrum Quarries/ Borrow pits, Sand Quarries, Bitumen Manufacturing Refineries, Solid Blocks / RCC Hume Pipe Manufacturing Industries, Fly Ash Producing Captive Thermal Power Plants and other construction material sources was collected from local Construction Contractors, local material suppliers throughout the project area, from other sources and also from direct observation through site Visits. The suitability of the materials sources was evaluated based on laboratory test results and detailed analysis. After analyzing the suitability of those material sources quantitatively and qualitatively, the lead chart was prepared.

6.4.1 Identification of Material Sources

6.4.1.1 Field Visits to Quarry and Material Sources

Field Visits were made to the following Quarry and Materials Sources located along the project road and nearby Project Road. The approximate area, quantity availability was assessed, recorded and the samplings were made, packed, labeled and transported to Materials Testing laboratory.

- Stone Metal Quarries
- Moorum Borrow pits
- Sand Quarries
- RCC Hume Pipe Manufacturing Industries
- Bitumen Refineries and Petrochemicals
- Fly Ash Producing Captive Thermal Power Plants

6.4.1.2 Sampling of Materials from Sources

The Stone Aggregates, Borrow pit Murrum and Sand Samples were collected, packed, labeled and transported to materials testing laboratory for carrying out relevant tests.

6.4.1.3 Laboratory Investigations

The following Laboratory tests were conducted on collected stone aggregate Samples, borrow pit Moorum and sand as per relevant Indian Standards / International standards.

6.4.1.4 Laboratory Tests on Borrow pit Murrum

- Field Moisture Content (FMC)
- Grain size Analysis – by Wet sieving (24 hours soaked)
- Atterberg's limits (LL, PL & PI)
- Differential Free Swelling Index
- Compaction Tests (MDD & OMC)
- CBR (under 4 days soaked condition at 97% of MDD)
- Soil classification as per IS, HRB & AASHTO

The test properties of borrow pit moorum is tabulated in **Table 6-5.**

6.4.1.5 Suitability of Borrow pit Moorum

Based on the laboratory test results, the borrow pit moorum is classified as Silty Sand (SM) / Gravelly Silt (GM), less plastic and less swelling in nature with 4 days soaked CBR strength varying from 7.5% to 8.2% which is suitable as subgrade, embankment and back filling.

6.4.1.6 Laboratory Tests on Stone Aggregates

The following Laboratory Tests were conducted on the collected Quarry Stone Aggregates.

- Water Absorption and Specific Gravity as per IS 2386 Part III - 1990
- Aggregate Impact Value as per IS 2386 Part IV - 1963
- Aggregate Crushing Strength as per IS 2386 Part IV - 1963
- Plasticity Characteristics as per IS 2720 Part V – 1985

6.4.1.7 Suitability of Aggregates

The Laboratory test results indicate that the quarry aggregates are Black Deccan Trap in type and possesses the required strength and tested properties are within the permissible limits. These Quarry aggregates are suitable for Road construction works and also for concrete works.

6.4.1.8 Laboratory Tests on Sand

Grain size Analysis – by Wet sieving (24 hours soaked) as per IS 2720 Part IV -1985.

6.4.1.9 Suitability of Sand

Based on the laboratory test results, the river sand is classified under Zone II and Zone I respectively and the percentage fines passing 150 microns are within the permissible limits. The sand is suitable for road works.

6.4.2 Recommendations of Material Sources

The list of identified Stone Metal Quarries, Sand Quarries and Bitumen refineries are tabulated below.

Material	Source	Average lead to project road
Coarse aggregates (stone)	Quarries at Ratangarh	250 Km
Fine aggregates (sand)	Kolayat	280 Km
Bitumen	Panipat	350 Km

7 Preliminary Road Design

7.1 Geometric Design

7.1.1 Carriageway Width

The width of a basic traffic lane is taken to be 3.5 m. Thus, for 2-lane, the carriageway widths will be 7.0 m.

7.1.2 Paved shoulder & Granular Shoulder

Full strength pavement for paved shoulders is proposed on main carriageway. Width of these shoulders shall be minimum 1.5m. This will provide for better traffic operation conditions, space for parking of the vehicles and movement of non-motorized traffic in the built-up areas and facility of directly using these as part of carriageway when the road is widened on these sides.

Granular shoulders are proposed to be 2.0m wide on either side of carriageway. Interlocking paver block shoulder is proposed for 1.5m (average) width in the initial 8.2km section.

7.1.3 Median Width

The median width of 2.5m is proposed for initial 8.2km of project road.

7.1.4 Cross fall/Camber

The cross fall of carriageway, paved shoulder, unpaved shoulder and median is given below:

Sl.No.	Elements	Cross fall
1	Carriageway	2.5%
2	Paved Shoulder	2.5%
3	Unpaved Shoulder	3.0%
4	Median	3.0%

7.1.5 Kerb Type

The insurmountable kerb without channel is adopted towards median side.

