Roads and Buildings Department

Government of Gujarat

Second Gujarat State Highway Project

GHG Emission Inventory

February 2017

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1 INTRODUCTION

1.1 Background

The Gujarat State Highways Project – II (GSHP-II) project funded by the World Bank is in active progress. The project has reached its mid-term stage of implementation in December 2016. Based on an updated strategic options study (SOS) and subsequent feasibility studies about 652 km. of the pre-identified roads were selected as part of GSHP II. Detailed engineering designs on the basis of the environmental, engineering, social and economic criteria were carried out for these roads. These DPRs included a detailed EIA as required. The GSHP II corridors, identified for implementation are as indicated in the Table 1-1.

Table 1-1: GSHP II Corridors – Works Details

Sr. No.	Pkg. No.	Name of work	Length KM	Estd. Cost Rs. in million	US $ Equiv. in Million	Const. Period (Month)
1	GSHP-II/NCB/01	Dabhoi-Bodeli (Amod-Karjan-Dabhoi)	66.80	1456.00	24.27	24
2	GSHP-II/NCB/02	Bayad – Dhoridungri - Lunawada Road	44.20	942.90	15.72	24
3	GSHP-II/NCB/03	Atkot-Gondal (Atkot-Paliyad) Road	51.50	116.80	1.95	24
4	GSHP-II/NCB/04	Karjan-Borsad	55.15	589.97	9.83	15
5	GSHP-II/NCB/05	Umreth-Vasad (including Kapadvanj-Ladvel)	41.03	1017.23	16.95	24
6	GSHP-II/NCB/06	Savarkundla-Dhasa,	46.58	656.00	10.93	15
7	GSHP-II/NCB/07	Dhansura - Malpur - Meghraj.	43.26	614.96	10.25	24
8	GSHP-II/NCB/08	Lunavada – Santrampur - Khedapa	54.05	1181.27	19.69	24
9	GSHP-II/NCB/09	Tharad –Deesa	29.89	331.50	5.53	11
10	GSHP-II/ICB/01	Mehsana-Himmatnagar Road (Modified Annuity)	60.00	334.80	55.80	12 Year Concession Period
11	GSHP- II/ICB/02	Dhandhuka - Dholera, Paliyad - Dhandhuka and Limbdi - Dhandhuka, (OPRC) * Surendranagar-Limbdi	130.00	2577.40	42.96	10 Year Concession Period
12	Road Safety	Bharuch-Dehgam, (Road Safety Demo Corridor) *Ankleshwar –Valia,	29.90	60.00	10.00	-
		Total	**652.36**	**9878.83**	**223.88**	

* Since Declared as National Highway later on i.e. after signing the loan agreement, both these corridors have been dropped form the purview of WB funded GSHP II.

The proposed project activities are generally restricted to the existing RoW except for certain minor realignments, to improve sub-standard geometric characteristics, short bypasses / detour to avoid urban settlements and related social issues. Hence, RoW has been the direct influence area, and an area covering 10 km. on either side of the road corridors has been considered as the indirect influence area of the project.

The road sections showing high natural or social environmental problems were screened out due to the high associated costs and resulting lower returns on investment (after conducting careful cost benefit analysis).

1.2 CONTEXT OF ANALYSIS

The GSHP II takes on board the World Bank's operational policies regarding environmental concerns within the project design and implementation. With the recent developments of Climate Change initiatives in the World Bank, it was recognized that Greenhouse Gas Analysis for transport is crucial for a greater role of transport in mitigation policies[1]. It was further emphasized during the World Bank Mid Term Review Mission to GSHP-II that GHG emissions analysis for investment lending is a corporate requirement, and is a part of the appraisal package preparation. The World Bank is also preparing a guidance note for project level GHG Emission Analysis, which states that at the stage for clearance and concurrence of the Negotiations package, Task Team Leaders are required to report GHG accounting estimates for the "With Project" and "Without Project" scenarios.

The present analysis of GHG for GHSP – II is a pilot analysis for Indian context of transport projects where the World Bank document on 'GHG Analysis for Low Emission Transport' by Mr. Andreas Dietrich Kopp provides the necessary guidance. All parameters as mentioned in the guidance note have been studied and data is collected for the project to apply the GHG emission analysis.

This pilot analysis is aimed at identifying the level of analysis, data availability and any issues faced by the consultants in undertaking the GHG Analysis. Further, this pilot analysis is used by the World Bank to assess the extent of data to be collected in the Indian Project context and any specific guidance that need to be provided to the consultants.

