Department of Roads, Ministry of Physical Infrastructure and Transport
Federal Democratic Republic of Nepal

PREPARATORY SURVEY FOR KOTESHWOR INTERSECTION IMPROVEMENT PROJECT IN NEPAL

FINAL REPORT

ADVANCED VERSION

JANUARY 2024

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.
PADECO CO., LTD.
CTI ENGINEERING INTERNATIONAL CO., LTD.

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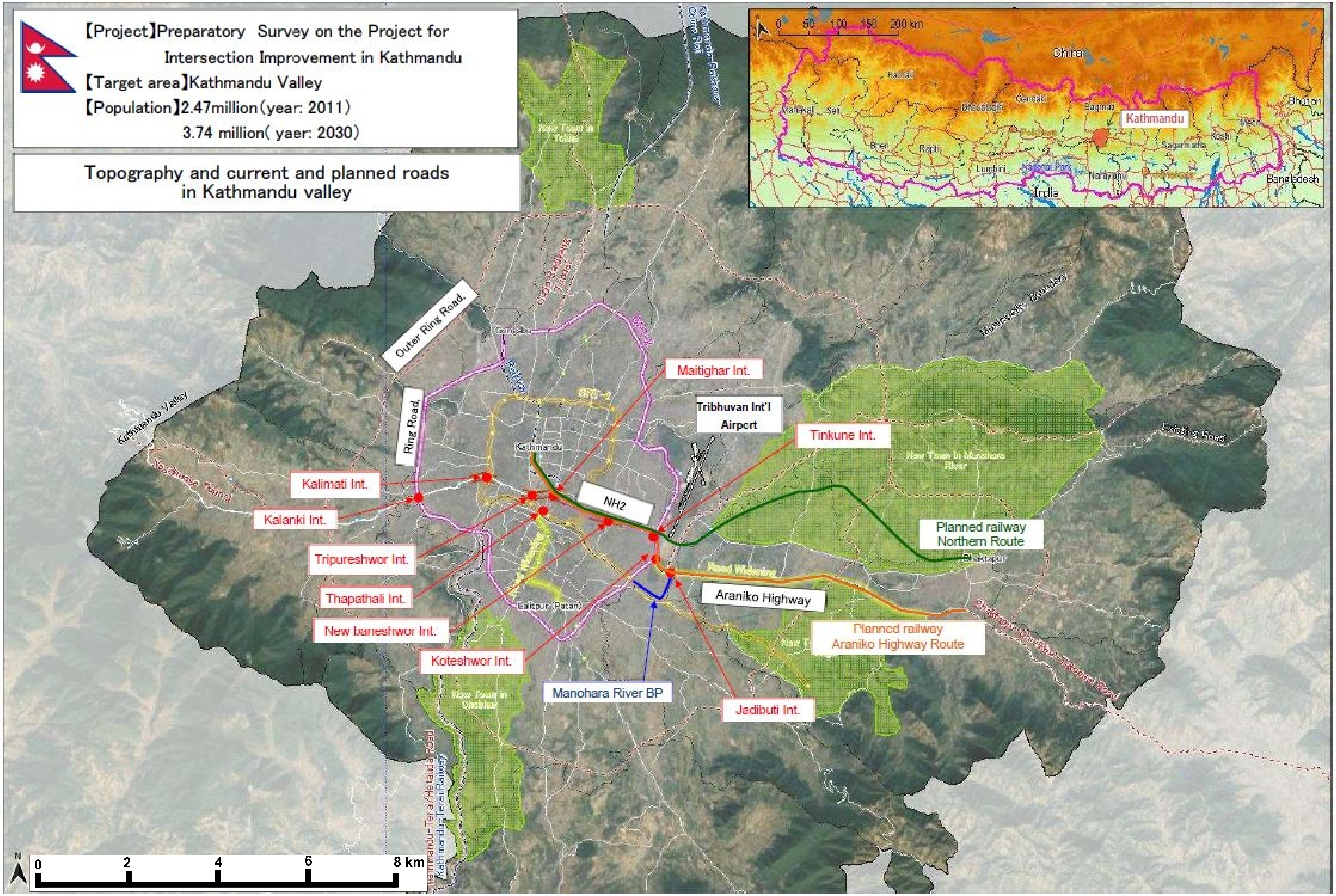
USD 1.00 = NPR 1.11 = JPY 145.0 (September 2023)

*NPR: Nepalese Rupee


【Project】Preparatory Survey on the Project for Intersection Improvement in Kathmandu
【Target area】Kathmandu Valley
【Population】2.47million(year: 2011)
3.74 million(yaer: 2030)
Topography and current and planned roads in Kathmandu valley
China
Kathmandu
Bhutan
Bangladesh
India
0 50 100 150 200 km
Outer Ring Road.
Ring Road.
Maitighar Int.
Tribhuvan Int'l Airport
Tinkune Int.
Kalimati Int.
Kalanki Int.
NH2
Tripureshwor Int.
Thapathali Int.
New baneshwor Int.
Koteshwor Int.
Manohara River BP
Jadibuti Int.
Araniko Highway
Planned railway Northern Route
Planned railway Araniko Highway Route
Kathmandu Valley
0 2 4 6 8 km

View-01
Overview of the Project

View-02
Start Point of the Project


View-03
Approach Section to Tinkune Intersection


View-04
Tinkune-West Intersection


View-05
Tinkune-South Intersection


View-06
Tinkune-South Intersection


View-07
Entrance to Box Culvert


View-08
Entrance to Box Culvert


View-09
Koteshwor Intersection


View-10
Koteshwor Intersection


View-11
Footpath Bridge Koteshwor Intersection


View-12
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View-13
To Jadibuti Intersection


View-14
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View-15
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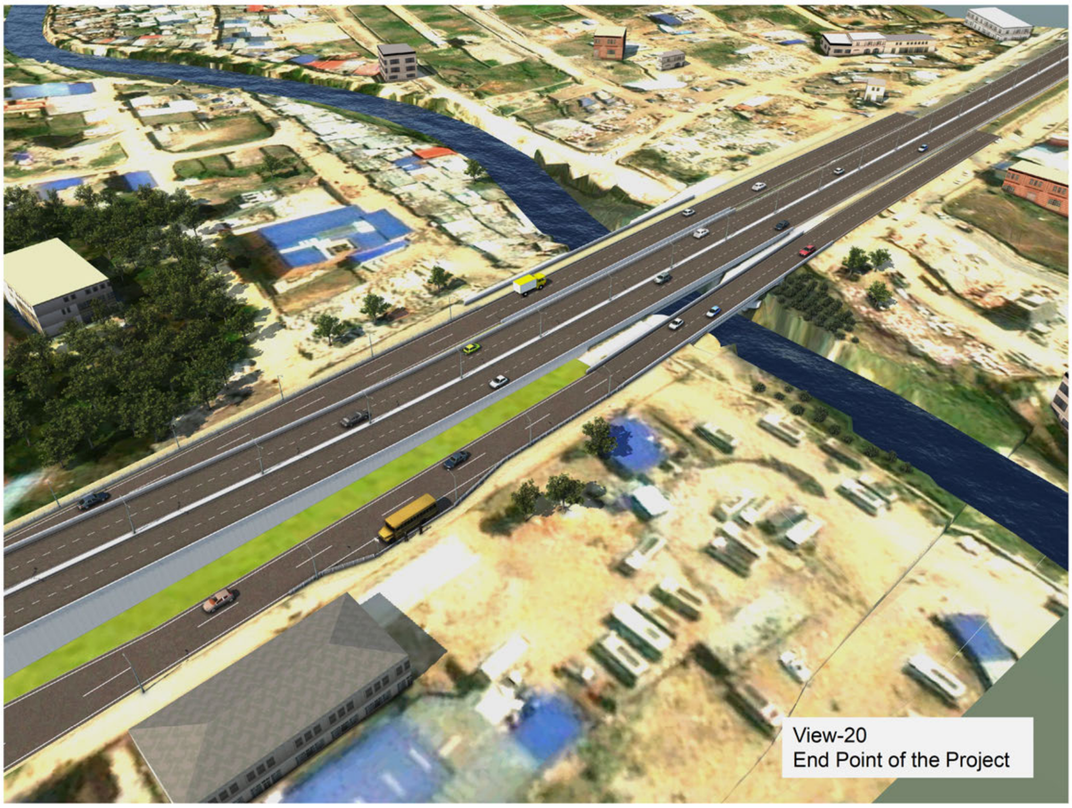
View-16
Approach to Jadibuti Intersection


View-17
Jadibuti Intersection


View-18
Jadibuti Intersection


View-19
Approach to Jadibuti Intersection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Preparatory Survey for Koteshwor Intersection Improvement Project

in

Federal Democratic Republic of Nepal

Final Report

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List of Abbreviations

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
AAGR	Average Annual Growth Rate
ADB	Asia Development Bank
ADB TA	Asia Development Bank Technical Assistance
ADT	Average Daily Traffic
AG	At-Grade
Alt	Alternative
AI	Artificial Intelligence
ARAP	Abbreviated Resettlement Action Plan
ARK	AranikoHighway
ASTM	American Society for Testing and Materials
BH	Bore Hole
BIM	Building Information Modeling
BOD	Biological Oxygen demand
BP	Bypass
BQ	Bill of Quantity
BRT	Bus Rapid Transit
C/Ps	Control Points
CAAN	Civil Aviation Authority of Nepal
CBS	Central Bureau of Statistics
CBR	California Bearing Ratio
CCCC	Chinese Communication Construction Company
CCES	Coating Cycle Extension Steel
CDC	Compensation Determination Committee
CFC	Compensation Fixation Committee
CIM	Construction Information Modeling/Management
CO	Carbon Oxide
CoI	Corridor of Impact
CRCC	China Railway Construction Corporation
C/P	Control Points
CSC	Construction Supervision Consultant
DDC	District Development Committee
DFR	Draft Final Report
DGPS	Differential Global Positioning System
DHV	Deign Hourly Vehicle
DME	Distance Measuring Equipment
DOLI	Department of Local Infrastructure
DOR	Department of Roads
DORW	Department of Railways
DOS	Department of Survey
DOTM	Department of Transport Management
DPR	Detailed Project Report
DRO	Division Roads Offices
DSM	Digital Surface Model
DX	Digital Transformation
EMU	Environmental Monitoring Unit
ENDP	Eastern New Town Development Project
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMP	Environmental Monitoring Plan
EPA	Environmental Protection Act
EPR	Environmental Protection Rules
E & S GL	Environmental and Social Guideline
ESMF	Environmental and Social Management Framework
ESS	Environmental and Social Standard
FRSMO	Federal Roads Supervision and Monitoring Offices
FHWA	Federal Highway Administration
FO	Flyover
FP	Floating Population
FR	Final Report
FS	Feasibility Study
FY	Finacial Year
G/A	Generation/Attraction
GDP	Gross Domestic Product

GESI	Gender Equality And Social Inclusion
GESU	Geo-Environment and Social Unit, Department of Road
GHG	Greenhouse Gas
GNSS	Global Navigation Satellite System
GON	Government of Nepal
GRC	Grievance Redress Committee
GRDP	Gross Regional Domestic Product
GRM	Grievance Redress Mechanism
GS	Grade Separation
GTV	Generated Traffic Volume
HCM	Highway Capacity Manual
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HPCIDBC	High Powered Committee for Integrated Development of the Bagmati Civilization
IA	Implementing Agency
ICB	International Competitive Bidding
ICAO	International Civil Aviation Organization
ICT	Information and Communication Technology
IEE	Initial Environmental Examination
IMF	International Monetary Fund
IoT	Internet of Things
IRC	The Indian Roads Congress
IRI	International Roughness Index
I/S	Intersection
ITR	Interim Report
JB	Jadibuti
JICA	Japan International Cooperation Agency
JICA E&S GL	JICA Guidelines for Environmental and Social Considerations (2010)
JIS	Japanese Industrial Standards
JST	JICA Survey Team
KMC	Kathmandu Metropolitan City
KPI	Key Performance Indicator
KSUTP	Kathmandu Sustainable Urban Transport Project
KTM	Kathmandu
KUKL	Kathmandu Upatyaka Khanepani Limited
KVDA	Kathmandu Valley Development Authority
LCC	Life Cycle Cost
LEST	Livelihood Enhancement Skill Training
LOS	Level of Service
LRN	Local Road Network
MHC	Mid-Hill East–West Corridor
MIMM	Mobile Imaging Technology System Mobile Mapping System
MM	Man Month
MOCTCA	Ministry of Culture, Tourism and Civil Aviation
MOF	Ministry of Finance
MOFAGA	Ministry of Federal Affairs and General Administration
MOFE	Ministry of Forests and Environment
MOUD	Ministry of Urban Development
MOPIT	Ministry of Physical Infrastructure and Transport
MRT	Mass Rapid Transit
MTOPS	Mass Transit Options and Prioritization Study
MUS:	Municipalities
MoWS	Ministry of Water Supply
MP	Mater Plan
MRT	Mass Rapid Transit
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MUTM	Modified Universal Transverse Mercator
NAAQS	National Ambient Air Quality Standards
NEPAP	National Environment Policy and Action Plan
NH	National Highway
NPR	Nepal Rupees
OC	Open Cut
OD	Origin-Destination
ODA	Official Development Assistance
OHS	Occupational safety and health
OLS	Obstacle limitation Space
O&M	Operation and Maintenance
ORR	Outer Ring Road
PA	Possible to Procure
PC	Pre-stressed Concrete

PAF	Project Affected Families
PAPs	Project Affected People
pcu	Passenger Car Unit
PD	Project Director
PI	Plasticity Index
PIC	Project In-Charge
PID	Project Implementation Department
PIP	Priority Investment Program
PIU	Project Implementation Unit
PLI	Poor Level Income
PPE	Personal Protection Equipment
PPHPD	Passenger Per Hour Per Direction
PPP	Private Public Partnership
RAs	Responsible Agencies
RAP	Resettlement Action Plan
RBN	Roads Board Nepal
RC	Reinforced Concrete
RCS	Resettlement Cost survey
RESA	Runway End Safety Area
RoR	Right of River
RMUS	Rural Municipalities
ROW	Right of Way
RR	Ring Road
RRN	Ring Road North
RRS	Ring Road South
RW(ER)	Retaining Wall
SASEC	South Asia Subregional Economic Cooperation
SDGs	Sustainable Development Goals
SDRS	Social Development and Resettlement Specialist hired by the Project Supervision Consultant.
SDMP	Strategic Development Master Plan
SLC	School Leaving Certificate
SPT	Standard Penetration Test
SPAF	Seriously Project Affected Family
SRA	Safety Risk Assessment
SRN	Strategic Road Network
STA.	Station Number
STD	Sexually Transmitted Diseases
STRADA	System for Traffic Demand Analysis
SRN	Strategic Road Network
TAZs	Traffic Analysis Zones
TBV	Tribhuvan Highway
TDF	Traffic Demand Forecast
TIA	Tribhuvan International Airport
T-M intersection	Tripureswor-Maitighar intersection
TOR	Terms of Refrence
TSP	Total Suspended Particles
TSS	Total Suspended Solids
TTC	Travel Time Cost
TX	Total Experiance
UD	Undisturbed Samples
UP	Underpass
USD	United States Dollar
UTM	Universal Transverse Mercator
V/C	Volume to Capacity
VDC	Village Development Community
VD	Vehicle Damage Factor
VOC	Vehicle Operation Cost
VOR	VHF Omnidirectional Range
VT	Vehicle based Trip
WB	World Bank
WGS	World Geodetic System
WHO	World Health Organization

CHAPTER 1. INTRODUCTION

1.1 Study Background

The Federal Democratic Republic of Nepal (hereinafter called “Nepal”) is a landlocked country. About 80% of its land is steep mountainous terrain, and about 90% of its transportation is land-based and depends on roads.

Nepal’s real GDP growth rate has been approximately 3% to 6% per year since 2010, falling to 0.6% in 2015 after The April 2015 Nepal earthquake, also known as Gorkha Earthquake)”. In the next five years, the growth rate is expected to recover approximately 5% to 7% in the next five years.

Because of its economic growth, the number of registered vehicles in Nepal has doubled in the past five years, and the values of trade transactions dependent on land transport increased by about 16% for exports and about 52% for imports from FY2009 to FY2016, increasing road traffic. However, the Nepal road network is still underdeveloped due to severe terrain conditions and effects of the past civil war, which remains diminished compared to neighboring countries.

In the capital city of Kathmandu, traffic congestion and air pollution have become social issues along with rapid population growth. Traffic congestion has worsened, especially at intersections connecting arterial roads with urban ones. The Government of Nepal has prioritized road network development in the 14th National Development Plan (2016/17-2019/20), aiming to achieve socio-economic growth while maintaining regional balance.

An intersection improvement at the Koteshwor and Tinkune Intersections in Kathmandu “the Project”) has been proposed as a priority project in the mid-term urban transport development plan in “Data Collection Survey on Urban Transport in Kathmandu Valley, JICA, July 2019” (hereinafter called By installing a grade-separated structure, flyover, or underpass from the Koteshwor Intersection to the Tinkune Intersection where Araniko Highway meets the Ring Road, the Project aims to smoothen traffic from and to the eastern region of Nepal, or the eastern part of the Kathmandu Valley where the large development projects are planned, to and from the central area of Kathmandu City.

The Government of Nepal requested Government of Japan to conduct a preparatory survey for the Project “the Survey”). In response to the request, JICA sent a survey team to Nepal to conduct the necessary Survey to realize the Project.

1.2 Objectives of the Project and the Study

The Project summary, including its objective, coverage area, and implementation agency, is shown in Table 1.2.1, named the Project Summary.

Table 1.2.1 Project Summary

Project Name	Koteshwor Intersection Improvement Project
Project Objectives	By improving the intersections with grade-separated structures, the Project will enhance traffic flow and mitigate congestion in Kathmandu City, especially in the eastern part of Kathmandu Valley and the inner city, contributing to regional economic growth and environmental improvement.
Project Area	Kathmandu City, Bhaktapur City, and Lalitpur City
Stakeholders	-Department of Roads (DOR), Ministry of Physical Infrastructure and Transport (MOPHIT) -Civil Aviation Authority of Nepal (CAAN), Ministry of Tourism and Civil Aviation (MOTCA) -Traffic Police -Kathmandu Valley Development Authority (KVDA), Ministry of Urban Development

Source: JICA Survey Team

The objective of the Survey is to prepare and compile all necessary information and data for JICA appraisal of the Project, such as outline creation, Project cost, implementation schedule and method, implementation system, operation and maintenance system post-completion, and environmental and social considerations under the loan scheme of Japan.

1.3 Contents and Schedule of the Study

The Survey contents, including the original tentative schedule, are shown in Table 1.3.1. Due to the site visit restrictions caused by COVID-19 worldwide, the Study schedule went under revision, as indicated in Table 1.3.2.

Due to the prolonged movement restrictions from COVID-19, stretching from March 2020 to the present, and a re-study of the traffic demand forecast for the Project, the Survey schedule had several rounds of modifications. Land issues in the Project coverage area were also a cause of delay.

The final schedule became complete in June 2023.

Table 1.3.1 Implementation Schedule and Contents of the Study (Original)

	2020								
	Feb	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.~Dec.
[Stage: 1] Justification of the Project and Selection of Most Suitable Intersection Improvement Plan									
Justification of the Project Intersection									
Update of Traffic Demand Forecast									
Confirmation of Aviation Requirement									
Natural Condition Survey [Phase-1]									
Confirmation of EAI or IEE									
Study on Manohara Bypath									
Study on Intersection Improvement Plan									
[Stage: 2] Preliminary Design and Establishment of the Project Implementation Plan by Yen Loan									
Natural Condition Survey [Phase-2]									
Preliminary Design									
Cost Estimation									
Project Evaluation									
Project Implementation Body and Operation and Maintenance Study									
Environmental and Social Consideration									
Report				ITR				DFR	FR

Note: ITR: Interim Report, DFR: Draft Final Report, FR: Final Report
Source: JICA Survey Team

Table 1.3.2 Implementation Schedule and Contents of the Study (the latest)

	2020				2021				2022				2023				2024	
	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2
[Stage: 1] Justification of the Project and Selection of Most Suitable Intersection Improvement Plan																		
Justification of the Project Intersection																		
Update of Traffic Demand Forecast																		
Confirmation of Aviation Requirement																		
Natural Condition Survey [Phase-1]																		
Confirmation of EAI or IEE																		
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Natural Condition Survey [Phase-2]																		
Preliminary Design																		
Cost Estimation																		
Project Evaluation																		
Project Implementation Body and O & M Study																		
Environmental and Social Consideration																		
Report											ITR-1		ITR-2		DFR		FR	

Note: ITR: Interim Report, DFR: Draft Final Report, FR: Final Report
Source: JICA Survey Team

CHAPTER 2. APPRECIATION AND RELEVANT DEVELOPMENT PLAN

2.1 Outline of Nepal

(1) Geography

Nepal is approximately 880 kilometers from east to west. Its Himalayan axis is 150 to 250 kilometers wide in the north-south, with an area of 147,516 km^2. It is a landlocked country bordered by China to the north and India on the other three sides.

Nepal features three geographical belts: the Terai Region, which is a lowland region bordered by India, containing hill ranges from 100m to 1,000m in altitude; the Hills Region, which features hill heights between 700-4,000m containing Kathmandu and Pokhara, and the Himalayas, which encloses famous Himalayan mountains such Mount Everest.

(2) Climate

Detail is described in Chapter 3.

(3) History

Nepal has experienced dramatic changes in politics since the late 1990s. Before the 1990s, an authoritarian monarchy ruled based on an exclusive and oligarchic social order. Table 2.1.1 shows recent major historical events, including political movements.

Table 2.1.1 Recent Major Historical Events

Year	Event Description
Late 1990s	A Maoist rebellion erupted and affected almost all 75 districts across the country.
2001	Murder of King Birendra and most of the royal family under mysterious circumstances. His brother, Gyanendra, succeeded him.
2004-2005	King Gyanendra staged a royal coup by claiming full sovereignty and assuming executive authority.
April 2006	Anti-regime groups such as the Seven Party Alliance and the Maoists forced King Gyanendra to restore the dissolved parliament.
January 2007	A comprehensive peace agreement concludes between the newly formed government and the Maoists.
April 2008	The Communist Party of Nepal and the Maoist Party won in a Constituent Assembly election and installed a new government.
May 2008	Nepal abolished its monarchy and became a federal democratic republic.

Year	Event Description
November 2013	The Nepali Congress occupied most constituency seats in the second Constituent Assembly election, forming a multiparty coalition in Feb. 2014.
April & May 2015	Two magnitude 7.8 earthquakes hit central Nepal.
September 2015	A new constitution came into effect
August 2016	The Congress-Maoist coalition took power, and the Maoist leader became Prime Minister based on the agreement to share the PM position.
June 2017	The Maoist PM voluntarily handed over the position to the Congress PM.
February 2018	As a result of the general election in November 2017, a coalition between the communist parties that later formed the Nepal Communist Party took power, and Mr. Oli was elected PM.
July 2021	Mr. Deuba of Congress became PM.
January 2023	Mr.Dahal of the Maoist Centre Party became PM in the latest general election, although the Congress party won most constituency seats.

Source：JICA Survey Team based on https://mofa.gov.np/about-nepal/history-of-nepal/

2.2 Socio-Economic Conditions in Nepal

Nepal is a multi-ethnic, multi-cultural, multi-religious, and multi-lingual country. The most spoken language is Nepali, followed by several other ethnic languages. Its population is 2,9192,480 people, according to the 2021 census.

According to the Nepal Profile provided by DFID (Department for International Development) in 2021, Nepal is the 16th poorest country worldwide and the second poorest in Asia after Afghanistan in per capita income. The country ranks 145th in the world in the Human Development Index. Its standing shows no recent improvement. However, in 2021, the United Nations Committee for Development Policy recommended that Nepal graduate from the least-developed country category in 2026.

Table 2.2.1 shows recent data on major socio-economic indicators for education, health, and the environment.

Table 2.2.1 Recent Major Socio-Economic Indicators

COUNTRY AT A GLANCE

Economic	2015	2016	2017	2018	2019[1]
GDP ($ billion, current)	21.4	21.2	25.2	29.0	30.7
GDP per capita ($, current)	763.6	745.2	873.5	993.9	1036.5
GNI per capita ($, atlas method)	780.0	770.0	850.0	960.0	…
GDP growth (%, in constant prices)	3.3	0.6	8.2	6.7	7.1
Agriculture	1.1	0.2	5.2	2.8	5.0
Industry	1.4	(6.4)	12.4	9.6	8.1
Services	4.6	2.4	8.1	7.2	7.3
Gross fixed investment (% of GDP)	28.0	28.7	31.4	34.7	36.9
Gross domestic saving (% of GDP)	9.2	4.1	13.4	17.8	20.5
Consumer price index (annual % change)	7.2	9.9	4.5	4.2	4.6
Liquidity (M2) (annual % change)	19.9	19.5	15.5	19.4	15.8
Overall fiscal surplus (deficit) (% of GDP)	0.8	1.3	(3.2)	(6.7)	(5.1)
Merchandise trade balance (% of GDP)	(31.1)	(30.3)	(33.5)	(37.5)	(37.1)
Current account balance (% of GDP)	5.1	6.2	(0.4)	(8.2)	(7.7)
External debt service (% of exports of goods and services)	8.1	9.9	10.8	8.3	8.2
External debt (% of GDP)	16.1	17.3	15.5	17.3	17.0

Poverty and Social	2006	Latest
Population (million)	24.8	29.2 [2018]
Population growth (annual % change)	1.2	1.4 [2017]
Maternal mortality ratio (per 100,000 live births)	281.0 [2005]	239.0 [2018]
Infant mortality rate (below 1 year/per 1,000 live births)	48.0 [2005]	28.4 [2016]
Life expectancy at birth (years)	62.0 [2001]	69.7 [2018]
Adult literacy (%)	48.0 [2004]	66.8 [2017]
Primary school gross enrollment (%)	122.0 [2004]	118.5 [2017]
Child malnutrition (% below 5 years old)	49.0	36.0 [2016]
Population below poverty line (%)	30.9 [2004]	18.7 [2018]
Population with access to safe water (%)	82.5	92.7 [2017]
Population with access to sanitation (%)	24.5	87.6 [2017]

Environment	Latest
Carbon dioxide emissions (kiloton)	8,031 [2014]
Carbon dioxide emissions per capita (tons)	0.3 [2014]
Forest area (million hectares)	3.6 [2016]
Urban population (% of total population) [2]	59.9 [2018]

ADB Portfolio (active loans and ADF grants)[3]	As of 31 December, 2018
Total number of loans and ADF grants	49 (36 projects)
Sovereign	49 (36 projects)
Nonsovereign	0
Total loan and ADF grant amount ($ million)[4]	2,809.4
Sovereign	2,809.4
Nonsovereign	0
Disbursements {sovereign}	
Disbursed amount, total ($ million, 2018)	246.7
Disbursed amount, excluding PBL ($ million, 2018)	246.7
Disbursement ratio, excluding PBL (%)	17.5

… = not available, ( ) = negative, [ ] = latest year for which data are available, ADB = Asian Development Bank, ADF = Asian Development Fund, GDP = gross domestic product, GNI = gross national income, M2 = broad money, OCR = ordinary capital resources, PBL = policy-based lending.

1 Preliminary estimates of GDP by the Central Bureau of Statistics.

2 Based on the administrative classification of 293 urban municipalities in 2017, 59.9% of the total population was living in urban areas in 2018.

3 Covers ADF and OCR financing for projects and programs, including policy-based lending, unless otherwise stated, and excludes cofinancing.

4 Net of droppages and cancellation.

Sources: Central Bureau of Statistics; National Planning Commission; Nepal Rastra Bank; World Development Indicators database. http://data.worldbank.org/data-catalog/world-development-indicators (accessed 1 July 2019).

Source: Country Strategy Paper Nepal, 2020–2024, ADB, September 2019

Nepali economy rebounded from the 2015 earthquakes and the 2015–2016 trade disruptions to achieve an average annual growth rate of 7.3% during 2017–2019. Due to the Corona pandemic from 2020 to the first half of 2022, which affected activities of all economic sectors, the ADB reports GDP growth in 2020 and 2021 at -2.1% and 2.3%, respectively. ADB projects growth to achieve 5.8%[1] in 2022. Table 2.2.1 shows recent trends for Nepali GDP, growth ratio, and government financial data.

As described in Table 2.1.1, the institutional change to a federal government stipulated by the 2015 constitution aims to produce greater accountability and better public services. Since political stability improved from the changes enacted in the 2017 elections, the prospects for sustained rapid growth have also increased.

However, although Nepal has reduced overall poverty significantly, it still has many challenges to overcome. According to Country Partner Strategy, Nepal 2020-2024, ADB, 2019:

- Poverty rates vary by gender, social group, and region. A sizeable proportion of the population is vulnerable to poverty.
- **Significant infrastructure gaps**, reflecting several decades of low investment, impede **connectivity** and raise **commercial costs**, deterring private sector investment, competitiveness, export growth, and job creation.
- Weak institutional capacity at the federal and sub-national levels impedes the complete transition to the proposed federal government.
- **Unplanned growth in urban areas** and haphazard construction of roads in rural areas are exerting pressure on the natural environment, creating adverse effects like deforestation, soil erosion, and landslides. They exacerbate the risks of climate change, natural hazards, and harmful factors from the urban environment.

2.3 Road Sector Performance Review

2.3.1 Introduction

The latest information about the Nepali road sector and its performance was well-described by the Nepal Infrastructure Sector Assessment issued in 2019 by the World Bank (WB).

2.3.2 Road Network and its Conditions

The Nepali road network features a central road network and a local one. The former comprises the Strategic Roads Network (SRN,) including national highways, feeder roads, and a few urban roads of national importance. The latter contains the remaining urban and local roads, including agricultural roads within the urban and rural districts and municipalities. Table 2.3.1 shows the road lengths of each road category and its surface conditions in the SRN. According to the table, approximately 52% of the SRN are blacktop (asphalt pavement), and the rest are graveled (16%) or earthen surfaces (31%).

[1] www.adb.org/outlook

Table 2.3.1 Road Network in SRN

(Unit: km)

Pavement Type / Road Class	Asphalt	Gravel	Earth	Total
National Highway	3,223.80	102.39	180.66	3,506.85
Feeder Roads	3,346.83	1,416.48	3,224.76	8,008.06
Mid-Hill Road	254.50	462.50	514.00	1,231.00
Postal Road	154.20	295.50	252.00	701.70
GROUND TOTAL	**6,979.33**	**2,276.87**	**4,191.42**	**13,447.62**

Source: Statistics of SRN Part-2, 2017/2018, DOR

Table 2.3.2 summarizes the Local Road Network (LRN), containing Urban Roads, District Core Roads, and Village Roads.

Table 2.3.2 Road Network in LRN

(Unit: km)

Pavement Type / Road Class	Asphalt	Gravel	Earth	Total
Urban Roads	204.35	101.07	62.97	368.39
District Core Roads	1,310.74	5,869.29	18,548.16	25,728.18
Village Roads	693.45	6,953.72	24,256.69	31,903.86
GROUND TOTAL	**2208.54**	**1,2924.08**	**4,2867.82**	**58,000.43**

Source: Statistics of Local Road Network (SLRN) 2016, DOR

To summarize, the whole road network in Nepal expanded to approximately 71,500 km, but only 13% is all-weather. The road density of the SRN is 9.26 km/100km^2, compared with 50km/100km^2 for the SRN and LRN together.

Pavement Conditions

Table 2.3.3 shows the pavement conditions on SRN by the International Roughness Index (IRI) in 2012. The table shows that 52% of the sealed roads in SRN were in poor or deteriorating conditions. 43% of the National Highways fall into this category. As mentioned above, this situation arose from continued low investment in the road sector, particularly in maintenance.

Table 2.3.3 Pavement Conditions by IRI for SRN[2]

Road Condition / Road Class	Pavement Conditions (IRI)				Total Length (km)
	Good <4	Fair 4-6	Poor >6-8	Bad >8	
National Highway	144.1 (5%)	1535.1 (52%)	958.7 (33%)	297.2 (10%)	2935.2 (100%)
Feeder Roads	4.0 (0%)	673.5 (36%)	706.3 (37%)	502.9 (27%)	1886.8 (100%)
All Sealed Roads	**148.1 (3%)**	**2208.7 (46%)**	**1664.9 (35%)**	**800.2 (17%)**	**4821.9 (100%)**

Source: Mid-Term Review of Sector Wide Road Program & Priority Investment Plan (2015)

[2] DOR has been measuring the average IRI for every one km section for the entire SRN every year. However, JST could not find the summarized results as shown in Table 2.2.3

Road Safety

According to the WHO data published in 2017, road traffic accident deaths in Nepal reached 4,921. The age-adjusted death rate is 20.13 per 100,000 people, ranking Nepal 79th worldwide.

Table 2.3.4 shows road accident data in Kathmandu Valley in the last five years, indicating a steady increase in traffic accidents and casualties after the earthquake.

Table 2.3.4 Road Accidents in the Last 5 Years in Kathmandu Valley

	Year	2015-2016	2016-2017	2017-2018	2018-2019
	Nos of Accidents	5,668	5,530	6381	8,511
	Fatal	166	182	194	254
	Seriously injured	275	201	219	317
	Ordinary Injured	3,901	3,914	4,333	5,890

Source: Traffic Police HQ, Feb. 2020

2.3.3 Institutional Framework for Roads

Under the Nepal federal government, the Ministry of Physical Infrastructure and Transport (MOPIT) is the regulatory and policy-making body responsible for plans, policies, programs, laws, and regulations for the road sector. Under the MOPIT, the Department of Road (DOR) oversees the development, maintenance, and management of the SRNs. On the other hand, for the LRN, the Ministry of Federal Affairs and General Administration (MOFAGA) functions the same as MOPIT, and the Department of Local Infrastructure (DOLI)[3] takes the same role as DOR.

For road maintenance, the RBN, an autonomous body, manages the funding for the road operation and maintenance of the SRN and LRN. The MOF collects fuel levies and vehicle registration charges and transfers the accumulated funds to RBN. RBN allocates them to the DOR and DOLI for new construction, improvement, upgrading, rehabilitation, and maintenance.

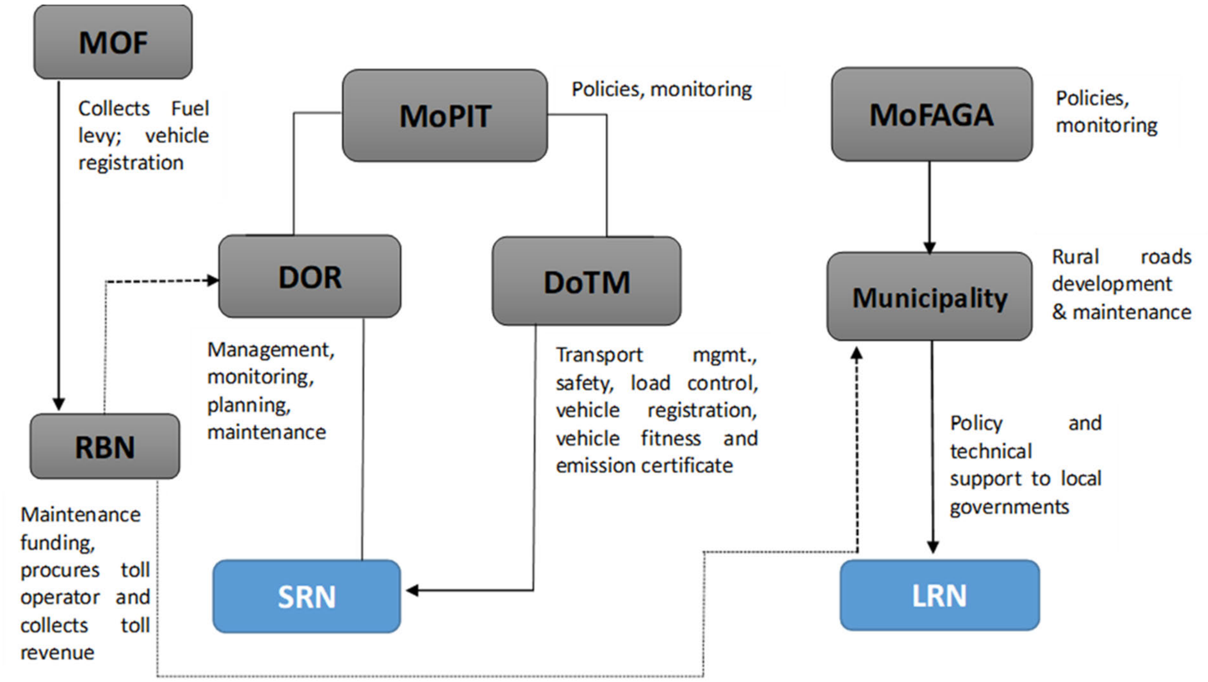
Chapter 18 details Operation and Maintenance. Figure 2.3.1 shows an institutional framework for roads.

On the legal and regulatory framework, some critical laws and regulations govern roads below:

- **Public Roads Act (1974)** is the primary legal document regulating the SRN, which defines road classifications, the Right-of-Way (ROW), temporary acquisition of land, and development tax collection from owners of land adjacent to roads. The law is currently under modification.
- **Roads Board Acts (2002) and Regulations (2004)** are laws and regulations that define the objectives and roles of the RBN.

[3] The Nepal Government announced to dissolve DOLI in the budget meeting speech on May 29th, 2022 because of transfer of its function to municipality as a result of adoption of federal system

- **Motor Vehicles and Transport Management Act (1993) and Regulations (1997)** are the only legal documents covering road safety. However, the government recently drafted the Road Safety Act, which fully empowers the Road Safety Council to own the road safety agenda. It awaits approval from the Nepal Parliament.



Note: DOLIDAR= Department of Local Infrastructure Development and Agriculture Roads; DOR= Department of Roads; DOTM= Department of Transport Management; LRN = Local roads network; MOF = Ministry of Finance; MOFAGA = Ministry of Federal Affairs and Local Development; MOPIT= Ministry of Physical Infrastructure and Transport; RBN= Road Board of Nepal; SRN = Strategic Roads Network.

Source: Nepal Infrastructure Sector Assessment

Figure 2.3.1 Institutional Framework for Roads[4]

2.3.4 Transport/Road Sector Development Plan

The 15th National Development Plan emphasizes the necessity to strengthen the transport sector. It aims to improve road management capacity with modern technologies and knowledge transfer. See Chapter 2.4.1 for details.

The following policies govern the development of the transport sector in Nepal:

1. National Transport Policy, 2002;
2. Strategic Plan of MOPIT, 2016–2020;
3. Sector-wide PIP (Priority Investment Program) by DOR;
4. South Asia Subregional Economic Cooperation (SASEC) Operational Plan, 2016–2025.