7.1.6 Embankment height

The alignment passes through flat agricultural land and the project area experiences low rainfall with dry weather prevailing for most of the months. The embankment height is governed by vertical alignment design considering the minimum free board requirement above HFL for bridges and other CD structures. The embankment height including pavement layers is kept generally more than 1.0 m in case of new construction, which would further depends on the height of CD structures proposed. The embankment height varies at approaches of bridges, underpasses depending on the height of these proposed structures. The embankment slope was kept at 2H: 1V.

The abstract of design standards relative to the geometric designs are shown in **Table 7-1**.

Table 7-1: Design Standards

Description	Standard	Remarks
Design speed	100/80 kmph	Except section through town/villages and at constraint locations
Min. Horizontal radius	400 m	For plain terrain
Desirable horizontal radius	1800 m	For normal camber

Description	Standard	Remarks
Min. vertical curve length	73.6 A	A = Algebraic difference between grades
Vertical clearance	5.5 m	Vehicular underpasses (VUP)
Vehicle underpass	10.5 m	Across major cross road in major realignments
Light vehicle underpass/pedestrian underpass/cattle pass	5.5m wide and 3.5m height	At identified locations along major realignments
Two lane carriageway	7.00 m	-
Four lane divided carriageway	7.25m X 2	Initial 8.2 Km section
Median width	2.5m	Initial 8.2 Km section
Paved shoulder	1.5 m	Same strength as pavement
Granular shoulder	2.0 m	-
Footpath	1.5 m	Adjacent to main carriageway in built-up areas
Embankment slope	2H: 1V	
Cross slope on carriageway and paved shoulder	2.5%	
Max. Super elevation	7%	
Cross slope on unpaved shoulder	3.0%	
Cross slope on median	3.0%	Away from centre line
Maximum longitudinal gradient	2.5%	At underpasses/grade separators
Minimum longitudinal gradient	0.3%	For drainage considerations

7.1.7 Cross sections

The Project Highway shall be widened to two/four lane dual configuration without Service Roads. A typical cross section along with different types of cross section required to be developed in different segments of the project highway are indicated in **Table 7-2**.

Table 7-2: Cross Section type along the project corridor

Proposed Chainage (Km)		Length, km	Proposed Cross-section Details
From	To		
0+000	8+200	8.200	4-lane Divided Carriageway with 2.5m median, 1.5m Interlocking paver block shoulder and Drain/Footpath
8+200	9+900	1.700	2-Lane carriageway with 1.5m Paved Shoulder and 2.0m Granular Shoulder
9+900	10+150	0.250	2-Lane carriageway with 1.5m Paved Shoulder and Drain/Footpath
10+150	16+700	6.550	2-Lane carriageway with 1.5m Paved Shoulder and 2.0m Granular Shoulder
16+700	17+375	0.675	2-Lane carriageway with 1.5m Paved Shoulder and Drain/Footpath
17+375	18+350	0.975	Existing CC Pavement Retained

Proposed Chainage (Km)		Length, km	Proposed Cross-section Details
From	To		
18+350	18+800	0.450	2-Lane carriageway with 1.5m Paved Shoulder and Drain/Footpath
18+800	41+000	22.200	2-Lane carriageway with 1.5m Paved Shoulder and 2.0m Granular Shoulder

7.1.8 Details of Bypasses and Realignments

Bypasses and major realignments are not envisaged as part of the project road.

7.1.9 Vehicular Underpass

No vehicular underpass is envisaged as part of the project road improvement.

7.1.10 Pedestrian cum Light Vehicle Underpasses

No pedestrian underpass is envisaged as part of the project road improvement.

7.2 Pavement design

Design of pavement is critical, as the economical returns are directly dependent on its performance. This report deals with the design methodology adopted for New Pavement proposed for the Project area. The IRC-37, 2012 guidelines have been followed for design of new pavement and IRC 81-1997 guidelines have been followed to design the flexible overlay layers.

7.2.1 Design Procedure of Flexible Pavement – IRC: 37-2012

The guidelines provide a Design catalogue giving pavement compositions for various combinations of traffic, layer configuration and assumed material properties. If the designer chooses to use any of these combinations and is satisfied that the layer properties assumed in the design catalogue can be achieved in the field, the design can be straightway adopted from the relevant design charts given in the catalogue.

The design thickness in the above chart are related to various CBR values ranging from 3% to 10% and for various levels of design traffic i.e. 2, 5, 10, 20, 30, 50, 100 and 150 MSA. Adoption of pavement design compositions specified in the above catalogue are relevant to Indian conditions, materials and specifications.

The standard designs given in various Plates of IRC 37:2012 specify the minimum thickness and specifications of various component layers for the given traffic in terms of cumulative standard axles and the sub grade CBR. For intermediate traffic ranges, the pavement layer thickness has been interpolated linearly. Following data has been collected for arriving at the cumulative million standard axles during the design life.

- Traffic intensity in terms of commercial vehicles per day
- Traffic growth rate
- Design life

7.2.2 Data for Design of Flexible Pavement

7.2.2.1 Design Life

The design life is defined in terms of the cumulative number of standard axles in msa that can be carried before a major strengthening, rehabilitation or capacity augmentation of the pavement is necessary.

IRC 37-2012 guidelines suggest adopting a design life of 15 years for new flexible pavements.