The GHG Emisison Inventory was not part of the GHG Analysis carried out for the project during the project preparation stage. However, with the extensive data available with the Roads and Buildings Department, GoG, which has been built upon during last two decades of project implementation from the World Bank support, it was presumed that GHG Emission Inventory and Analysis would not have data availability issues in GSHP context. The Project Management Consultants (PMC) have been entrusted the task of pilot GHG Emission Inventory and Analysis for GSHP-II leveraging the experience of several projects in India where GHG Analysis for transport projects during the design stage. The following sections of this document present an Inventory of GHG Emissions from the GSHP-II project

[1] GHG Analysis for Low-emission Transport, ANDREAS DIETRICH KOPP

2 GHG Emissions

With the unequivocal acceptance of the phenomenon of Climate Change due to anthropogenic activities, it has become imperative to be aware of the GHG emissions that are being released into the earth's system with the burning of fossil fuels from proposed interventions of the project. The GHG emission inventory for entire project is worked out for operation stage impacts. This section is aimed at providing a brief outlook on the GHG emissions and the context of the analysis.

2.1 GHG Emissions

Human activities result in emissions of four principal greenhouse gases: Carbon Dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O) and the halocarbons (a group of gases containing fluorine, chlorine and bromine). These gases accumulate in the atmosphere, causing concentrations to increase with time. Significant increases in all of these gases have occurred in the industrial era (*IPCC fourth Assessment Report, 2007 (AR4), Chapter 2*).

As per the IPCC Fifth Assessment Report, 2014, it is stated that "*Annual anthropogenic GHG emissions have increased by 10 GtCO2eq between 2000 and 2010, with this increase directly coming from energy supply (47 %), industry (30 %), transport (11 %) and buildings (3 %) sectors (medium confidence)*". It further confirms, "*Globally, economic and population growth continue to be the most important drivers of increases in CO2 emissions from fossil fuel combustion. The contribution of population growth between 2000 and 2010 remained roughly identical to the previous three decades, while the contribution of economic growth has risen sharply (high confidence)*".

Even with the development of more fuel efficient vehicles since the introduction of Bharat II standards in India, the emissions from road transport contributed to 11 to 13% of the overall GHG emissions. This could be attributed to the increase in GDP of the country as a strong correlation between economic growth and GHG emissions has been widely recognised with a high degree of confidence in the analysis. However, the per capita transport emission correlates strongly with annual income but can differ widely even for regions with similar income per capita (*IPCC Fifth Assessment Report, 2014*).

With the development of roads, there will be increased motorized mobility which will produce large increases in GHG emissions but give significant social benefits such as better access to markets and opportunities to improve education and health. Travel patterns vary with regional locations and the modes available.

Assessments of transport GHG emissions require a comprehensive understanding of trends and drivers that impact on the movement of goods and people. As economies have shifted from agriculture to industry to service, the absolute GHG emissions from transport and the share of total GHG emissions by the transport sector have risen considerably.

As the GHG Emissions are of varying nature and composition, only the gases identified to be from Vehicular Emissions are considered. There are more than eighty types of greenhouse gases, but the scope of the present study is limited to top three concentrations of GHG emissions i.e., the CO2, CH4 and N2O. The water vapour component i.e., H2O as a greenhouse gas is not a by-product of the petrol or diesel engine exhaust and hence, it has not be included as part of the emission inventory.

2.2 GHG Emission Trends

The GHG Emissions as observed in the project tend to depend heavily on the volume of traffic and usage of heavy vehicles. The immediate short term period of five to ten years of design and implementation period involves an increasing trend of emissions for heavy duty passenger vehicles. The long term period of fifteen to twenty years indicate a saving of GHG emissions when compared with the without project scenario. In rest of the modes of transport, there are savings in GHG Emissions throughout the design, construction and operation periods.

In terms of the overall trend, total transportation CO2 emissions increased by more than 15% due, in large part, to increased demand for travel as fleet wide light-duty vehicle fuel economy was relatively stable. The number of light-duty motor vehicles (i.e., passenger cars and light-duty trucks) increased manifold during the last three decades, as a result of a confluence of factors including population growth, economic growth, urban sprawl, and low fuel prices during the beginning of this period. Almost all of the energy consumed for transportation was supplied by fossil fuel based products, with more than half being related to petrol / diesel consumption in automobiles and other highway vehicles. The trends are presented in detail in the next section.

2.3 Global Warming Potential

Gases in the atmosphere can contribute to climate change both directly and indirectly. Direct effects occur when the gas itself absorbs radiation. Indirect radiative forcing occurs when chemical transformations of the substance produce other greenhouse gases, when a gas influences the atmospheric lifetimes of other gases, and/or when a gas affects atmospheric processes that alter the radiative balance of the earth (e.g., affect cloud formation or albedo). The IPCC developed the Global Warming Potential (GWP) concept to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas.

The GWP of a greenhouse gas is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kilogram (kg) of a trace substance relative to that of 1 kg of a reference gas (IPCC 2013). Direct radiative effects occur when the gas itself is a greenhouse gas. The reference gas used is CO2, and therefore GWP - weighted emissions are measured in million metric tons of CO2 equivalent (MMT CO2 Eq.). All gases in this document are presented in units of MMT CO2 Eq.