[4] Municipalities are to be responsible for the LRN under the monitoring by MOFAGA

National Transport Policy, 2002

The National Transport Policy, formulated and approved by the government in 2002, aimed to develop a reliable, cost-effective, and sustainable transport system that promotes economic, social, cultural, and tourism development. It features an objective, three overall strategies, 16 policies covering sub-sectors, and an action plan.

Strategies from the Policy include:

1. The government shall indicate the limit and scope of work and take responsibility for constructing transport structures from the central level;
2. Strengthening the decentralized sections of government;
3. Encourage private sector involvement in expanding and preserving the transport system.

The road sector policies below use the National Transport Policy as a framework. As of 2022, there has been no update to the National Transport Policy.

Strategic Plan of MOPIT, 2016-2021

MOPIT prepared The 5-year Strategic Plan for the transport sector in Nepal, effective from 2016-2021. It has included road, railway, and traffic management fields since its conception in 2015.

The 5-year Strategic Plan has five strategic pillars:

1. Background and status of the existing road network
2. Overall objective and development concepts
3. Major programs covering the road and railway sector and traffic management;
4. Expected achievement of goals;
5. Estimated investment amount. A description of the road sector occupies the bulk of this section.

The concepts of the 5-year Strategic Plan are as follows:

1. Development and improvement of the national road network to secure accessibility for people and promote economic and tourism activities by connecting the capital city of Kathmandu to provinces;
2. Emphasizing the necessity of developing electric railways as economical and efficient freight and passenger transport modes;

3. Improving traffic management systems to create safe, reliable, and cost-effective transport modes;

4. Cite traffic safety and air pollution issues.

In the road sector program, the 5-year Strategic Plan emphasized:

a) Reconstruction of road structures damaged by the 2015 earthquake;
b) Road network expansion;
c) Development of major highways;
d) Development of commercial and essential roads connecting North to South;
e) Development of roads connecting bilateral trade points;
f) Strengthening road network in Kathmandu Valley: Outer Ring Road construction;
g) Construction and maintenance of bridges: targeting 650 bridges in completion;
h) Tunnel road development: including Nagudhunga tunnel;
i) Maintenance of road network;
j) Implementation of road safety measures according to the Nepal Road Safety Action Plan (2013-2020);
k) Implement strategies with social and environmental considerations. PPP promotion, universal access, procuring modern equipment, and establishing a Heavy Equipment Leasing Center are essential.

To implement the 5-Year Strategic Plan, an estimated NR 816 billion investment was necessary, mobilizing the Nepal government budgets and foreign funds, including Japanese ODA.

Sector-wide PIP 2, 2007

The 2007 Sector-wide PIP 2 was a road development program active from 2007 to 2017, and the priority projects were listed based on the objectives of the PIP 2, including:

1. Connecting the regional centers to 75 district headquarters;

2. Completing the Mid-Hill East-West Corridor ;

3. Strengthening road maintenance.

The PIP 2 conducted a mid-term review in 2016. It proposed to extend the plan up to FY2022. The network met PIP2 targets. However, re-designating existing locally-built earth tracks as part of the strategic network and including longer-distance links in areas with relatively low population density did not receive correct priority. The strategic functions of these roads and the actual demand for them over the years are reviewed. Consideration of proposed new works will be case-by-case.

In 2021, ADB provided the TA study to formulate the national highway network expansion plan and prepare the PIP for 2023-2033. Now, a new PIP is under study.

SASEC Operation Plan, 2016-2025

The SASEC has been enhancing cooperation through projects that drive economic growth and benefit the impoverished, focusing on transport, trade facilitation, and energy links outside the region.

The SASEC Operational Plan 2016–2025 is the first comprehensive long-term plan for economic and industrial corridor development using improved connectivity as a foundation. The SASEC Operational Plan includes a substantial list of potential projects for the next ten years.

2.3.5 Budget Allocation for the Road Sector

The road sector has suffered chronic under-investment, although the government highly prioritized it in recent years, according to numerous data sources. The National Planning Commission clarified in a 2017 study that Nepal was required to invest 2.3% to 3.5% of its annual GDP in transport infrastructure during 2010-2020.

According to the Strategic Investment Plan prepared by DOR, the road sector will require USD 6.5 billion (NPR 698 billion[5]) for five years, which started in 2016. Furthermore, in the Federal Budget speech for FY 2019-2020, the Finance Minister presented an NPR 1.53 trillion budget for the new fiscal year, a 16% increase from the previous FY, to achieve targeted economic growth of 8.5% and allocate a sum of NPR 163 billion to the sector.

The new budget also facilitates an underpass along the Tinkune-Koteshwar-Jadibuti route, an underpass in New Baneshwor, a flyover between Tripureshwar-Maitighar, and the Ring Road expansion.

Table 2.3.5 shows the trend of government spending in the last four years, indicating a steady increase in total budget and allocation to the transport sector.

[5] It was calculated by the average exchange rate in 2016 between NPR and US$

Table 2.3.5 National Expenditure Plan and its Allocation to the Transport Sector

Unit (Million NPR)

Year	2016-2017	2017-2018	2018-2019	2019-2020
Total Expenditure Budget Plan (Increase ratio)	819,000	1,278,994 (156%)	1,315,161 (103%)	1,532,967 (117%)
Transport sector (Increase ratio)	61,057	118,267 (193%)	126,480 (107%)	185,476 (147%)
Share (%)	7.5%	9.2%	9.6%	12.1%

No obvious fund allotment for the road sub-sector exists in the budget for the transport sector. However, the bulk of the transport sector budget is estimated to go to the road sector, considering no railways and ports are present.
Source: Budget speech, Ministry of Finance

In addition, Table 2.3.6 indicates the DOR budget for only road rehabilitation and improvement projects, including bridge works. It demarcates between DOR funds and foreign aid.

Table 2.3.6 DOR budget for Road and Bridge Projects, Excluding Maintenance Works

FY	FY in English Calendar	Net Budget (NRs)	Breakdown	
			Foreign Aid (NRs)	Nepal Gov. (NRs)
2074/75	2017/18	103,309,680,322	15,151,440,000	88,158,240,322
2075/76	2018/19	108,521,994,000	-	108,521,994,000
2076/77	2019/20	120,975,552,400	51,807,700,000	69,167,852,400
2077/78	2020/21	104,617,872,919	-	104,617,872,919
2078/79	2021/22	129,801,320,000	76,117,200,000	52,369,600,000

The budget does not include maintenance works allocated from RNB.
Source: DOR

The table indicates a large portion of the budget has been allocated to the road sector in the past, accounting for around 10% of the total. The total budget for the road sector is almost stable regardless of the amount of foreign aid.

2.3.6 Challenges in the Road Sector

The Nepal Infrastructure Sector Assessment raises several concerns for the road sector:

- The necessity of improvement for planning and prioritization in the Road Sector, avoiding political influences for more objective criteria and planning processes.
- The government must prioritize the maintenance of the SRN to respond to inadequate maintenance funds from RBN.
- Determine the limits of the capability of the RBN to implement the roles defined by the Road Board Acts, which holds only 17 staff and insufficient human resources.
- Inefficient use of allocated funds by agencies due to weak procurement, contract management, and implementation capacity.

- The Nepali private sector has limited investment capabilities. This factor results in project delays and poor-quality work due to insufficient management and low financial capacity.
- MOF transfers less revenue than the RBN entitlement, which resulted in a maintenance backlog.
- The government and foreign donors provide insufficient financing sources against funding requirements for the road sector in Nepal.

2.4 Relevant Development Plan and Program

2.4.1 National Development Plan: 15th Five-Year Plan in Nepal

The 15th plan for FY2020–FY2024, prepared by the National Planning Commission, clarifies the long-term government vision of a *prosperous Nepal, happy Nepali*. Its main aims are:

- To achieve graduation from least-developed country status by 2022,
- To be comfortably in the ranks of middle-income countries by 2030,
- To achieve the Sustainable Development Goals (SDGs).

The objectives of the 15th plan also include:

- High and equitable national income;
- Economic and social justice and poverty reduction;
- Human capital development;
- Universal, affordable, and modern infrastructure for connectivity in both urban and rural contexts;
- High and sustainable production and productivity;
- Healthy and balanced ecosystem;
- Good governance.

The plan asks for a smooth implementation of the federal system of governance based on cooperation, coexistence, and coordination. An investment-friendly environment must be present for the private sector, which the government expects to invest, compete, and contribute to overall development.

The 15th plan targets average annual GDP growth of 10.1% over five years, increasing per capita income to $1,595 by FY2024. The income poverty ratio must drop to 11% and the multidimensional poverty rate to 13%. The gender development index must rise from 0.925 to 0.963. The 15th plan will also require an average annual investment totaling 39.1% of GDP. The public sector will provide 39% of the total investment (15.2% of GDP).

2.4.2 20-Year Strategic Development Master Plan (SDMP) 2025 in Kathmandu Valley

The Kathmandu Valley Development Authority (KVDA), which prepares and implements an integrated physical development plan for the Kathmandu Valley, drafted a 20-year Strategic Development Master Plan in 2016, or SDMP (2035). The SDMP considers the existing and emerging trends of urbanization, the environment, and the current socio-political and economic situations within the framework of the JICA MP. It focuses on 11 strategic areas:

- Two-level planning (valley and municipal level);
- Constraints/sensitivity-based zoning and risk-sensitive land use planning;
- Risk-resilient urban infrastructure;
- An environment-friendly and resilient planning approach;
- Urban regeneration of the historic city core;
- Identification of economic opportunities and growth areas;
- Gender equity and social inclusion;
- Safety and security in urban development;
- Private sector involvement in urban development activities;
- Information, communication, and advocacy;
- Youth mobilization and participation in urban decision-making processes and development activities.

2.5 Development Plan in Kathmandu Valley

2.5.1 New City Development Plan in Eastern Kathmandu Valley

(1) The New Development Area in the North of Araniko Highway

Planning is complete for a new urban expansion area of 50 sq. km with an approximately 1.0 million floating population North of Araniko Highway. Helen & Co. Architect, in association with JK Associate, a Finnish firm hired by KVDA, developed the conceptual land use map in the Detailed Project Report (DPR) for the Development of a New Town in Kathmandu Valley in October 2019.

The land use plan features divisions, like the natural resources area (45%) and the settlement-promotion areas, such as government service, commercial, industrial, residential, and heritage developments (55%).

The proposed Outer Ring Road (ORR), a significant development corridor for the entire Kathmandu Valley, will serve as an essential commercial, industrial, and transportation hub of the proposed new town. ORR will pass through it from the south to the north and almost divide it into two areas. The transport plan is a proposed Bus Rapid Transport (BRT) system.

The timeline of the new town development is in Table 2.5.1.

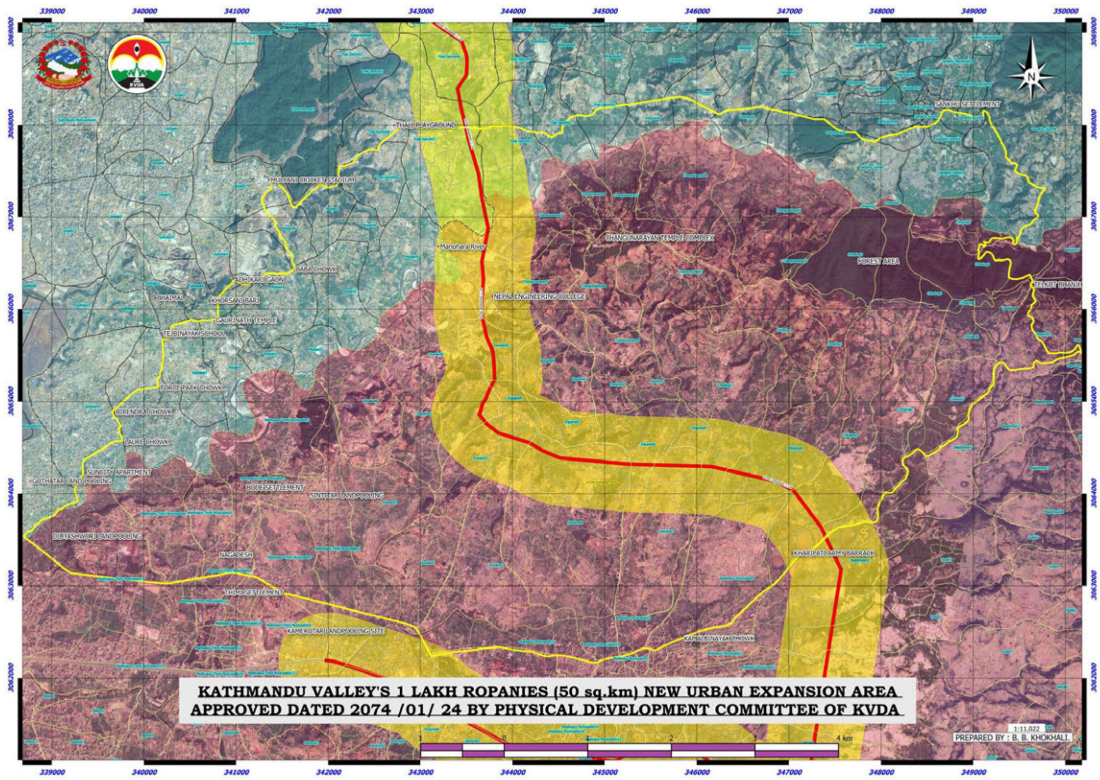
As of March 2020, the MP is under review for government approval, and KVDA has just submitted the financial plan for its implementation. According to KVDA, various players, including private investors, will share the workload of constructing and managing the new town.

Figure 2.5.1 shows the target area of the new urban development highlighted in a yellow line boundary. The red line with the yellow buffer represents the planned ORR. Figure 2.5.2 shows the conceptual land use map north of Araniko Highway.

Table 2.5.1 Timeline of New Town Development in the North of Araniko Highway

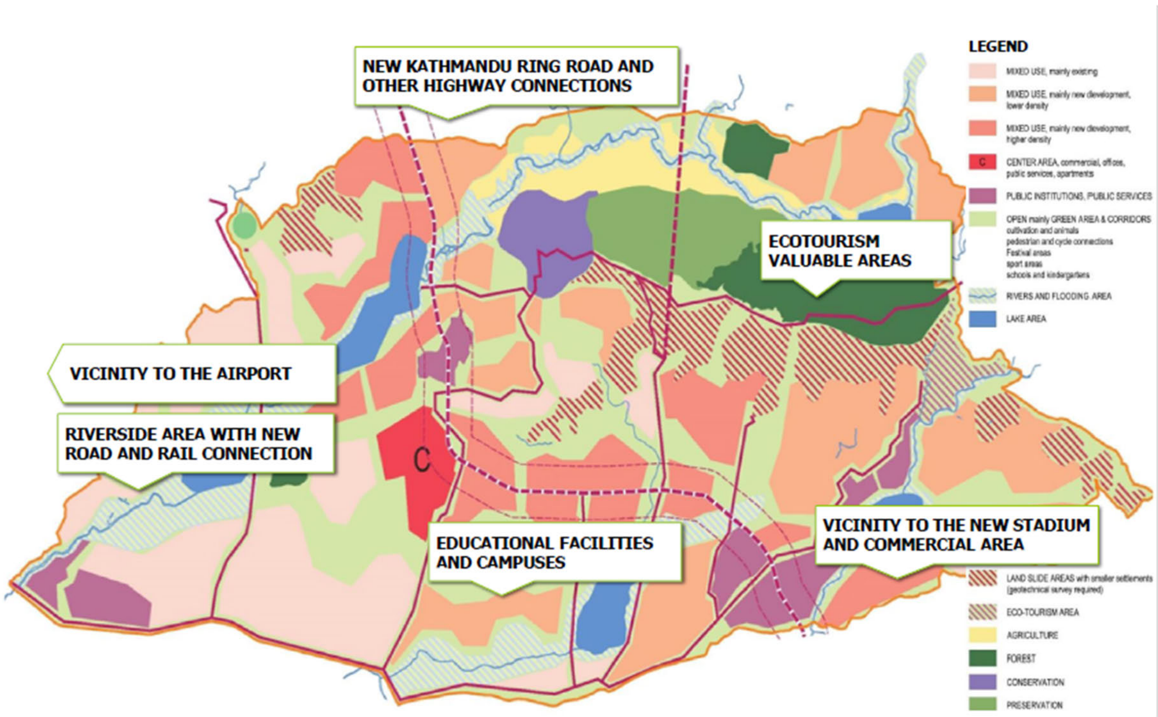
Target year	Activities
1st Quarter 2019	Finalize the project after stakeholder consultation
2nd Quarter 2019	Official announcement of the project
3rd Quarter 2019	Start infrastructure development, including land acquisition
1st Quarter 2020	Components development and construction
1st Quarter 2022	Completion of tourism component; completion of the first model of residential community

Source: KVDA (2019)
As of June 2022, the project has not yet attained government approval.



Source: KVDA (2019)

Figure 2.5.1 Target Area of New Urban Development in North of Araniko Highway



Source: KVDA (2019)

Figure 2.5.2 Conceptual Land Use Map North of Araniko Highway

The land use plan for the river corridor construction along the Manohara River will specify a 50-meter necessary width for the river basin and a 20-meter ROW on both sides. KVDA supports integrated land use with transport plans proposed by the JICA pre-survey. The new town will adopt a Japanese land re-adjustment approach. Up to 10% of land will be for sale, and revenue will be for the development. Even with the minimum land value, the project will be feasible.

In line with the new town development, KVDA plans to relocate the brick factories in Bhaktapur further east, out of Kathmandu Valley.

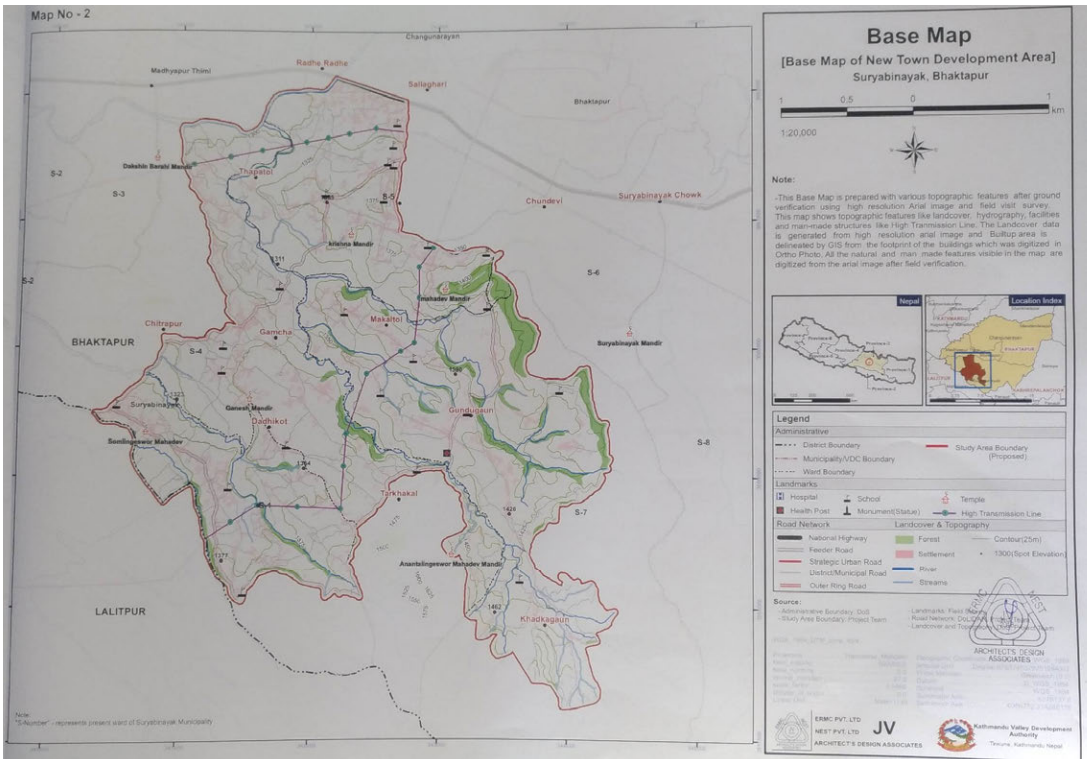
(2) New Development South of Araniko Highway

The proposed plan covers 25 sq. km south of Araniko Highway, roughly half the size of the development area in the north. Local consultants were responsible for preparing the concept plan and DPR. The new development plan targets to accommodate 0.1 million population, and construction will start only after the commencement of the one in the north.

The red highlighted boundary in Figure 2.5.3 shows the target area of the proposed new development. Figure 2.5.4 is the base map prepared with various topographic features after ground verification using high-resolution aerial imagery and field visit surveys. The map contains topographic features, including land cover, hydrography, facilities, and artificial structures like high transmission lines.

Source: KVDA (2019)

Figure 2.5.3 Proposed New Development Area in the South



Source: KVDA (2019)

Figure 2.5.4 Base Map in South of Araniko Highway

2.5.2 Other Relevant Plans and Projects

(1) Province-3 Capital Designation

In line with adopting a federal government in 2015, Nepal became seven provinces. In Jan. 2020, the Province-3 assembly, which includes the Kathmandu Valley in its jurisdiction, named the province Bagmati and designated Hetauda as its province capital, located 150 kilometers south of Kathmandu.

(2) Fast Track Project

The Fast Track Project aims to connect Kathmandu to Terai directly. It involves building an expressway 72.5 km in total length, comprising 55.5 km of roads, 10.59 km of tunnels, and 6.41 km of bridges.

The realization of the Fast Track Project dramatically shortens the travel length from Kathmandu to Terai, which is currently 256 km. It also reduces travel time, accruing savings from freight transport costs and facilitating new trade and economic activities.

The project was formulated and proposed in 2008 by ADB TA. The Nepal Army started construction in 2017. As of February 2022, approximately 21% of the construction works were complete. In July 2022, the bulk of planned earthworks were at 100%, and the project will potentially finish in January 2025.

(3) Nagdhunga Tunnel Construction Project

The Nagdhunga Tunnel Construction Project aims to construct a 2.69 km tunnel and improve the road conditions around Nagdhunga Pass, thereby making the transportation network between Kathmandu and other principal cities and areas in Nepal more efficient. The estimated project cost was USD 188.19 million, with financial support from the Japanese Yen Loan Scheme. As of August 2022, the project is in progress.

2.6 Related Road/Railway Projects

2.6.1 Introduction

Various road and railway project plans are active in Kathmandu Valley, and many are closely associated with the project. The following sub-chapter summarizes their contents, schedule, and present status.

2.6.2 Ring Road Development

(1) Inner Ring Road

Two new Ring Road projects are underway. The Inner Ring Road (the blue circle) is a 27km four-lane, two-way circular road, upgraded in three phases.

In 2011, China agreed to provide grant assistance with USD 40 million for the first phase of upgrading and widening the Ring Road. A Chinese company, Shanghai Construction Group, completed the 10.5km road expansion between Kalanki and Koteshwor in December 2018, closing the first phase of the Kathmandu Ring Road Improvement Project. The 800 m-long

Kalanki Underpass in the first phase is the first-grade separation structure in Nepal. Work began in 2013 and finished in 2018 after a suspension from the Nepal Earthquake in 2015.

The second phase includes an 8.2km section between Kalanki and Maharajgunji, originally planned to start in 2020 under Chinese funding. As of June 2022, the second phase has not yet begun. The third phase includes the remaining section from Maharajgunji to Tinkune. Today, a DPR for the Tinkune – Tilganga section is under preparation.

(2) Outer Ring Road

The Outer Ring Road is a 72 km-long road passing through three valley districts, with 35.08 km in Kathmandu, 15.80 km in Lalitpur, and 21.05 km in Bhaktapur. At the March 2019 Nepal Investment Summit, the government unveiled the Kathmandu Outer Ring Road Development Project, featuring an eight-lane road with 50m of ROW and a proposed commercial hub. The objectives of the ORR are:

1. Interconnect isolated three cities through a single road network to manage urbanization and improve urban-rural mobility;
2. Create a new and planned settlement for the valley.

For the second objective, land acquisition along the corridor – 250m on either side from the road center line– will offer vast opportunities to accelerate planned urbanization, making the construction of business centers, high-rise apartments, and other structures more efficient.

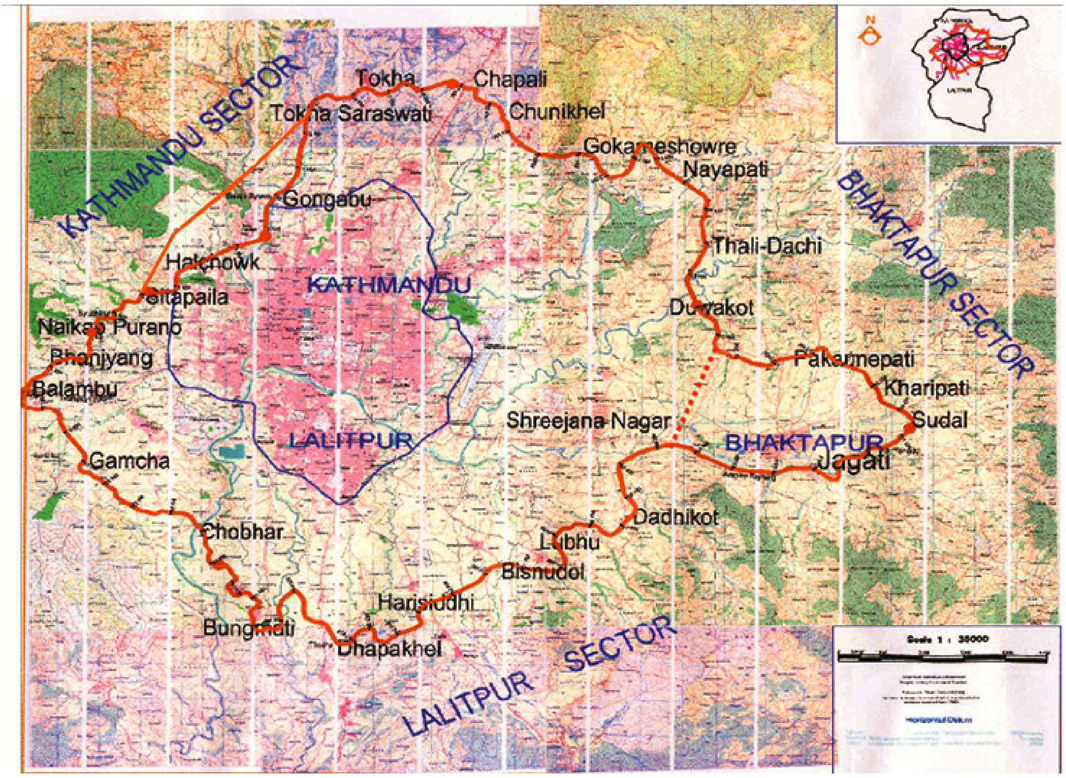
Private investment will lead the development. Public and private players will have different roles. Table 2.6.1 summarizes the key features of the project.

Four firms submitted a detailed proposal in May 2019, responding to the announcement of open bidding. A Chinese firm, Chinese Communication Construction Company (CCCC), was selected by the Investment Board in Sep. 2019. Nepal requests the CCCC to re-evaluate the present ORR plan. As of June 2022, no further activity occurred on this front.

Table 2.6.1 Overview of Kathmandu Outer Ring Road Development Project

<table>
<tr><th>Project Name</th><td>Kathmandu Outer Ring Road Development Project (PPP scheme)</td></tr>
<tr><th>Funding modality</th><td>Private Investment</td></tr>
<tr><th>Indicative financials</th><td><table><tr><td>Total Cost (Road Development)</td><td>USD 1,871 million</td></tr><tr><td>• Land acquisition</td><td>USD 1,544 million</td></tr><tr><td>• Road construction</td><td>USD 327 million</td></tr></table></td></tr>
<tr><th rowspan="2">Roles</th><td>Government of Nepal:
• Facilitation of various legal approvals
• Government permits and approvals
• Facilitation of land acquisition to provide Right-of-Way and required land for the project</td></tr>
<tr><td>Private Sector:
• Plan, design, finance, construct, and develop the facilities and other components of the project (Road and other physical infrastructure)
• Handover road project to the government after completion
• Business development along the corridor</td></tr>
<tr><th>Timeline</th><td>• Feasibility study – 1 year
• Detailed project report (Financial closure) – 1 year
• Construction – 5 years</td></tr>
</table>

Source: Nepal Investment Summit (2019)



Source: KVDA

Figure 2.6.1 Proposed Alignment of Ring Road

2.6.3 East-West Corridor (MRT) by ADB under KSUTP

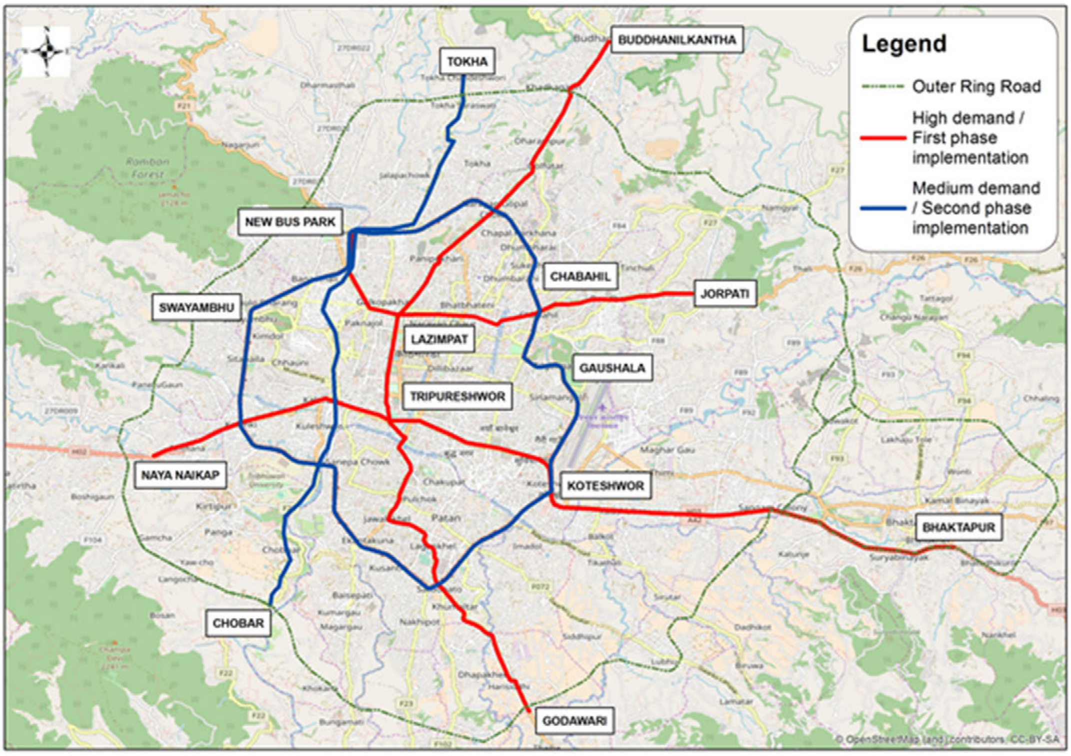
The KSUTP (Mass Transit Options and Prioritization Study - MTOPS) reviewed several mass transit plans and proposals. Previous studies assessed suitable mass transit options and recommended a steel rail-based mass transit system (MRT).

MTOPS considered three high-demand corridors (red) for MRT and two medium-demand corridors (blue) for bus rapid transit (BRT), as shown in Figure 2.6.2 (a) for alignment. The red corridors will support 20,000 to 40,000 passengers per hour per direction (PPHPD), while the blue ones can accommodate 10,000 to 20,000 PPHPD by 2040.

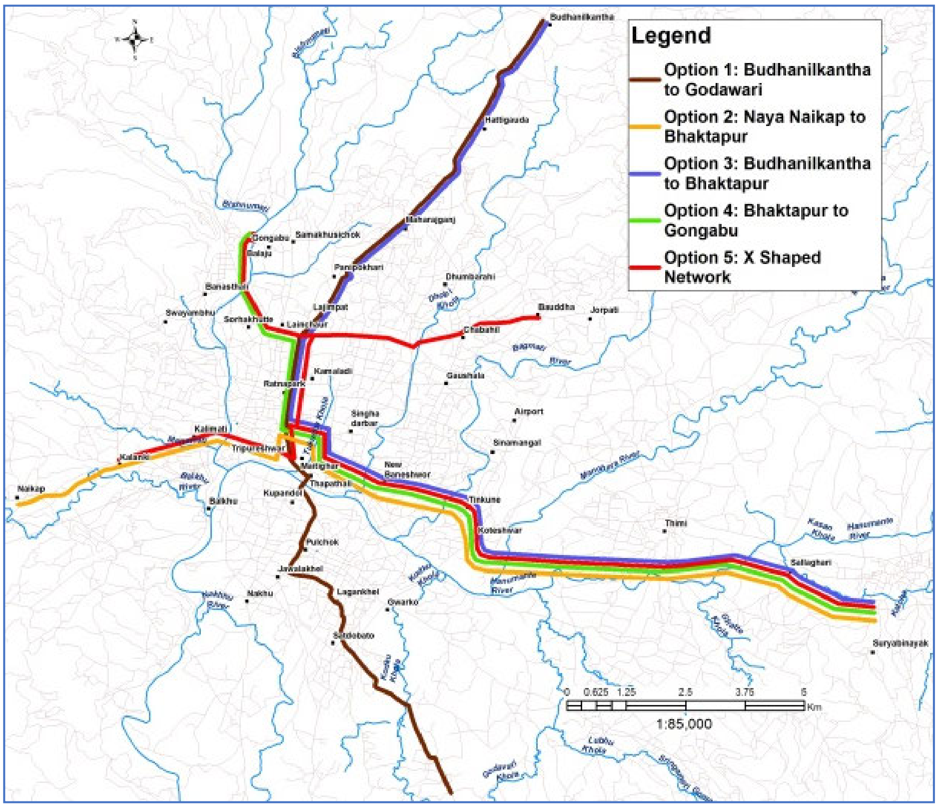
The MRT on the segregated red corridors will run completely independent of mixed traffic in their right-of-way (ROW), whereas the BRT on the dedicated blue ones will run at grade in their ROW. Furthermore, as shown in Figure 2.6.2 (b), the five corridors were comparatively assessed to select a Priority Corridor for the first implementation.

Based on a multi-criteria evaluation, Option 4: Bhaktapur to Gongabu emerged as the recommended Priority Corridor (Figure 2.6.2 (c)). The study also featured a feasibility analysis and suggested a hybrid alignment viaduct in the suburban and underground sections inside the Ring Road. Based on Option 4, a pre-survey by JICA further analyzed a preferable route with the new town development plan in the north and the concentration of mode movement for road and railway on Araniko Highway.

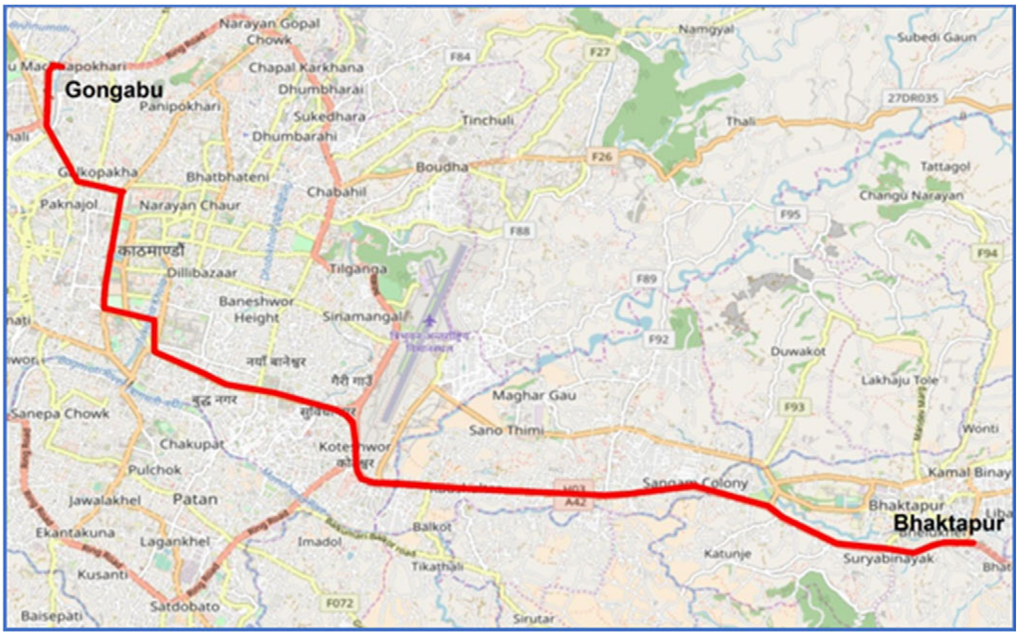
The pre-survey recommended a route passing through the new town area shown in Figure 2.6.2(d) as a green line or green-line-plus-blue-line. Accommodating the future railway route was essential during project planning.