No stage construction is adopted, thicknesses of pavement layers have been provided for the full design period of 15 years as per IRC SP: 73-2015 with minimum design traffic of 20 MSA.

For this project, we have considered 15 years design life for all the pavement layers excluding construction period of 18 months.

7.2.2.2 Design CBR of Subgrade

Keeping in view of the availability of borrow soil, effective CBR value of 7% has been considered in the Pavement Design for the project road sections.

7.2.2.3 Pavement Materials Composition Adopted

The project road sections with widening and strengthening, reconstruction and new construction have been designed as per Para 10.1 of IRC: 37-2012 having conventional composition of bituminous layer (BC & DBM), Granular Base and Granular Sub base over subgrade soil for widening portion and shall have required overlay thickness as per IRC: 81-1997 for the strengthening portion above the existing bituminous layer with necessary profile corrective course.

7.2.2.4 Design Traffic

The Average Annual daily traffic (AADT) of commercial vehicles derived for the project as given in **Table 7-3** has been considered as the design traffic in the base year 2014. At this stage of feasibility, we have generalized the traffic without giving importance to the section wise variations. The average traffic of all the seven locations shall form the basis for calculation of CSA for the entire project road.

Table 7-3: Design Traffic Volume (AADT) – Year 2014

Location	Buses	LCV	2AT	3AT	MAV
Km 10	323	86	147	179	29
Km 29	302	78	96	174	113
Max. Traffic on Project Road	**302**	**78**	**96**	**174**	**113**

7.2.2.5 Traffic Growth Rates

The ToR specifies adopting 5% growth rate for the feasibility study. This suggested growth rate may be used for revenue determination during the financial analysis. The annual growth of registered vehicles in Rajasthan stood at 8.2% and also IRC: 37 suggest use of 7.0% growth for commercial vehicles for the pavement design. Due to recent change in the technology in the manufacture of heavy commercial vehicles, there is an on-going tendency to change over to higher load carrying trucks and the growth of 2-AT's have reduced comparatively with respect to 3-AT's and MAV's. In view of this the higher growth rates are warranted in CV's category in estimating the traffic loading for the pavement design.

In order to be on the conservative side, for estimating the future traffic loading on pavement in terms of cumulative million standard axles (MSA), higher traffic growth rates as in **Table 7-4** is suggested..

Table 7-4: Traffic Growth Rates

Growth Period	LCV	2-AT	3-AT	MAV	Bus
2014-2019	6.5%	5.0%	7.5%	7.5%	6.0%
2020-2025	6.5%	5.0%	7.5%	7.5%	6.0%
2026 and beyond	6.5%	5.0%	7.5%	7.5%	6.0%

7.2.2.6 Traffic Loading

As suggested in IRC: 37 – 2012, the design traffic loading is considered in terms of the cumulative number of standard axles in the lane carrying maximum traffic, to be carried during the design life of the road. Design Traffic loads were computed using the following equation:

$$N = 365 \times \left\{ (1+r)^n - 1 \right\} \times A \times D \times \frac{F}{r}$$

Where,

N = the cumulative number of standard axles to be catered for in the design
A = Initial traffic in the years of completion of construction (number of CVs per day).
D = lane distribution factor as per IRC: 37 – 2012 (Para 4.5.1)
F = Vehicle Damage Factors
n = Design life in years
r = Annual growth rate of commercial vehicles

The traffic in the year of completion is estimated using the following formula:

$$A = P\ (1+r/100)^x$$

Where,

P = Number of commercial vehicles
x = Number of years between the count and the year of completion of construction
A = Traffic in the year after completion of construction
r = Average Annual growth rate (as estimated)

The design traffic (msa) is worked out for the entire project road as per IRC: 37-2012 Para 4.5.1. Traffic loading in terms of MSA (Million Standard Axles) have been arrived and presented in **Table 7-5** for 2-lane carriageway configuration.

Table 7-5: Traffic Loading (MSA)

VDF	LCV	2-Axle	3-Axle	MAV	BUS	Standard Axles in the Year	Cumulative Standard Axles	CUMULATIVE MSA	No of Years
	1.00	2.50	5.00	10.50	1.00				
Year									
Base Year 2014	78	96	174	113	302	489280	Traffic Survey Year		1.00
2015	82	101	183	119	318	513744			2.00
2016	86	106	192	125	333	539431			3.00
2017-HY	88	108	197	128	342	276376			3.50
2017-HY	91	111	201	131	350	283202	Construction Period 18 months		4.00
2018	93	114	206	135	359	580563			5.00
2019	98	119	217	141	377	609591	609591	**0.61**	**1.00**
2020	102	125	228	148	396	640071	1249662	**1.25**	2.00
2021	108	132	239	156	416	672074	1921737	**1.92**	3.00
2022	113	138	251	164	436	705678	2627415	**2.63**	4.00
2023	119	145	263	172	458	740962	3368377	**3.37**	5.00
2024	125	152	277	180	481	778010	4146387	**4.15**	6.00
2025	131	160	290	189	505	816911	4963298	**4.96**	7.00
2026	137	168	305	199	530	857756	5821054	**5.82**	8.00
2027	144	176	320	209	557	900644	6721698	**6.72**	9.00
2028	151	185	336	219	585	945676	7667374	**7.67**	10.00
2029	159	195	353	230	614	992960	8660334	**8.66**	11.00
2030	167	204	371	242	645	1042608	9702942	**9.70**	12.00
2031	175	214	389	254	677	1094738	10797680	**10.80**	13.00
2032	184	225	409	266	711	1149475	11947156	**11.95**	14.00
2033	193	236	429	280	746	1206949	13154105	**13.15**	15.00
2034	203	248	451	294	783	1267297	14421401	**14.42**	16.00
2035	213	261	473	308	823	1330661	15752063	**15.75**	17.00
2036	224	274	497	324	864	1397194	17149257	**17.15**	18.00
2037	235	287	522	340	907	1467054	18616311	**18.62**	19.00
2038	247	302	548	357	952	1540407	20156718	**20.16**	20.00
2039	259	317	575	375	1000	1617427	21774145	**21.77**	21.00