UNFCCC GWP values from the IPCC Fifth Assessment Report (AR5) (IPCC 2014) are used throughout the report. The GWP values used in this report are listed below in **Table 2-1**. The Global Warming Potential (GWP)[2] of the considered gases for over 100 year period as presented below:

Table 2-1: Global Warming Potential (GWP)

Sl. No.	Type of GHG	Global Warming Potential
1	Carbon Di Oxide (CO_2)	1
2	Methane (CH_4)	28
3	N_2O	265

Source: Global Warming Potentials, IPCC Fifth Assessment Report, 2014 (AR5)

[2] Global warming potential (GWP) is a relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide.

2.4 Emission Factors

The estimation of emissions from the sources of fossil fuel combustion is carried out with the aid of Emission Factors of fuels for transport use for various modes as specified by the Emission Factor Database of IPCC. These emission factors are for GHG emissions i.e., the CO2, CH4 and N2O. GHG Emission Factors specifically for Indian vehicles are not available yet.

There are emission factors for pollution parameters like CO, NOx, SO2 but for GHG emissions, the EF are not available. Hence, IPCC EFDB as updated in 2006 is utilised for arriving at the emission factors in grams / litres of fuel burnt. The emission factor is adjusted for the densities of fuel available in Indian conditions based on the specifications of Indian Oil Corporation fuel data. Hence, the GHG emissions derived out of the application of IPCC EFDB emission factors are presumed to represent the local fuel available.

The emission factors are based on several factors as the mode, gross vehicle weight, emission regulations followed. In all cases, the specified vehicle characteristics are matched to the Indian conditions and emission factors are selected. With respect to the emission regulations, since the Bharat Standards of vehicular emissions are closely related to the Euro Standards, the emission factors of the vehicles that are adopting Euro Standards are selected. The Emission Factors used in this study are listed as in the below **Table 2-2**.

Table 2-2: Emission Factors by Mode and Fuel Type

Mode	Fuel	CO2	CH4	N2O	Combined EF, in CO2e
Car	Petrol	2289.6	0.216	0.576	2448.29
2-wheel	Petrol	2289.6	3.6	0.036	2399.94
Auto	CNG	2750	14.5	1.461	3543.11
Taxi	CNG	2750	14.5	1.461	3543.11
Bus	CNG	2750	13.3	0.353	3216.08
LCV	Petro	2289.6	0.576	0.043	2317.18
LCV	Diesel	2574.8	0.049	0.164	2619.64
2 Axle	Diesel	2574.8	0.164	0.082	2601.12
3 Axle	Diesel	2574.8	0.164	0.082	2601.12
MAV	Diesel	2574.8	0.164	0.082	2601.12

Note: The emissions are in g/lit for petrol and diesel and g/kg for CNG (2) GWP for CO_2 is 1; for CH_4 is 28 and N_2O is 265. To calculate the combined EF in CO_2e, the emission factors need to be multiplied with GWP.

Reference: IPCC Emission Factor Database (IPCC-EFDB), 2006

http://www.ipcc-nggip.iges.or.jp/EFDB/main.php

IPCC Source Category	Mode & Fuel and GHG type	Source of Data & Assumptions as per IPCC EFDB	Emission Factor Detail (ID) for GHG as per IPCC EFDB 2006		
			CO2	CH4	N2O
1.A.3.b - Road Transportation	Car, Petrol	Estimated EF for European Cars with Three Way Catalyst	19188	19176	19185
	2-wheelers, Petrol	Estimated EF for European Motorcycles >50cc 4 stroke Uncontrolled: Assumed Fuel Economy 19.6 km/l	19350	19338	19347
	Auto, CNG	Estimated emission factors for US Light - and Heavy - Duty Natural Gas Vehicles (Passenger Cars): Advanced Control: Assumed Fuel Economy: 14.9 km/m3	19365	19356	-
		Emission Factor for Alternative Fuel Vehicles: LDV	-	-	118726
	Taxi, CNG	Estimated emission factors for US Light -	19425	19356	-