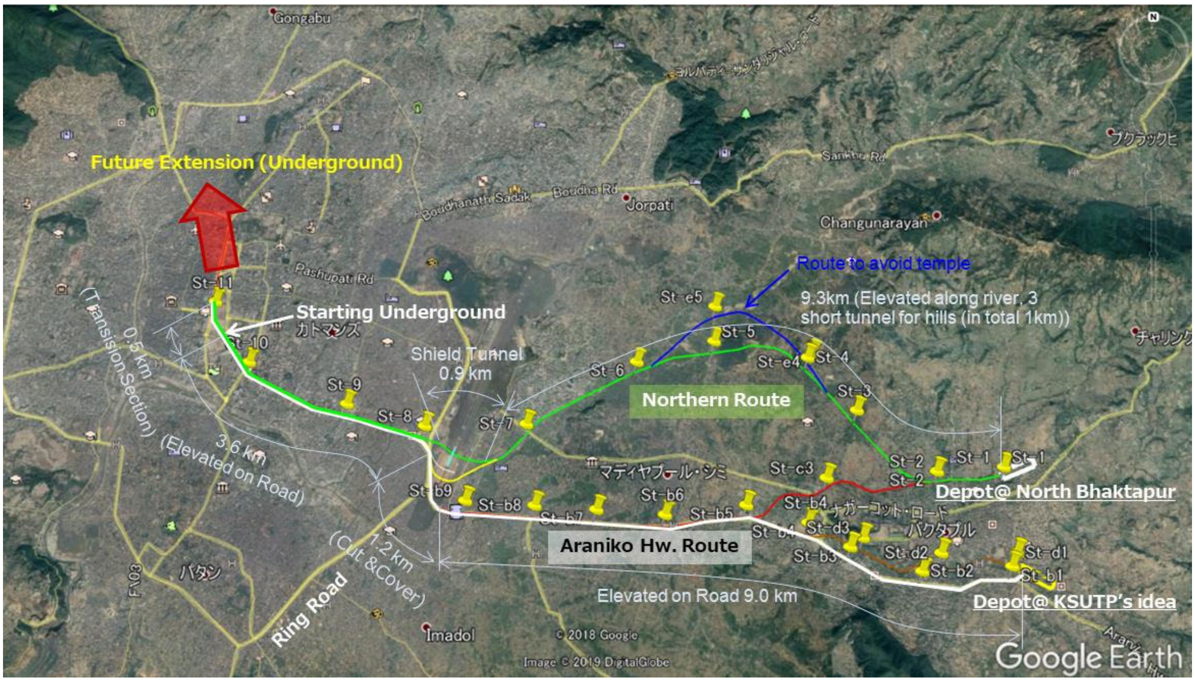
(a) High/Medium Demand Mass Transit Corridors



(b) Mass Transit Corridor Options



(c) Recommendation on the Priority Corridor



Source: JICA Survey Team

(d)Alternative Route Plans (Northern Route)

Figure 2.6.2 East-West Corridor (MRT) by ADB under KSUTP

2.6.4 Monorail along the Ring Road by the Kathmandu Metropolitan City (KMC) and China

In December 2018, the KMC signed a memorandum of understanding (MOU) with China Railway Construction Corporation (CRCC) to conduct the DPR for the proposed monorail along the 27-km Ring Road. Before this, the Chinese state-owned firm submitted a feasibility study in September 2018, which estimated a project cost of NPR 116 billion. The DPR was 100% complete by the end of 2019. However, the CRCC did not get the opportunity to share results with the KMC yet.

The Mayor of KMC is very keen to materialize the project and asked for government support. However, the Office of Investment Board of Nepal considered the project not untenable due to the low carrying capacity of the monorail.

Araniko Highway UpgradeThe two-lane road between Kathmandu, the Tinkune Intersection, and Bhaktapur, the Suryabinayak Intersection, was upgraded to four lanes for 9.1km. The improvement included five enhanced intersections and the provision of lay-bys for 14 bus stops. The Japanese government shouldered project costs, and the road opened in November 2011. The 2015 earthquake damaged some sections, which received rehabilitation at a later date.

Today, two bridges on both sides of the Manohara River Bridge on Araniko Highway are under construction by DOR[6]. This project is a part of the improvement project for the entire Araniko Highway, which will upgrade the existing four-lane road to an eight-lane road, comprising a four-lane main carriageway and two-lane frontage roads at both sides, same as the cross-section of Tribhuvan highway, completed in 2022.

The DOR began widening the road section between Judibuthi to Koteshwor Intersection with two additional lanes for Kathmandu-bound vehicles and one lane for Bhaktapur-bound vehicles to ease traffic congestion at the Koteshwor intersection. DOR acquired and utilized airport land from CAAN in February 2020 for this project. As of June 2022, the widening work was complete.

2.6.5 Upgrade of Bouddha Road

The Bouddha Road upgrade, stretching from Chabahil to Sangu, with a total length of 11.5km, is underway. It will widen Bouddha Road from its current width of 18m (dual 2-lane) to 22m under the Kathmandu Road Expansion Project (KVREP)[7,] financed by the local government since October 2015. However, the project has faced difficulty with implementation due to obstruction from locals opposing house demolition while asking for higher compensation. Although DOR extended its contract period to Jan 2021, the project was not yet complete as of Jun 2022.

2.6.6 River Corridor Development

The High Powered Committee for Integrated Development of the Bagmati Civilization (HPCIDBC) pushes for river improvement works in Kathmandu Valley in line with the Bagmati Action Plan (2009-2014). The plan includes:

1. River training,
2. River corridor development
3. Installation of interceptors along the rivers.

Although the bulk of the work is complete thanks to the HPCIDBC, various agencies were involved in implementing its plan, as shown in Table 2.6.2.

6 There are four bridges across the Manahara river on Araniko Highway at present, a new bridge by DOR in 2022 at the north end or upstream side, one constructed by Japanese Grant Aid in 2011, the oldest one constructed by Chinese aid in 1973, and a new one by DOR in 2022 at the southern end or downstream side.

7 The Project aims to widen the total 112km of the existing 2-lane roads to 4-lane ones in the Kathmandu valley initiated by local government in order to ease traffic congestions. It started in 2007 but not completed yet as of Sep. 2022 due to compensation issues on resettlement.

Table 2.6.2 Work Section and Responsibility for Implementation

River Name	River Training	River Corridor	Interceptor
Bagmati River	HPCIDBC	HPCIDBC	HPCIDBC
Bishnumati River	HPCIDBC	DOR	HPCIDBC
Hanumante River	PID, KUKL	HPCIDBC	PID, KUKL
Dhobi River	KVDA	KVDA	HPCIDBC
Manohara River	PID, KUKL	HPCIDBC, DOR, Local Government, KVDA	PID, KUKL

KUKL: Kathmandu Upatyaka Khanepani Limited, PID: Project Implementation Department
Source: JICA Survey Team

The Manohara River has been designated as an administrative boundary among the Kathmandu, Bhaktapur, and Lalitpur municipalities by the government. Table 2.6.3 shows work sections along the river corridor and its administrative territories.

Although Table 2.6.2 indicates that HPCIDBC is the implementation agency for the Manohara River corridor, other agencies control project progress in various sections. Project completion varies depending on the work section.

Table 2.6.3 Work Sections and its Administrative Territory

Work Section	Administrative Territory	Progress of River Corridor Development
Section 1: Araniko Highway Bridge to Confluence Point with the Hanumante River	-	
- Left bank side	Bhaktapur	Completed
- Right bank side	Kathmandu	Partially under construction
Section 2: Confluence Point with the Hanumante River to the Ring Road Bridge	-	
- Left bank side	Lalitpur	Under construction
- Right bank side	Kathmandu	Nearly completed, and only pavement work remains

Source: JICA Survey Team

2.6.7 Pedestrian Bridge Plan on Project Roads

Two pedestrian bridge plans are active on the connecting road section of the project intersections. The DOR will construct the first one north of the Koteshwor intersection. Another bridge in the South of Tinkine Section is under planning from the Kathmandu Metropolitan City. Due to difficulty obtaining acceptance from the Civil Aviation Authority of Nepal (CAAN), as the bridges might obstruct airplane operations and opposition from the residents nearby, the project has been suspended for a long time.

2.6.8 Flyover Plan on Ring Road

DOR plans to construct three flyovers on the Ring Road at Gwarko, Satdobato, and Ekantakuna intersections in Lalitpur (see Location Map). Local consultants were responsible for the DPR and design of the project.

The local government will mobilize funds to construct those flyovers. According to the Kathmandu Post, the four-lane flyover construction at Gwarko started in February 2023 with a Rs 170 million budget, which will reach completion in February 2024.

CHAPTER 3. NATURAL CONDITIONS SURVEY

3.1 Topographical Survey

3.1.1 Introduction

Topographical survey and mapping are essential initial tasks in a survey of any infrastructure development project. Surveying project areas will allow a designer to determine setting out project components in appropriate location and prepare quantity estimation. Topographic mapping is also for geological mapping and environmental and social studies.

DGPS (Differential Global Positioning System) and Total Station are instruments for producing topographical surveys. The National Grid Control Point 102-039, located at Lakhe Dada, Lalitpur, Bagmati, and the second order national grid point, transferred to the project site to generate the DGPS Static Survey. The Static Global Navigation Satellite System (GNSS) technology was instrumental in establishing the horizontal and vertical control network.

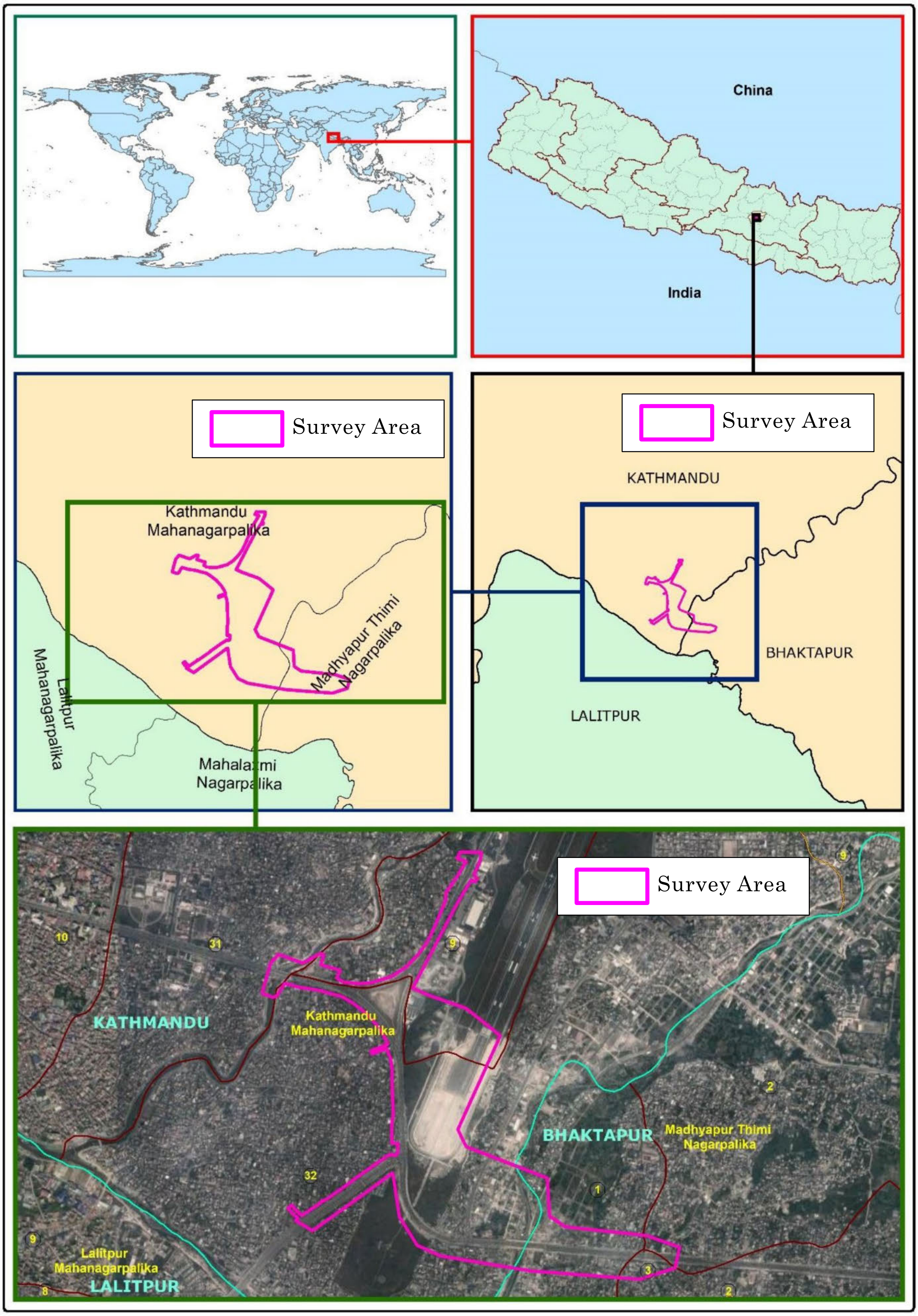
3.1.2 Location

The project is located in Tribhuvan International Airport (TIA) in Kathmandu Valley, encompassing Koteshwor, Balkumari, Tinkune and Jadibuti. areas, located in Kathmandu, Lalitpur, and Bhaktapur districts of Bagmati zone in Bagmati Province (Province No. 3). Table 3.1.1 presents relevant information on the survey area.

Table 3.1.1 Location of Survey Area

SN	Project Name	Description
1	Plane survey location	Santinagar,Tinkune,Airport road,Koteshwor and Jadibuti.
2	Province name	Province (No-3)
3	District	Kathmandu, Lalitpur and Bhaktapur
4	Latitude	27°41'7.07"N
5	Longitude	85°20'55.61"E
6	Nearest Airport	Tribhuvan International Airport
7	Nearest Town	Kathmandu
8	Nearby River	Bagmati, Manohara and Hanumante River

Source: JICA Survey Team



Source: JICA Survey Team

Figure 3.1.1 Survey Location Map

3.1.3 Coordinates

The MUTM (Modified Universal Transverse Mercator) is generally used as a local coordinate in Nepal. For easy application to the survey and design, the coordinates of the survey map were converted into WGS (World Geodetic System) - UTM (Universal Transverse Mercator).

3.1.4 Survey Items

The topographic survey consists of survey items listed in Table 3.1.2.

Table 3.1.2 Survey Items

S.N.	Items
1	Benchmark Installation
2	Plane Survey
3	Cross Section Survey of the Project Road
4	Cross Section Survey of Rivers
5	Profile Leveling Survey of Rivers
6	Data Collection of Existing Underground Utilities

Source: JICA Survey Team

3.1.5 Survey Results

(1) Benchmark Installation

Major benchmarks (control points) were established at ten (10) locations at various places around the project area. Surveyors drilled nut bolts on solid surfaces like concrete structures to establish control points, as shown in Figure 3.1.2, so that they are not quickly moved and displaced and can be easily located and used during the construction stage in the future.

Source: JICA Survey Team

Figure 3.1.2 Benchmark Installation

During the preliminary design, surveyors established control points, and locations were recorded in a logbook (description card) by taking at least three references near the control point. The description card contains detailed information about the location, the X, Y, and Z coordinates of the control points, the location and measurement of reference points, and pictures. Appendix 1 documents the description cards, and Table 3.1.3 lists the installed control points.

Table 3.1.3 Installed Control Points

SN	MUTM		WGS 1984		Elevation	Station Name	Location
	Easting	Northing	Longitude	Latitude			
1	632718.78	3063828.353	85.343303	27.686401	1294.401	GCP-1	Bagmati Bridge, Towards Baneshowr
2	632833.17	3063802.447	85.344459	27.686156	1294.392	GCP-2	Bagmati Bridge, Towards Tinkune
3	633679.084	3064398.189	85.353099	27.691448	1306.877	GCP-3	Airport Road, Sinamangal
4	633726.713	3064505.6	85.353594	27.692412	1312.297	GCP-4	Airport Road, Sinamangal
5	633963.751	3062596.544	85.355784	27.675164	1297.594	GCP-5	Jadibuti Bridge, Towards Lokanthali
6	633988.902	3062650.836	85.356045	27.675652	1296.704	GCP-6	Jadibuti Bridge, Towards Lokanthali
7	633706.373	3061812.97	85.353088	27.66812	1291.909	GCP-7	Hanumante Bridge, Bhaktapur
8	633575.088	3061774.659	85.351754	27.667787	1289.138	GCP-8	Manohara River Bank, Lalitpur
9	632690.819	3062498.796	85.342872	27.674408	1304.651	GCP-9	Koteshwor - Balkumari Road, Kathmandu
10	632541.608	3062337.351	85.341342	27.672966	1287.216	GCP-10	Koteshwor - Balkumari Road, Lalitpur

Source: JICA Survey Team

(2) Plane Survey

Before the field mobilization, the Department of Survey (DOS) of the government of Nepal provided all relevant information and data, including the two numbers of second order trig control point of Lalitpur and Kavre districts and the National Trig Point (102-039) at Lakhe Dada.

The trig point of DOS only provides horizontal coordinates. Therefore, it was necessary to derive the vertical coordinates using the elevation of Gravity No. 79.4. Table 3.1.4 presents the information and status of the national trig points and benchmarks in the field. Based on the national trig points, coordinates (X,Y,Z) were determined for the benchmarks.

Table 3.1.4 National Trig Points

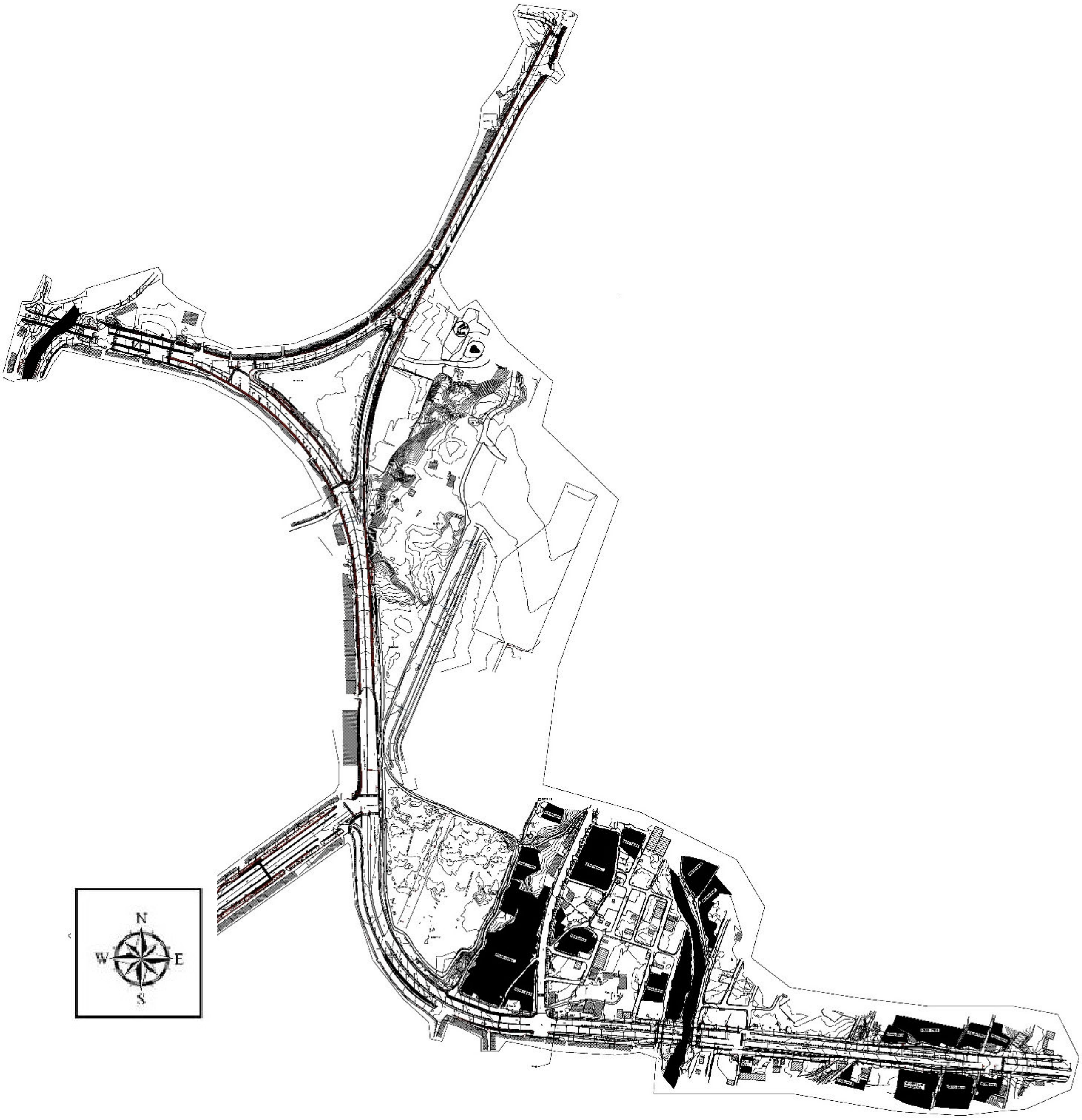
Grid Sheet	Trig/Benchmark/ Gravity No.	Easting (m)	Northing (m)	Elevation (m)	Location	Status
102	Trig No. 039	629195.032	3057473.026	N/A	Lakhe Danda	Found at site and used
115	79.4	-	-	1308.448	Traffic office Koteshwor	Found at site and used

Source: JICA Survey Team

National Trig Point: Gravity No. 039 is approx. 7 km away from No. 79.4 in the south-west direction.
Source: JICA Survey Team

Figure 3.1.3 Plane Survey Area

Figure 3.1.4 shows the plane survey result.



Source: JICA Survey Team

Figure 3.1.4 Plane Survey Result

(3) Cross Section Survey for the Project Roads

In order to study the width of cross-section elements of the project road in sections between the Tinkune Intersection and Koteshwor Intersection, cross-section surveys were executed at 100-meter interval at locations shown in Figure 3.1.5.

Cross sections were taken at approximately 100m interval.
Source: JICA Survey Team

Figure 3.1.5 Target Locations for Cross Section

The current lane layout near the Koteshwor intersection on the road section between A-A to E-E consists of three lanes and one bus lane for each direction. However, as the lane markings of this road is not clear, vehicles run unaligned to the designed traffic lanes, creating four to five lanes of vehicles in heavy traffic.

Appendix 2 shows the existing carriageway layout indicated by arrows.

3.1.6 Topographic Survey within the Tribhuvan International Airport

(1) Objective

The DOR proposed an alternative route for the project during the discussions held at the Inception Report meeting between the Nepal side and JICA. This route passes through the land belonging to the TIA at the south of the runway. As they considered it one of the conceivable routes, they conducted a survey of the area.

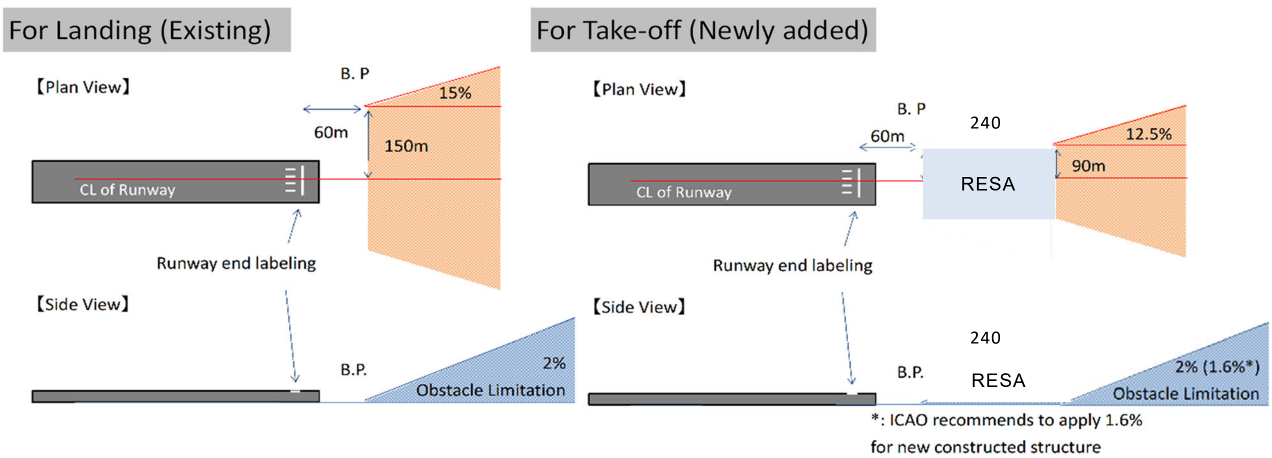
Source: JICA Survey Team

Figure 3.1.6 Target Area

Obstacle limitation space in and immediately around the TIA exists to impose and secure safe landing and taking off in the airport. Authorities permit any permanent and temporary objects during operation within the airport. In addition, the TIA informed the authorities that the expected completion date of the runway expansion work towards the south of the current runway to facilitate take-off to this direction was May 2020. With this expansion, the project needs to provide new obstacle limitation spaces. In this survey, surveyors utilized existing and new obstacle limitation spaces for the target area in Figure 3.1.6

(2) Obstacle Limitation Spaces and Runway End Safety Area

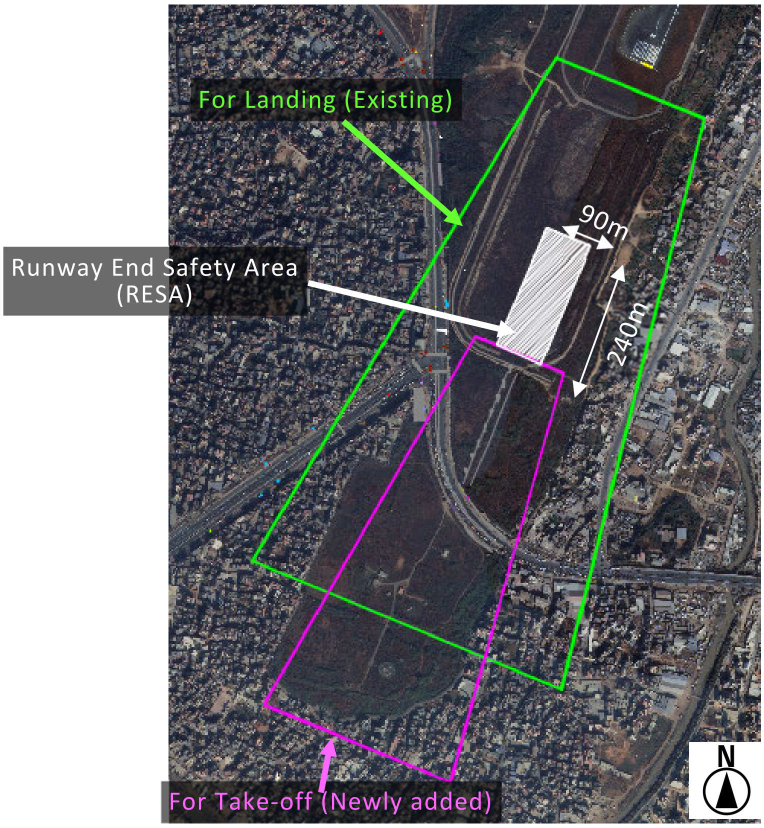
Figure 3.1.7 presents the obstacle limitation Space (OLS) for existing landing and new take-off. The Runway End Safety Area (RESA) in the take-off, where objects are restricted, needs to be set.



Source: JICA Survey Team

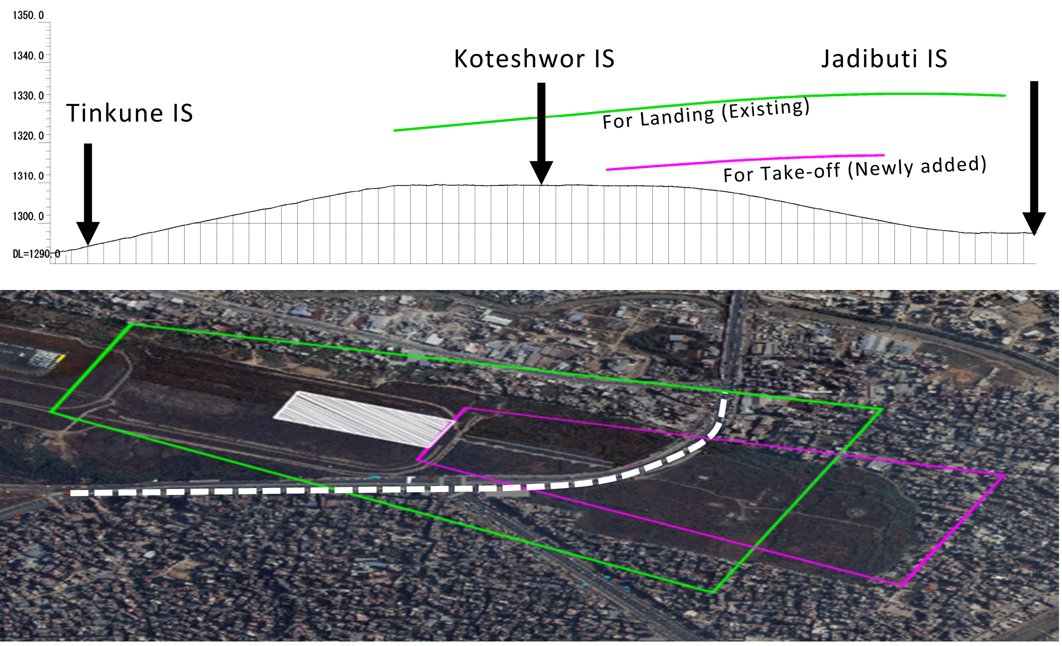
Figure 3.1.7 Regulation of Obstacle Limitation Space

The new OLS was set 240 meters ahead (to the south side) from the existing runway end point, as shown in Figure 3.1.8 and Figure 3.1.9. The generated coordinates of the runway end through the GPS survey are (337,617.627, 3,063,264.332, 1,314.446).



Source: JICA Survey Team

Figure 3.1.8 Obstacle Limitation Space (1/2)

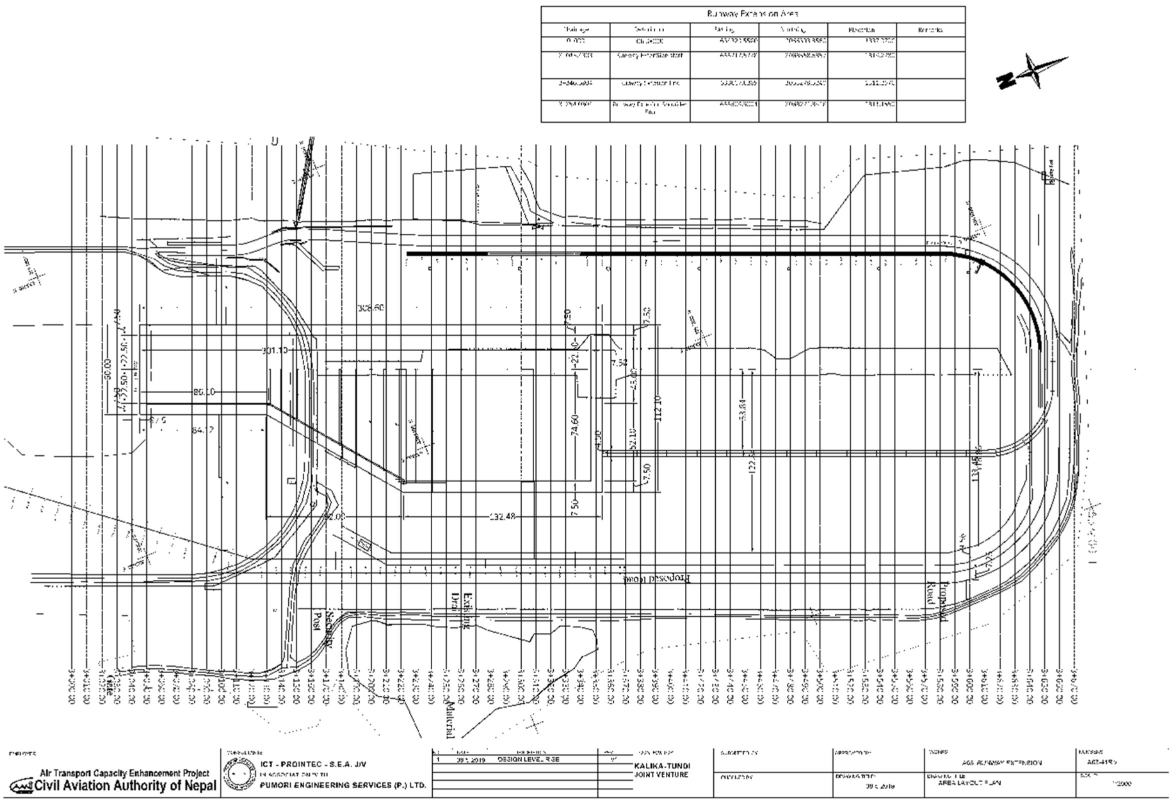


Source: JICA Survey Team

Figure 3.1.9 Obstacle Limitation Space (2/2)

(3) Existing Topographic Map

The CAAN completed the topographic survey and design work for the runway expansion. Figure 3.1.10 shows the plan drawing of the design. Utilizing such data, JICA Survey Team (JST) carried out additionally the plane and cross-section survey for the area, necessary for planning the project road and supplementing existing survey results.



Source: JICA Survey Team

Figure 3.1.10 Existing Topographic Map of Expansion Area in TIA

3.2 Existing Utility Survey

3.2.1 Existing Underground Utilities

The three main kinds of underground utilities around the project site are telecommunication cable, old water supply line, and new water supply line installed 1 to 2 meters deep under the ground surface. Figure 3.2.1 to Figure 3.2.3 show the network of each utility.

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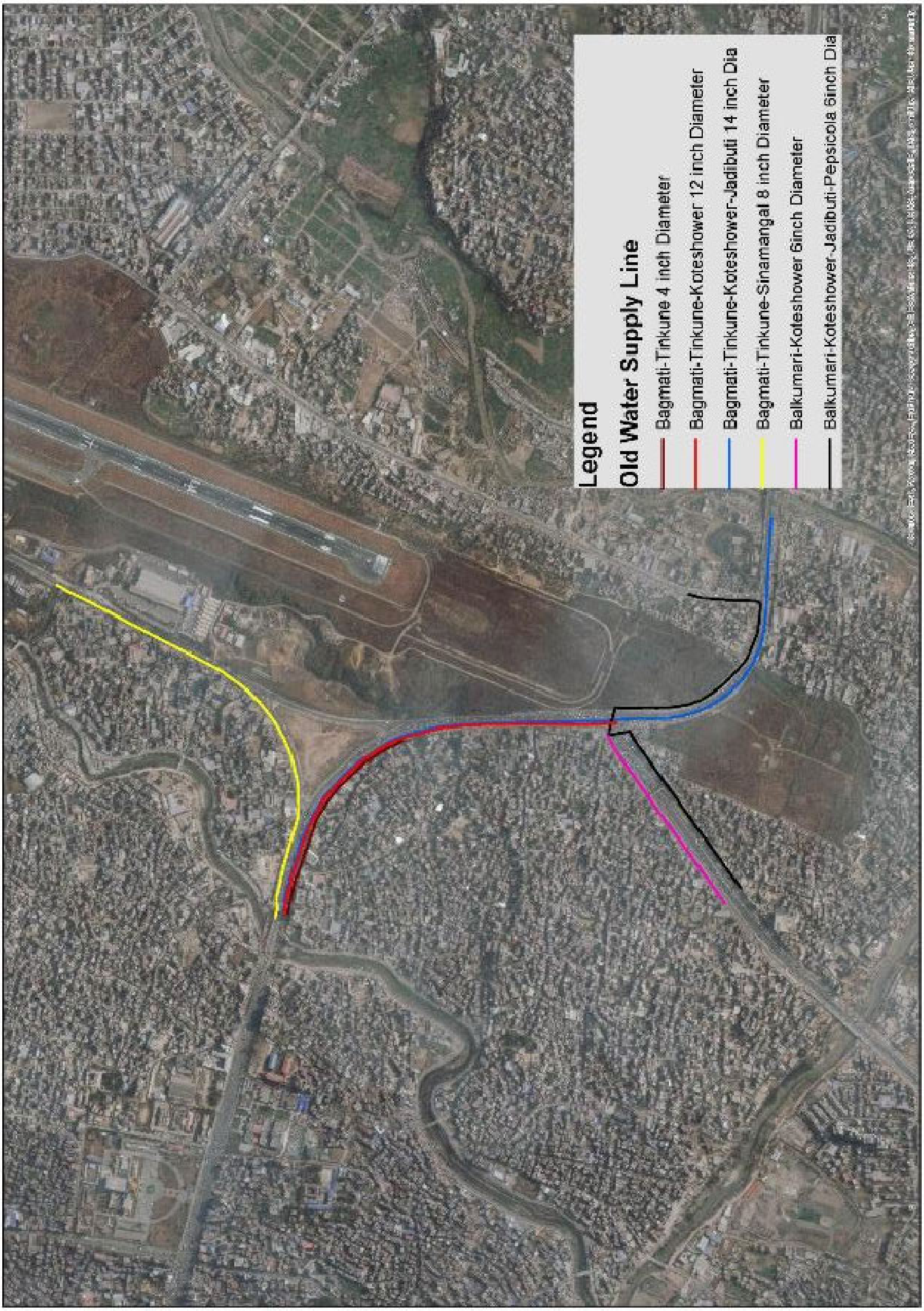
Source: Nepal Telecom

Figure 3.2.1 Telecommunication Cable



Source: Kathmandu Upatyaka Khanepani Limited, Project Implementation Directorate (KUKL PID)

Figure 3.2.2 Old Water Pipe

Source: Kathmandu Upatyaka Khanepani Limited, Project Implementation Directorate (KUKL PID)

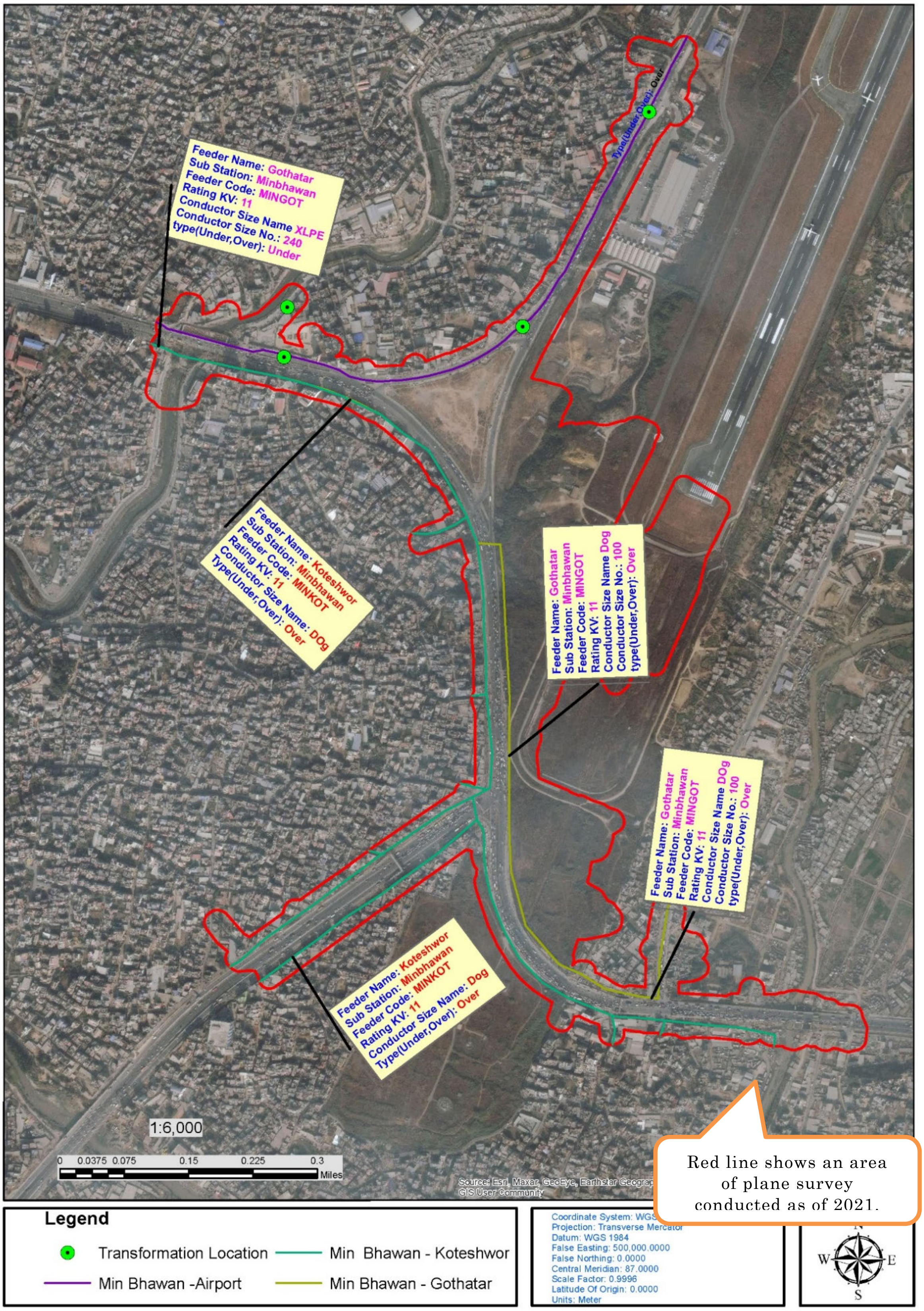
Figure 3.2.3 New Water Pipe

3.2.2 Existing Ground Utilities

There are overhead high voltage electricity transmission lines with 11kV around the project site, as shown in Figure 3.2.4. In addition to the transmission line, general power supply cables for private or commercial use with low voltage are along the project roads. Table 3.2.1 and Table 3.2.2 summarize the inventory of the overhead power supply cables at road-crossing points. No overhead cables violate the Obstacle Limitation Space.