7.2.3 Design of Flexible Pavement

The design inputs i.e. CBR value for the proposed subgrade material, Traffic loading in terms of cumulative standard axles in million (MSA) considered for pavement design have been summarized in **Table 7-6.** Pavement layers have been designed for 15 years (excluding construction period) as per IRC SP: 73-2015 with minimum design traffic loading of 20 MSA.

Table 7-6: Design Inputs for Flexible pavement

Design Parameter	Entire Project Road length
Design life Years	15
Lane Distribution factor	0.5
Directional Split	50:50
CBR (Effective)	7%
Traffic Loading (MSA) for 15 years	20 (actual 13.15)

For re-construction with widening and new construction sections, the pavement composition and layer thicknesses considering the above design parameters are presented in **Table 7-7**.

Table 7-7: Pavement Layer Thicknesses (mm)

Pavement Composition	New Construction
Bituminous Concrete (BC)	40
Dense Bituminous Macadam (DBM)	90
Wet Mix Macadam (WMM)	250
Granular Sub base (GSB)	230
Subgrade (Effective CBR=7%)	500

The Benkelman beam deflection study on the representative sections of project road yielded an average deflection of 0.52 mm (0.43 to 0.62 mm). The overlay requirement by considering 20 MSA design life for surface layers, is only 40mm BC as obtained from IRC: 81-1997 design chart.

For widening and strengthening sections, the widening portion shall have composition that of new pavement and for strengthening of the existing pavement overlay layer of 50mm DBM and 40mm BC is proposed over a profile corrective course in DBM.

The rigid pavement design is based on the IRC: 58 and IRC: SP-73 and the composition recommended for toll plaza is presented below **Table 7-8.**

Table 7-8: Rigid Pavement Details for Toll Plaza

Material Type	Layer Thickness in mm
Pavement Quality Concrete (M-40)	300 mm
Dry Lean Concrete (M-10)	150 mm
Granular Sub-base	150 mm
Subgrade	500 mm

Pavement Treatment Details - Sri Ganganagar to Pacca Saharana

Carriageway Width = 7.00 m
Paved Shoulder Width = 1.50 m
Granular Shoulder Width = 2.00 m
Total Formation Width = 14.00 m
Embankment Slope = 1V:2H

Chaiange		Length	Proposed BT Width, m	Treatment Proposal	Widening					Strengthening		Reconstruction				Existing CW width retained
From	To	Km			BC	DBM	WMM	GSB	Subgrade	BC	DBM	BC	DBM	WMM	GSB	
0.000	4.000	4.000	4-Lane DCW (7.25m x 2) 1.5m ILPB shoulder with 2.5m Median	Widening and Strengthening	40	90	250	230	500	40	50	-	-	-	-	5.0m on each side
4.000	8.200	4.200	4-Lane DCW (7.25m x 2) 1.5m ILPB shoulder with 2.5m Median	Widening and Strengthening	40	90	250	230	500	40	50	-	-	-	-	4.5m centrally (excluding median) (Concentric)
8.200	16.000	7.800	10.0	Widening and Strengthening	40	90	250	230	500	40	50	-	-	-	-	6.7m centrally
16.000	17.375	1.375	10.0	Reconstruction with Widening	40	90	250	230	500	-	-	40	90	250	230	6.5m centrally
17.375	18.350	0.975	10.0	Existing CC pavement retained	-	-	-	-	-	-	-	-	-	-	-	-
18.350	19.000	0.650	10.0	Reconstruction with Widening	40	90	250	230	500	-	-	40	90	250	230	6.5m centrally
19.000	40.000	21.000	10.0	Widening and Strengthening	40	90	250	230	500	40	50	-	-	-	-	6.7m centrally
40.000	41.000	1.000	10.0	Reconstruction with Widening	40	90	250	230	500	-	-	40	90	250	230	6.5m centrally
		41.000														

Note:

1. WMM and GSB are in two layers
2. GSB layer shall be extended to full width of embankment
3. In reconstruction sections, subgrade layer is optional only if existing subgrade does not meet the design requirements
4. Subgrade borrow soil CBR is taken as 7% for the design.
5. Reconstruction with widening: Widening on eitherside with new pavement layers and Reconstructing over existing base layer with GSB and WMM by scarifying existing BT (retaining central 6.5m wide existing CW)
6. Widening & Strengthening: Widening on eitherside with new pavement layers and strengthening the existing carraigeway with PCC, DBM and BC layer (for the existing retained width)

7.3 VUP/PUP, ROB/RUBs, Toll Plaza Proposed

Proposed VUP/PUP

No VUP/PUP have been suggested

Proposed ROB/RUBs

No at-grade railway line crossing is observed along the project road. No ROB/RUB have been suggested

Proposed Tolling Sections

Project road section from Sri Ganganagar to Pacca Saharana from Km 0.0 to Km 41.0 is envisaged as part of the project. Thus 41.0 Km length of the project road is considered as part of the project and tolling.

Two toll plazas are proposed along the entire project road length. Toll plaza shall have 2 lanes in each direction and one additional lane for Exempted Vehicles. The tentative sections for tolling (proposed toll plazas) purposes are presented in **Table 7-9**.

Table 7-9: Tolling Section

Section	Toll Plaza	Length km	Toll Road Section	Toll Plaza Location
Sri Ganganagar to Lalgarh Jattan	TP-1	41.0	Km 0.0 to Km 41.0	Km 10.4
Lalgarh Jattan to Pacca Saharana	TP-2			Km 35.0

7.4 Bus Shelters

Bus shelters are proposed along the entire project road length on both sides. The tentative locations are presented in **Table 7-10**.

Table 7-10: Bus Shelter Locations

Locations of bus shelters (Design Chainage)	Total Nos. (Both sides)
4+500, 7+200, 9+400, 15+600, 17+700, 26+200, 28+900, 39+800	16 Nos.

Between the bus shelter and paved shoulder of the carriageway, an additional paved area of 2.5m width and 20m length should be provided in order to enable the bus to stop without obstructing the flow of traffic

7.5 Overhead Sign Boards

The tentative locations for overhead sign boards are presented in **Table 7-11** below.

Table 7-11: Locations of Overhead Sign Boards

Sl. No.	Location	Size
1	Sri Ganganagar, at km.0.200	Full width Gantry (1no.)
2	Pacca Saharana, at km.40.800	Full width Gantry (1no.)
3	Sri Ganganagar, Junction at km 4.850	Cantilever Gantry both side (2nos.)
4	Industrial Area, Junction at km 8.010	Cantilever Gantry both side (2nos.)
5	Lalgarh Jattan, Junction at km 18.400	Cantilever Gantry both side (2nos.)

8 Preliminary Design of Structures

8.1 DESIGN STANDARDS FOR STRUCTURES

8.1.1 General

This section deals with the standards to be adopted vis-à-vis ROBs, flyovers, bridges, underpasses and culverts. It also provides for the type of materials and their specifications that would be adopted for the above structures, the loads and forces to be considered.

It is intended that the project road is accommodate traffic 2-lane/Intermediate lane/Single lane at present and to be widened to 2-lanes with granular shoulder.

8.1.2 Cross-sectional Elements

Structural width for bridges / flyovers / Road over Rail Bridge

The structural width for all bridges is being kept the same and the entire formation width is carried out on to the structure as per IRC:SP-73-2015. At the approaches, the carriageway is widened from 9.75 m to 11.00 m.

8.1.3 Specification for Material

Concrete

The grades of concrete are either equal to or higher than those prescribed in IRC: 112-2011. Grade of concrete in various structural elements is for moderate conditions of exposure.

Superstructure

PSC Members	M 40
RCC T-Girder and Deck Slab	M 30
RCC Solid Slab	M 30
RCC Crash Barriers	M 40

Substructure

RCC substructures and foundations	M 35
All PCC structural members	M 20
All PCC non-structural members	M 15

Pedestals for bearings

Pot/PTFE	M 40
Elastomeric	M 30

Steel

This is conform to provisions given in IS: 1786, IS: 432 (Part I).

i) Reinforcement Steel

High yield strength deformed bars conforming to Fe 500 / TMT.

ii) Pre-stressing Steel

These should conform to IS: 14268-1995

System: 19 K13 or 12 T13 low relaxation multiple strands system

Cables: 19 K13 or 12 T13 system with strands of 12.7 mm nominal diameters.

Sheathing: 90 mm / 75mm Corrugated HDPE sheathing duct.

Bearings

i) Elastomeric Bearings

Elastomeric bearing is provided under RCC T-beams and RCC solid slabs type superstructures as per IRC: 83 (Part II)-2002 and shall conform to clause 2005 of MoRT&H specification for Road and Bridge Works.

ii) POT cum PTFE Bearings

POT cum PTFE bearings is provided where we have to cater for large loads. This is conforming to IRC: 83 (Part III) and clause 2006 of MoRT&H specifications for Road & Bridge works.

Expansion Joints

Elastomeric strip seal type expansion joints is provided on all the bridges and ROBs as per Clause No. 2607 of MoRT&H specification for road and bridge works and interim specifications for expansion joints issued subsequently vide MoRT&H letter no. RW/NH-34059/1/96-S&R dated 25.01.2001 and addendum there to circulated vide letter of even no; dt. 30.11.2001.