IPCC Source Category	Mode & Fuel and GHG type	Source of Data & Assumptions as per IPCC EFDB	Emission Factor Detail (ID) for GHG as per IPCC EFDB 2006		
			CO2	CH4	N2O
		and Heavy - Duty Natural Gas Vehicles (Passenger Cars): Advanced Control: Assumed Fuel Economy: 14.9 km/m3			
		Emission Factor for Alternative Fuel Vehicles: LDV	-	-	118726
	Bus, CNG	Estimated emission factors for US Heavy - Duty Vehicles: Lean Burn Engine (compare with diesel): Advanced Control: Assumed Fuel Economy: 2.4 km/m3	19425	-	-
	Bus, CNG	Estimated emission factors for US Heavy - Duty Vehicles: Lean Burn Engine (compare with diesel): Advanced Control: Assumed Fuel Economy: 2.4 km/m3	-	19416	-
1.A.3.b.iii - Heavy-duty trucks and buses:	Bus, CNG	Emission Factor for Alternative Fuel Vehicles: Buses	-	-	118735
1.A.3.b - Road Transportation:	LCV, Petrol	Estimated emission factors for European Gasoline Light-Duty Vehicles with Moderate Control	19278	19266	19275
1.A.3.b - Road Transportation:	LCV, Diesel	Estimated emission factors for European Diesel Light-Duty Vehicles: Moderate Control	19242	19230	19239
1.A.3.b - Road Transportation:	2 Axle Truck, Diesel 3 Axle Truck, Diesel MAV, Diesel	Estimated emission factors for European Diesel Heavy-Duty Vehicles: Moderate Control	19260	19248	19257

2.5 GHG Analysis

The GHG Emissions are to be estimated based on the method suggested by the Draft World Bank Guidance Note titled, "GHG Analysis for Low-emission Transport", by Andreas Dietrich Kopp, 2015. The note provides a guidance on various parameters that will be required for GHG Analysis in time series i.e., for past few years, which will be projected for the proposed design period of the project.

A summary of the method suggested as per the document is presented in the box below:

BOX – 1: GHG Analysis as Per Low – Emission Transport Guidance Document, 2015 (Draft)

The document provides an excel worksheet for analysis of GHG Emissions. There is a worksheet for each of the mode of transport to work out the emissions.

As per the document, each modal sheet includes historical trend data, the discrete changes due to project or policy interventions and forecasts for trend changes in the post-project situation. Historical data for the trends driving transport demand are required to estimate the parameters of user responses. They are included in the sheets to calculated changes in GHG emissions to allow an immediate check on the plausibility of the forecast of developments after the implementation of the project.

Each modal sheet contains three parts for past trends, potential policy interventions, and future developments

a. for socio-economic and demographic developments,

b. for monetary and time costs as well as quality indicators, and

c. for vehicle and fuel use (including potential changes in vehicle and fuel technologies) to calculate summary changes in fuel use and emissions.

The three parts report endogenous trend changes as well as project- and policy-impacts on transport supply and the drivers of demand.

How projects and policies impact on trend developments is calculated by using behavioral parameters indicated on the top of the columns. The parameters indicate quantitative responses of passengers in their demand for modal transport services. The estimation of the behavioral parameters does not require data that go beyond what is included in the modal sheets. The estimation is done by using estimation tools made available to the project teams, and explained in the guidance note. The estimation procedure ensures that predicted market shares of all modes add up to one.

Socio-economic determinants of transport development

Baseline changes of transport demand are dominated by income changes. Income changes follow from changes in per-capita incomes and the number of users. Behavioral responses to income changes depend on per-capita or household income levels. If local data on income developments are unavailable, they may be approximated by using data of the lowest jurisdictional level that provides income time series. In general, behavioral responses reflect a shift from non-motorized transport to mass transit and individual motorization with incomes increasing from low- to middle- to high-income levels. At the local level government policies (settlement projects, changes in the zoning regulation) can strongly change the number of potential users of the transport system, and therefore local transport demand.[3]

Price and quality determinants of transport demand

Modal travel demand depends on monetary time costs, travel times and quality characteristics of the different modes. Trends in monetary costs will differ between the different modes. For individual motorized transport they will be strongly influenced by gasoline and diesel prices. Without significant levels/trend changes in infrastructure charges they should dominate the development of monetary costs. In the absence of local data on fuel prices, trends could be approximated by the forecasts of the IEA and expected exchange rate developments. This may also hold for taxis and minibuses, unless there prices were administered by government agencies or regulators. In the latter case future price information should be obtained from these agencies. The same holds for ticket prices of bus and rail operations.

Travel times are in general of greater importance for modal transport demand than monetary costs. For individual vehicle use travel time is only in-vehicle time. They, in turn, depend on congestion, i.e. the number of vehicles in use relative to the infrastructure capacity. In the absence of direct survey information on travel times, we can approximately calculate trip durations from traffic density – speed relationships, using road capacity statistics (lane-km) and statistics on registered vehicles.[4] In-vehicle travel times for taxis and mini-buses can be determined in the same way. Waiting times for taxis and mini-buses depend on local service densities and market forms (cruising vs. queuing markets)

For bus and rail services, in-vehicle travel times are determined by schedules. The schedules also determine the waiting times. They are usually approximated as being half the differences between

[3] Recent discussions of benefit taxation in transport infrastructure investment (or “transit-oriented development”) focus on rent and settlement changes which are induced by investment in transport infrastructure. To account for such changes in the framework is straightforward but requires a revision of the estimation of the behavioral parameters, to simultaneously capture travel and location decisions.