Source: JICA Survey Team

Figure 3.2.4 Electricity Transmission Lines (11kV)



Source: Nepal Electricity Authority

Figure 3.2.5 Electricity Transmission Line Network

Table 3.2.1 Inventory of Overhead Power Supply Cables (1/2)

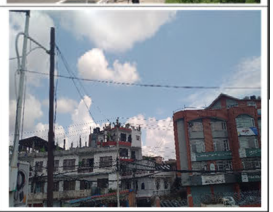
S.N.	Code	Coordinate			Height from GL	Wire Elevation	Wire Type	Pole Type	Remarks
		Easting	Northing	GL Elevation					
1	P1	337566.173	3064090.021	1304.547	5.850	1310.397	Multiple Cable Wire	Galvanized iron Pole	
		337579.162	3064080.827	1304.758		1310.608			
2	P2	337579.162	3064080.827	1304.758	5.950	1310.708	Multiple Cable Wire	Iron Pole	
		337551.964	3064060.865	1303.352		1309.302			
3	P3	337371.151	3063715.812	1293.726	5.950	1299.676	Multiple Cable Wire	Galvanized iron Pole	
		337392.295	3063723.783	1294.087		1300.037			
4	P4	337371.151	3063715.812	1293.726	6.250	1299.976	Multiple Cable Wire	Galvanized iron Pole	
		337383.066	3063706.031	1293.969		1300.219			
5	P5	337336.405	3063659.016	1293.432	6.550	1299.982	Multiple Cable Wire	Tree	
		337353.177	3063652.054	1293.206		1299.756			
6	P6	337257.144	3063575.305	1292.606	9.350	1301.956	Hightension Line	Galvanized iron Pole	
		337273.221	3063555.033	1292.508		1301.858			
7	P7	337191.181	3063531.075	1292.268	6.650	1298.918	Multiple Cable Wire	Iron Pole	
		337197.255	3063517.324	1292.459		1299.109			
8	P8	336962.377	3063501.610	1292.513	7.150	1299.663	Multiple Cable Wire	Concrete pole-Iron pole-Concrete pole	
		336955.614	3063481.594	1292.533		1299.683			
		336952.504	3063464.975	1292.803		1292.803			

Table 3.2.2Inventory of Overhead Power Supply Cables (2/2)

S.N.	Code	Coordinate			Height from GL	Wire Elevation	Wire Type	Pole Type	Remarks
		Easting	Northing	GL Elevation					
9	P9	336739.652	3063551.490	1294.667	6.450	1294.667	Multiple Cable Wire	Tree- Galvanized iron pole	
		336725.808	3063537.225	1294.521		1300.971			
10	P10	337073.281	3063384.828	1292.487	5.850	1292.487	Single Cable	Concrete pole- Street Lamp post	
		337078.027	3063401.493	1292.284		1298.134			
11	P-11	337174.526	3063241.103	1295.324	6.650	1295.324	Multiple Cable Wire	Galvanized iron Pole	
		337206.976	3063239.475	1295.786		1302.436			
12	P-12	337202.190	3063281.304	1294.745	9.950	1294.745	Hightension Line	Galvanized iron Pole	
		337227.993	3063259.626	1295.335		1305.285			
13	P-13	337204.518	3063153.504	1299.457	8.850	1299.457	Hightension Line	Galvanized iron Pole	
		337236.533	3063158.367	1301.475		1310.325			
14	P-14	337241.869	3063134.523	1301.637	6.850	1301.637	Multiple Cable Wire	Galvanized iron Pole	
		337204.679	3063132.824	1298.884		1305.734			
15	P-15	337206.882	3062656.634	1309.096	7.350	1309.096	Multiple Cable Wire	Concrete pole	
		337210.329	3062649.075	1308.972		1316.322			
16	P-16	337384.440	3062372.597	1299.859	7.050	1299.859	Multiple Cable Wire	Concrete pole- Iron pole	
		337357.633	3062337.665	1301.467		1308.517			

Source: JICA Survey Team

3.3 Geotechnical Investigation

3.3.1 Introduction

Geotechnical Investigation is another essential survey for any infrastructure development project to obtain geological and geotechnical information on the survey area to understand the distribution of the soil types/layers, including the physical and mechanical properties for the planning and design of the project. Another major objective is to test the quality of various construction materials used during construction. Table 3.3.1 summarizes the scope of work for geotechnical investigation conducted under the survey.

Table 3.3.1 Scope of Works for Geotechnical Investigation

No.	Description	Unit	Q`ty	Remarks
1	**Preliminary Work**	LS	1	
2	**Core Drilling and Laboratory Tests**			
2-1	**Boring Survey**			
	Drilling works (BH1, BH2, BH3, BH4)	m		
	- BH1, BH2, BH3, BH4	m	200	50m @ 4nos.
	Standard Penetration Test (SPT) [ASTM D1586]	Nos.	200	1m interval
	Disturbed/undisturbed soil sampling	Borehole	4	
	Water level measuring in boreholes	Nos.	4	
2-2	**Laboratory Tests for Borehole Material**			
	Natural moisture/water content [ASTM D2216]	Nos.	40	10 samples per borehole
	Specific gravity [ASTM D854]	Nos.	40	
	Sieve analysis [sieving + hydrometer test, ASTM D422]	Nos.	40	
	Liquid limit & plastic limit [ASTM D431]	Nos.	40	
	Unit weight test with undisturbed soil samples [ASTM D7263]	Nos.	40	
	Unconfined compression test for clay [ASTM D2166]	Nos.	20	5 samples per borehole
	Consolidation test for clayey soil [ASTM D2435]	Nos.	20	
	Direct shear test for sandy soil [ASTM D3080]	Nos.	20	
3	**CBR Tests**			
	Field in-place CBR test [AASHTO T193]	location	4	
	Test pitting and soil sampling	samples	12	4 locations*3 layers (base course, subbase course, and subgrade)
	Soil classification [ASTM D 2487]	samples	12	
	Natural moisture/water content [ASTM D2216]	samples	12	
	Specific gravity [ASTM D854]	samples	12	
	Sieve analysis [4.5kg rammer method, AASHTO T180]	samples	12	
	CBR test [AASHTO T193]	samples	12	
4	**Material Investigations**			
4-1	**Laboratory Tests for Borrow Material**			
	Test pitting and soil sampling	location	3	
	Soaked CBR Test [AASHTO T193]	sample	3	
	Specific gravity [AASHTO T100]	sample	3	
	Liquid and plastic limit [AASHTO T90]	sample	3	
	Sieve analysis [sieve+ hydrometer test, AASHTO T88]	sample	3	

No.	Description	Unit	Q`ty	Remarks
	Natural moisture/water content [AASHTO T265]	sample	3	
4-2	**Laboratory Tests for Quarry Material (Base and Subbase Course)**			
	Test pitting and aggregate/rock sampling (base and subbase course)	location	3	
	Compaction test [4.5kg rammer method, AASHTO T180]	samples	6	
	Soaked CBR test [AASHTO T193]	samples	6	
	Specific gravity [AASHTO T100]	samples	6	
	Liquid and plastic limit [AASHTO T90]	samples	6	
	Sieve analysis [sieve + hydrometer test, AASHTO T88]	samples	6	
	Natural moisture/water content [AASHTO T265]	samples	6	
4-3	**Laboratory Tests for Quarry Material (for Asphalt Pavement)**			
	Test pitting and aggregate/rock sampling	location	3	
	Los Angels abrasion test [AASHTO T96]	sample	3	
	Flakiness index [AASHTO M147-6S]	sample	3	
	Absorption and specific gravity test [AASHTO T84]	sample	3	
	Sieve analysis [AASHTO T27]	sample	3	
	Soundness of aggregate [AASHTO T104]	sample	3	
4-4	**Laboratory Tests for Quarry Material (for Concrete)**			
	Test pitting and aggregate/rock sampling	location	3	
	Los Angels abrasion test [AASHTO T96]	sample	3	
	Absorption and specific gravity test [AASHTO T84]	sample	3	
	Soundness of aggregate [AASHTO T104]	sample	3	
	Sieve analysis [AASHTO T27]	sample	3	
	Alkali reactivity [ASTM C289]	sample	3	
	Organic impurities in fine aggregate [AASHTO T21]	sample	3	
	Materials finer than 75-µm (No. 200) sieve [AASHTO T11]	sample	3	
	Clay lumps and friable particles in aggregate [AASHTO T112]	sample	3	
5	**Data Collection**	LS	1	
6	**Documentation and Report (1 Hard, 1 Soft Copy)**	LS	1	
7	**Overhead Cost**			
	Accommodation, Security, transportation, etc.	LS	1	

Source: JICA Survey Team

3.3.2 General Geology of the Project Area

The project area lies almost at the central part of Kathmandu Valley, the most densely populated valley in the country and located in the middle of the Lesser-Himalayas. The valley, formerly used as a lake (Paleo-Kathmandu Lake), is a basin (bowl-shaped) formed due to the uplift of Mahabharat Thrust. Mountains and fluvial-lacustrine sediments overlying basement rocks surround it. The sediments were derived from the mountains and are composed of blackish plastic clayey silts, sandy silts, silty sands, and sands with fine to coarse gravels. The maximum depth of the valley sediment is reported to be more than 550m (Sakai: 2008, Suresh Krishnan and Kim: 2017), at the central part of the valley.

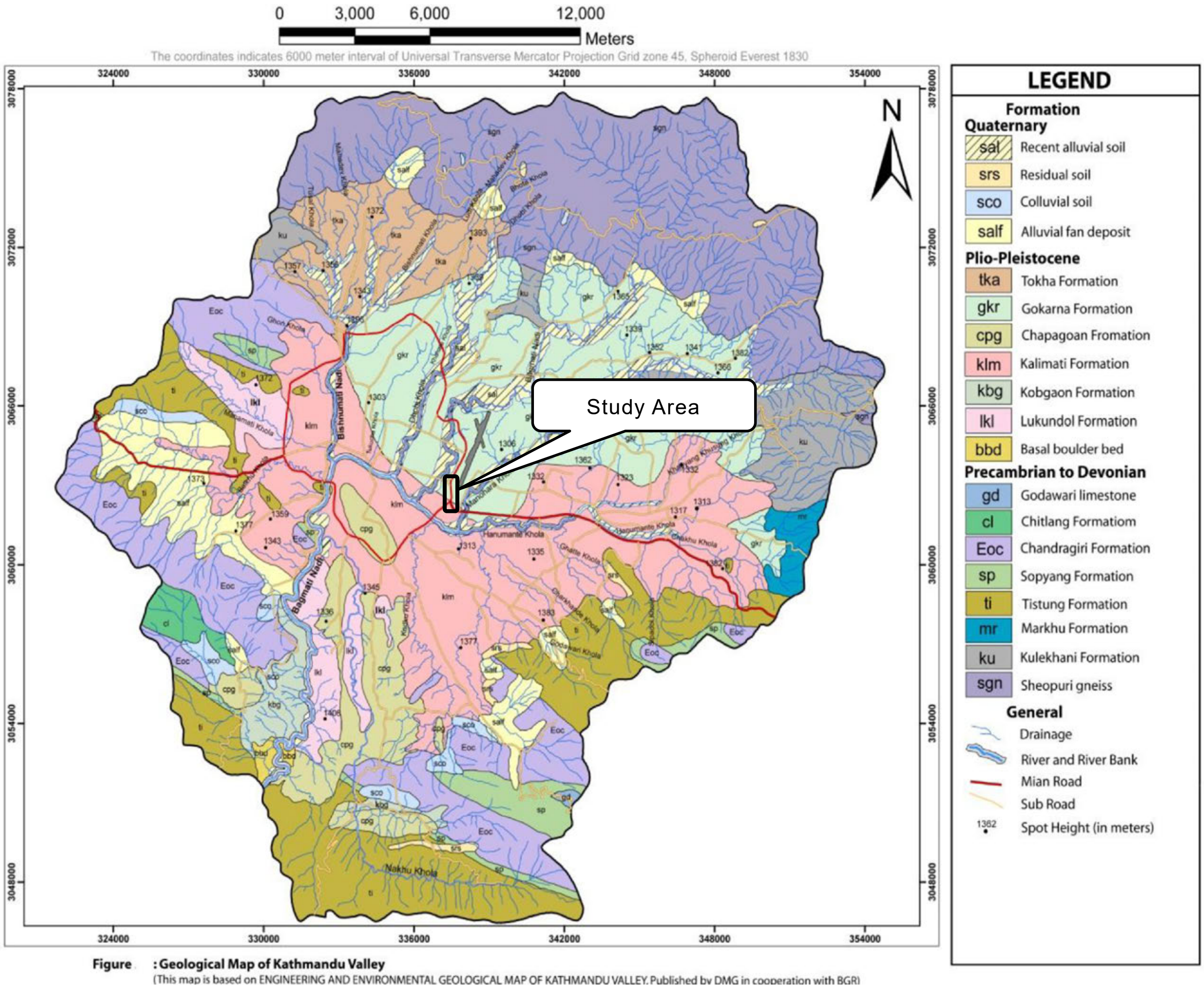
3.3.3 Investigation Location

A geotechnical investigation was conducted at several locations in the Kathmandu District in the Kathmandu Valley from Tinkune to Jadibuti through Koteshwor, as shown in Figure 3.3.1. It consists of core drillings, CBR tests, and laboratory tests. The locations of drillings based on the alignment of Grade-Separated Section, which was defined in Chapter 8, are shown by yellow circles in Figure 3.3.2. Depths to be bored for each drilling hole are in Figure 3.3.2. Although the boring survey at BH-2 was conducted in TIA land, it took two weeks to start site work after letter submission to CAAN for permission. The reply letter from CAAN requested a survey plan (schedule, area, a list of surveyors and equipment, survey methodology, and expected survey duration).

The further instructions given by CAAN for the survey works within TIA land to restore security and safety in the airport are as follows:

- Never enter inside of service road (towards runway). Fore reference: The yellow color center line indicates taxiway and the white color center line indicate the runway.
- Follow the speed limit for vehicle use. The speed limit is 20 kph for perimeter road and 10 kph for airside road and adjacent apron.
- Only work in the schedule approved by the TIA authority. Every work activity to be under the supervision of accompanying staff of TIA Airside Operation Management Division.
- Do not carry nor use the fire and other inflammable material in the working area.
- Do not throw any garbage, even plastic bottle, its cover, mask etc. in airport area as it is carried away in the air to the runway and creates massive problems in landing and take-off.
- Do not throw any food item covers or food inside the airport as it attracts monkeys and birds, which creates problems for the airport operation.
- Only send the permitted persons with a pass issued for the same name. Do not send other persons with the pass issued for another person. Invigilators will cross check it as required.
- Obey instruction provided by the control tower in case of emergency.
- Never go near airplanes, as its engine may cause accidents.
- Do not take any materials strictly prohibited by the airport rules.
- Always wear adequate safety gears (jacket, shoe, gloves, ear cotton, etc.) while entering and working inside airport. Use the provided storeroom to keep equipment when not in use.

Figure 3.3.3 maps the locations of the trial pitting for CBR tests. It is important to note that the trial pitting was carried out just beside the existing road in order not to avoid smooth traffic flow.

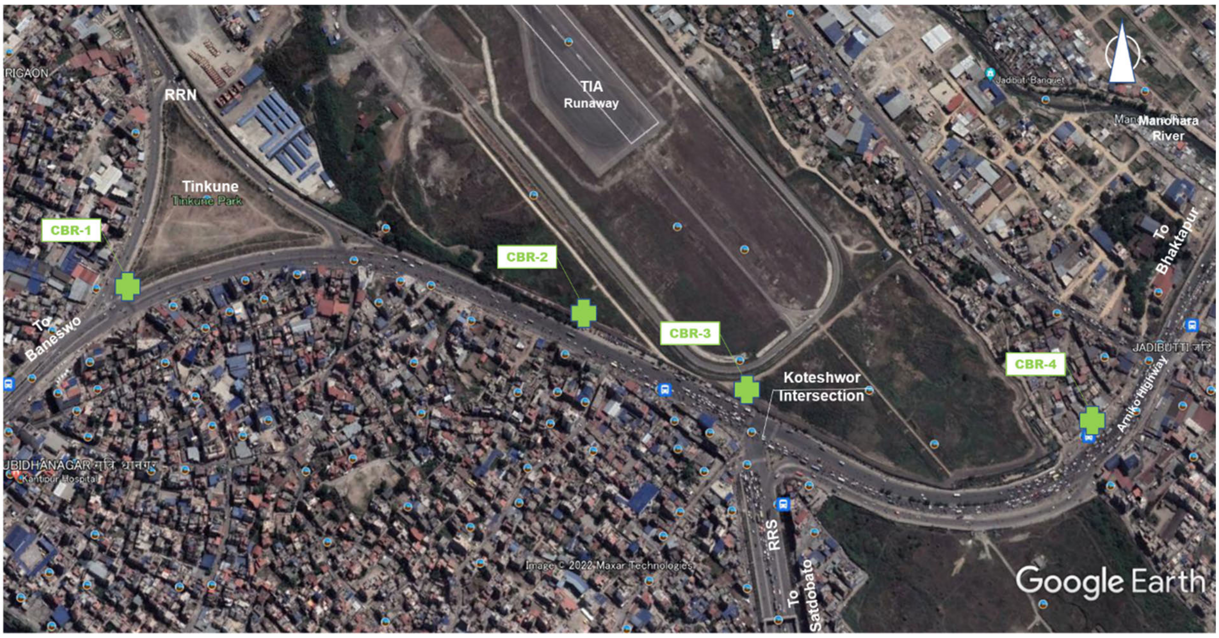


Source; Engineering and Environmental Geological Map of Kathmandu valley, Department of Mines and Geology, Nepal

Figure 3.3.1 Geological Map of Kathmandu Valley

Source: JICA Survey Team

Figure 3.3.2 Investigation Locations of Drilled Boreholes (in Google Earth)

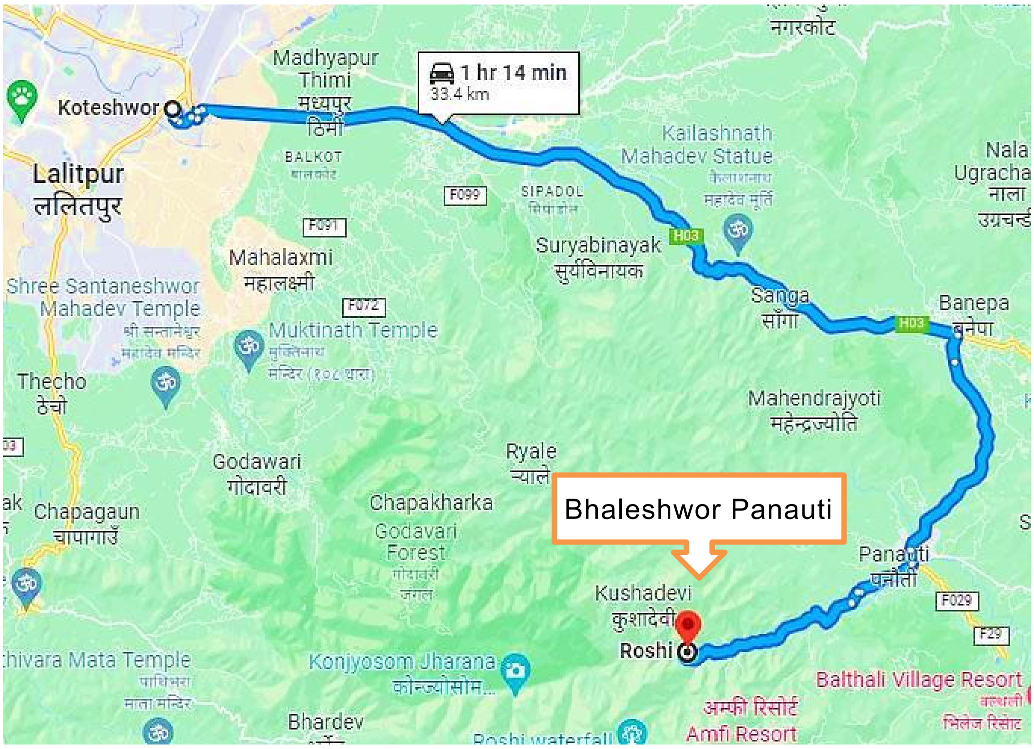


Source: JICA Survey Team

Figure 3.3.3 Investigation Locations for CBR Test (in Google Earth)

Figure 3.3.4 to Figure 3.3.6 show the locations for extracting samples for laboratory tests for the borrow and quarry material to be investigation. The other three test pits were about 20 to 50 km away from the project site.

Figure 3.3.4 Route Map to Rayabari Quarry Site



Source: JICA Survey Team

Figure 3.3.5 Route Map to Bhaleshwor Panauti Quarry Site

Source: JICA Survey Team

Figure 3.3.6 Route Map to Sipaghat Quarry Site

3.3.4 Investigation Items

(1) Core Drilling

The core barrels and drilling bits used in drilling are double tube equipped with inner tubes and diamond bits sized to produce an “NQ” or “NX” size core, whatsoever was feasible. The holes were cased with bentonite as appropriate to prevent hole wall collapse. The drilling foreman and recorder kept the record of drilling for each drilling shift.

Samples recovered from the SPT tube and core barrel are measured and placed in core boxes. Geotechnical investigators preserve sludge (slime) samples, collected for representative depth, as a washed sample, but not measure it as a recovery. They also collect undisturbed (UD) samples on clayey samples at an appropriate depth interval.


Source: JICA Survey Team

Photo 3.3-1 Core Drilling

(2) SPT (Standard Penetration Test)

Geotechnical investigators did the Standard Penetration Test using boreholes to estimate the index and engineering properties through empirical corrections. The interval for the SPT test was 1 meter. The standard 50.80 mm outer diameter split spoon sampler was driven to penetration of 450 mm (150 mm pre-knocking, 300 mm main-knocking) into the soil at the test depths by repeated blows of a 63.5 kg monkey hammer falling through a height of 760 mm. Investigators disregarded the number of blows required for the initial 150 mm penetration. Subsequently, they recorded the number of blows for every 150 mm penetration until 300 mm, noting the sum as the Standard Penetration Test Number (N value). The test blow continued until the N value did not exceed 50, at which point they considered the test a refusal case.


Source: JICA Survey Team

Photo 3.3-2 Ongoing SPT assembly at drilled hole BH3 and BH4

(3) Laboratory Test

While boxes/samples of two initial boreholes were transferred to the laboratory in Kathmandu for the necessary index (physical) tests, those from the remaining boreholes BH2 and BH3 were set to Hetauda, where the laboratories of the contractors are located. All tests were conducted in accordance with the specified ASTM standards.

Source: JICA Survey Team

Photo 3.3-3 Core Box/Sample

(4) CBR Test for Existing Roads

Four locations along the existing road shoulder underwent field in-place CBR test. The collected soil sample consists of subgrade, subbase course, and base course for laboratory testing and investigation. The field in-place CBR and laboratory tests were based on the ASTM and AASHTO specifications while utilizing available equipment.

(5) Borrow Material and Laboratory Testing

Geotechnical investigators conducted one test pit was performed within the airport premises along the proposed alignment. They placed all the samples extracted from the pit in sacks. The bags indicate the soil sample number, test pit number, sampling location and depth, and soil and rock types. Additionally, the geotechnical investigators gathered a small amount of soil samples for the moisture content test and stored them in plastic bags to protect them from direct sun exposure. They safely transported the sample bags to the laboratory for testing purposes.

(6) Quarry Material Investigation

Geotechnical investigators collected samples from three quarry site less than 50 km from the project site. They placed them in bags indicating the aggregate and rock sample number, test pit number, sampling location and depth, and soil and rock types. Additionally, they took a small amount for each soil sample, preserving them in plastic bags for moisture content testing to prevent direct exposure to the sun. They safely transported the sample bags to the laboratory for testing purposes.

3.3.5 Investigation Results

(1) Boring Survey

Based on the field observation and drilling data, observers concluded that the project area lies on a recent filling deposit at the top, followed by sandy to silty soil and lacustrine clayey soil at deeper depths. The general water table lies within upper depth (i.e., within 20 m depth).

The following describes the geological features at the project area and the date extracted from the survey. Appendix 3 presents the borehole logs generated from the boring surveys.

1) Bore Hole 1

- N-values at Bore Hole 1 are less than 20 through its depth (0 m to 50 m)
- The medium to dense sandy layers are up to 8 meters deep, followed up to 50 m by blackish grey medium to very stiff plastic clayey silt layers.
- The hydrometer grain size analysis indicates that the soil layers are poorly or ununiformly graded (uniformity coefficient less than 4) and the soil layers are slightly to medium plastic.
- The soil layers are normally consolidated.

2) Bore Hole 2

- N-values at Bore Hole 2 are similar to those of Bore Hole 1 except that the N-value at depth of 4 m to 6 m deep is 49 and the soil layer is sandy. However, the layer immediately beneath is sandy soil with an N-value of less than 20. The layer below is a conglomerate of sandy and clayey soil but indicate N-values of less than 20.
- The soil distribution at 20 m deep is medium to dense sandy layers. The layers below are blackish low to stiff plastic clayey silt layers (Patan Formation).
- The hydrometer grain size analysis indicates that the soil layers are well-graded (uniformity coefficient bigger than 4) and medium to highly plastic.
- The soil layers are normally consolidated.

3) Bore Hole 3

- The composition of the soil strata at Bore Hole 3 is also a conglomerate of sandy and clayey soils. It has a soil layer with an N -value of 50. The layers beneath are all clayey soil with N-values less than 50.
- The medium to dense sandy layers are observed up to 10 m depth, which is followed by 50 m of blackish grey medium to very stiff plastic clayey silt layers.
- The hydrometer grain size analysis indicates that the soil layers are well-graded and medium to highly plastic.
- The soil layers are generally consolidated.

4) Bore Hole 4

- N-values at Bore Hole 4 up to a depth of 10 m indicate that the soil is sandy, but the N-values are less than 20. The layers beneath are Patan Formation (blackish and clayish low plastic clayey silt with traces of fine sand with N-values less than 20).
- The medium to dense clean sandy layers are observed up to 10 m depth, followed up to 50 m by blackish grey medium to very stiff plastic clayey silt with traces of fine sand.
- The hydrometer grain size analysis indicates that the soil layers are poorly or ununiformly graded (uniformity coefficient less than 4) and medium to highly plastic.
- The soil layers are normally consolidated.

From the four bore logs in the project area, the rock bed is beyond the 50m depth. Based on the general geology of the project area, the rock bed can be assumed to be very deep (at about 550 m). In addition, a sandy layer with an N-value of higher than 20 and thickness of 3 m to 5 m cannot be confirmed. Accordingly, bearing piles cannot be applied for a foundation to support structures like bridges and viaducts. Therefore, the design should consider the application of friction piles.

(2) CBR

Based on the site CBR tests conducted on the shoulder or outside of the existing road, the CBR of the existing sub-base course shows more that 40% and is satisfactory for using the subgrade of the new pavement structure. To check CBR of the existing base, am additional CBR test on the existing pavement needs to be conducted at the detailed design stage to determine an appropriate pavement structure on the at-grade road sections of the project road.

(3) Borrow Material for Embankment and Subgrade

Borrow materials obtained within TIA land are suitable for both embankment and the subgrade materials as CBR shows 29.74% and PI (Plasticity Index) is 1.00%.

(4) Quarry Material for Subbase Course and Basecourse

According to major specifications required for the subbase course (CBR value > 30% and PI < 10%) and the basecourse (CBR value > 80% and PI < 4%), applicability of the sampled quarry materials is summarized in Table 3.3.2.

Table 3.3.2 Applicability of Quarry Material for Subbase Course and Basecourse

Quarry Site		Rayabari	Bhaleshwor Panauti	Siphaghat
CBR		17.09%	38.03%	42.84%
PI (Plasticity Index)		1.10%	1.50%	1.60%
Applicability	Subbase Course	Not applicable	Applicable	Applicable
	Basecourse	Not applicable	Not applicable	Not applicable

Source: JICA Survey Team

From these results above, the basecourse materials from other quarry sites and the application of stabilized materials are recommended. However, the CBR tests on the existing pavement are required to verify at the detailed design stage since there is a possibility to utilize the existing basecourse for pavement design for the project at-grade roads.

(5) Quarry Material for Aggregate of Asphalt Pavement

According to the major specifications required for the aggregate of asphalt pavement (Los Angeles Abrasion Value < 30% and Flakiness Index < 30%), the applicability of the sampled quarry materials is summarized in Figure 3.3.3.

Table 3.3.3 Applicability of Quarry Material for Aggregate of Asphalt Pavement

Quarry Site	Rayabari	Bhaleshwor Panauti	Siphaghat
Los Angeles Abrasion Value	26.84%	27.83%	28.31%
Flakiness Index	12.41%	9.69%	11.46%
Applicability	Applicable	Applicable	Applicable

Source: JICA Survey Team

(6) Quarry Material for Aggregate of Concrete

According to the major specification required for the aggregate of concrete (Los Angeles Abrasion Value < 40% (< 35% for concrete pavement), and Specific Gravity > 2.5), the applicability of the sampled quarry materials is summarized in Table 3.3.4

Table 3.3.4 Applicability of Quarry Material for Aggregate of Concrete

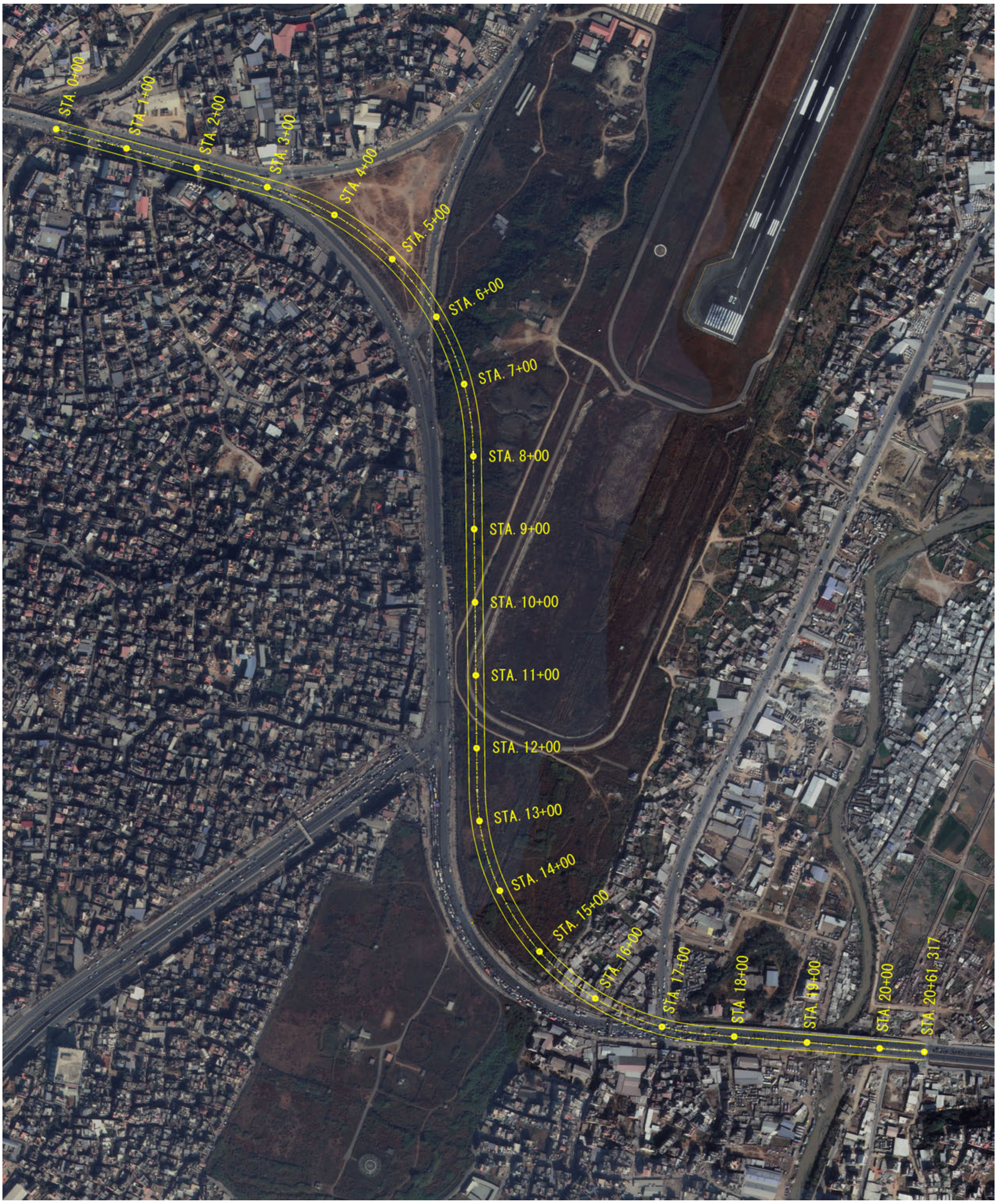
Quarry Site	Rayabari	Bhaleshwor Panauti	Siphaghat
Los Angeles Abrasion Value	25.84%	26.81%	28.15%
Specific Gravity	2.732	2.726	2.730
Applicability	Applicable	Applicable	Applicable

Source: JICA Survey Team

Based on the alkali reactivity test results, alkali-aggregate reaction is unlikely since the aggregate has a small reactive silica content.

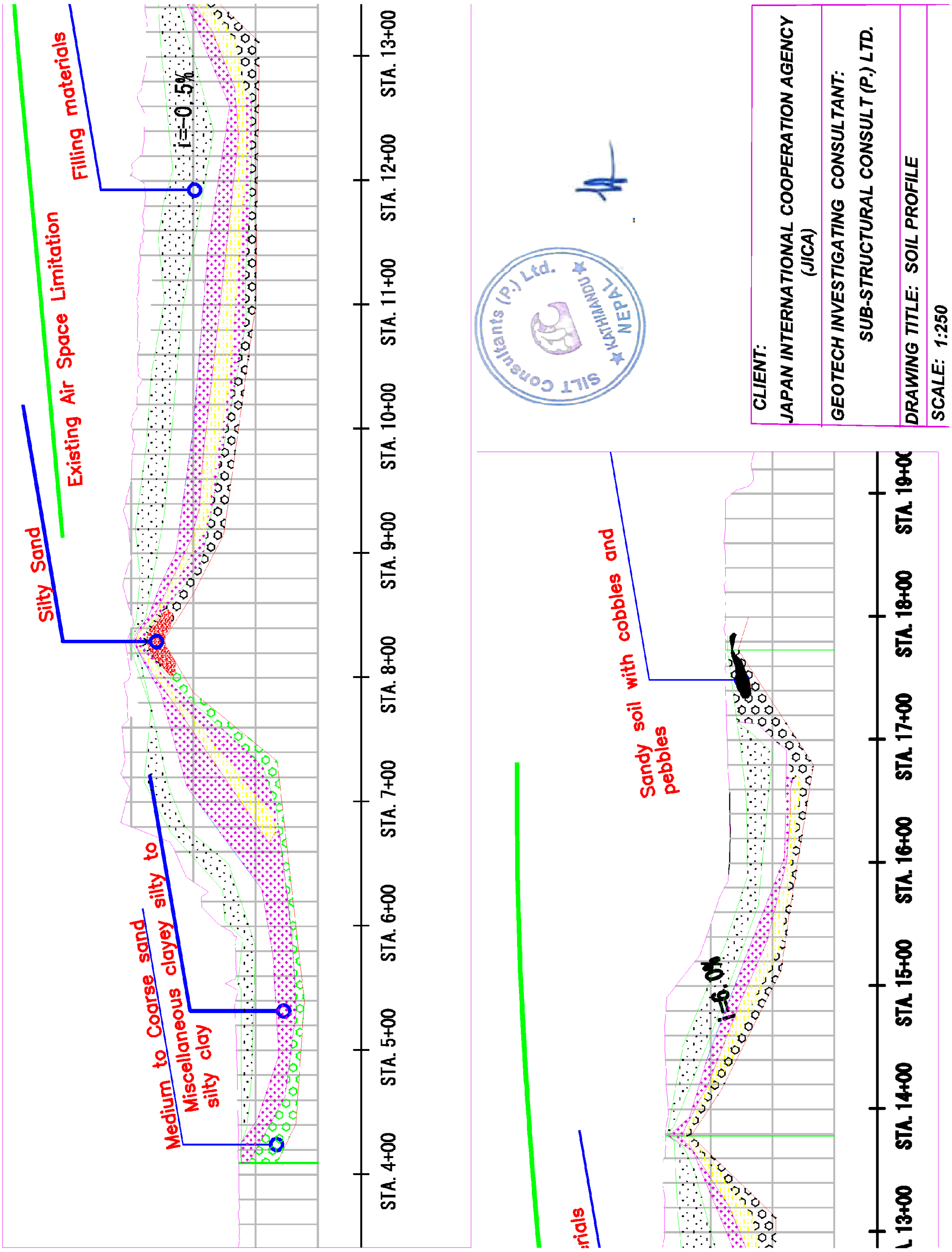
(7) Soil Profile

Location (station number of the alignment for the GS facility along TK-3) and their soil profiles are indicated in Figure 3.3.7 and Figure 3.3.8, respectively.