In case of bridges with smaller spans slab seal type expansion joint is provided.

8.2 Loads and Forces to be considered in Design

Vertical Loads

a) Dead Loads

Following unit weights is assumed in the design as per IRC Codes.

Prestressed Concrete	-	2.5 t / cu.m
Reinforced Concrete	-	2.4 t / cu.m
Plain Cement Concrete	-	2.2 t / cu.m
Structural steel	-	7.85 t / cu.m
Dry Density of Backfill Soil	-	1.80 t / cu.m
Saturated Density of Backfill Soil	-	1.9 t / cu.m

b) Superimposed Dead Loads

Wearing Coat: 65mm thick Bituminous [15 Mastic asphalt + 50 BC] with total 0.2 t / sq.m (2.2 t / cum for 11.0 m wide c / way including allowance for an overlay).

Crash barriers: From design (i.e. 1.0 t / m per side)

c) Live Loads

Carriageway Live Loads: The following load combinations are considered in the analysis and whichever produces the worst effect is considered.

- One / Two / Three lanes of IRC Class A.
- One lane of IRC Class 70R (wheeled/ tracked)
- One lane of IRC Class 70R (wheeled) with one lane of IRC Class A

Minimum clear distance between 70R vehicle and Class A vehicle, when placed side by side in combination, is as per Table 2 Live Load Combinations for IRC:6-2014.

Reduction in longitudinal effect on bridges is as per Cl.205 of IRC: 6-2014.

Impact factor is as per Cl. 208 of IRC: 6 for the relevant load combinations. For simplicity in design, Impact factor for continuous structures are calculated for the smallest span of each module and used for all the spans of that module.

d) Horizontal Forces

i) Longitudinal Forces due to live load

Following effects are considered in the design.

Braking forces as per the provision of Cl. 211 of IRC: 6.

Distribution of longitudinal forces due to horizontal deformation of bearings/frictional resistance offered to the movement of free bearings as per Cl. 211.5 of IRC: 6-2014.

ii) Horizontal Forces due to Water Currents

The portion of bridge, which may be submerged in running water, is designed to sustain safely the horizontal pressure due to force of water current as per the stipulations of Cl. 210 of IRC: 6.

iii) Earth Load

Earth forces are calculated as per the provisions of Cl. 214 of IRC:6 assuming the following soil properties:

Type of soil assumed for backfilling: As per Appendix 6 of IRC: 78 with dry density of 2.07 t / cu.m and submerged density of 1.2 t / cu.m.

Angle of Internal Friction : $\Phi = 30^{O}$

Angle of Wall Friction : $\delta = 20^{O}$

Coefficient of Friction 'μ' at base : tan (2/3 Φ), while Φ is the angle of internal friction of substrata immediately under the foundations.

iv) Surcharge Load

Live load surcharge is considered as per the provisions of Cl. 714.4 & Cl. 715.1.5 of IRC: 78 i.e. equivalent to 1.2m height of fill in case of abutments and return / wing walls.

v) Centrifugal Forces

Centrifugal forces is calculated as per the provisions of Cl. 212 of IRC: 6 for a design speed applicable at horizontal curves.

vi) Wind Effect

Structures are designed for wind effects as stipulated in Cl. 209 of IRC: 6.

vii) Seismic Effect

The road stretch is located in Seismic Zone-III as per the revised seismic map of India as per Cl.219 of IRC:6-2014. The seismic forces is coefficient method as per Cl.219 of IRC:6-2014.

e) Other Forces / Effects

i) Temperature Effects

The bridge structure / components i.e. bearings and expansion joints, is designed for a temperature variation of + 25^0 C considering extreme climate.

The superstructures shall also be designed for effects of distribution of temperature across the deck depth as given in Fig. 10(a) of IRC: 6-2014, suitably modified for the surfacing thickness.

ii) Construction Stage Loadings / Effects

A uniformly distributed load of 3.6 KN /m2 of the form area is considered to account for construction stage loadings in the design of superstructure elements, wherever applicable, as per Cl. 4.2.2.2.2 of IRC: 87-1984.

iii) Buoyancy

100% buoyancy is considered while checking stability of foundations irrespective of their resting on soil/weathered rock / or hard rock. However, the maximum base pressures shall also be checked under an additional condition with 50% buoyancy in cases where foundations are embedded into hard rock. Pore pressure uplift limited to 15% is considered while checking stresses of the substructure elements.

f) Load Combinations to be considered in Design

All members are designed to sustain safely the most critical combination of various loads and forces that can coexist. Various load combinations as per Table 3.1 to 3.4 of IRC:6-2014 shall be considered.

g) Exposure Condition

Moderate exposure conditions are considered while designing various components of the bridge.

h) Design Codes

The main design criteria being adopted is to evolve design of a safe structure having good durability conforming to the various technical specifications and sound engineering practices.