[4] Cf. Vanek et al (2014) and Small and Verhoef (2007)

departure times.

Policy induced changes in in-vehicle travel times for individual mobility and minibuses are achieved by investment in road infrastructure, or improvements in vehicle-stock. Investment in transport infrastructure reduces the ratio of average usage to infrastructure capacity and reduces travel times according to the relevant speed-density relationship. For scheduled bus and rail services, travel time reduction may be possible with an upgrading of the rolling stock. They will be reflected in the rescheduling of services.

Other quality changes influence the distribution of transport demand across modes. Discrete improvements of the convenience of buses, improvements in security can for example increase considerably the attractiveness of mass transit.[5]

The third part of the modal GHG accounting sheets translates changes in passenger-km into changes in vehicle-km, changes in fuel use and emissions.

As changes in emissions depend on vehicle-usage, the developments in passenger-km (trend changes and policy-induced changes) have to be translated into changes in vehicle use. This is done by dividing the values for passenger-km by the relevant occupancy rates. Occupancy rates will usually not change very much for individual vehicles (changes in passenger demand will be closely related to changes in vehicle use) while changes in demand for bus and rail services often lead to changes in the occupancy rate as the rolling stock does only gradually change over time.

Changes in fuel use are calculated by multiplying changes in vehicle-km by fuel coefficients. An average value for the change in fuel use can be obtained by using the average fuel coefficient for the average vehicle type. The table can be differentiated to allow more multiple vehicle and fuel types. The third section of the modal sheet shows the trend changes and policy induced changes in fuel use.

Changes in GHG emissions are calculated multiplying the changes in fuel use by emission factors. The emission factors could be obtained from local regulatory agencies, in case fuel qualities are regulated. The modal tables account for possible changes in fuel coefficients and emission coefficients by new technical standards for engines and fuels implemented by regulatory agencies. Standard values are available from the IPCC air pollutant data base, containing national reports.[6]

A cover sheet summarizes the changes across modes. It indicates total changes in GHG for individual modes and the total emission reduction across modes.

2.6 Limitations of data

With the GHG Emission method described in the previous section, data has been collected for all the parameters required to undertake the analysis. However, there are several data gaps that were to be addressed before application of the method for analysis. The availability of data for all parameters in time series has been assessed prior to implementation of the suggested method. The issues and limitations of data availability and quality of data for various parameters is presented in the below paragraphs.

[5] Discrete quality changes enter the estimation of behavioral parameters as dummy variables, with the value 0 before and 1 after the improvement.
[6] www.apef-library.fi, as North American reference Davis, Diegel and Boundy (2013), for Europe EMEP/EEA (2013)

Elasticity Factors:

Effect of income change on the traffic can be determined through the use of income elasticity if empirical equations are available. But these empirical equations or value of "Income Elasticity" are not available in the Indian context. The Road Development Plan, 2001 provides elasticity values for three modes – cars, bus and trucks for the five year periods from 2001 to 2021. However, state level or district level details of elasticity are not available. Given that constraint, the income elasticity is to be assumed as 1 and the change to be nil. Similar situations have been come across different elasticity factors i.e., Change in Passenger Kilometer Travelled (PKT) due to Fuel Price, Speed, Road Capacity etc.,. In all these cases the elasticity values had to be assumed as 1 and change to be nil in order to proceed with the computations.

Policy change

There are several factors that contribute to the change in traffic characteristics, distribution and modal choice. The policies of the government that affect these factors contribute significantly to the changes in the traffic for a particular geography or across the nation. Although these may or may not be related to the transport sector in particular, they have an impact on the traffic characteristics and projections. These changes were proposed to be captured as part of the above methodology for quantification of these effects of policy change. But there are no studies or guidelines on how to incorporate the relevant changes into the quantification of change in PKT or traffic. Hence, no policy change factors could be incorporated into the calculation of GHG Emissions consequently as per the proposed methodology.

Occupancy rate

Occupancy rates are not usually captured during the traffic surveys except for public transport modes. For private transport modes, a very minute sample is collected if not nil, in the traffic surveys. In case of GSHP-II occupancy rates are available from the traffic surveys, hence this has been used. However, for projection of occupancy rates, there are no specific algorithms and hence, the maximum occupancy rate of the particular mode has been used for projections. These occupancy rates provide for estimation of VKT or conversion of PKT to VKT and vice-versa as per the proposed methodology for GHG emission estimations.

Change in Fuel use with Regualtory Changes in Fuel characteristics

The changes in regulatory characteristics are hypothesised to have its impact on its usage in vehicles as per the guidance note. The approach and methods to capture these changes are not available for translating into vehicle usage / VKT. This is one of the limitations that could not be addressed as part of the methodology implemented for estimating the GHG emissions.