Source: JICA Survey Team

Figure 3.3.7 Locations for Soil Profile



Source: JICA Survey Team

Figure 3.3.8 Soil Profile along Alignment

3.3.6 Technical Observations

(1) Consolidation Settlement

Generally, in the design of structures in Kathmandu Valley, it is required to consider the possible effects of consolidation settlement due to the soil layer features clarified in the geological investigation in the study. Consolidation settlement can be triggered primarily by two factors: i) subsidence of the Valley, and ii) introduction of new loads. Careful consideration for foundation design of structures is required.

1) Subsidence of the Valley

As aforementioned, the soil sediment of the Kathmandu Valley is continuously subsiding. The subsidence is contributed primarily to seismic activity and rapid and excessive groundwater withdrawal. Groundwater is a significant source of water supply for the ever-growing domestic and industrial demand. Results of Suresh Krishnan and Kim (2017) indicate that the annual subsidence rate has significantly increased after the Gorkha earthquake from -8.2 cm per year to -12 cm per year.

2) Introduction of Loads

The project may plan a high embankment road section, including heavy structures such as viaducts, to alleviate chronic traffic congestions in the project site and its vicinity. Since the geological features of the area is composed of very thick fluvial-lacustrine sediments and the ground is normally consolidated and susceptible to subsidence.

In conclusion, the consideration of the subsidence of the sediments is only necessary if the embankment height is significantly high (more than 10 m) while examined during the design stage.

(2) Consolidation Settlement

Since the supporting layer where N value is 50 or more was not confirmed in the project area, the application of friction piles is necessary for the foundation design of bridges. If the pile length is relatively short, the examination of consolidation settlement is essential for the foundation design in the detailed design stage.

(3) Liquefaction

Since the soil contains sand layers observed in the shallow depth range, the liquefaction survey is required. According to the Specification of Road Bridge published by Road Association Japan, the reduction factor to soil parameters for design is not necessary as a whole, but liquefaction can happen at a few layers by observation.

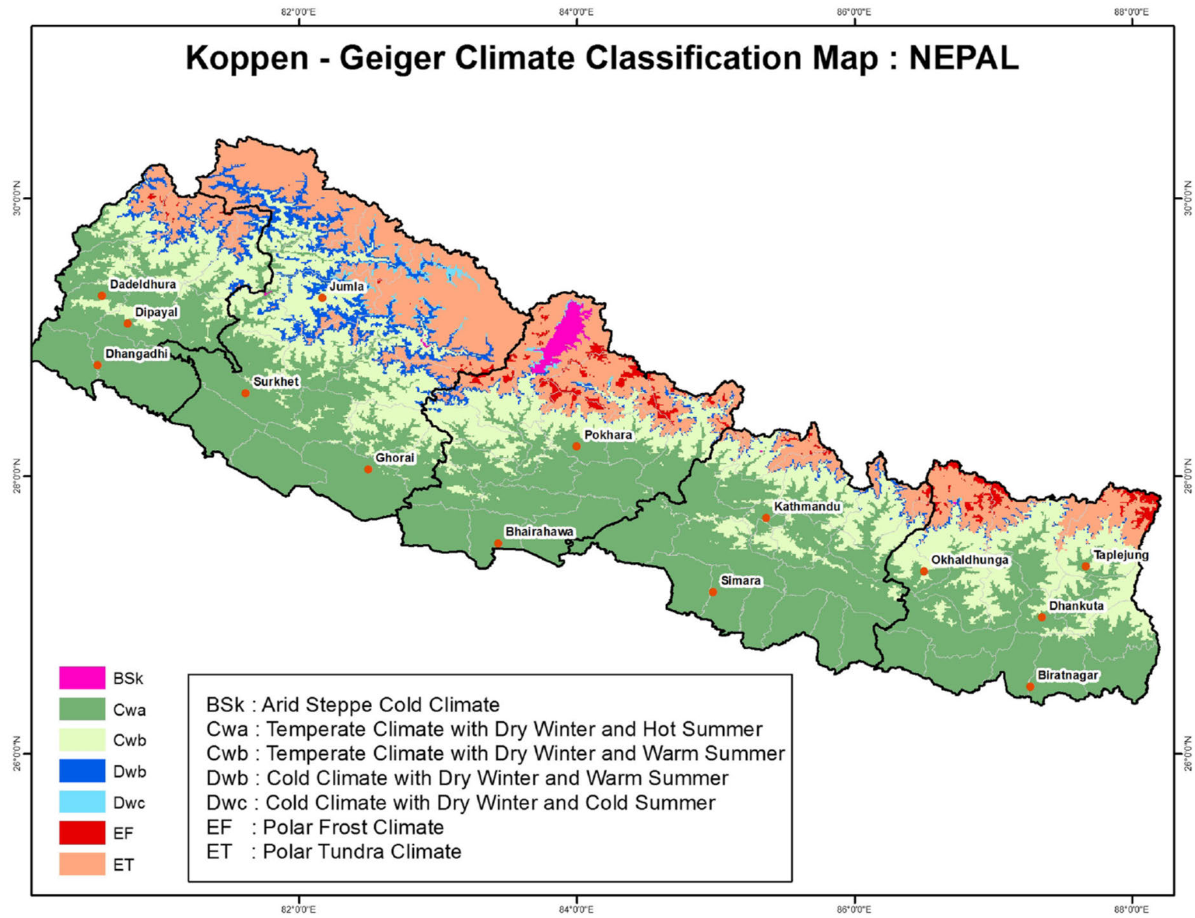
3.3.7 Recommendations for the Detailed Design

- The Kathmandu Valley lies in an active seismic zone that has experienced several devastating earthquakes where the Gorkha earthquake occurred in 2015. Although studies do not confirm active faults are near the project area, the area is prone to impact from earthquake. Therefore, the design of structures must consider seismic resiliency and liquefaction analysis.
- The distribution of soil layers in the project area may not be consistent and could vary as the sediment thickness is thicker at the center of Kathmandu Valley. Therefore, geotechnical investigation by drilling at the precise locations of the piers and abutments (desirably two drillings per substructure) along the project flyovers is recommended. Furthermore, they recommended additional drilling at several locations along the UP section of the project road.
- The project area lies in and around the premises of the TIA, where access within the premises is strictly restricted. The project requires close and timely coordination with relevant authorities (CAAN, TIA, etc.) for effective implementation of the detailed design study and construction works.

3.4 Meteorology

3.4.1 General Climate Condition

The survey area is in Kathmandu Valley, whose elevation is 1,300 m to 1,400 m above sea level. The climate is mild and generally warm and is classified as Cwa in The Köppen-Geiger climate classification shown in Figure 3.4.1. The precipitation amount in summer is much higher than that in winter. The average annual temperature and precipitation are 18.8°C (2010-2019) and about 1,474 mm (1980-2017) at TIA (Tribhuvan International Airport).



Source: Karki et al., New climate classification of Nepal, Theor. Appl. Climatol., Vol.1225, pp.799-808 (2016)

Figure 3.4.1 Köppen-Geiger Climate Classification

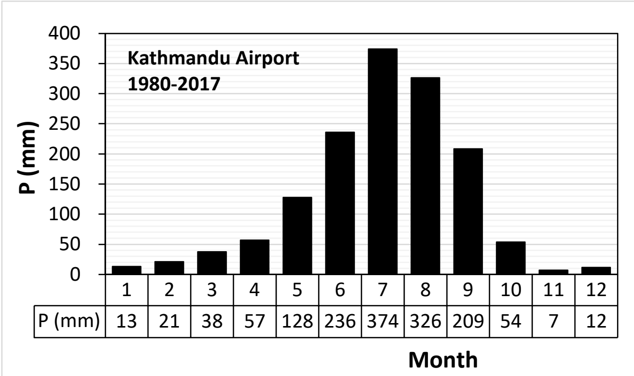
3.4.2 Rainfall

Figure 3.4.2 present the seasonal variation of rainfall. More than 80% of the annual precipitation amount is mainly due to the rainy season from May to September. Table 3.4.1 shows the number of rainy days with more than 10 mm/day from 1980 to 2017. On average, 46.5 days in a year can be rainy.

Table 3.4.1 Number of Rainy Day with More Than 10mm/day

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of Rainy days	0.5	0.7	1.2	2.0	4.0	7.2	11.2	10.6	6.7	1.7	0.3	0.4	46.5

Source: JICA Survey Team based on the observed meteorological data at TIA from 1980-2017

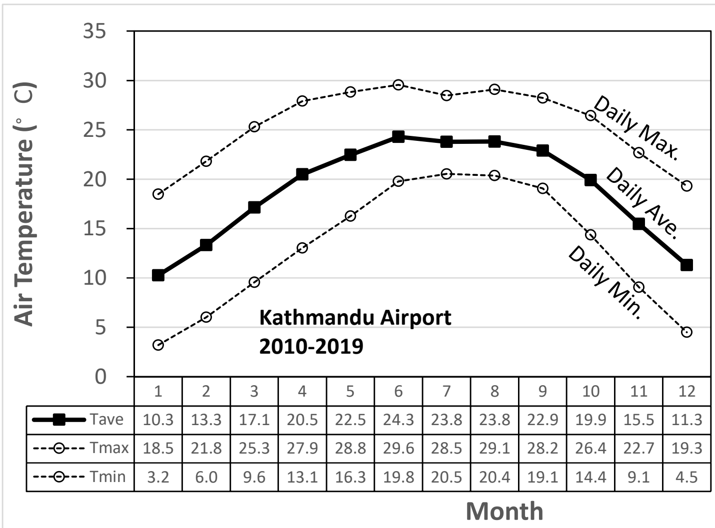


Source: JICA Survey Team based on the observed meteorological data at TIA from 1980-2017

Figure 3.4.2 Seasonal Variation of Rainfall Amount at TIA

3.4.3 Other Parameters

Figure 3.4.3 presents the seasonal variations of daily average, maximum, and minimum air temperature. In summer, the daily maximum temperature reaches to about 30°C, whereas the daily minimum temperature falls to about 3 °C in winter. The difference in temperature within a day range from 8 °C to 15 °C.



Source: JICA Survey Team based on the observed meteorological data at Kathmandu Airport from 2010-2019

Figure 3.4.3 Seasonal Variation of Air Temperature at TIA

Table 3.4.2 shows the relative humidity and average wind speed. The relative humidity varies from 56% to 83% throughout the year, which reflects a higher value from June to October. The average wind speed ranges 1.2 m/s to 2.1 m/s with slightly higher value from March to June. The maximum wind speed at TIA during 2010-2019 is 21.6 m/s.

Table 3.4.2 Relative Humidity and Average Wind Speed

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average
Relative Humidity (%)	67.1	63.0	57.3	56.3	64.5	74.1	82.7	82.6	80.4	72.0	69.7	68.6	69.9
Average Wind Speed (m/s)	1.30	1.69	2.04	2.09	2.00	1.91	1.65	1.63	1.58	1.55	1.33	1.21	1.70

Source: JICA Survey Team based on the observed meteorological data at TIA from 2010-2019

CHAPTER 4. RE-STUDY OF TRAFFIC DEMAND FORECAST

4.1 Background of Re-Study of Traffic Demand Forecast and its Direction

(1) The Background and Outline of Re-Study on Traffic Demand Forecast

This sub-chapter describes the background and outline of the Re-Study of the Traffic Demand Forecast (TDF), including the direction of the TDF model revision. The initial stage of the Study found that the latest TDF model, updated in ADB TA 2018 for an urban railway priority study based on the JICA MP model, cannot represent the 2020 traffic movement around the Project intersections, which showed an "overestimation tendency" from a comparison between the observed traffic by traffic count survey results and the ones forecasted by the said latest TDF model.

The causes of the overestimation tendency are considered:

1. Incorporation of the 30% floating population (FP) in the latest model of ADB-TA requested by Nepal;
2. Adaptation of an optimistic development scenario for the Eastern New City Development (ENCD) initiated by KVDA;
3. Changes in traffic movement trends from the inflow and settlement of new residents because of the 2015 Nepal earthquake and electricity supply improvements in KTM. The remaining persecution by Maoist activities in rural regions since early 2000 caused the evacuation of the rural residents to Kathmandu.

In addition, some limitations to the TDF exist, such as limited available data, etc. Only VT-OD (vehicle-based-trip OD) was available from ADB-TA.

Furthermore, JICA proposed these requirements for the TDF revision:

A. Reflect the traffic movement trend within the entire KTM valley;
B. Reflect the assumed causes of the overestimation tendency of the TDF model;

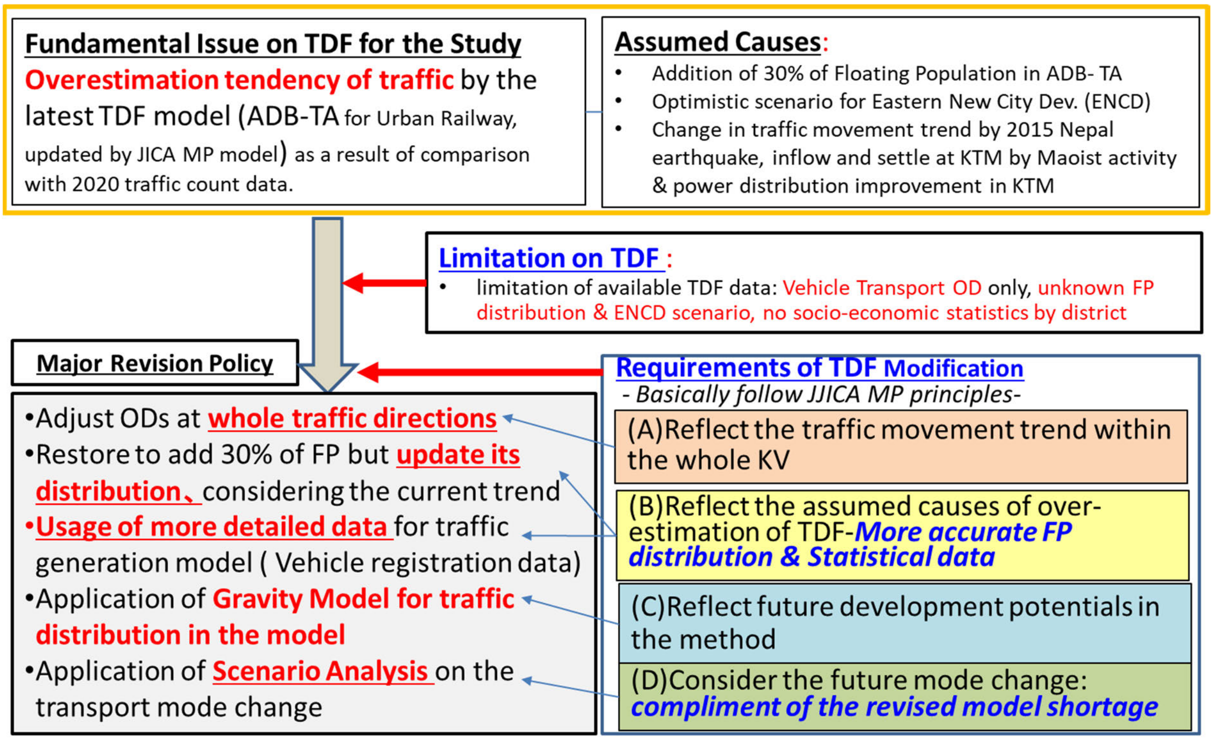
C. Reflect future development potentials;

D. Consider mode change.

The development of the revised TDF model/method incorporated the above aspects by modifying the previous model/method applied at the initial stage of the Study (see Figure 4.1.1).

(2) Direction of TDF revision

To fulfill requirements A, B, C, and D, the new TDF model and method incorporates the following measures in Figure 4.1.1. The following sub-chapters describe these measures further.



Source: JICA Survey Team

Figure 4.1.1 TDF Modification Outline and Direction

Table 4.1.1 summarizes the comparisons between the original policy and the revised version.

Table 4.1.1 Comparison between the Previous TDF Model/Method & the Revised TDF

Items	Previous Model/Method	Revised Model/Method
OD Adjustment for 2020 Traffic Reproduction	Adjusted with Eastern screen line.	Adjusted with three screen lines (East/South/Northwest)
Eastern New City Development Scenario	1 mil. Population by 2060	1 mil. population by 2060
30% FP consideration & Distribution Method	-Consider CBS population data	-Consider recent population change trend and zonal capacity
Traffic Distribution Method	-Present pattern method	-Gravity model
Future Traffic Forecast Method	-Forecast by vehicle type using vehicle registration and GDP growth data	- Forecast by vehicle type using distributed population data by zone, vehicle registration and GDP growth data

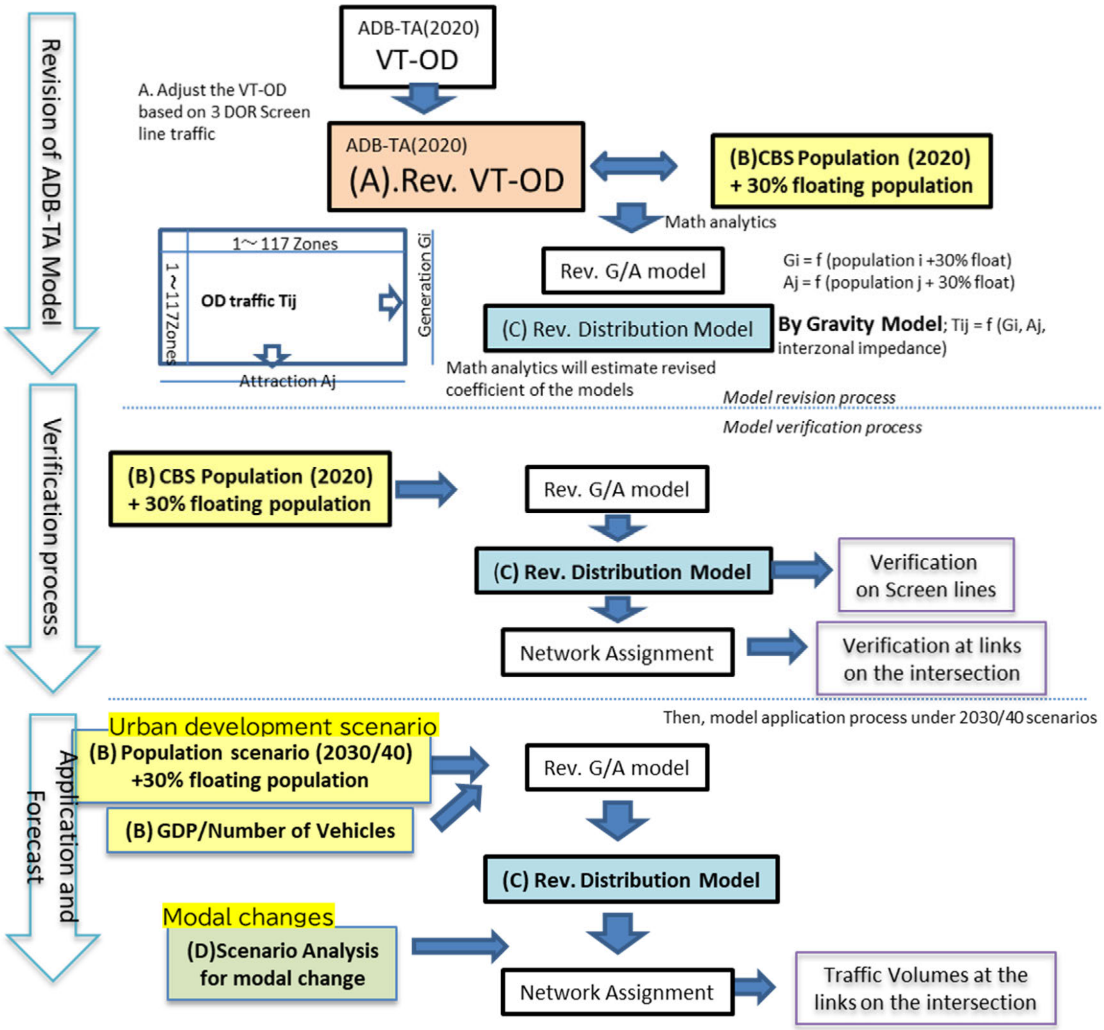
Source: JICA Survey Team

The 2020 adjustments to the revised model feature the adoption of three screens to improve the accuracy of OD, covering the significant directions of traffic flows in the Kathmandu Valley.

The model adopts ENCD scenarios acknowledged by the KVDA. However, the revision considers the floating population on top of them. The model features revised traffic distribution patterns with the new gravity model concept, which may improve the accuracy of the traffic movement in proportion to future population growth.

Regarding the future traffic forecast, the revised methodology adopted an estimated vehicle registration data distributed by zones in proportion to the zonal population data, which may improve vehicle traffic generation and attraction. The following sections explain the methodology in more detail.

Figure 4.1.2 shows the general procedure of the TDF methodology. Note that items A to D in this figure also presents the modifications shown in Figure 4.1.1.



Source: JICA Survey Team

Figure 4.1.2 TDF Procedures in the Revised Model

The TDF procedure has three phases:

1. Revision of the original ADB-TA model;
2. Verification;
3. Application

In the revision, a new estimated VT-OD has three screens. It also features the Generation/Attraction (G/A) model and the new Distribution model for the new population scenarios accounting for the floating population. Those models were estimated by the four vehicle types, with data from 2020 to represent the general traffic generation and movements.

The following phase verifies those models. The 2020 population was input to the G/A model. Then, G/A volume was input to the Distribution models before assignment to the present network. The estimated OD traffic and assigned traffic volumes, the traffic volumes of the screen lines, and link volumes at the Project intersections received comparisons, respectively. A repetition of the model estimation and verification ensured proper reproducibility.

The verified models applied to the TDF of target years 2030 and 2040. Before its application, the population scenarios for the target years, GDP, and the cumulative numbers of vehicles in the valley featured estimates from urban development scenarios. Today, the G/A and Distribution models accounted for the population scenarios before OD assignment to the future network. This process produces estimates for traffic at the Project intersections. A sensitivity analysis applied to the network assignment results considers potential modal change.

4.2 The Framework of the TDF

4.2.1 Introduction

Before discussing the significant revisions to the TDF, this section explains the essential setting of the analytical framework for traffic demand forecasting, including target years, zoning, socio-economic data, road network, etc.

4.2.2 Forecast Target Year

(1) Forecast Target Year for the Study

Future traffic demand will change significantly depending on the progress of new projects such as the 1-million-population scaled ENCD project formulated by KVDA (see 4.2.5 (2)), the construction of the Outer Ring Road (ORR), and the new development of satellite cites along the ORR. Therefore, it is unproductive to make a very long-term traffic demand forecast.

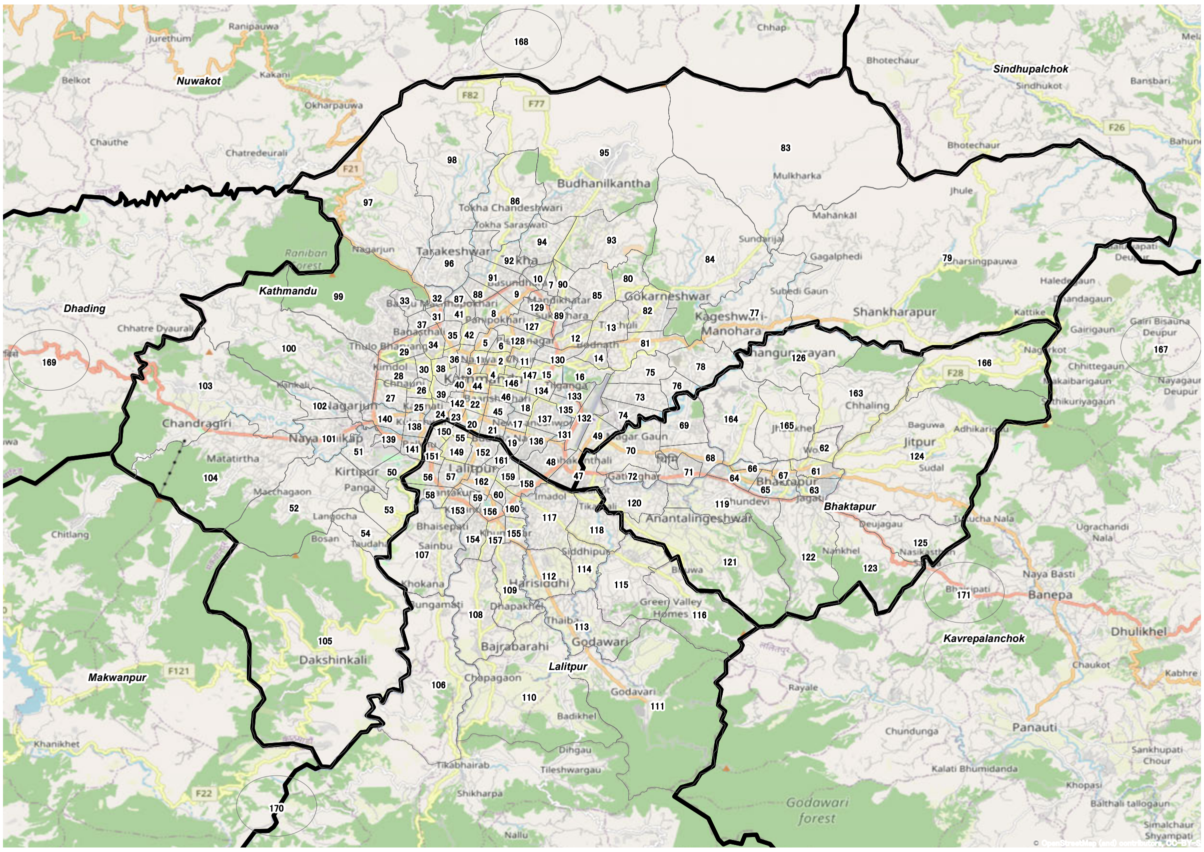
In this study, we will forecast the traffic demand when these new projects achieve implementation as planned. To flexibly deal with the forecast target years and determine the Project facility scale, the TDF will target both 2030 and 2040. Depending on the target year for the Project, the necessary TDF data will come from interpolation or extrapolation of the said two results.

(2) Forecast Target Year for Project Formulation

As described in Chapter 5, the target years to determine the scale of the Project facility are 2033, five years after its operability, and 2038, ten years later. For economic analysis, researchers will project up to 2048.

4.2.3 Zoning

Zoning for the TDF in the Study uses the 171-zone system adopted in the 2019 ADB-TA. Figure 4.2.1 shows the zoning allocation.



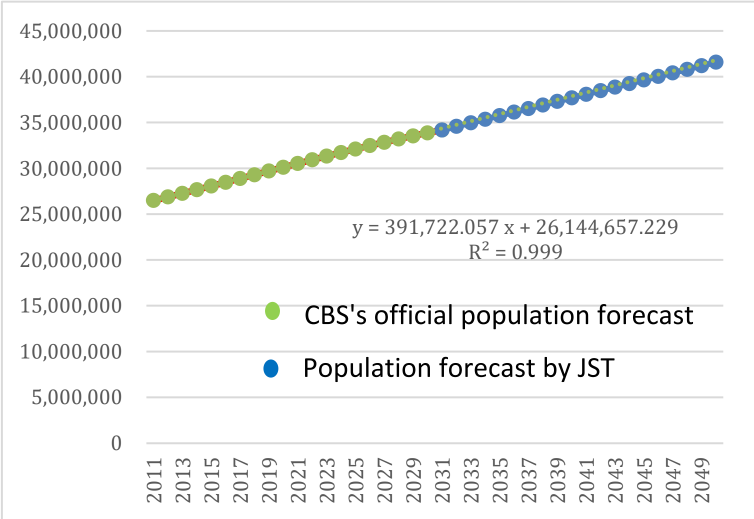
Source: JICA Survey Team

Figure 4.2.1 Zoning Map

4.2.4 Population of Nepal

Estimates of the future population of Nepal adopt mid-range projections from CBS until 2031, which used 2011 census data, and post-2031 by applying an approximate curve from the Survey team. Note that the 2021 population census data has not been finalized yet as of June 2022, when this study was conducted, due to a delay in the survey due to COVID-19.

The estimated population in 2050 was 41,590,000, 1.38 times the estimated population of 30,120,000 in 2020.



Source: JICA Survey Team

Figure 4.2.2 Future Population of Nepal

4.2.5 Population by district in the Kathmandu Valley

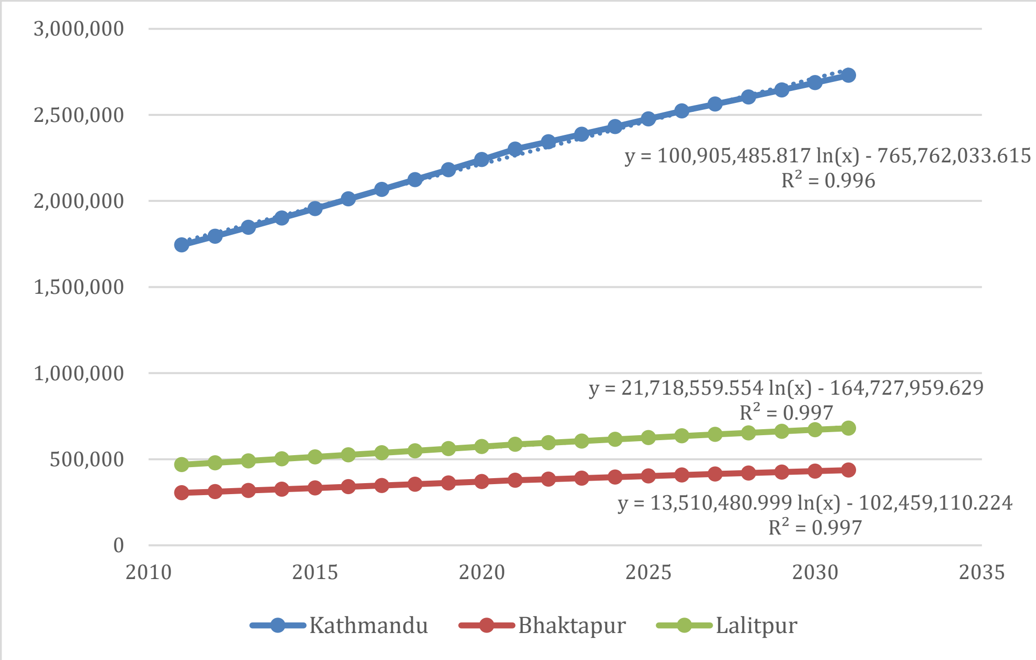
(1) Trend estimates

The Kathmandu Valley has three districts: Kathmandu, Bhaktapur, and Lalitpur. In the study, we adopted the mid-range population in the Kathmandu Valley district-by-district predicted by CBS up to 2031 (See Table 4.2.1), and the subsequent figures for the future were extrapolated by applying approximate curves to the population up to 2031 (see Figure 4.2.3). The graph indicates a higher growth ratio for the Kathmandu District than the other two districts.

Table 4.2.1 Mid-Range Population by CBS up to 2031

District	2011	2016	2021	2026	2031
Kathmandu	1,744,240	2,011,978	2,300,890	2,522,103	2,729,056
Bhaktapur	304,651	340,066	377,660	408,472	436,553
Lalitpur	468,132	525,211	585,982	635,151	680,157

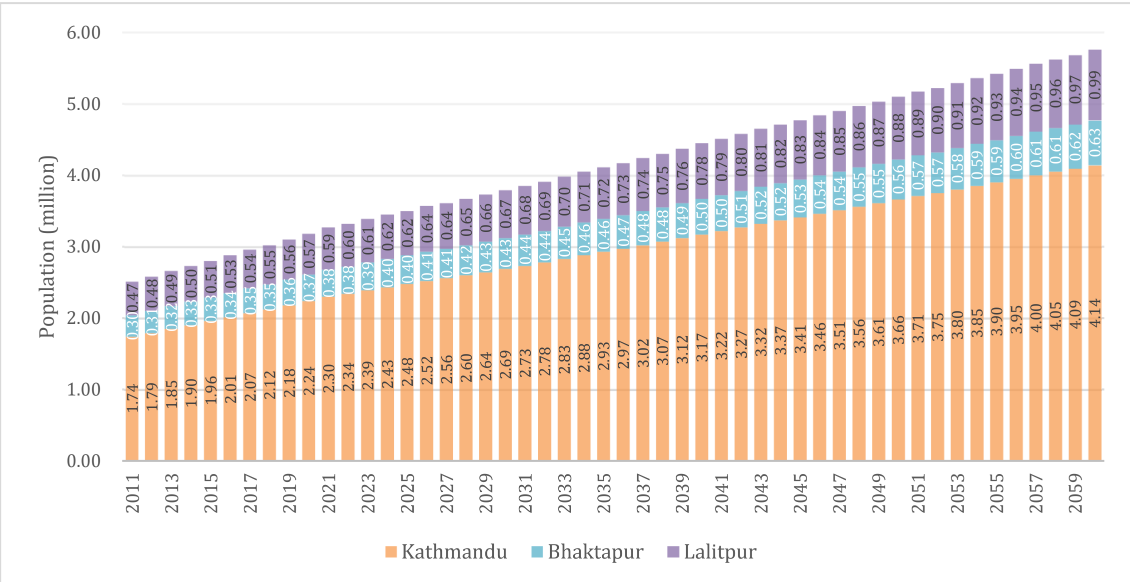
Source: CBS



Source: CBS

Figure 4.2.3 Population Estimates by District in the Kathmandu Valley by CBS

The district-based population in the Kathmandu Valley in 2060 is estimated to be 4,140,000 in the Kathmandu District, 630,000 in the Bhaktapur District, and 990,000 in the Lalitpur District, which will increase by 1.7 to 1.9 times compared to the 2020 population.



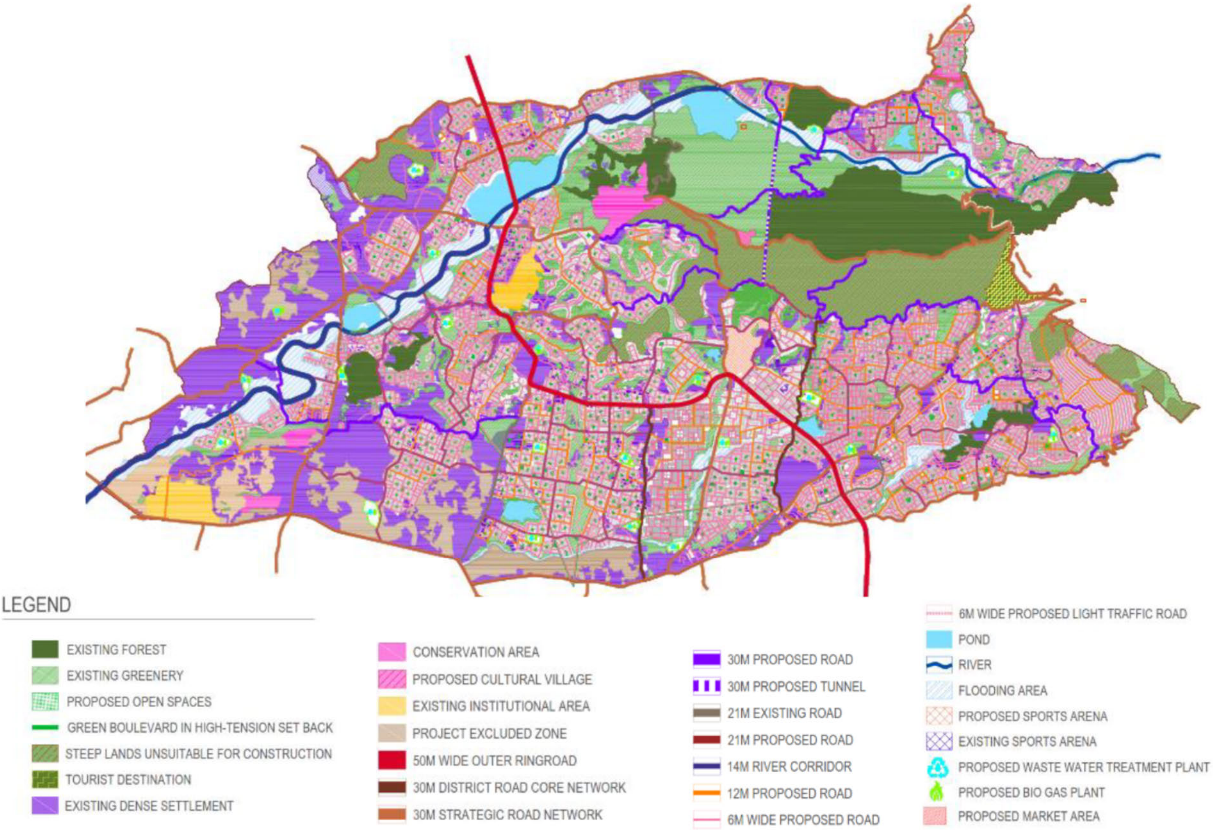
Note: CBS's official population forecast up to 2031, JST's forecast after 2032
Source: CBS and JST

Figure 4.2.4 Trends in Population by District

(2) Impact of the Eastern New City Development (ENCD) Project

The ENCD Project is one of the four new town development plans formulated by KVDA, a subordinate Ministry of Urban Development (MOUD) agency responsible for urban development within the Kathmandu Valley. The ENCD envisaged a new city with a planned population of 1 million north of the Araniko Highway in the Bhaktapur District.

Finnish consultants finished the Preparatory Plan for Detailed Projects for New Town Development in the Kathmandu Valley (the ENCD Master Plan) report, which is the master plan for this project, in October 2019. The Minister of MOUD has approved the technical part of the ENCD Master Plan. The financial plan (investment plan) is still pending approval as of June 2022 due to delays from COVID-19 and a government change in 2021.



Source: KVDA

Figure 4.2.5 Proposed Masterplan

KVDA planned that as soon as the master plan and budget receive approval from the cabinet, the ENCD will launch, and migration to new cities will begin in 2026 after completing the necessary infrastructure and housing. By 2060, the city will reach its planned population of 1 million.

The prerequisites presented by KVDA for implementing the TDF, accounting for the ENCD, are as follows:

(I) The number of people migrating to the new city will reach one million in 35 years after the start of migration in 2026.

(II) The population goal is to allow 60% of the planned population to live within one-third of the migration period by 2037 and 90% within two-thirds by 2048.

See 4.3 (2) and (3) for a revision of this section.