Various Codes of Practices referred to, are as under:

- IRC: 5-1998
- IRC: 6-2014
- IRC: 22-2008
- IRC: 45-1972(reprint 1996)
- IRC: 54-1974
- IRC: 78-2014
- IRC: 83-2002 (Part II)
- IRC: 83-2006 (Part I-III)
- IRC:112-2011
- IRC: SP: 13-2004
- IRC: SP:73-2015
- BS 5400 – Part IX (For design of POT/POT-PTEE Bearings)
- IS 1893-2002 – (Part-I)

8.3 Improvement Proposals

8.3.1 ROB/RUB

The Concessionaire is not required to build any ROB/RUB on the Project Highway.

8.3.2 Major Bridges

The Concessionaire is not required to build any Major Bridges on the Project Highway.

8.3.3 Minor Bridges

Minor Bridges shall be provided, widened, reconstructed or rehabilitated as follows

(a) Details of new/ proposed Minor Bridge

S. No.	Existing Chainage (In Km.)	Design Chainage	No. of spans	Total Width
1	5/290	5.182	1 x 22 PSC girder bridge, parallel to the existing span	11.0m

(b) Details of Minor Bridges to be Widened

In pursuance of Paragraph 7.3 (iv) of the Manual, the following existing structures shall be widened on the Project Highway:

S. No.	Existing Chainage	Design Chainage	No. of spans	Total Width
1	8/900	8.850	2 x 5.0m	16.0m
2	29/880	29.850	2 x 3.0m	16.0m
3	39/580	39.550	2 x 3.5m	16.0m

(c) Details of Minor Bridges to be reconstructed

Nil

(d) Details of Minor Bridges to be rehabilitated

Nil

(e) Details of Minor Bridges to be retained

Nil

8.3.4 Culverts

Culverts as listed below shall be provided, Retained/Widened/Reconstruction.

(a) Retained /Widened / Reconstruction of Culverts

S. No	Existing Chainage	Design Chainage	Existing			Proposed width, m	Development Proposed (widening/ reconstruction/ rehabilitation)
			Type	No. of Spans	Total width (m)		
1	1.825	1.625	RCC Slab	2 x 1.5	15.2	4-lane	Reconstruction
2	2.804	2.636	RCC Slab	1 x 1.5	14.1	4-lane	Widening
3	4.204	4.036	Hume Pipe	1 x 0.4	15.6	4-lane	Reconstruction
4	4.866	4.696	RCC Slab	1 x 1.5	10.7	4-lane	Widening
5	5.290	5.106	RCC Slab	1 x 1.5	12	4-lane	Widening
6	6.105	6.010	RCC Slab	1 x 0.9	12	4-lane	Widening
7	6.514	6.422	RCC Slab	1 x 1.5	12	4-lane	Widening
8	7.042	6.950	RCC Slab	1 x 1.5	11.9	4-lane	Widening
9	9.403	9.354	RCC Slab	1 x 1.5	10	14.0m	Widening
10	12.000	11.965	RCC Slab	1 x 1.5	9.2	14.0m	Widening
11	12.100	12.062	RCC Slab	1 x 1.5	9.2	14.0m	Reconstruction
12	13.666	13.620	RCC Slab	1 x 2.5	12	14.0m	Widening
13	14.103	14.052	RCC Slab	1 x 1.5	9.7	14.0m	Reconstruction
14	14.522	14.470	RCC Slab	1 x 1.5	12	14.0m	Widening
15	15.067	15.020	RCC Slab	1 x 1.5	12	14.0m	Widening
16	16.119	16.080	RCC Slab	1 x 1.5	11.8	14.0m	Widening
17	16.619	16.580	RCC Slab	1 x 1.5	11.9	14.0m	Widening
18	17.105	17.074	RCC Slab	1 x 1.5	8.2	14.0m	Widening
19	17.226	17.195	RCC Slab	1 x 1.5	11.8	14.0m	Widening
20	17.405	17.374	Hume Pipe	2 x 1.2 dia	9.5	14.0m	Widening
21	18.584	18.556	RCC Slab	1 x 1.0	9.1	14.0m	Widening
22	20.000	19.975	RCC Slab	1 x 1.5	9.8	14.0m	Widening
23	20.090	20.065	RCC Slab	1 x 1.5	11.7	14.0m	Widening
24	20.296	20.270	RCC Slab	1 x 1.5	9.6	14.0m	Widening
25	20.821	20.800	RCC Slab	1 x 1.5	9.8	14.0m	Widening
26	20.921	20.900	RCC Slab	1 x 1.5	9.8	14.0m	Widening
27	21.122	21.100	RCC Slab	1 x 1.5	10	14.0m	Widening
28	22.100	22.078	RCC Slab	1 x 2.0	9.8	14.0m	Widening
29	23.100	23.078	RCC Slab	1 x 1.5	9.8	14.0m	Widening
30	23.300	23.278	RCC Slab	1 x 1.5	9.7	14.0m	Widening
31	23.854	23.830	RCC Slab	1 x 1.5	11.1	14.0m	Widening
32	24.100	24.080	RCC Slab	1 x 1.5	9.5	14.0m	Widening
33	24.983	24.960	RCC Slab	1 x 1.5	9.7	14.0m	Widening
34	25.800	25.779	RCC Slab	1 x 1.5	9.6	14.0m	Widening
35	26.895	26.871	RCC Slab	1 x 1.5	9.6	14.0m	Widening
36	28.088	28.067	RCC Slab	1 x 1.5	9.7	14.0m	Widening
37	29.497	29.473	RCC Slab	1 x 1.5	11.8	14.0m	Widening
38	29.654	29.630	RCC Slab	1 x 1.5	12	14.0m	Widening
39	29.958	29.931	RCC Slab	1 x 1.5	11.8	14.0m	Widening
40	30.127	30.100	RCC Slab	1 x 1.5	11.8	14.0m	Widening