Emission Factors

Emission Factors for estimation of GHG is required for each mode of vehicles and by fuel type. While emission factors are available for Indian vehicles for pollution parameters as indicated in the previous sections, EF for GHG are not yet developed. Hence, IPCC Emission Factors Data base are used, which is perceived to be a limitation as no specific factors are available for driving and traffic conditions in India.

2.7 Alternative Method of GHG Analysis

On application of the above suggested method of GHG Analysis, with the above limitations, the output turns out to be similar to methods being used in India for estimation elsewhere in other projects. A sample of the method used for GHG analysis using the suggested World Bank Methodology is provided as Annexure 2.1.

In view of this scenario, an alternative method as an interim method analysis is suggested in this section. This method utilises the existing economic analysis methods using RUCS 2001 and estimation of fuel coefficients. The steps involved in this method are as indicated below:

- Application of the Road User Cost Study, 2001 as per the IRC for estimating the fuel coefficients
- Application of the RUCS 2001, for working out the traffic volumes by fuel use and mode
- Application of the RUCS 2001, to work out the vehicle – km travelled
- Application of the Emission Factors for estimation of GHG
- Consolidation of Emissions for GHG estimation across the entire project

3 GHG Emissions Inventory

The estimation of GHG Emissions is carried out using the alternative methodology discussed in the previous section. The GSHP-II corridors were subjected to economic analysis as per the Road User Cost Study 2001 equations. The fuel coefficients calculated as per the RUCS 2001, provides the fuel use as per the methodology provided by each corridor and fuel type. The IPCC Emission Factors are applied subsequently for each corridor over the economic life of the project.

The project period for widening and upgradation projects is 30 years while the project period for maintenance corridors is 15 years. The estimation of emissions are carried out upto 2026 for the entire project.

A summary of the emissions estimated are presented in the Table 3-1.

Table 3-1: Summary of GHG Emissions in the Project (with project scenario)

Year	GHG in tCO2e / year											
	1a. Dabhoi Bodeli	1b. Amod Karjan	2A. Bayad Lunavada	3a. Atkot Gondal	3b. Atkot Paliyad	4. Karjan Borsad	5. Umreth Vasad	6. PM Savarkundla Dhasa	7. Dhansura Meghraj	8. Lunawada Khedapa	9. Tharad Deesa	Total GHG, GSHP-II
2016	53764	33141	10233	23826	33141	18158	29086	14950	4967	16964	35302	273533
2017	56957	35056	10739	25084	35056	19383	30930	15868	5206	17728	37878	289884
2018	60363	36979	11271	26411	36979	20615	32905	16799	5456	18528	40417	306726
2019	64024	38917	11831	27813	38917	21860	35023	17749	5719	19368	42985	324206
2020	67923	40859	12421	29294	40859	23108	37295	18713	5995	20249	45559	342275
2021	71927	42626	13035	30882	42626	24199	39616	19552	6282	21175	48071	359990
2022	76275	43867	13687	32583	43867	24622	42113	20493	6586	22143	50517	376753
2023	80675	45617	14373	34374	45617	25686	44429	19314	6906	23160	53020	393172
2024	85340	47377	15096	36269	47377	26755	46881	20055	7242	24227	55532	412151
2025	90285	49036	15858	38273	49036	27751	49478	20700	7596	25346	58054	431412
GHG, tCO2e Total	**707533**	**413475**	**128545**	**304808**	**413475**	**232137**	**387757**	**184193**	**61956**	**208888**	**467334**	**3510103**

A similar method is used for estimating emissions without project as indicated in the Table 3-2.

Table 3-2: Summary of GHG Emissions in the Project (without project scenario)

Year	GHG in tCO2e / year											
	1a. Dabhoi Bodeli	1b. Amod Karjan	2A. Bayad Lunavada	3a. Atkot Gondal	3b. Atkot Paliyad	4. Karjan Borsad	5. Umreth Vasad	6. PM Savarkundla Dhasa	7. Dhansura Meghraj	8. Lunawada Khedapa	9. Tharad Deesa	Total GHG, GSHP-II
2016	56404	33499	10182	24067	33499	18501	31678	15542	5157	16966	34617	280114
2017	60116	35489	10703	25411	35489	19799	33975	16585	5443	17732	37222	297964
2018	64102	37497	11255	26861	37497	21114	36470	17657	5751	18536	39853	316592
2019	68430	39524	11839	28439	39524	22448	39183	18761	6085	19380	42122	335734
2020	73272	41591	12426	30076	41591	23800	42063	19906	6406	20255	44741	356127
2021	78626	43044	13076	31939	43044	24626	45125	20274	6783	21183	47313	375033
2022	84589	44984	13765	33971	44984	25855	48458	21358	7186	22159	49920	397229
2023	91087	46942	14496	36159	46942	27114	52088	22474	7620	23184	52647	420753
2024	98177	48919	15273	38518	48919	28390	56048	23622	8088	24262	54854	445072
2025	105590	50941	15969	40937	50941	29685	60107	24805	8488	25352	57583	470398
GHG, tCO2e Total	**780394**	**422430**	**128986**	**316379**	**422430**	**241332**	**445195**	**200983**	**67007**	**209009**	**460872**	**3695017**