4.2.6 Population Distribution by Zones

There are 171 Traffic Analysis Zones (TAZs) for the target area, as shown in Figure 4.2.1. The TAZ groupings include an administrative zone and three levels.

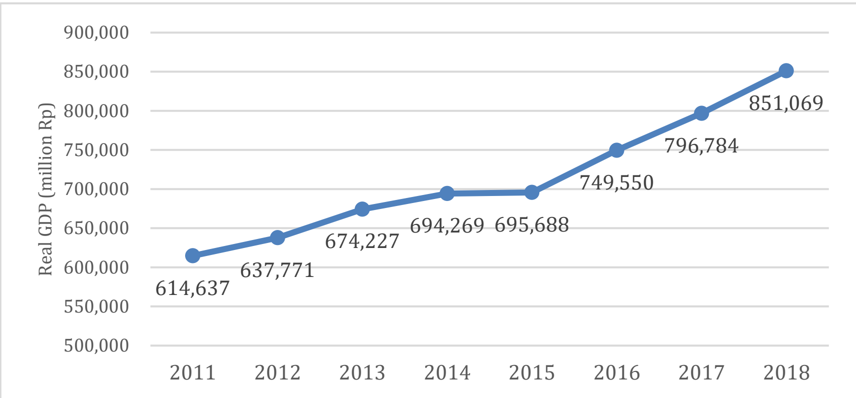
The top level has three zones: Kathmandu, Bhaktapur, and Lalitpur. The medium-level TAZs consist of 18 zones featured in CBS population data. Researchers proportionally allocated population distribution in the medium-level TAZs to CBS statistics for the original analysis. See 4.3. (2) for revisions.

The smallest-level TAZ contains 171 zones, and their population is allocated proportionally by dividing the population data of the medium zone by the area ratio.

4.2.7 GDP

CBS statistics indicate the average annual growth rate of real GDP across Nepal for 2011-2018 was 4.76% per year. (See Figure 4.2.6). So, the future growth rate[1] in the Study is 4.5% for 2019-2030, 4.0% for 2031-2040, and 3.5% for 2041- 2050 (see Table 4.2.2).

This set GDP per capita at 31,000 NRP (1.0 times) in 2020 and increased it to 43,000 NRP (1.4 times), 57,000 (1.8 times), and 72,000 NRP (2.3 times) in 2030, 2040 and 2050, respectively.



Source: CBS

Figure 4.2.6 Trends in Real GDP (1 million Rp, base year: 2000/21)

[1] Under the 15th National Plan (2019-2024), the Government of Nepal has set high targets for nominal GDP growth of 9.4% (- 2024), 10.3% (- 2030), and 10.5% (- 2044), but the World Bank and ADB forecasted it at most at around 6%. When the nominal GDP growth rate is converted to a real GDP basis, the value becomes even smaller.

Table 4.2.2 GDP/Population Scenario Setting

FY	Real GDP (million Rp)	Estimated GDP (Million Rp)	AAGR	Population	GDP/capita (Rp)	Multiplying factor*
2011	614,637	-	4.76%	26,494,504	23,199	-
2012	637,771			26,875,445	23,731	
2013	674,227			27,264,592	24,729	
2014	694,269			27,660,775	25,099	
2015	695,688			28,062,832	24,790	
2016	749,550			28,469,460	26,328	
2017	796,784			28,879,636	27,590	
2018	851,069			29,291,746	29,055	
2019	-	889,367	4.5%	29,704,501	30,000	
2020		929,389	4.5%	30,116,424	31,000	1.0 (base)
2025		1,158,187	4.5%	32,104,281	36,000	1.2
2030		1,443,312	4.5%	33,864,043	43,000	1.4
2035		1,756,010	4.0%	35,742,327	49,000	1.6
2040		2,136,455	4.0%	37,690,470	57,000	1.8
2045		2,537,438	3.5%	39,638,613	64,000	2.1
2050		3,013,680	3.5%	41,586,756	72,000	2.3

Note:*) represents the value of GDP/Capita in 2020 as 1.0.
Source: JICA Survey Team

4.2.8 Road Network and Network Assignment

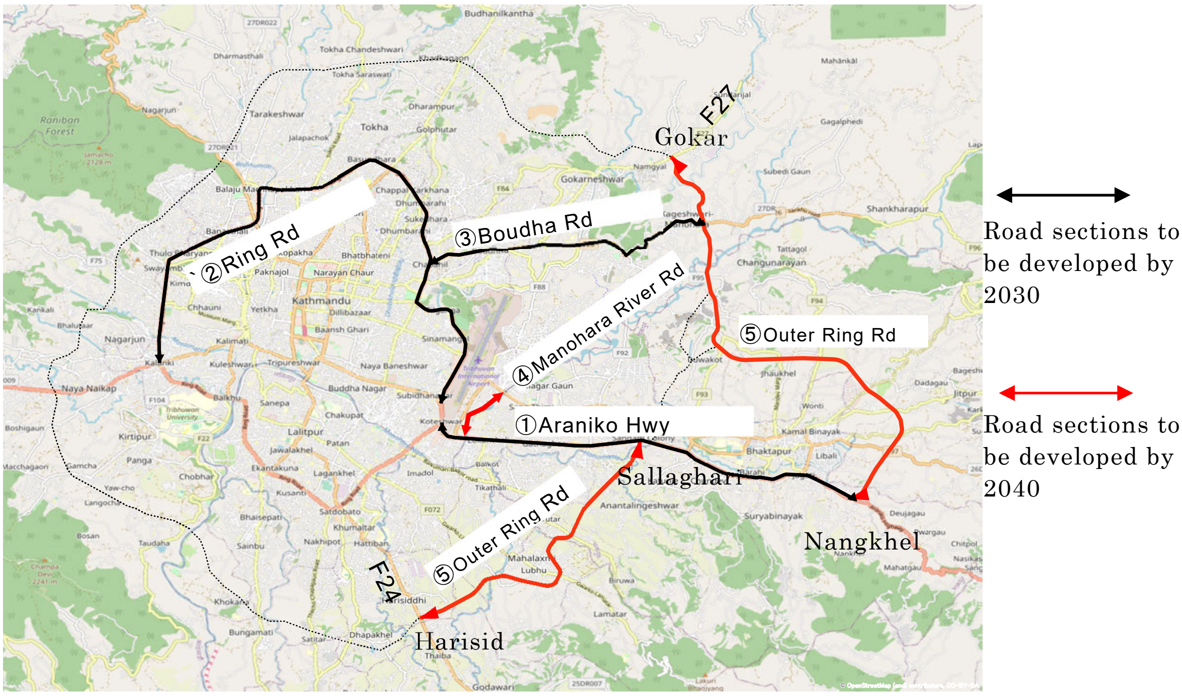
(1) Setting up a future road network

In the target year 2030, researchers assume completion of the upgrade and development of the trunk road network (in black).

① Eight lanes in four-lane sections of Araniko Highway
② Eight lanes in four-lane parts of Ring Road
③ Four lanes in two-lane regions of Boudha Road
④ New 2-lane road development along the Manohara River located side by side on the east side of Pepsi Cola Road

By the target year of 2040, the road network in red will open to the public:

1. New six-lane road development of two sections of Outer Ring Road; i) from the intersection with F24 (Satdobato-Godavari Road) in Harisiddhi to the intersection with Araniko Highway in Sallaghari, and ii) from the intersection with Araniko Highway in Nangkhel to the intersection with F27 (Jorpati-Sundarijal Road) in Gokarna.



Source: JICA Survey Team

Figure 4.2.7 Future Road Network Scheduled for Development by 2030/2040

(2) Assignment Method

Researchers based the traffic assignment on an incremental assignment method. The assignment ratio allows vehicles to select different routes to prevent road congestion for motorcycles and passenger cars. Trucks and buses must take the shortest route. The following shows the 6-phased share of the applied increment assignment.

- Motorcycles and passenger cars: 35%, 25%, 15%, 15%, 5%, 5%
- Track and Bus: 50%, 25%, 10%, 5%, 5%, 5%

(3) Assignment Cases

In the allocation case for the Study, Case -0 refers to an eventuality where the future road network is developed without improvement of the Project intersection by grade separation. Cases -1 to -4 refer to the alternative (ALT -1 to -4) of the improvement-by-grade-separation scenarios at the Koteshwor and Tinkune intersections.

This section briefly describes four alternative improvements of the Project intersections:

- ALT-1(RRS-RRN) connects the north and south sides of Ring Road,
- ALT-2(RRS-ARK Hwy North) connects the Ring Road South with Araniko Highway North,

- ALT-3(ARK Hwy South -RRN) connects the Araniko Highway with the north side of Ring Road,
- ALT-4(ARK Hwy South - ARK Hwy North) connects the north and south sides of the Araniko Highway.

Table 4.2.3 Alternatives for Elevated Roads

Alternatives	ALT-1	ALT-2	ALT-3	ALT-4
Image of grade separation road				
Case Name	Case-1	Case-2	Case-3	Case-4

Source: JICA Survey Team

4.3 Major Revision Works for the Revised Model

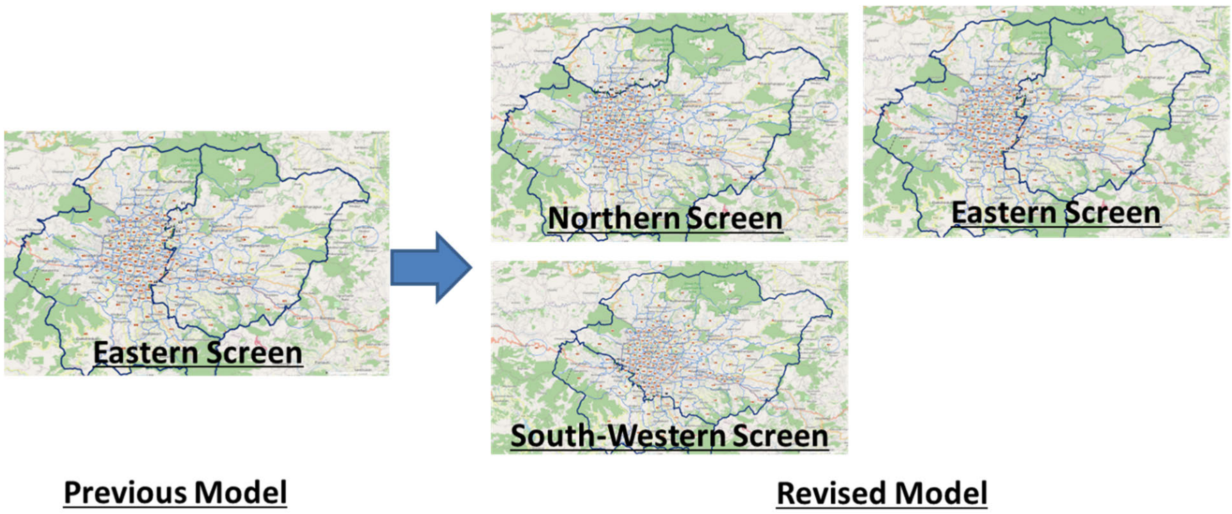
This section shall provide a more detailed explanation of the model revisions.

(1) Adjustment of ADB-TA OD for 2020 traffic reproduction by three screen lines

For the VT-OD reproducibility validation, JST initially applied the single screen line, i.e., the eastern side of Kathmandu. The target intersection of this Study is on the screen line of the east side, which may explain its suitableness for reproducibility validation.

However, JST revised this application and adopted three screen lines covering all directions of traffic to and from Kathmandu City, which may improve the reproducibility of the TDF model and the accuracy of traffic forecasts.

The Project intersections are on the regional arteries of the Kathmandu Valley. Therefore, JST considered that screen lines are necessary to cover the region. The settings of the screen lines for initial and revised consideration are in Figure 4.3.1. The screen lines cover eastern, northern, and south-western directions around Kathmandu City.



Source: JICA Survey Team

Figure 4.3.1 Screen Line Setting Revision

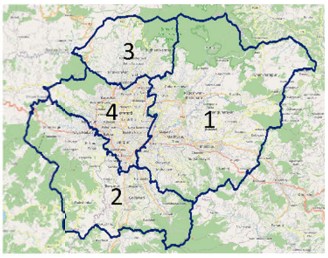
Table 4.3.1 shows the three screen lines containing the results of the traffic reproduction of the model. The table shows total and classified traffic volumes and compares the counted traffic and estimated OD volumes in the three directions[2]. The difference is less than 6%, which infers the revised models have sufficient reproducibility. Appendix 4 outlines the details of this adjustment.

[2] The figures in the tables present OD traffic (classified vehicle traffic on the three screens) between the large zones. The zone 1 to 4 represents zone of eastern, southern/western, northern and central respectively as shown in the map in the right of the table. For example, the figure for 3-4 in the table shows screen traffic between northern and central zones.

Table 4.3.1 Result of the OD Reproduction

Counted Traffic volume ⟷ Estimated OD Volume | Comparison result

		Directional Traffic Volume based on (A) (a)				Directional Traffic Volume based on (B) (b)				Rate (b/a)
Total		1-2	1-3	1-4	total	1-2	1-3	1-4	total	
	E	17,676	13,009	223,826	254,511	30,422	18,028	219,898	268,348	5%
		1-2	2-3	2-4	total	1-2	2-3	2-4	total	
	S	17,676	4,074	166,925	188,675	30,422	11,642	153,642	195,706	4%
		1-3	2-3	3-4	total	1-3	2-3	3-4	total	
	N	13,009	4,074	97,421	114,504	18,028	11,642	88,727	118,397	3%
Bike		1-2	1-3	1-4	total	1-2	1-3	1-4	total	
	E	10,269	6,334	95,926	112,529	14,420	8,308	95,404	118,132	5%
		1-2	2-3	2-4	total	1-2	2-3	2-4	total	
	S	10,269	757	57,276	68,302	14,420	4,228	51,589	70,237	3%
		1-3	2-3	3-4	total	1-3	2-3	3-4	total	
	N	6,334	757	33,389	40,480	8,308	4,228	29,044	41,580	3%
Car		1-2	1-3	1-4	total	1-2	1-3	1-4	total	
	E	3,065	1,940	60,416	65,421	6,328	4,370	58,801	69,499	6%
		1-2	2-3	2-4	total	1-2	2-3	2-4	total	
	S	3,065	702	47,641	51,408	6,328	3,138	44,643	54,109	5%
		1-3	2-3	3-4	total	1-3	2-3	3-4	total	
	N	1,940	702	32,662	35,304	4,370	3,138	29,532	37,040	5%
Truck		1-2	1-3	1-4	total	1-2	1-3	1-4	total	
	E	1,728	872	16,764	19,364	2,916	1,097	16,603	20,616	6%
		1-2	2-3	2-4	total	1-2	2-3	2-4	total	
	S	1,728	859	24,398	26,985	2,916	1,569	23,871	28,356	5%
		1-3	2-3	3-4	total	1-3	2-3	3-4	total	
	N	872	859	9,624	11,355	1,097	1,569	9,113	11,779	4%
Bus		1-2	1-3	1-4	total	1-2	1-3	1-4	total	
	E	2,614	3,863	50,720	57,197	6,758	4,253	49,090	60,101	5%
		1-2	2-3	2-4	total	1-2	2-3	2-4	total	
	S	2,614	1,756	37,610	41,980	6,758	2,707	33,539	43,004	2%
		1-3	2-3	3-4	total	1-3	2-3	3-4	total	
	N	3,863	1,756	21,746	27,365	4,253	2,707	21,038	27,998	2%



The second row with the figure pairs like 1-2 indicates the OD pair in the right-side figure.

Source: JICA Survey Team

(2) More Accurate Floating Population Distribution Scenario for 2020

CBS has issued the population forecast by municipality and county in Kathmandu Valley (KV) for 2020 based on a 2010 census. Their figures may be smaller than the factual number, and researchers must replace them with a floating population.

The ADB-TA model added 30% of CBS's estimated population to create the FP. However, it's the distribution figures for each zone were unclear. The JST applied revisions to the 30% distribution pattern in the models.

The distribution of the FP to the municipality/county level now meets **the recent population growth trend from 2010-2020 and the latest** **VT-OD generation by region** based on screen-line volume. Therefore, the share ratios of the population have become different from the 2020

CBS forecast. Researchers adjusted these figures to accommodate the recent motorization in Lalitpur and Bhaktapur.

Table 4.3.2 shows the revised 2020 population scenario in the KV. The FP distribution was heavier in Lalitpur than in the other two districts.

See population ratio by district.

Table 4.3.2 Population Scenario Setting for 2020

						2020 Scenario	
Seq	City and County	2010-CBS-Pop	2020-CBS-Pop	Area	PopDensity	Population	PopDensity
1	Kathmandu-Metrocity + Institutional	1,020,404	1,178,548	49.65	23,737	1,347,422	27,138
2	Budanilkantha	107,505	184,788	34.98	5,283	211,266	6,040
3	Chandragiri	85,611	103,442	43.86	2,358	118,264	2,696
4	Dakshinkali	24,297	20,977	42.72	491	23,983	561
5	Gokarneshwar	107,351	152,425	58.37	2,611	174,266	2,986
6	Kageshwari Manohara	60,237	86,246	27.37	3,151	98,604	3,603
7	Kirtipur	65,602	81,618	14.78	5,522	93,313	6,313
8	Nagarjun	67,420	103,981	29.89	3,479	118,880	3,977
9	Shankharapur	25,338	21,396	60.22	355	24,462	406
10	Tarakeshwar	81,443	133,657	34.92	3,828	152,809	4,376
11	Tokha	99,032	172,888	16.93	10,212	197,661	11,675
12	Bhaktapur + Institutional	87,695	93,004	6.56	14,177	133,601	20,366
13	Changunarayan	55,430	56,590	62.82	901	81,292	1,294
14	Madhyapur Thimi	83,036	123,605	11.03	11,206	177,559	16,098
15	Suryabinayak Municipality	78,490	96,623	42.71	2,262	138,800	3,250
16	Lalitpur Metropolitan City + Institutional	295,448	373,429	36.16	10,327	690,929	19,108
18	Godawari Municipality	78,301	81,408	96.51	844	150,623	1,561
20	Mahalaxmi Municipality	62,172	91,376	22.51	4,059	169,066	7,511
	Total （Σ1-21)	2,484,812	3,183,078	691.99	3,591	4,102,801	5,929
	KTM (1~11)	1,744,240	2,239,966	414	4,216	2,560,931	6,190
	Bakhtapur (11~15)	304,651	369,823	123	2,474	531,251	4,315
	Lalitpur (16~21)	435,921	546,212	155	2,809	1,010,619	6,513
	KTM (1~11)	70.2%	70.4%			62.4%	
	Bakhtapur (11~15)	12.3%	11.6%			12.9%	
	Lalitpur (16~21)	17.5%	17.2%			24.6%	

Note: Zones 17/19/21 are eliminated as they are villages outside KV with tiny populations.
Source: JICA Survey Team

BOX: Preliminary Result of the Census 2021 and Comparison

The Census 2020 in Nepal was reschedule into 2021 due to the COVID-19 pandemic, and its preliminary report was recently issued. Table 4.3.3 shows the difference between the adopted population scenario in 2020 for this Study and the preliminary results of the census 2021 as a reference. Note that Institutional population accounts for a large portion of population, particularly in a big city.

Table 4.3.3 Comparison with 2021 Census Preliminary Results

						Ratio of difference		Difference	
Seq	City and County	2010-CBS-Pop	2020-CBS-Pop	2021-Pre	2020 Scenario	2020CBS	2020 Scenario	2020CBS	2020 Scenario
1	Kathmandu-Metrocity + Institutional	1,020,404	1,178,548	845,767	1,347,422	excluded			
2	Budanilkantha	107,505	184,788	179,688	211,266	3%	18%	5,100	31,578
3	Chandragiri	85,611	103,442	136,928	118,264	-24%	-14%	-33,486	-18,664
4	Dakshinkali	24,297	20,977	26,744	23,983	-22%	-10%	-5,767	-2,761
5	Gokarneshwar	107,351	152,425	151,200	174,266	1%	15%	1,225	23,066
6	Kageshwari Manohara	60,237	86,246	133,327	98,604	-35%	-26%	-47,081	-34,723
7	Kirtipur	65,602	81,618	81,782	93,313	0%	14%	-164	11,531
8	Nagarjun	67,420	103,981	115,507	118,880	-10%	3%	-11,526	3,373
9	Shankharapur	25,338	21,396	30,414	24,462	-30%	-20%	-9,018	-5,952
10	Tarakeshwar	81,443	133,657	151,508	152,809	-12%	1%	-17,851	1,301
11	Tokha	99,032	172,888	135,741	197,661	27%	46%	37,147	61,920
12	Bhaktapur + Institutional	87,695	93,004	78,854	133,601	excluded			
13	Changunarayan	55,430	56,590	88,612	81,292	-36%	-8%	-32,022	-7,320
14	Madhyapur Thimi	83,036	123,605	119,955	177,559	3%	48%	3,650	57,604
15	Suryabinayak Municipality	78,490	96,623	137,971	138,800	-30%	1%	-41,348	829
16	Lalitpur Metropolitan City + Institutional	295,448	373,429	299,843	690,929	excluded			
18	Godawari Municipality	78,301	81,408	100,972	150,623	-19%	49%	-19,564	49,651
20	Mahalaxmi Municipality	62,172	91,376	118,710	169,066	-23%	42%	-27,334	50,356
							Sum	-46,899	100,008

Source: JICA Survey Team, CBS, Note: The zones 1, 12 and 16 having the Institutional populations (institutional residences including barracks, hostels, cantonments, prisons etc. at the time of census), which are not reported in the preliminary report of 2021 census, therefore, this comparison excluded those zones.

The comparison may suggest that;

The comparison among 2021 Preliminary result and 2020 CBS shows approx. 20-30% shortness of the 2020 CBS estimation generally, which may suggest the existence of FP.

The comparison among 2021 Preliminary result and 2020 scenario seems have less difference compared to the CBS 2020 estimation, which may justify the scenario.

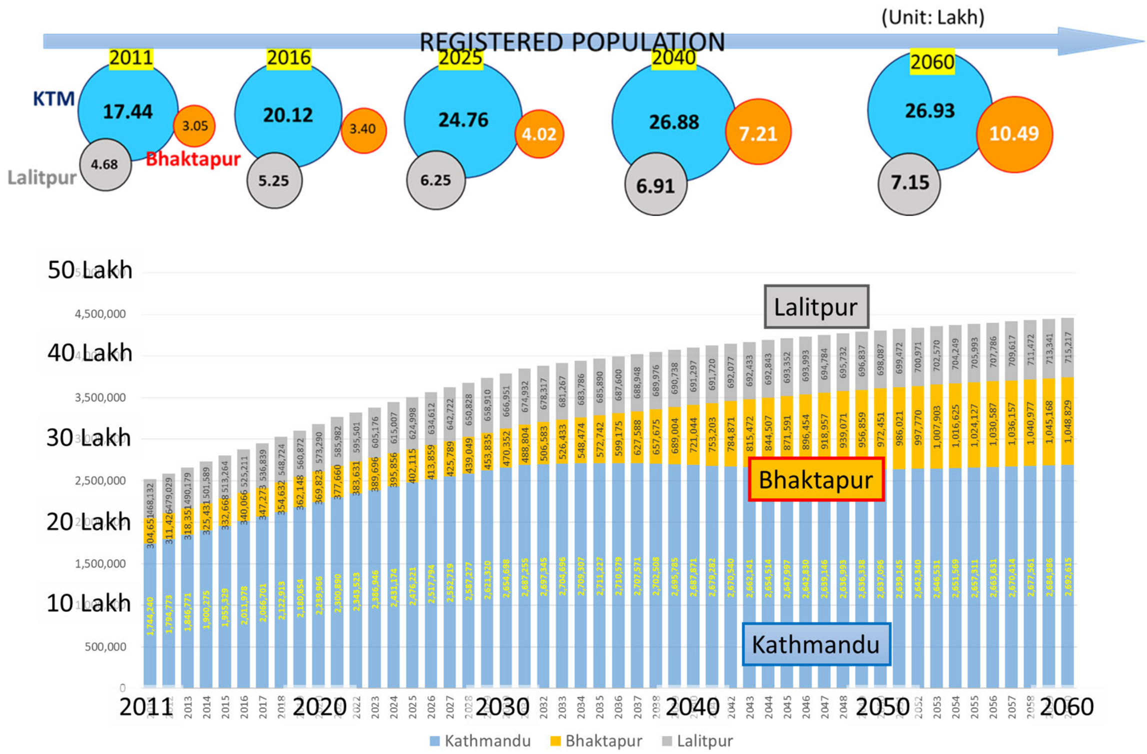
For the zones of 14, 15, 18 and 20, which are located in the vicinity of the Project intersection of the Study, the CBS estimations are much smaller to the 2021 census, however, the populations in the Scenario are much larger to the 2021 census.

For the zones of 13, 15, 6, which have KVDA's township projects, the CBS estimation are too small and the Scenario has better setting compared to the Preliminary result of 2021, however, the population in the zone 6 in 2021 census has larger population than the Scenario, which may suggest a rapid population growth in the area of KVDA township projects.

(3) More Accurate Floating Population Distribution Scenario for 2030 and 2040

JST and KVDA revised to the long-term population forecast of the KV by county level as shown Figure 4.3.2. The original population scenario in the ADB-TA model adopted rapid growth due to the ENCD. However, parties agreed that the 1 million population will migrate into the ENCD area by 2060, revised from 2040. Figure 4.3.2 shows the revised population growth scenario for the three districts in KV. This slower development scenario has the following settings:

1. Easing of the population concentration in KTM district by 2030,
2. The Bhaktapur population will continue to grow even after 2030 until it achieves the target population in the chart. Note that this population scenario does not include the FP.



Source: JICA Survey Team

Figure 4.3.2 KVDA Population Settings for 2030 and 2040

JST finalized the population scenario accounting for the FP. Specifications of the FP distribution at the city/county maintain the following conditions:

1) Population will not exceed 32,000 people /km^2

2) Provision of a scenario for mountainous counties that have limits in population density.

3) Distribution of more FPs in the eastern hill development areas.

The final scenarios are in Table 4.3.4. KV's aggregate population will total 4.93 million in 2030 and 5.34 million in 2040.

Table 4.3.4 Final Population Scenario for 2030 and 2040

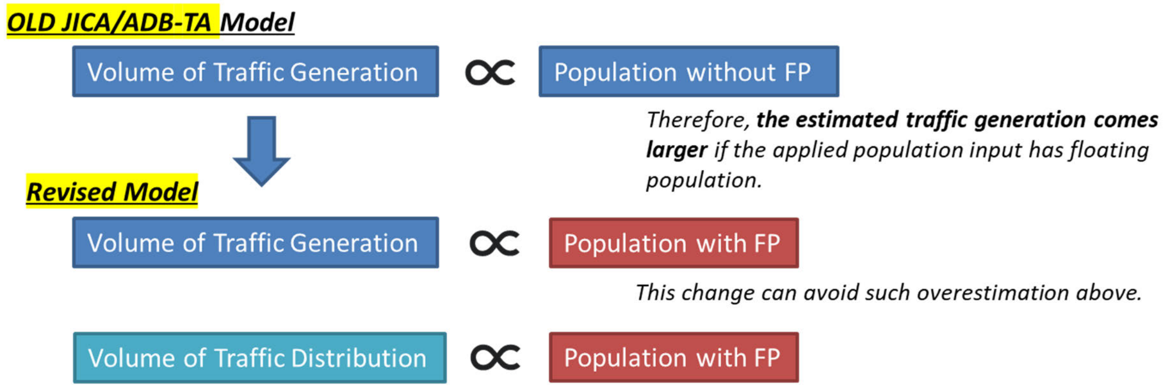
					2030 Scenario		2040 Scenario	
Seq	County	2020PopScenario	Area	Density	Population	Density	Population	Density
1	Kathmandu-Metrocity + Institutional	1,347,422	49.65	27,138	1,566,045	31,542	1,508,185	30,376
2	Budanilkantha	211,266	34.98	6,040	284,718	8,139	284,245	8,126
3	Chandragiri	118,264	43.86	2,696	157,868	3,599	157,613	3,594
4	Dakshinkali	23,983	42.72	561	23,983	561	23,983	561
5	Gokarneshwar	174,266	58.37	2,986	232,623	3,985	232,247	3,979
6	Kageshwari Manohara	98,604	27.37	3,603	164,220	6,000	218,960	8,000
7	Kirtipur	93,313	14.78	6,313	124,561	8,428	124,360	8,414
8	Nagarjun	118,880	29.89	3,977	161,394	5,400	161,120	5,390
9	Shankharapur	24,462	60.22	406	24,462	406	24,462	406
10	Tarakeshwar	152,809	34.92	4,376	206,684	5,919	206,337	5,909
11	Tokha	197,661	16.93	11,675	266,557	15,745	266,113	15,718
12	Bhaktapur + Institutional	133,601	6.56	20,366	135,388	20,638	183,702	28,003
13	Changunarayan	81,292	62.82	1,294	157,050	2,500	314,100	5,000
14	Madhyapur Thimi	177,559	11.03	16,098	192,057	17,412	272,352	24,692
15	Suryabinayak Municipality	138,800	42.71	3,250	170,396	3,990	271,432	6,355
16	Lalitpur Metropolitan City + Institutional	690,929	36.16	19,108	726,715	20,097	744,196	20,581
18	Godawari Municipality	150,623	96.51	1,561	158,425	1,642	162,236	1,681
20	Mahalaxmi Municipality	169,066	22.51	7,511	180,527	8,020	184,787	8,209
pop	Total（Σ1-21)	4,102,801	691.99		4,933,674	7,130	5,340,430	7,717
pop	KTM (1~11)	2,560,931	413.69		3,213,115	7,767	3,207,625	7,754
	Bakhtapur (11~15)	531,251	123.12		654,892	5,319	1,041,587	8,460
	Lalitpur (16~21)	1,010,619	155.18		1,065,667	6,867	1,091,218	7,032
share	KTM (1~11)	62.4%			65.1%		60.1%	
	Bakhtapur (11~15)	12.9%			13.3%		19.5%	
	Lalitpur (16~21)	24.6%			21.6%		20.4%	

Source: JICA Survey Team

(4) G/A Model and Distribution Model Revision

Figure 4.3.3 outlines the significant revisions to the G/A and Distribution models. The previous models feature estimates based on the population without the FP.

The estimated traffic generation becomes more sizeable when the population input accounts for the FP, so JST re-estimated both models inclusive of the FP.



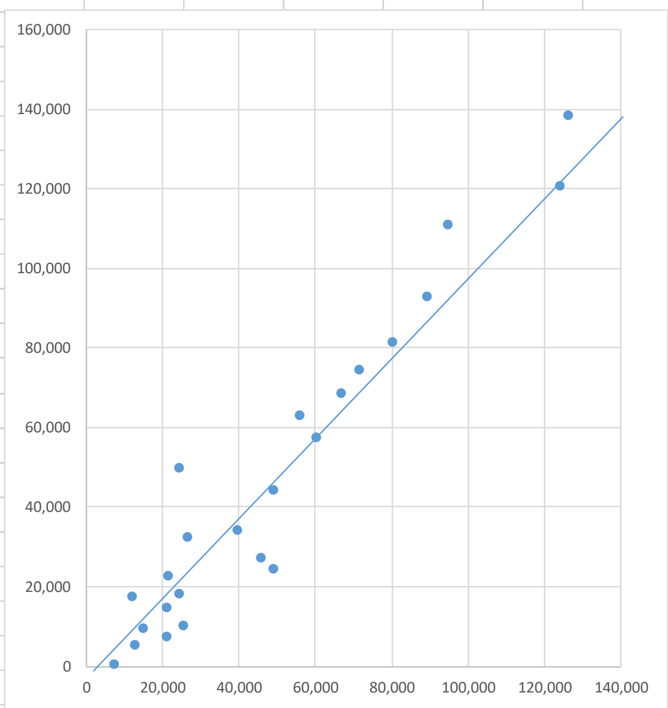
Source: JICA Survey Team

Figure 4.3.3 Revision of the Models

The distribution model adopted the gravity model instead of the present pattern model, which the previous model featured. The current pattern method will not reflect the effect of population distribution and new developments in KV in the future.

Figure 4.3.4 shows the reproduction of the assigned traffic in 2020 at the Project intersections and their surroundings after applying the revised models.

		Obs.	Assin.	Diff.
Near Koteshowor Intersection	NH2-1	89,153	92,818	4%
	NH2-2	24,334	18,234	-25%
	NH2-3	71,643	74,584	4%
	NH2-4	7,312	551	-92%
	RRN-1	80,113	81,488	2%
	RRN-2	55,779	63,254	13%
	A-A	126,134	138,389	10%
	RRS	66,825	68,818	3%
	ARK-1	123,981	120,884	-2%
	ARK-2	94,563	110,950	17%
	Pepsi	39,455	34,198	-13%
Other Section	E4	12,216	17,732	45%
	E5 (Bouda Rd.)	48,865	44,231	-9%
	E8	45,566	27,281	-40%
	S2	60,397	57,430	-5%
	S4	26,521	32,654	23%
	S5	25,615	10,408	-59%
	S6	21,084	7,503	-64%
	S7	21,084	14,939	-29%
	S8	24,492	49,987	104%
	N1	12,855	5,478	-57%
	N2	21,553	22,919	6%
	N5	14,764	9,711	-34%
	N6	48,933	24,404	-50%



R = 0.990 (only near Koteshowor IS.)
R = 0.964 (Koteshowor IS + Other Section)

Source: JICA Survey Team

Figure 4.3.4 Comparison of Observed and Assigned Traffic at the Project Intersection

The R figures near the Koteshwor intersection came to 0.990, validating the high relativity between the observed and estimated traffic from the revised model.

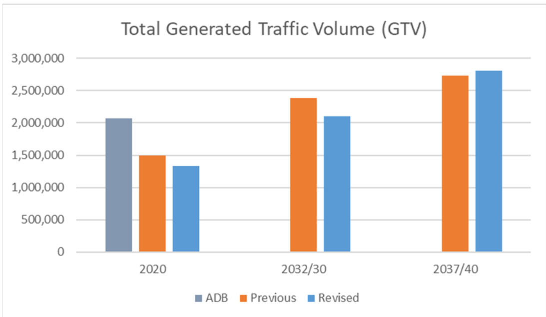
4.4 Traffic Forecast for 2030 and 2040

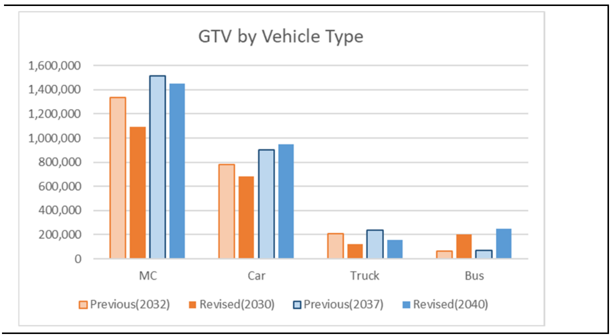
(1) Road Network Setting

JST applied the revised model to forecast the traffic situation in 2030 and 2040. The following road network development scenarios were applicable before the estimation. See details in Section 4.2.8.

(2) G/A and OD estimations and their difference from the previous estimations

Figure 4.4.1 shows the estimated generated traffic volume from the revised model and compares them with previous models to ascertain the total and classified traffic.





Source: JICA Survey Team

Figure 4.4.1 Estimation of Generated Traffic with Comparison

The comparison results suggest the following:

- Based on the results of traffic volume adjustment by 3-screen lines, the total Generated Traffic Volume (GTV) in 2020 by the previous and revised is around 30% smaller than the figures from the ADB VT-OD.
- The total GTV by the previous and revised models in 2032/30 is not much different, but the revised figures are 10% bigger in the 2037/2040 comparison.
- GTVs for motorcycles, cars, and trucks for the previous model are more sizeable than the ones for the revised. The GTV for buses in the previous one is much smaller, accounting for the screen adjustment results in all directions.

Table 4.4.1 shows the OD traffic of the previous and the revised model in large zones with their comparisons. The upper table, from left to right, shows the 2032 OD traffic of the previous model, the 2030 OD traffic of the revised model, and the differences between them, respectively. The lower table compares 2037 and 2040 OD and displays their differences.