S. No	Existing Chainage	Design Chainage	Existing			Proposed width, m	Development Proposed (widening/ reconstruction/ rehabilitation)
			Type	No. of Spans	Total width (m)		
41	30.500	30.480	RCC Slab	1 x 1.5	9.7	14.0m	Widening
42	30.916	30.890	RCC Slab	1 x 1.5	11.8	14.0m	Widening
43	34.106	34.080	RCC Slab	1 x 1.5	9.4	14.0m	Widening
44	34.417	34.390	RCC Slab	1 x 1.5	11	14.0m	Widening
45	34.887	34.860	RCC Slab	1 x 1.5	11.6	14.0m	Widening
46	35.183	35.150	RCC Slab	1 x 1.5	11.2	14.0m	Widening
47	37.487	37.450	RCC Slab	1 x 1.5	12	14.0m	Widening
48	38.921	38.890	RCC Slab	1 x 1.5	11	14.0m	Widening
49	39.862	39.830	RCC Slab	1 x 1.5	12	14.0m	Widening
50	40.142	40.110	RCC Slab	1 x 1.5	11.6	14.0m	Widening
51	40.894	40.800	RCC Slab	1 x 1.5	8.8	14.0m	Widening

Note: Culverts which are to be reconstructed/widening shall be in accordance with para 7.3 (iii) of Manual.

(b) Construction of New Culverts - Nil

Besides the above, the provision of Hume pipe / slab culverts at junctions of cross roads shall be provided / augmented as per site requirement in consultation with Independent Engineer and it shall not be treated as change of scope.

9 Cost Estimates

9.1 Preliminary Construction Cost

The quantities of various item of work were worked out and major pavement quantities were derived on the basis of cross sections applied for various treatment options like reconstruction, strengthening and new construction recommended in the project road and also for different proposed lane configurations.

The cost estimates for the project road construction were developed from the basic unit rates of BSR of 2016, PWD Rajasthan. For the suggested pavement design and also on the basis of maintenance regime suggested for cross drainage structures, broad bill of quantities (enclosed at the end of the report) are worked out.

The Broad estimation of construction cost for **41.0 Km** of project road is given in **Table 9-1**

Table 9-1: Preliminary Construction Costs (INR)

Bill No.	Description of Items	Amount (Rs.)	Amount (Crores)	% cost
1	BILL NO. 1 – SITE CLEARANCE	39,13,351	0.39	0.48%
2	BILL NO. 2 - EARTHWORKS	353,63,701	3.54	4.37%
3	BILL NO. 3 – SUB-BASE COURSE & BASE COURSE	2065,89,100	20.66	25.54%
4	BILL NO. 4 – BITUMINOUS WORKS	3950,88,866	39.51	48.85%
5	BILL NO.5 - CULVERTS	216,62,819	2.17	2.68%
6	BILL NO.6 - BRIDGES, ROBs, FLYOVERS, UNDERPASSES, ETC	165,90,899	1.66	2.05%
7	BILL NO. 7– DRAINAGE AND PROTECTION WORK	206,81,225	2.07	2.56%
8	BILL NO. 8 – TRAFFIC SIGNS, MARKINGS & OTHER ROAD APPURTENANCES etc.	239,36,000	2.39	2.96%
9	BILL NO. 9– TOLL PLAZA	450,00,000	4.50	5.56%
10	BILL NO. 10 – JUNCTIONS, BUSBAYS & TRUCK LAYBYE	209,44,000	2.09	2.59%
11	ILCPB shoulder for 8.2 Km in 4-L DCW section (1.5m wide) both sides	190,65,000	1.91	2.36%
	TOTAL COST	**8088,34,961**	**80.88**	**100%**
	Add Contingency (Physical & Price Contingency, risk Premia & financing cost etc) @25%	2022,08,741	20.22	
	Total Project Cost	**10110,43,702**	**101.10**	

10 Financial Analysis

Project is financially viable for the VGF less than 40%.

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11 Social Impact Assessment

Social impact assessment (SIA) for the project road is provided as a separate attachment.

12 Environmental Impact Assessment

Environmental impact assessment (EIA) for the project road is provided as a separate attachment.

13 Bill of Quantities

Detailed bill of quantities for the project road is provided as a separate attachment.

Annexure

Annexure – 1: Road Inventory Details
Annexure – 2: Pavement Condition Survey Details
Annexure – 3: CD Structures Inventory Details
Annexure – 4: CD Structures Condition Survey Details
Annexure – 5: Traffic Survey Hourly and Day-wise Data
Annexure – 6: Benkelman Beam Deflection Data