The above analysis has been taken further forward to estimate the quantity of GHG Savings achieved from the project during the ten year period. However, it may be noted that the projections does not account for any emissions arising out of the construction activities. The amount of GHG savings is presented in the Table 3-3.

Table 3-3: Total GHG Savings in the Project Corridors

Year	GHG Savings in tCO2e / year											
	1a. Dabhoi Bodeli	1b. Amod Karjan	2A. Bayad Lunavada	3a. Atkot Gondal	3b. Atkot Paliyad	4. Karjan Borsad	5. Umreth Vasad	6. PM Savarkundla Dhasa	7. Dhansura Meghraj	8. Lunawada Khedapa	9. Tharad Deesa	Total GHG Savings, GSHP-II
2016	2640	358	-51	242	358	343	2592	592	190	2	-685	6581
2017	3159	433	-36	327	433	416	3045	716	237	4	-656	8080
2018	3739	518	-16	449	518	499	3565	858	295	7	-565	9867
2019	4406	607	8	626	607	588	4160	1012	366	12	-863	11528
2020	5349	733	5	782	733	692	4768	1192	411	6	-818	13853
2021	6700	418	41	1057	418	426	5510	722	501	9	-758	15044
2022	8314	1117	78	1388	1117	1233	6345	865	600	15	-597	20476
2023	10412	1325	123	1785	1325	1428	7659	3160	714	24	-374	27581
2024	12837	1543	177	2249	1543	1635	9167	3567	845	36	-678	32920
2025	15304	1905	111	2665	1905	1934	10629	4105	892	5	-470	38986
GHG Savings, tCO2e Total	**72861**	**8955**	**441**	**11570**	**8955**	**9195**	**57438**	**16790**	**5051**	**121**	**-6462**	**184914**

APPENDICES

GHG Emissions as per the World Bank Recommended Method

A	B	C	D	E	F	G	H
					Initial ridership, pkt private vehicles		Initial ridership, pkt private vehicles
					Elasticity Input		Elasticity Input
Socio-demographic data	Year	Income per capita, trend	Population, trend	Aggregate income changes in %	Change in pkt due to income change	Policy change	Policy induced pkt change, income
	2005	20000	55000000		0	0	0
	2006	21130	55848522	5.65%	0	0	0
	2007	23090	56968786	9.28%	0	0	0
	2008	25302	57952508	9.58%	0	0	0
	2009	27692	59023654	9.45%	0	0	0
	2010	30311	60109239	9.46%	0	0	0
	2011	33337	61206342	9.98%	0	0	0
	2012	36753	62173940	10.25%	0	0	0
	2013	40507	63176173	10.22%	0	0	0
	2014	44637	64207337	10.19%	0	0	0
	2015	49178	65269486	10.17%	0	0	0
	2016	53455	66358352	8.70%	0	0	0
	2017	58114	67454105	8.72%	0	0	0
	2018	63177	68570422	8.71%	0	0	0
	2019	68699	69687956	8.74%	0	0	0
	2020	74703	70826192	8.74%	0	0	0
	2021	79392	71985561	6.28%	0	0	0
	2022	84374	73166505	6.28%	0	0	0
	2023	89666	74369474	6.27%	0	0	0
	2024	95287	75594931	6.27%	0	0	0
	2025	101258	76843348	6.27%	0	0	0