Table 4.4.1 Comparison of OD Traffic with Previous Model Estimation

		Previous					Revised					Difference (Revised-Previous)				
2032/30		1:East	2:South	3:North	4:Center	total	1:East	2:South	3:North	4:Center	total	1:East	2:South	3:North	4:Center	total
	1	268,091	57,206	44,168	469,964	839,429	369,916	42,225	30,667	425,577	868,385	101,825	-14,981	-13,501	-44,387	28,956
	2	0	36,483	8,010	314,566	359,059	0	25,983	6,857	276,298	309,138	-	-10,500	-1,153	-38,268	-49,921
	3	0	0	2,075	197,312	199,387	0	0	1,581	149,868	151,449	-	-	-494	-47,444	-47,938
	4	0	0	0	991,122	991,122	0	0	0	775,316	775,316	-	-	-	-215,806	-215,806
	tot	268,091	93,689	54,253	1,972,964	**2,388,997**	369,916	68,208	39,105	1,627,059	**2,104,288**	101,825	-25,481	-15,148	-345,905	**-284,709**
				Total Inner Traffic		1,297,771			Total Inner Traffic		1,172,796			Total Inner Traffic		-124,975
				Ratio of Inner Traffic		54.3%			Ratio of Inner Traffic		55.7%					
				Total Traffic		1,091,226			Total Traffic		931,492			Total Traffic		-159,734
2037/40		1:East	2:South	3:North	4:Center	total	1:East	2:South	3:North	4:Center	total	1:East	2:South	3:North	4:Center	total
	1	341,575	67,348	55,614	552,278	1,016,815	721,031	60,010	43,420	594,760	1,419,221	379,456	-7,338	-12,194	42,482	402,406
	2	0	42,020	9,500	351,662	403,182	0	30,055	7,819	310,100	347,974	-	-11,965	-1,681	-41,562	-55,208
	3	0	0	2,516	227,688	230,204	0	0	1,841	169,715	171,556	-	-	-675	-57,973	-58,648
	4	0	0	0	1,078,104	1,078,104	0	0	0	862,876	862,876	-	-	-	-215,228	-215,228
	tot	341,575	109,368	67,630	2,209,732	**2,728,305**	721,031	90,065	53,080	1,937,451	**2,801,627**	379,456	-19,303	-14,550	-272,281	**73,322**
				Total Inner Traffic		1,464,215			Total Inner Traffic		1,615,803			Total Inner Traffic		151,588
				Ratio of Inner Traffic		53.7%			Ratio of Inner Traffic		57.7%					
				Total Traffic		1,264,090			Total Traffic		1,185,824			Total Traffic		-78,266

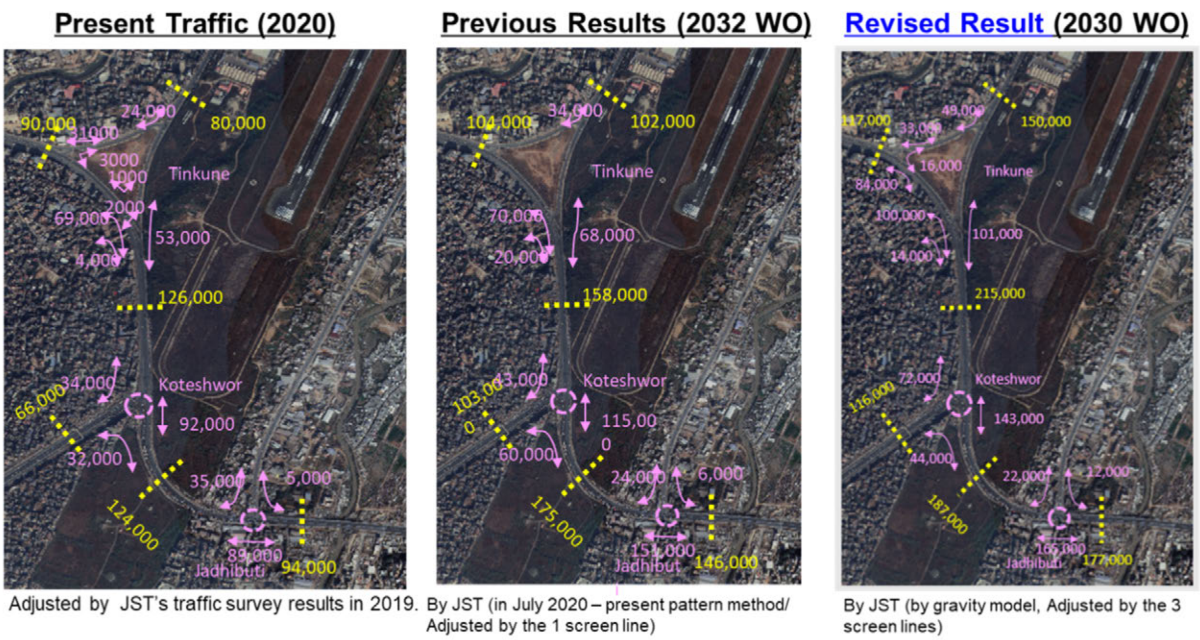
Source: JICA Survey Team

The comparison may suggest that:

- While the inner traffic volume within the east zone is higher than the revised figures, the interior numbers for the center are much lower.
- In general, the traffic volumes of the center zone show higher tendencies for a more sizeable reduction.
- Researchers assume the tendencies are products of a difference in the FP distribution in each traffic zone in the revised model accounting for the recent population trend.

(3) Assignment results at the Project Intersections with Comparison

Figure 4.4.2 summarizes the results of vehicle traffic assignments of the revised model for 2030 without grade separation interventions. It compares previous estimations for 2032 with the present observed traffic in 2020.



Note: WO means Without grade separation
Source: JICA Survey Team

Figure 4.4.2 Assignment Result and Comparison

The comparison suggests that:

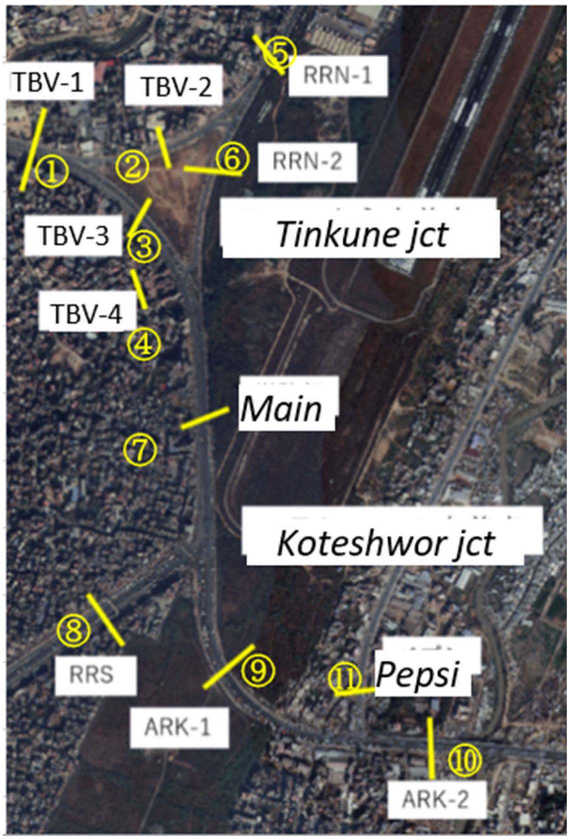
- The revised TDF shows changes in traffic flow influenced by network improvement from the application of the gravity model.
- For instance, the widening of the northern part of the Ring Road (RR) affected its traffic growth (102K to 150K), which resulted in traffic growth at the target combined section (158K to 215k) directly.
- Similarly, the expansion of the Araniko Highway caused its growth (146K to 175K).
- On the other hand, traffic on the southern RR did not grow because its width stayed the same.

Table 4.4.2 summarizes the results of the traffic demand forecast for 2030 and 2040 without displaying these causes. Figure 4.4.3 shows the location of the traffic volume in Table 4.4.2.

Table 4.4.2 TDF for Without Cases in 2030/2040

			Traffic Volume[PCU/day]			Ratio			AAGR		
			2020	2030	2040	2030/20	2040/20	2040/30	2030/20	2040/20	2040/30
Intersections for Comparison	①	TBV-1	92,818	116,166	145,528	1.25	1.57	1.25	2.27%	2.27%	2.28%
	②	TBV-2	18,234	49,328	48,388	2.71	2.65	0.98	10.46%	5.00%	-0.19%
	③	TBV-3	74,584	100,868	128,846	1.35	1.73	1.28	3.06%	2.77%	2.48%
	④	TBV-4	551	14,069	16,600	25.53	30.13	1.18	38.26%	18.56%	1.67%
	⑤	RRN-1	81,488	150,285	160,658	1.84	1.97	1.07	6.31%	3.45%	0.67%
	⑥	RRN-2	63,254	100,957	112,270	1.60	1.77	1.11	4.79%	2.91%	1.07%
	⑦	Main	138,389	215,308	251,340	1.56	1.82	1.17	4.52%	3.03%	1.56%
	⑧	RRS	68,818	103,577	136,201	1.51	1.98	1.31	4.17%	3.47%	2.78%
	⑨	ARK-1	120,884	186,983	215,122	1.55	1.78	1.15	4.46%	2.92%	1.41%
	⑩	ARK-2	110,950	210,693	244,475	1.90	2.20	1.16	6.62%	4.03%	1.50%
	⑪	Pepsi	34,198	33,801	52,915	0.99	1.55	1.57	-0.12%	2.21%	4.58%

Note: AAGR: Average Annual Growth Ratio
Source: JICA Survey Team



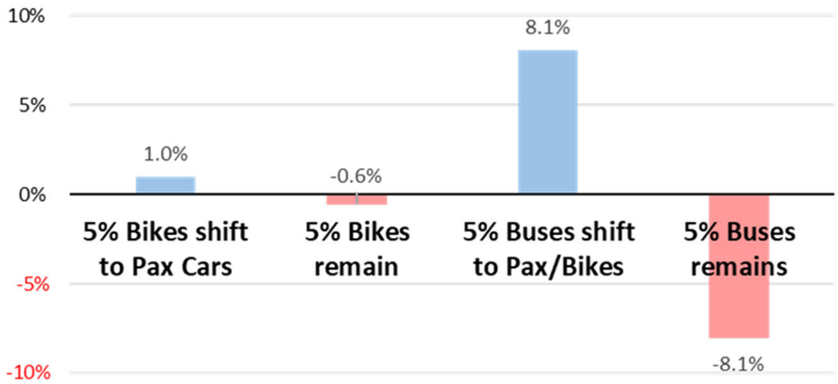
Source: JICA Survey Team

Figure 4.4.3 Location of Traffic Volume Comparison

(4) Influence in modal change in the future

JST changed the share of the vehicle classification at the intersection of the TDF results in 2030 and 2040 and checked the fluctuation of the results to consider future potential modal change. The scenarios and results are as follows.

- [5% Bike shift to Passenger Car]: +1.0% pcu volume increased.
- [5% bikes with no modal shift]: a slight difference from the original estimation
- [5% Buses shift to Passenger cars or Bikes]: Traffic may increase by 8%
- [5% Buses with no modal shift]: traffic congestion may be avoided.



Source: JICA Survey Team

Figure 4.4.4 Traffic Volume Fluctuation with Mode Change Possibility

The result suggests that;

- There is almost no sizeable effect from the modal change to passenger cars from bikes or no modal shift to bikes.
- The noticeable alteration of transport modes from buses to bikes and passenger cars does not carry a modal shift from bus users.

4.5 Justification of the Revised Model and TDF

Based on the previous discussions, the future TDF results from the Revised Model have the following justifications:

- The growth pace of traffic volume lies between the future average GDP growth ratio and average population growth. In the revised model, the average traffic growth ratio is 3.7% for the whole KV, which lies between average GDP growth of 4.5% and average population growth of 1.33% from 2020 to 2040.

- The population trend changes reflect the tendency of traffic flow directions, which the population forecast and its distribution process analyzed (*e.g., population saturation in the KTM district resulted in decreased traffic volumes in the center zone*).
- Traffic flow changes around the Project intersections also reflected the major revised works for the revised model, application of the gravity model, and heavier FP distribution to and around the Eastern New City Development (ENCD) areas.
- The analysis of future modal change influences confirms that the mode change from bike-to-passenger-car does not affect the traffic volumes in the PCU level forecasted by the revised model. However, it has a sizeable impact on bus-to-bike or bus-to-passenger-car transitions.

Nepal should carefully monitor the ENCD progress, which will influence the future population distribution and traffic flow shifts in the entirety of KV.

CHAPTER 5. VERIFICATION OF PRIORITY PROJECT

5.1 Background of the Priority Project Selection for Intersection Improvement in Kathmandu Valley

5.1.1 Consideration of Recent Traffic Volumes at Intersections along the Ring Road

The Department of Roads (DOR) and JICA Survey Teams (JST) conducted traffic volume counts at major intersections along the inner Ring Road, as summarized in Figure 5.1.1. The figure depicts seven major intersections, labeled A to G clockwise from the north, where the DOR assessed traffic volumes evaluate the need for signal installations. Blue arrows on the figure represent traffic volumes in the radial direction, while green arrows indicate traffic volumes in the circular direction. The former is measured in Passenger Car Units (pcu), while the latter values are actual measurements from DOR 2018-19. The values in red are extrapolated from the Project on Urban Transport Improvement for Kathmandu Valley, JICA, 2017 (JICA MP).

Source: DOR Statistics and JICA MP

Figure 5.1.1 Recent Traffic Volumes at Intersections along the Ring Road

Table 5.1.1 shows the traffic volumes in pcu/day and the total pcu/day for the major intersections in the circular and radial directions. The intersection with the highest total traffic volume is Tinkune-Koteshwor, with 150,100 pcu/day, selected as the priority project for intersection improvement in Kathmandu Valley in the data collection surevey.

Table 5.1.1 Traffic Volumes in pcu in 2018/19 at Major Intersections along the Ring Road

(Unit: pcu/day)

#	Junction Name	Circular Direction	Radial Direction	Total
A)	Naraya Gopal	72,089	44,270	116,359
B)	Chabahil	72,089	49,075	121,164
C)	Tinkne-Koteshwor	59,518	90,582	150,100
D)	Satdobato	59,518	56,555	116,073
E)	Balkhu	46,869	21,585	68,454
F)	Kalanki	35,485	60400	95,885
G)	Balaju	58,512	22,711	81,223

Source: DOR Statistics and JICA MP

Based on observations, the qualitative considerations on each intersection are as follows:

- Intersections A and G have large traffic volumes in the circular direction, but the growth of traffic in the circular direction is slow due to the small hinterland;
- Intersection B has a large hinterland, but the specifications for road widening in the radial direction are low, only from two to four lanes, and future development in the hinterland has not progressed as much as in Intersections C and D.
- Intersection E has a narrow hinterland, and Intersection F has already undergone a multi-level crossing; and
- Intersections C and D each have large hinterland and future development plans, but Intersection C in particular has a large eastern development plan, ENDP, and future traffic growth is expected to be significant.
- In addition, the airport is located to the north of C), making it challenging to construct a parallel road from the east area to the city center. Currently, there is about 5 km distance between two major roads, Boudha Road and Araniko Highway, connecting the eastern areas to the city center. As a result, traffic tends to concentrate at Intersection C.

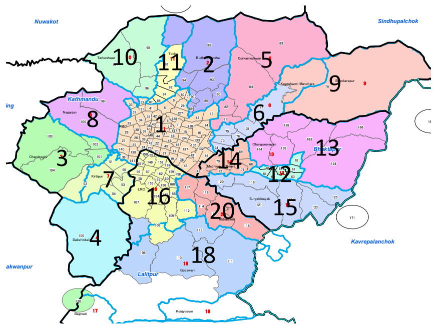
5.1.2 Consideration of Population Growth at Zones in Kathmandu Valley

Supplementary to Section 5.1.1, Table 5.1.2 summarizes the current population growth trends and future scenarios in the Kathmandu Valley. Chapter 4 also provides details.

Table 5.1.2 contains the 2010 population (by CBS) in the Kathmandu Valley and at the administrative district level, as well as the predicted population in 2020 by JST, including the floating population. The table also shows the 2010-2020 growth rate (AAGR) and net increments. The location in the table indicates the relationship to intersections A to G, and the map on the right side shows the location of each administrative district within the Kathmandu Valley.

Table 5.1.2 Population Setting of 2020, AAGR between 2010-2020 at Medium Zones

Seq	Med-Zone	Location	CBS_Pop_2010	Sce_pop_2020	AAGR-2010-2020	Net Growth
1	Kathmandu-Metrocity + Institutional	inside	1,020,404	1,347,422	3.14%	327,018
2	Budanilkantha	A	107,505	211,266	7.80%	103,761
3	Chandragiri	F	85,611	118,264	3.66%	32,653
4	Dakshinkali	E	24,297	23,983	-0.14%	-314
5	Gokarneshwar	A	107,351	174,266	5.53%	66,915
6	Kageshwari Manohara	B	60,237	98,604	5.63%	38,367
7	Kirtipur	E	65,602	93,313	3.99%	27,711
8	Nagarjun	F	67,420	118,880	6.50%	51,460
9	Shankharapur	B	25,338	24,462	-0.39%	-876
10	Tarakeshwar	G	81,443	152,809	7.24%	71,366
11	Tokha	G	99,032	197,661	7.98%	98,629
12	Bhaktapur + Institutional	C	87,695	133,601	4.79%	45,906
13	Changunarayan	C	55,430	81,292	4.35%	25,862
14	Madhyapur Thimi	C	83,036	177,559	8.81%	94,523
15	Suryabinayak Municipality	C	78,490	138,800	6.54%	60,310
16	Lalitpur Metropolitan City + Institutional	inside	295,448	690,929	9.90%	395,481
18	Godawari Municipality	D	78,301	150,623	7.54%	72,322
20	Mahalaxmi Municipality	C	62,172	169,066	11.76%	106,894
	Total（Σ1-21)		2,484,812	4,102,801	5.73%	
	KTM (1~11)		1,744,240	2,560,931	4.36%	
	Bakhtapur (12~15)		304,651	531,251	6.37%	
	Lalitpur (16~21)		435,921	1,010,619	9.79%	



#	Junction Name	Net Pop Growth 2010-2020
A)	Naraya Gopal	170,676
B)	Chabahil	37,491
C)	Tinkne-Koteshwor	333,495
D)	Satdobato	72,322
E)	Balkhu	27,397
F)	Kalanki	84,114
G)	Balaju	169,995

Source: CBS and JST
Note: The zones 17, 19, 21 in Lalitpur are excluded because they are out of the Kathmandu Valley.

The potential for future traffic concentration at each intersection is possible to assess by studying the relationship between the incremental trend by zone and the intersection location. The net increments are large in Zone 1 with 327,018 and 16 with 395,481, but most are inside of the Ring Road. Accordingly, they are not incoming traffic flow. The table on the lower right shows the population growth in the hinterland of the intersections. In conclusion, the population growth in the Koteshwor-Tinkune neighborhood is the largest due to the influence of the recent development in the eastern area.

Considering the current traffic volume and future traffic concentration in response to the population growth in the eastern area, the Koteshwor-Tinkune intersection should be a priority for the grade separation around the Ring Road.

5.2 Justification of the Project Intersection among Two Intersections Proposed in Previous JICA Studies

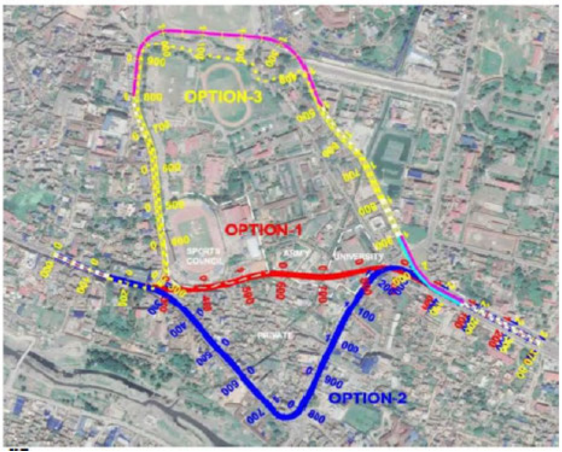
5.2.1 Introduction

In the pre-survey, The Improvement of Koteshwor Intersection, covering Tinkune Intersection, was recommended as a priority project in the mid-term plan of the urban transport project in the Kathmandu Valley, which also can be justified by the analysis results described in 5.1. On other hand, the Project on Urban Transport Improvement for Kathmandu Valley, JICA, 2017 (JICA MP) proposed the improvement of Tripureshwor - Maitighar Intersection (T-M Intersection) as a priority project.

In this section, validity of the selected the Koteshwor intersection will be reconfirmed based on the traffic demand forecast model updated in the survey, revising the population growth scenario for the Eastern New City Development Project and road network development plan.

5.2.2 Outline of Improvement of Tripureshwor - Maitighar Intersection

Figure 5.2.1 shows the improvement plan for T-M Intersection. JICA MP conducted a pre-feasibility study for the T-M Intersection improvement and concluded Option 1 among three options, which is the shortest alignment, as the most feasible option by multi-criteria evaluation method.



Source: JICA MP

Figure 5.2.1 Flyover Options for T-M Intersections

5.2.3 Methodology for Re-confirmation

(1) Procedure

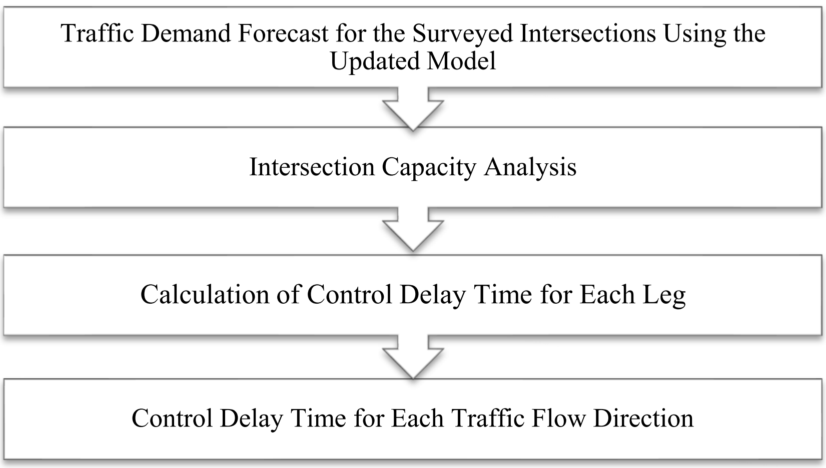
Figure 5.2.2 shows the verification procedure for the prioritized Koteshwor Intersection improvement in the survey.

At first, traffic demand is calculated by using updated model. Although Pre-survey assessed the Koteshwor intersection was more severely congested than the T-M intersection. However, this result includes an effect of development railway which is recommended as a long term project. On other hand, pre-condition of this study is effect of railway is not considered, re-calculation is required.

Next, in order to confirm traffic congestion, saturated ratio was calculated.

After that, control delay time by each leg was calculated. The basis of the evaluation of the priority project must be the travel time delay when passing through the intersection instead of the traffic volume capacity ratio (V/C) since the V/C is an inappropriate indicator for comparing the impacts on economic and social activities between intersections. For example, a) an intersection with the capacity of 100 pcu/day taking 500 pcu/day traffic, b) an intersection with the capacity of 1000 pcu/day taking 5000 pcu/day traffic, V/C of both intersections is same as 5, but adverse social impact of the latter is beyond that of the former. Accordingly, an indicator of control delay time[1] at intersections shall be introduced as a priority criterion to evaluate the degree of traffic congestions at the surveyed intersections. The assessment of the effectiveness of the grade separation direction requires the computation of the control delay time for each traffic flow direction.

Lastly, total control delay time by each OD pair was calculated because both projects propose continuous a viaduct which passes through several intersections.



Source: JICA Survey Team

Figure 5.2.2 Procedure for Verification of Priority Project

[1] Additional travel time taken for passing through the intersection in consideration of reduction of travel speed or stoppage by traffic control device (e.g. Signal) and interaction between vehicles

(2) Assumptions for Analysis

The assumptions for the intersection analysis by the updated traffic demand forecast model are the following:

- ✓ Design year: 2020
- ✓ Peak ratio: 10% (the common value and the same assumption as the pre-survey)

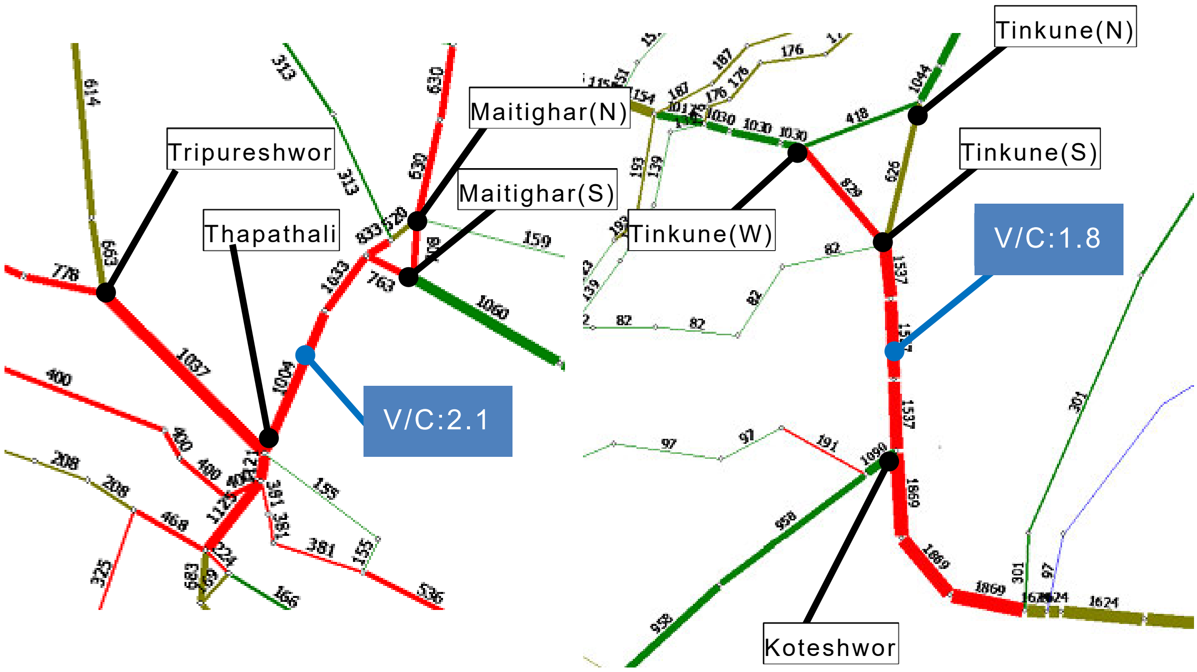
5.2.4 Traffic Demand Forecast

Figure 5.2.3 shows the results of traffic demand forecast around the survey intersections. The survey intersections and connecting roads will be in saturated conditions in 2020. The V/C of the road segment between the Koteshwor Intersection and the Tinkune Intersection, and between the Maitighar Intersection and Thapathali Intersection are 1.8 and 2.1, respectively, which T-M Intersection has a higher value than the Koteshwor case.

Units:100pcu/day

T-M Intersection

Koteshwor~Tinkune intersection



Source: JICA Survey Team

Figure 5.2.3 The Result of Traffic Demand Forecast

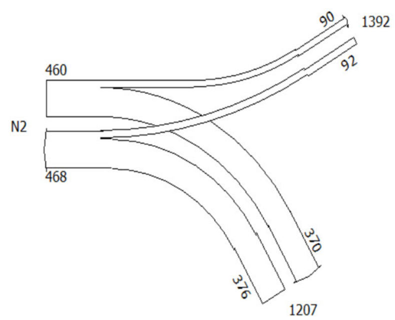
5.2.5 Analysis of Intersection Capacity for Survey Intersections

(1) Traffic Volume in Each Direction

Table 5.2.1 shows the traffic volumes around the survey intersections calculated by the updated traffic demand forecast model.

Table 5.2.1 Traffic Demand in Each Direction at Koteshwor and Tinkune Intersections

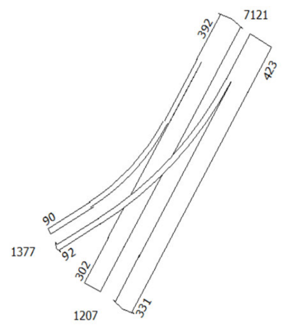
Tinkune Intersection (West)



Node=1377

	1207	N2	1392
1207	0	37, 584	0
N2	37, 000	0	9, 000
1392	0	9, 234	0

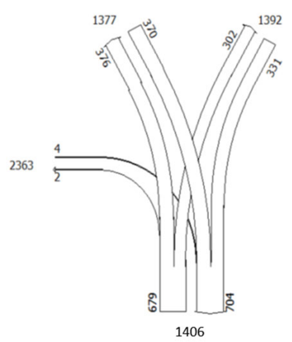
Tinkune Intersection (North)



Node=1392

	1207	1377	7121
1207	0	0	30, 187
1377	0	0	9, 000
7121	33, 067	9, 234	0

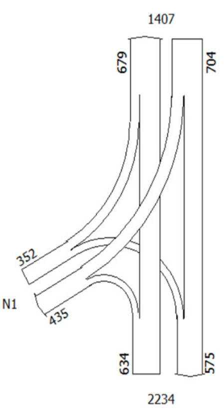
Tinkune Intersection (South)



Node=1207

	1406	2363	1377	1392
1406	0	175	37, 584	30, 187
2363	376	0	0	0
1377	37, 000	0	0	0
1392	33, 067	0	0	0

Koteshwor Intersection



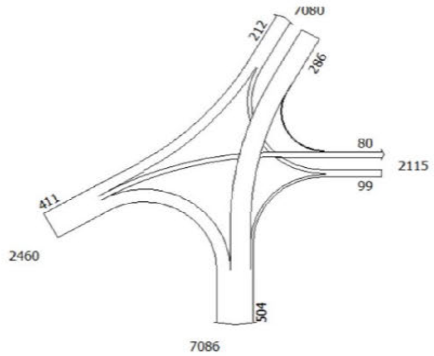
Node=7038

	2234	N1	1407
2234	0	15, 764	47, 620
N1	14, 826	0	20, 326
1407	42, 674	27, 769	0

Source: JICA Survey Team

Table 5.2.2 Traffic Demand in Each Direction at T-M intersection

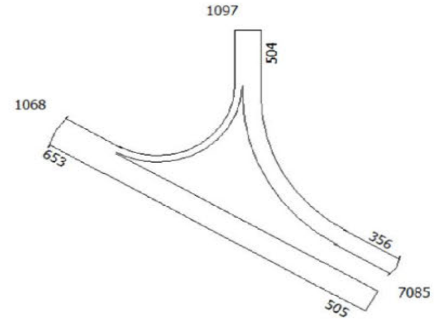
Maitighar(N) Intersection



<1097>

	2115	7086	2460	7080	
2115	0	3, 845	0	6, 093	99
7086	0	0	0	0	0
2460	7, 405	18, 570	0	15, 127	411
7080	643	27, 994	0	0	286
	80	504	0	212	

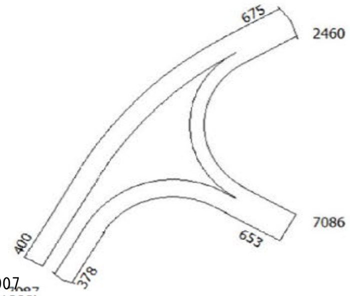
Maitighar(E) Intersection



<7086>

	7085	1068	1097	
7085	0	50, 493	0	505
1068	0	0	0	0
1097	35, 609	14, 800	0	504
	356	653	0	

Maitighar(S) Intersection

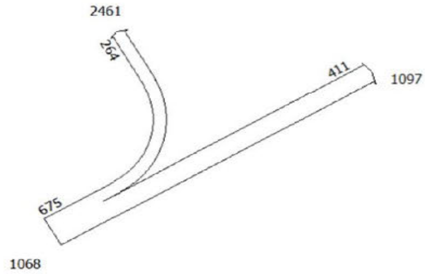


7007

<1068>

	7086	7087	2460	
7086	0	37, 765	27, 528	653
7087	0	0	39, 956	400
2460	0	0	0	0
	0	378	675	

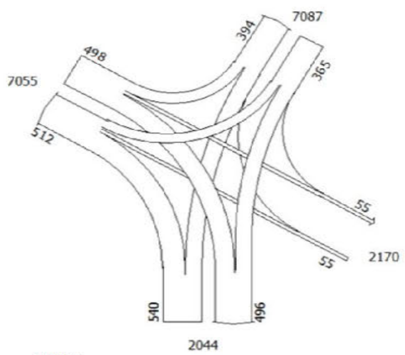
Maitighar(W) Intersection



<2460>

	1068	2461	1097	
1068	0	26, 382	41, 102	675
2461	0	0	0	0
1097	0	0	0	0
	0	264	411	

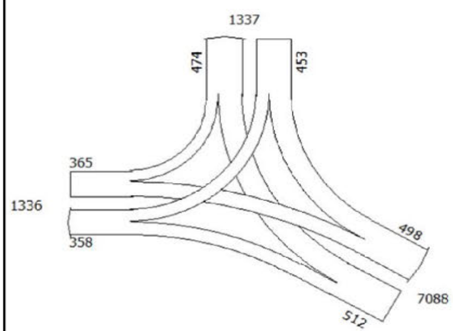
Thapathali Intersection



<7088>

	2170	2044	7055	7087	
2170	0	0	5, 421	111	55
2044	0	0	31, 502	22, 518	540
7055	5, 439	27, 537	0	16, 820	498
7087	110	22, 109	14, 294	0	365
	55	496	512	394	

Tripureswor Intersection



<7055>

	7088	1336	1337	
7088	0	19, 068	32, 149	512
1336	21, 190	0	15, 260	365
1337	28, 606	16, 721	0	453
	498	358	474	

Source: JICA Survey Team

(2) Intersection Capacity Analysis by Delay Time

1) Reference Standard

The intersection analysis using the control delay time for the survey intersections is based on the "Plan and Design of At-grade Intersection" (Japan Society of Traffic Engineering,2018), also known as the Japanese Standard and Highway capacity Manual, Highway capacity Manual, 2010.

2) Control Delay Time by Each Approach

A control delay time under an unsaturated condition is calculated by the equation below based on the Japanese Standard.

$$D = \frac{sqR^2}{2(s-q)} = \frac{qR^2}{2(1-\lambda)}$$

Where;

D: Delay Time (s)

s: Adjusted Saturation Flow Ratio $(\frac{\mathrm{pcu}}{\mathrm{h}})$

q: Traffic Demand $(\frac{\mathrm{pcu}}{\mathrm{h}})$

R: Red Time

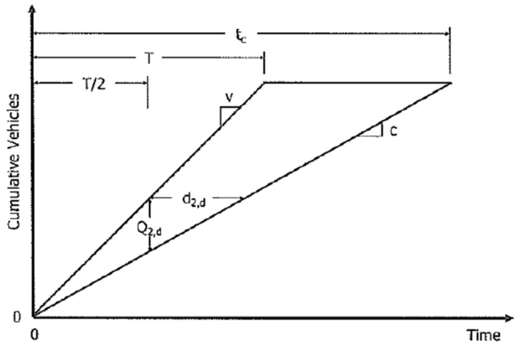
λ: $\frac{\text{Green Time}}{\text{Red Time}}$

Although there is no equation under the saturated condition in the Japanese Standard, according to HCM 2010, the control delay time is represented by a triangle shown in Figure 5.2.4. Thus, a control delay time under the saturated condition is calculated by the equation below.

$$\text{Delay Time} = (\mathrm{v} - \mathrm{c}) \times \text{analysis period}(\mathrm{h})^2 \div 2$$

v: Traffic Demand $\left(\frac{pcu}{h}\right)$

c: Traffic Capacity $\left(\frac{pcu}{h}\right)$



Source: HCM 2010

Figure 5.2.4 Cumulative Arrival and Departures during an Oversaturated Analysis Period

3) Analysis Results

Although the T-M Intersection has been operated by traffic police during congestion hours at present, it is calculated the Control Delay time of the intersection on the condition of the signalized intersection.

Figure 5.2.5 to Figure 5.2.12 present the analysis results of the following traffic parameters:

- Intersection V/C[2]
- V/C for each lane group
- Control Delay time for per vehicle

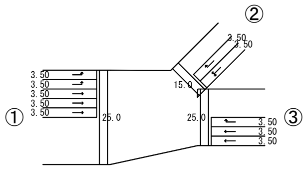
Results show that the critical flow ratio exceeds critical intersection V/C in all cases of the survey intersections. Therefore, all survey intersections are in the saturated condition.

Tinkune (W) Intersection

Intersection V/C ratio		
Critical Flow Ratio	Critical intersection V/C	NG
1.458	＞0.920	

②			
	V/C for lane group		Delay time for per vehicle(min/pcu)
R	0.000	OK	11.07
L+R	1.585	NG	0.00

①			
	V/C for lane group		Delay time for per vehicle(min/pcu)
R	0.272	OK	0
T	1.051	NG	1.5



③			
	V/C for lane group		Delay time for per vehicle(min/pcu)
R	0.000	OK	0.00
T	1.601	NG	11.26

Source: JICA Survey Team

Figure 5.2.5 Capacity Analysis Result of Tinkune (W) Intersection

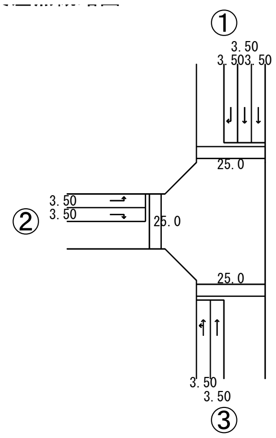
[2] Total of highest flow ratio (volume/ (saturation flow × No of lane) by each phase

Tinkune (N) Intersection

Intersection V/C ratio		
Critical Flow Ratio	Critical intersection V/C	NG
1.268	＞0.920	

①			
	V/C for lane group		Delay time for per vehicle(min/pcu)
T	0.905	OK	0.05
R	1.374	NG	8.16

②			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L	0.000	OK	0.00
R	0.543	OK	0.00



③			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L+T	1.398	NG	8.54

Source: JICA Survey Team

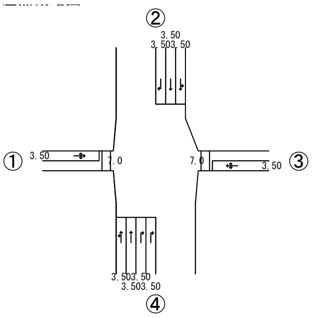
Figure 5.2.6 Capacity Analysis Result of Tinkune (N) Intersection

Tinkune (S) Intersection

Intersection V/C ratio		
Critical Flow Ratio	Critical intersection V/C	NG
3.709	＞0.887	

②			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L+T	4.205	NG	22.86
R	0.000	OK	0.00

①			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L+T+R	0.049	OK	0.37



③			
	V/C for lane group		Delay time for pe vehicle(min/pcu
L+T+R	4.229	NG	22.91

④			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L+T	2.251	NG	16.67
R	3.967	NG	22.44

Source: JICA Survey Team

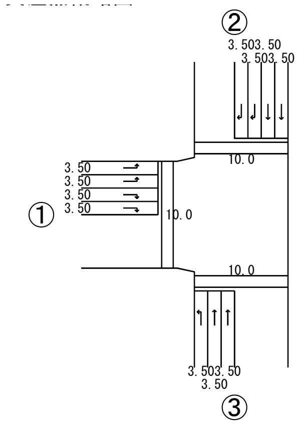
Figure 5.2.7 Capacity Analysis Results of Tinkune (S) Intersection

Koteshwor Intersection

Intersection V/C ratio		
Critical Flow Ratio	Critical intersection V/C	NG
2.938	＞0.900	

②			
	V/C for lane group		Delay time for per vehicle(min/pcu)
T	2.389	NG	17.44
R	2.899	NG	19.65

①			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L	1.869	NG	13.94
R	3.281	NG	20.86



②			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L	2.201	NG	16.37
T	3.270	NG	20.82

Source: JICA Survey Team

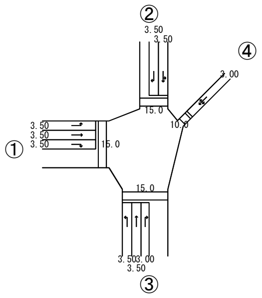
Figure 5.2.8 Capacity Analysis Result of Koteshwor Intersection

Tripureshwor Intersection

Intersection V/C ratio		
Critical Flow Ratio	Critical intersection V/C	NG
3.713	＞0.920	

②			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L+T	3.635	NG	21.75
R	3.981	NG	22.46

①			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L	0.921	OK	0.00
T	0.000	OK	0.00
R	4.013	NG	22.52



④			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L+T+R	0.000	OK	0.00

③			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L	1.152	NG	3.95
T	4.085	NG	22.66
R	0.000	OK	0.00

Source: JICA Survey Team

Figure 5.2.9 Capacity Analysis Result of Tripureshwor Intersection

Thapathali Intersection

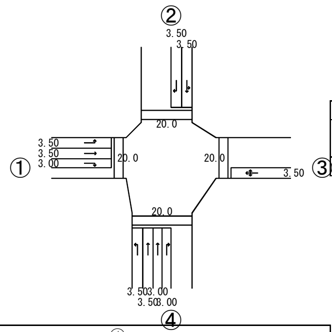
Intersection V/C ratio		
Critical Flow Ratio	Critical intersection V/C	NG
1.112	1.530	

②

	V/C for lane group		Delay time for per vehicle(min/pcu)
L+T	4.070	NG	22.63
R	3.780	NG	22.06

①

	V/C for lane group		Delay time for per vehicle(min/pcu)
L	1.031	NG	0.89
T	3.701	NG	21.89
R	3.991	NG	22.48



③

	V/C for lane group		Delay time for pe vehicle(min/pcu)
L+T+R	3.687	NG	21.86

④

	V/C for lane group		Delay time for per vehicle(min/pcu)
L	0.016	OK	0.48
T	1.930	NG	14.46
R	2.060	NG	15.44

Source: JICA Survey Team

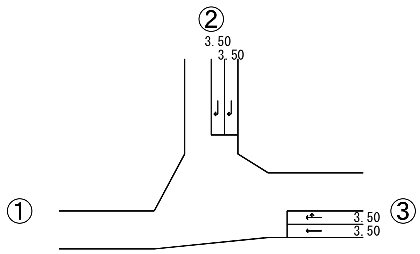
Figure 5.2.10 Capacity Analysis Result of Thapathali Intersection

Maitighar (S) Intersection

Intersection V/C ratio		
Critical Flow Ratio	Critical intersection V/C	NG
2.176	>0.933	

②

	V/C for lane group		Delay time for per vehicle(min/pcu)
R	2.284	NG	16.86



③

	V/C for lane group		Delay time for per vehicle(min/pcu)
T+R	2.343	NG	17.20

Source: JICA Survey Team

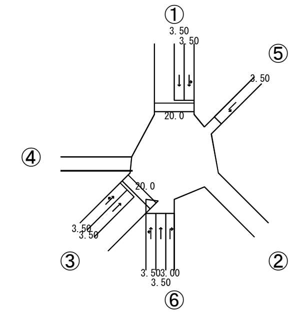
Figure 5.2.11 Capacity Analysis Result of Maitighar (S) Intersection

Maitighar (N)

Intersection V/C ratio		
Critical Flow Ratio	Critical intersection V/C	NG
2.162	＞0.933	

①			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L+T	2.294	NG	16.92

⑤			
	V/C for lane group		Delay time for pe vehicle(min/pcu
L	0.736	OK	0.77



③			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L+T	1.289	NG	6.73

②			
	V/C for lane group		Delay time for per vehicle(min/pcu)
L+T	1.200	NG	5.00
R	2.328	NG	17.11

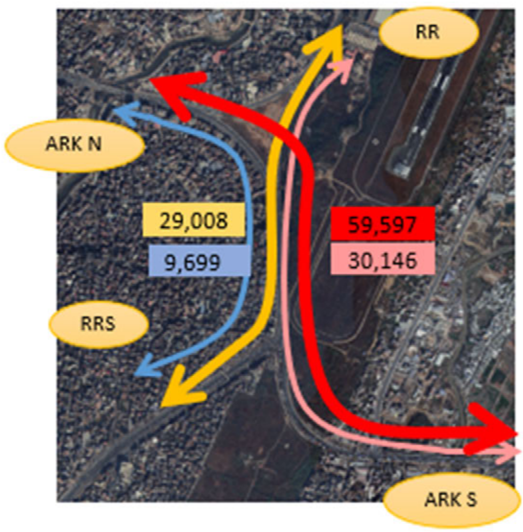
Source: JICA Survey Team

Figure 5.2.12 Capacity Analysis Result of Maitighar (N) Intersection

5.2.6 Control Delay Time in Each OD Pair

Figure 5.2.13 and Figure 5.2.14 represent the traffic volume in each direction at Koteshwor – Tinkune Intersection and T-M Intersections, respectively.