I	J	K	L	M	N	O	P	Q	R	S	T	U	V
			Initial ridership, pkt private vehicles										
			Elasticity Input		Elasticity Input			Formula Input	Elasticity Input				
Modal data private vehicles	Gasoline price, trend	Diesel price, trend	Change in pkt due to price change	Policy change	Policy induced pkt change, fuel price	Average number of cars per day	Road capacity	Car speed	Change in pkt due to speed change	Policy change	Policy / Project induced pkt change, road capacity	Total trend change in pkt, G+M+S (F+L+R)	Project and policy induced change in pkt, I+G+U (H+M+S), H+M+T*
	46	35	0	0	0	592	2000	40	0	0	56000	0	0
	50	37	0	0	0	626	2000	40	0	0	56000	0	0
	48	35	0	0	0	660	2000	40	0	0	56000	0	0
	53	38	0	0	0	695	2000	40	0	0	56000	0	0
	46	35	0	0	0	730	2000	40	0	0	56000	0	0
	55	40	0	0	0	898	2000	40	0	0	56000	0	0
	68	45	0	0	0	704	6000	40	0	0	252000	0	0
	75	49	0	0	0	739	6000	40	0	0	252000	0	0
	75	57	0	0	0	776	6000	40	0	0	252000	0	0
	75	62	0	0	0	815	6000	40	0	0	252000	0	0
	71	55	0	0	0	856	15000	55	0	0	840000	0	0
	70	55	0	0	0	899	15000	55	0	0	840000	0	0
	72	57	0	0	0	944	15000	55	0	0	840000	0	0
	75	60	0	0	0	991	15000	55	0	0	840000	0	0
	77	62	0	0	0	1040	15000	55	0	0	840000	0	0
	80	65	0	0	0	1092	15000	55	0	0	840000	0	0
	82	67	0	0	0	1147	15000	55	0	0	840000	0	0
	85	69	0	0	0	1204	15000	54	0	0	840000	0	0
	87	72	0	0	0	1265	15000	54	0	0	840000	0	0
	90	74	0	0	0	1328	15000	54	0	0	840000	0	0
	92	77	0	0	0	1394	15000	54	0	0	840000	0	0

* Corrected based on guidance provided in the note as there were changes in the column ID in the work sheet provided

W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
								2.44829					
Changes in GHG Emissions per Mode	Occupancy rate	Total trend change in vkt, V/Y (U*X) (U/X)*	Total policy or project change in vkt, W/Y (V*X) (V/X)*	Fuel coefficient (liter / vkt) WO Project	Regulatory change in fuel standards	Policy / Project induced change in fuel coefficient	Total induced change in fuel use, AAxAB (Z*AA)*	Induced changes in emissions, AA x AF5 (tCO2e) (AB*AC)*	Total change in GHG emissions private vehicles, (V+W)xADxAF5 [(U*V)+AA+AC]*	Total change in GHG emissions private vehicles at full road capacity	Total GHG emissions CARS With Project, tCO2e / year	Total GHG emissions CARS Without Project, tCO2e / year	Total Change in GHG emissions CARS
	2	0	0	0.0566	1.0000	0.0566	0.0000	0.0566	0.11313	1396	413	413	0.00
	2	0	0	0.0565	1.0000	0.0565	0.0000	0.0565	0.11297	1394	436	436	0.00
	2	0	0	0.0564	1.0000	0.0564	0.0000	0.0564	0.11281	1392	459	459	0.00
	2	0	0	0.0563	1.0000	0.0563	0.0000	0.0563	0.11265	1390	483	483	0.00
	2	0	0	0.0562	1.0000	0.0562	0.0000	0.0562	0.11249	1388	507	507	0.00
	2	0	0	0.0562	1.0000	0.0562	0.0000	0.0562	0.11233	1386	622	622	0.00
	3	0	0	0.0561	1.0000	0.0561	0.0000	0.0561	0.11217	4152	487	487	0.00
	3	0	0	0.0560	1.0000	0.0560	0.0000	0.0560	0.11202	4147	511	511	0.00
	3	0	0	0.0559	1.0000	0.0559	0.0000	0.0559	0.11186	4141	536	536	0.00
	3	0	0	0.0558	1.0000	0.0558	0.0000	0.0558	0.11169	4135	562	562	0.00
	4	0	0	0.0562	1.0000	0.0564	0.0000	0.0564	0.11257	10430	595	594	-1.41
	4	0	0	0.0562	1.0000	0.0563	0.0000	0.0563	0.11246	10423	625	623	-1.79
	4	0	0	0.0561	1.0000	0.0563	0.0000	0.0563	0.11235	10415	655	653	-2.23
	4	0	0	0.0560	1.0000	0.0562	0.0000	0.0562	0.11223	10407	687	685	-2.73
	4	0	0	0.0559	1.0000	0.0562	0.0000	0.0562	0.11210	10399	721	718	-3.31
	4	0	0	0.0560	1.0000	0.0561	0.0000	0.0561	0.11217	10390	757	755	-1.29
	4	0	0	0.0560	1.0000	0.0564	0.0000	0.0564	0.11235	10437	798	792	-6.05
	4	0	0	0.0559	1.0000	0.0563	0.0000	0.0563	0.11223	10430	837	830	-6.99
	4	0	0	0.0558	1.0000	0.0563	0.0000	0.0563	0.11210	10422	879	871	-8.04
	4	0	0	0.0557	1.0000	0.0563	0.0000	0.0563	0.11197	10414	922	913	-9.22
	4	0	0	0.0558	1.0000	0.0562	0.0000	0.0562	0.11200	10406	967	960	-7.60

* Corrected based on guidance provided in the note as there were changes in the column ID in the work sheet provided