Traffic Volume (PCU/Day)	
RRN-RRS	29,008
ARK N-RRS	9,699
RRN-ARKS	30,146
ARK N-ARK S	59,597

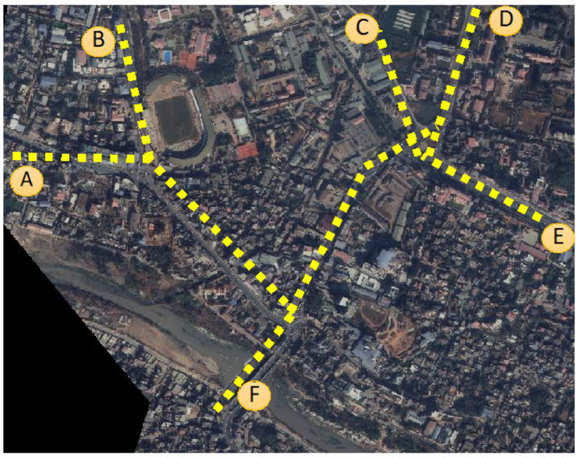


Source: JICA Survey Team

Figure 5.2.13 Traffic Volume in Each OD Pair at Koteshwor ~ Tinkune Intersection

Traffic Volume (PCU/Day)	
A-B	31,981
A-E	21,364
B-F	50,657
C-E	24,840
D-E	19,727
D-F	18,511
E-F	13,969

Network of T-M Intersection



Traffic Volume (Unit PCU/Day)
*Represent only the direction where traffic volume exceeds 10,000PCU/day

Source: JICA Survey Team

Figure 5.2.14 Traffic Volume in Each OD Pair of T-M Intersection

The control delay time in each traffic flow direction is calculated to test the effectiveness of the grade separation in its direction, Table 5.2.3 shows the results.

In summary, the total control delay time for all vehicles during peak hours at the Koteshwor - Tinkune Intersection tends to be higher than that at the T-M Intersection. For instance, the highest value is 4,009 hours during the peak hour, specifically for the route to/from Araniko Highway - TBV Highway Intersection. In contrast, the peak hour delay at the T-M Intersection reaches a maximum of 3,434 hours for the route to/from Intersection B to F. Additionally, when considering the overall accumulated control delay time for all vehicles passing through each intersection, it becomes evident that Koteshwor-Tinkune Intersection experience nearly twice the delay compared to T-M Intersection.

K-T Intersections

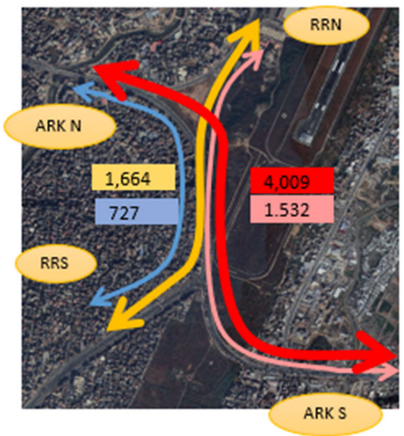
Traffic Volume (PCU/Day)		Direction	Average Delay time (min/veh) Koteshwor Direction	Koteshwor Average	Thinkune(S) Direction	Thinkune(S) Average	Thinkune(W) Direction	Thinkune(W) Average	Thinkune(N) Direction	Thinkune(N) Average	Total Delay time (min/peak hour)	Total Delay time (peak hour)
RRN-RRS	29,008	N⇒S S⇒N	18.7 19.0	18.9	0.1 22.4	11.2	- -	0.0	0.1 8.5	4.3	99,824	1,664
ARK N-RRS	9,699	2⇒S S⇒2	18.7 19.0	18.9	22.9 16.7	19.8	1.5 11.3	6.4	- -	0.0	43,647	727
RRN-ARKS	30,146	N⇒A A⇒N	10.5 19.4	15.0	0.1 22.4	11.2	- -	0.0	0.1 8.5	4.3	91,949	1,532
ARK N-ARK S	59,597	N⇒A A⇒2	10.5 19.4	15.0	22.9 16.7	19.8	1.5 11.3	5.6	0.0 -	0.0	240,536	4,009
											Total	7,933

T-M Intersection

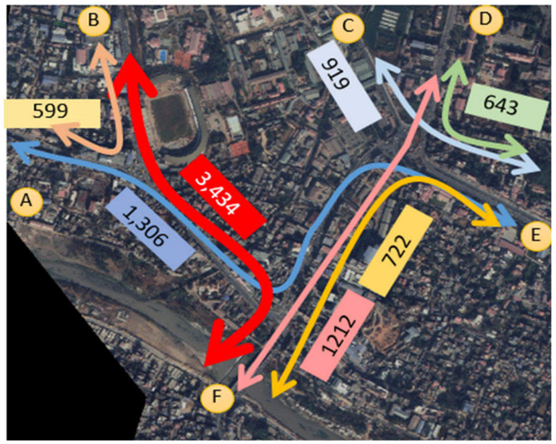
Traffic Volume (PCU/Day)		Direction	Average Delay time (min/veh) Tripureshwor Direction	Tripureshwor Average	Thapathali Direction	Thapathali Average	Maitighar(S) Direction	Maitighar(S) Average	Maitighar(N) Direction	Maitighar(N) Average	Total Delay time (min/peak hour)	Total Delay time (peak hour)
A-B	31,981	A⇒B B⇒A	0.0 22.5	11.2	- -	0.0	- -	0.0	- -	0.0	35,921	599
A-E	21,364	A⇒E E⇒A	22.5 3.9	13.2	0.9 22.1	11.5	- 17.2	8.6	6.7 -	3.4	78,356	1,306
B-F	50,657	B⇒F F⇒B	21.7 22.7	22.2	22.5 14.5	18.5	- -	0.0	- -	0.0	206,034	3,434
C-E	24,840	C⇒E E⇒C	- -	0.0		0.0	 17.2	17.2	 5.0	5.0	55,139	919
D-E	19,727	D⇒E E⇒D		0.0		0.0	 17.2	8.6	16.9 5.0	11.0	38,587	643
D-F	18,511	D⇒F F⇒D	- -	0.0	22.6 15.4	19.0	16.9 	8.4	16.9 6.7	11.8	72,732	1,212
E-F	13,969	E⇒F F⇒E		0.0	22.6 15.4	19.0	17.2 	8.6	 6.7	3.4	43,298	722
											Total	3,496

Figure

K-T Intersections



T-M Intersection



Source: JICA Survey Team

Table 5.2.3 Total Delay Time for Each Traffic Flow Direction

5.2.7 Justification of Priority Project for Intersection Improvement

As a result of the intersection analysis by using the updated traffic demand forecast mentioned above and below, the Koteshwor-Tinkune Intersection needs improvement to reduce severe traffic congestions around the intersection.

- Serious traffic congestion at both the Koteshwor – Tinkune Intersection and T-M Intersection is confirmed in 2020, requiring intersection improvements.
- However, considering the accumulated control delay time at Koteshwor – Tinkune Intersection, which causes adverse social impacts and economic loss, higher priority should be given to improving the Koteshwor – Tinkune Intersection than the T-M intersection.

CHAPTER 6. DESIGN CONDITIONS

6.1 Road Design Conditions

6.1.1 Project Roads

The project roads, which comprise Araniko Highway and Ring Road, are classified as "National Highway" and Class I or II according to a Nepal Road Standard 2070. Design speeds of Class I and II are determined depending on the type of terrain. The road standards specify a design speed of 100 to 120 km/h for Class I or II in the flat terrain where the project roads are situated.

The project roads are currently in service as intra-urban roads for commuters and commercial activity. They are in the Central Business District (CBD) in Kathmandu, where there are a lot of access points from the roads to roadside facilities, including bus stops used by vehicles and pedestrians. In addition, chronic traffic congestion occurs on the project roads, particularly around the Koteshwor Intersection, due to concentrated traffic in overlapping sections of Ring Road and Araniko Highway.

Considering the functions and quality of the project roads, a 100 kph design speed or higher is unrealistic, although the project roads are Class I or II.

6.1.2 Target Level of Service for Project Roads & Intersections

(1) General

Level of Service (LOS) for roads and intersections is the operating conditions of vehicles on the facility in terms of traffic performance measures related to travel speed and time, freedom to maneuver, traffic interruptions, and comfort and convenience for drivers. Table 6.1.1 and Figure 6.1.1 show the general relation between the LOSs and the operating conditions.

Table 6.1.1 Description of LOS

LOS	General Operating Conditions
A	Free flow
B	Reasonable free flow
C	Stable flow
D	Approaching unstable flow
E	Unstable flow
F	Forced or breakdown flow

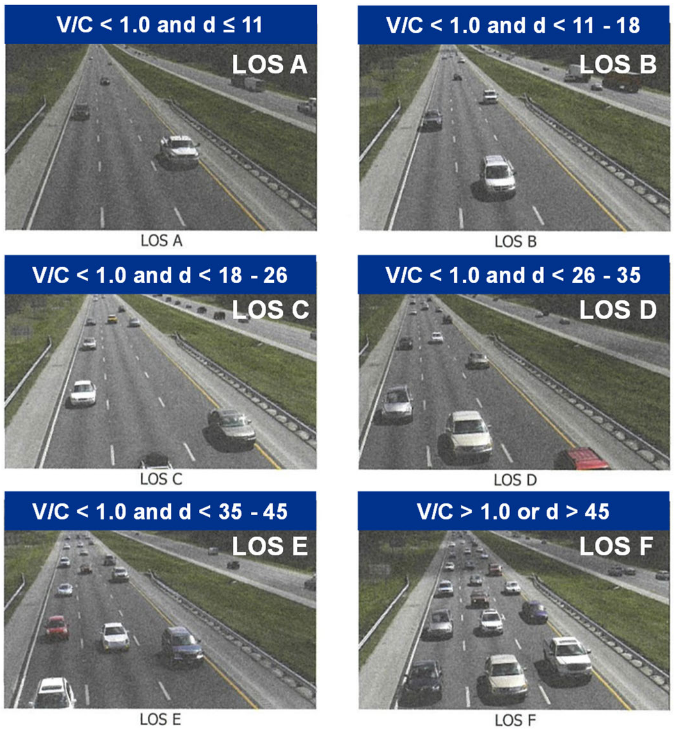
Source: Highway Capacity Manual

(2) Determination of Target LOS

In case the target for the project roads and intersection is LOS B to the project roads and intersections as recommended in the Nepal Standard, the project roads will be designed on an unreasonable scale and will increase the project cost due to the large number of lanes to accommodate future traffic volume to meet LOS B.

Accordingly, setting a target LOS D is reasonable and efficient since the LOS is calculated based on a future peak hourly traffic volume on the project roads and intersections so that the traffic condition is mostly better than LOS D in a day.

JST discussed with DOR and reached a consensus that the target is LOS D.



*V/C : Volume-to-Capacity Ratio
*d : Traffic Density (PCU/mile/lane)

Source: Highway Capacity Manual

Figure 6.1.1 LOS Examples for Freeway

6.1.3 Basic Design Condition

(1) Design Conditions to Apply

The following must be considered in deciding an applied design standard since project site is in the urban area, especially in the center of Kathmandu and the border of the TIA with hilly topography:

- Limited Right of Way (ROW)
- Obstacle Space Limitation for TIA
- Consistency with existing connecting roads, and ongoing relevant projects and plans
- Traffic safety for pedestrians
- Project cost
- Environmental and social impacts
- Accessibility and usability by the neighbors after project completion
- Applicable construction methods

Although there is a Nepal Road Standard 2070, the latest version of the road standard in Nepal and authorized by the government of Nepal, it is only applicable for rural road design.

On the other hand, the Nepal Urban Road Standard 2076 was drafted for the urban road design but has not been authorized yet. However, the Urban Standard clearly stated that the draft Standard does not apply to urban expressways with uninterrupted and controlled-access roads and strategic roads. Hence, this project roads with urban road functions cannot utilize any design standards specific to Nepal. Therefore, Japanese Standards and AASHTO, generally used in urban areas, are applied to cover to the items and conditions not determined in the Nepal Standards. Moreover, the design vehicle, overhead clearance and footpath width must comply with the Nepal Standards for respecting local traffic situations.

(2) Design Speed

According to the Nepal Road Standard 2070, the design speed depends on the road category. Given that the project roads are categorized as Class I, allowing a 100 km/h to 120 kph, it is impractical to apply the standards specified in Section 6.1.1 to the project roads within urban areas.

In the Nepal Urban Road Standard 2076, the maximum design speed ranges from 10 kph to 50 kph. It means that 50 kph is an upper limit for roads with realistic and suitable reasons in the urban area, considering traffic volume, land constraints, and topographic conditions.

To set a well-shaped road alignment and avoid a negative environmental and social impacts by applying high design speed to the surrounding residential property, a design speed of 50 kph is reasonable so that the alignment enables flexibility and adjustability to the site conditions. Currently, the same design speed is applied to the entire Ring Road.

(3) Basic Conditions

From a comparison result of the design standards mentioned above and through the discussions with DOR, Table 6.1.2 details the design conditions for the project roads. The items determined in the Japanese Standard are recommended to ensure a reasonable road improvement scale while considering various constraints imposed by the control points.

Table 6.1.2 Basic Design Conditions

Items		Nepal Road Standard 2070	Nepal Urban Road Standard 2076	Japan	AASHTO	**Applied**
Road Category		Class I or II	Arterial roads	Urban Road (Class4-1)	Urban Arterial Street	-
Design Speed (km/h)		120 or 100	**50**	40~60	30~75	**50**
Carriageway Width (m)		3.75 or 3.5	3.5	**3.25**	3.3	**3.25**
Shoulder Width (m)		0.75～3.75	0.5	**0.5**	0.6	**0.5**
Median Width (m)	Barrier Width	1.2～1.5	5.0	**1**	0.6	**1**
	Lateral Offset			**0.25**	0.6	**0.25**
Footpath Width (m)		2.5~**3**	4.5	2～3.5	2.4	**3**
Design Vehicle (m)	Width	**2.5**		2.5	WB-12 ~ WB-19	**Nepal Standard**
	Height	**4.75**		3.8		
	Length	**18**		16.5		
Overhead Clearance (m)		**5**		4.5～4.7	4.3～4.9	**5**
Base Capacity	(pcu/day/lane)	8,750~10,000		-	-	**Japan and AASHTO standard 2,300 PCU/h/lane**
	(veh/day/lane)	-		12,000	-	
	(veh/h/lane)	-		2,200	2,200	
	pcu factor	In accordance with Nepal Standard				
	Peak Ratio	6.7%				
For Comparison	(pcu/h/lane)	875～1,000		**2,300**	**2,300**	
Target Level of Service (LOS)		B	-	-	C or **D**	**D**

Source: JICA Survey Team

Regarding the typical cross-section of the project roads, a reduced-carriageway width (3.25 m), shoulder width (0.5 m) and median width (1.5 m to 2.0 m, which varies depending on the section) are the proposed minimum requirements. In additional space becomes available for the road, the standard width of 3.5 m, will be applied to the maximum feasible extent.

6.1.4 Road Geometric Conditions

For road geometric conditions, stopping sight distance and widening shall comply with the Nepal Standard since both items are locally determined values for securing traffic safety. Other items shall align with the Japanese Standards to achieve harmony with the cross-sectional elements (carriageway, shoulder, and median width) within the specified fundamental conditions.

The Japanese Standard is utilized for the road design in the urban area, similar to the project site. Consequently, the road structure can be adjusted based on the various constraints, such as control points or topographic conditions.

However, the maximum grade shall be set at 6.0%, ensuring a more gradual incline compared to other standards, considering the limited performance and capability of heavy vehicles in Nepal.

By the design speed for the project road mentioned above, road geometric conditions are set as listed in Table 6.1.3.

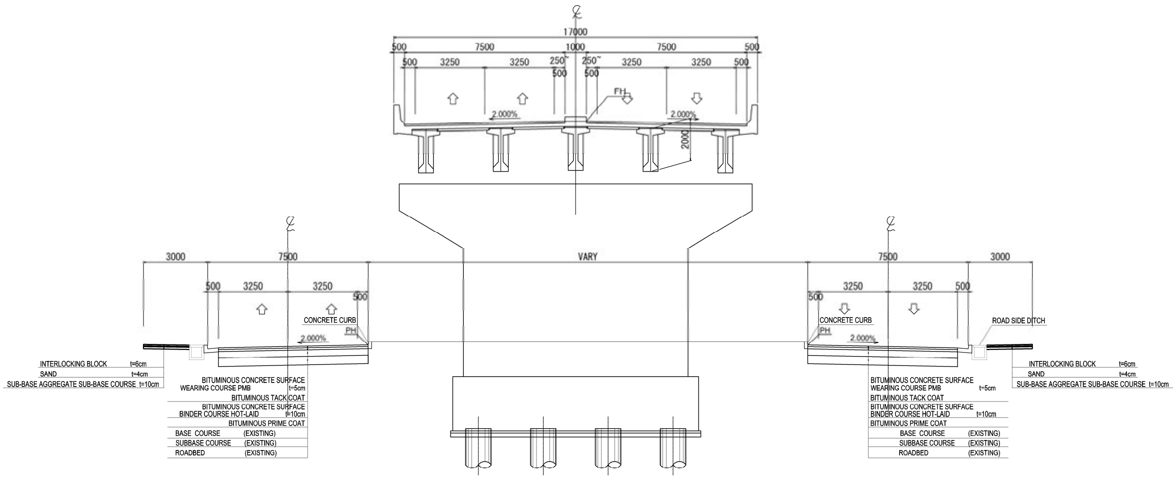
Table 6.1.3 Road Geometric Conditions

Items		Nepal Road Standard 2070		Nepal Urban Road Standard 2076	Japan	AASHTO	**Applied**
Design Speed (km/h)		40	60	50	50	50	**50**
Minimum Radius (m)	Preferable	70	200	-	150	N/A	**100**
	Standard	40	110	105	100	86	
	Special	90	190	-	80	N/A	
Minimum Curve Length (m)	θ=7° or more	N/A	N/A	N/A	80～100	45	**80**
	θ=7° or less	N/A	N/A	N/A	600/θ	N/A	**600/θ**
Minimum Spiral Curve Length (m)		17	42	45	40	47	**40**
Superelevation Transition Ratio		N/A	N/A	N/A	1/115	1/154	**1/115**
Maximum Superelevation (%)		7.0	7.0	4.0~7.0	4.0~9.0	4.0~10.0	**4.0**
Crossfall (%)		2.5	2.5	1.7~3.0	2.0	2.0	**2.0**
Stopping Sight Distance (m)		50	80	65	55	65	**65**
Maximum Grade (%)		9.0	7.0	-	6.0~8.0	7.0	**6.0**
K Value (m/%)	Summit	3.6	8.2	-	8.0	7.0	**8.0**
	Valley	4.1	9.2	-	7.0	13.0	**7.0**
Minimum Vertical Radius (m)	Summit	360	820	-	800	700	**800**
	Valley	410	920	-	700	1300	**700**
Minimum Vertical Curve Length (m)		N/A	N/A	30	40	N/A	**40**
Maximum Vertical Slope Length (m)		400	300	400	500	N/A	**500**
Limiting Superelevation (%)		N/A	N/A	-	10.5	11	**10.5**
Widening (m/lane)		0.6		0.6	0.5	1.2	**0.6**

Source: JICA Survey Team

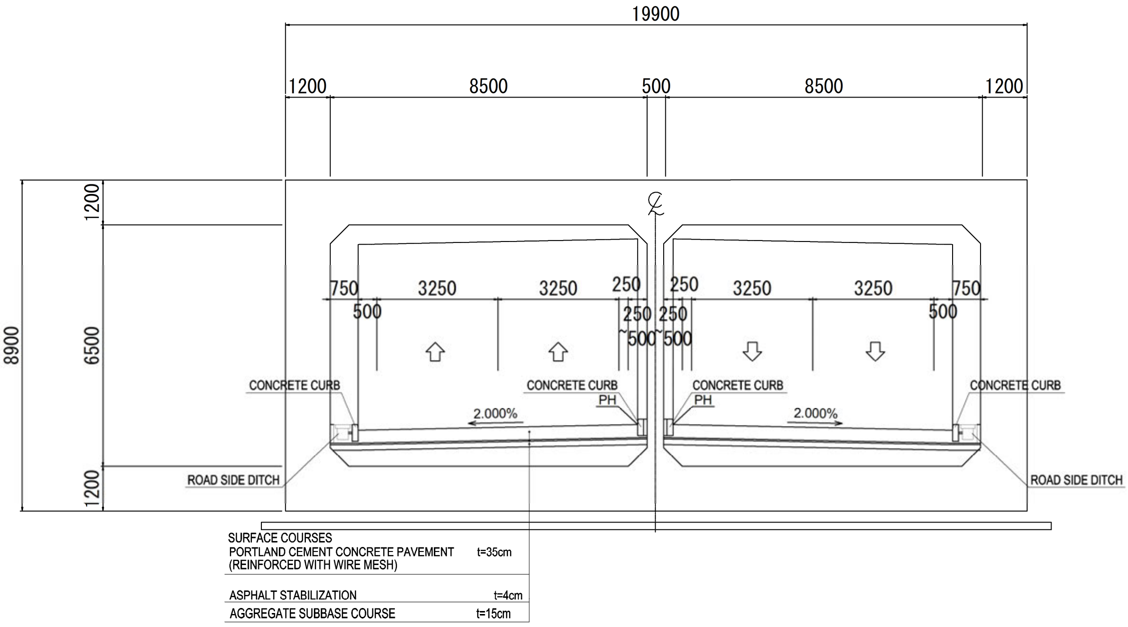
6.1.5 Typical Cross-Section

Considering the road design conditions mentioned above, typical cross-sections for both a flyover and an underpass section for the project, including the at grade portions, are described in Figure 6.1.2 and Figure 6.1.3, respectively.



Source: JICA Survey Team

Figure 6.1.2 Typical Cross Section (Flyover Section)



Source: JICA Survey Team

Figure 6.1.3 Typical Cross Section (Underpass Section)

6.1.6 Design Hourly Volume

Design hourly volume (DHV) is from the future traffic volume, estimated in Chapter 4 using K and D factors. K factor is set as 6.7 %, referring to an actual record observed in a specific city in the US, which is stated in HCM, although the traffic count survey in 2019 showed around 10 % of K factor. Generally, it decreases as traffic volume increases. On the other hand, the D factor is set as 51% and approaches 50 % as traffic volume increases in the CBD. Indeed, the D factor was recorded as 50.6% of traffic volume in the traffic survey result in 2019.

6.2 Pavement Design Conditions

The Japanese Standard will be applied for both flexible and rigid pavement designs to estimate the project cost during the outline design stage of the study. As pavement design standards of Nepal requires a vehicle damage factor (VDF) calculated from the axle load survey, it is recommended to conduct the survey in the detailed design stage and apply the standards of Nepal for pavement design.

6.3 Structure Design Conditions

6.3.1 Design Code

The principal design standard for the road bridge in Nepal is Nepal Bridge Standards-2067, published by DOR in 2010.

However, according to Nepal Bridge Standards, all permanent loading shall be followed by The Indian Roads Congress (IRC) or AASHTO loadings. IRC loadings are recently the most used in Nepal. Accordingly, the IRC loading codes are applied for the road bridge design for the Study.

6.3.2 Dead Load

Dead loads, including the weight of all components of the structure and facilities, are calculated based on those prescribed in IRC:6-2017 Standard Specifications and Code of Practice for Road Bridges, as shown in Table 6.3.1.

Table 6.3.1 Unit Weight for Dead Load Calculation

Material	Unit Weight [t/m3]
Steel*1	7.85
Plain Concrete	2.50
Reinforced Concrete	2.50
Prestressed Concrete	2.20

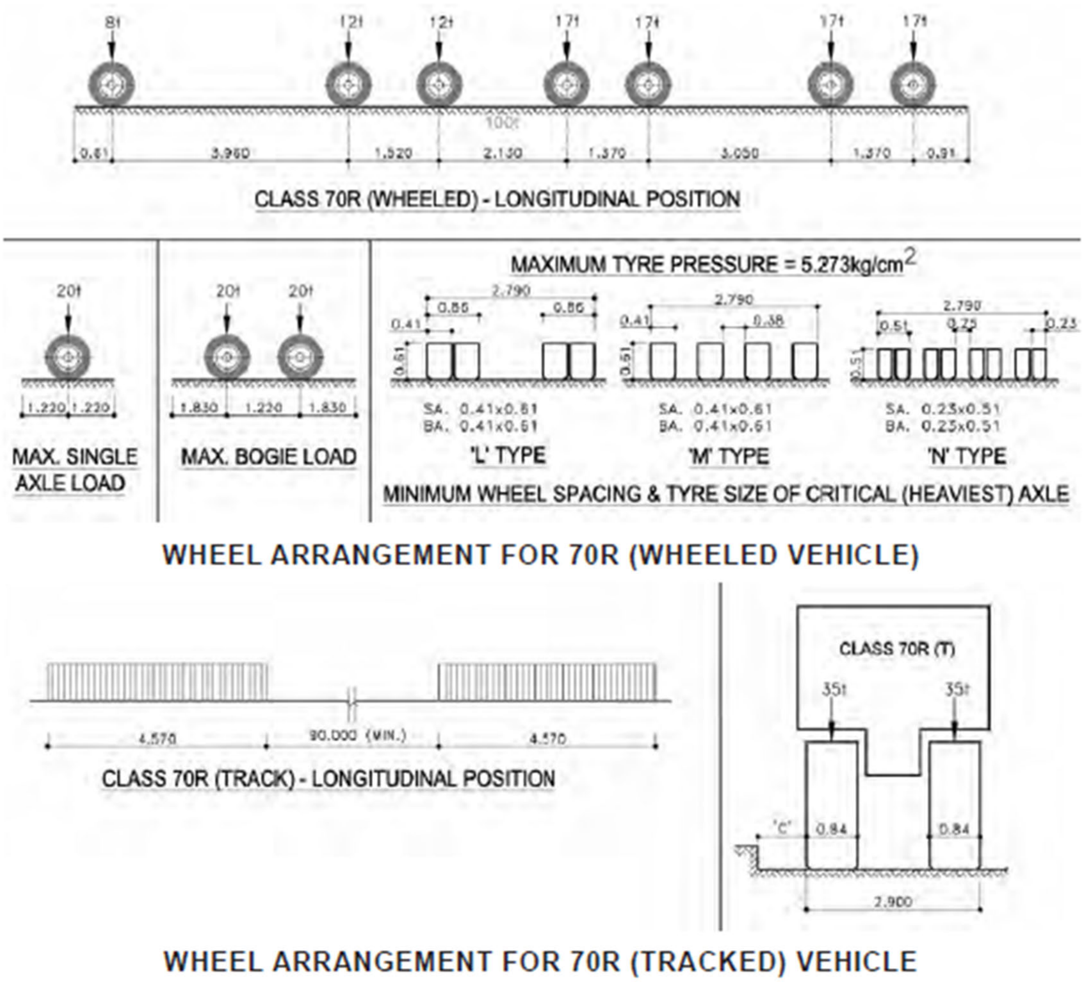
Note: *1: Unit weight of steel is applied for JSHB value since no description is available in IRC:6-2017
Source: IRC:6-2017 and JSHB

6.3.3 Live Loads

According to IRC:6-2017, the following live loads are considerations for bridge design:

(1) Class 70R

Class 70R loading consists of standard wheeled or tracked vehicles. Figure 6.3.1 shows the layout of the loading.

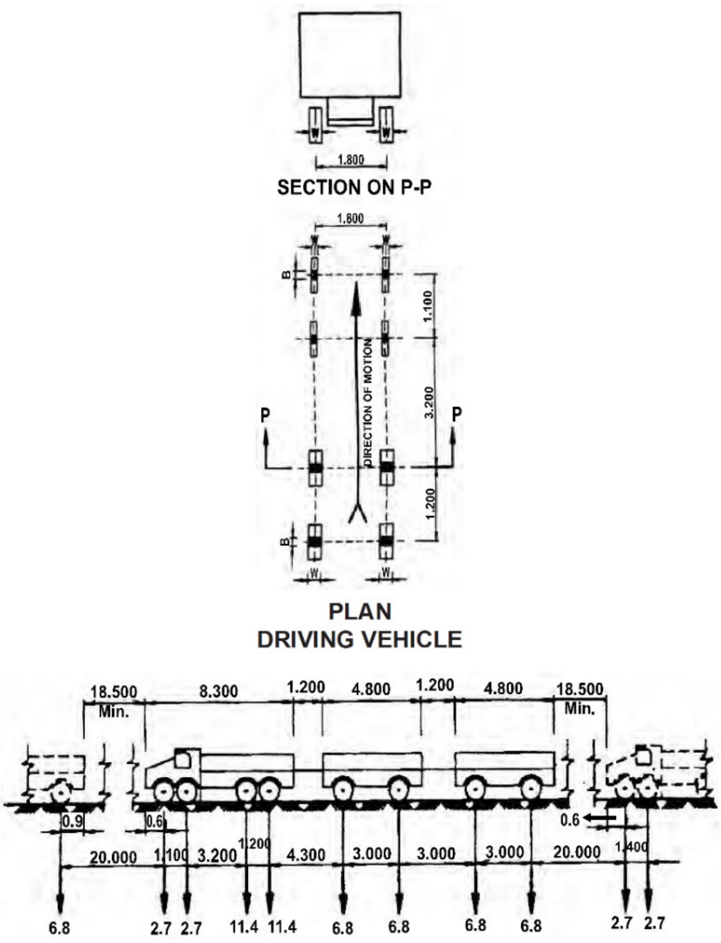


Source: IRC:6-2017

Figure 6.3.1 Layout of Class 70R Loading

(2) Class A

Class A loading consists of a train of vehicles. Figure 6.3.2 shows the layout of the loading.



Class A Train of Vehicles

Source: IRC:6-2017

Figure 6.3.2 Layout of Class A Loading

(3) Combination of Live Loads

Table 6.3.2 shows the different combinations of the live loads based on carriageway width.

Table 6.3.2 Combination of Live Load

Carriageway Width	Number of Lanes for Design Purposes	Load Combination
Less than 5.3m	1	A lane for Class A is assumed to occupy 2.3m. The remaining portion of the carriageway shoulder should bear a 500kg/m^2.
5.3m and above but less than 9.6m	2	One lane for Class 70R or two lanes for Class A
9.6m and above but less than 13.1m	3	One lane for Class 70R for every two lanes with one lane for Class A on the remaining lanes, or 3 lanes for Class A
13.1m and above but less than 20.1m	4	One lane for Class 70R for every two lanes with one lane for Class A on the remaining lanes, if any, or one lane for Class A on each lane.
16.6m and above but less than 20.1m	5	
20.1m and above but less than 23.6m	6	

Source: IRC:6-2017

6.3.4 Seismic Force

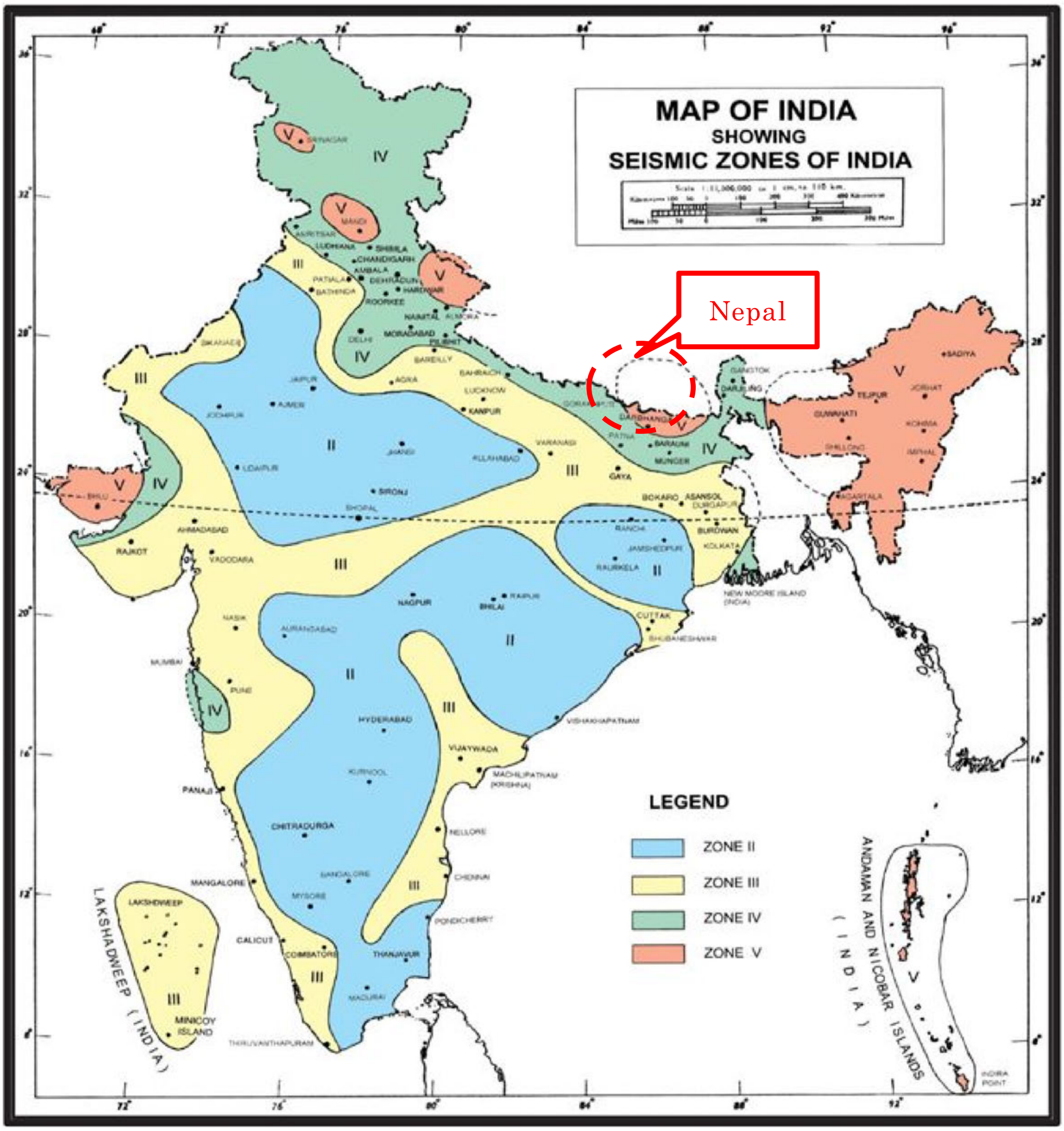
(1) General

Seismic forces are estimated following the guideline outlined in IRC:SP:114-2018, titled Guidelines for Seismic Design of Road Bridges.

The computation of the seismic coefficient relies on factors such as the zone factor, natural period, response reduction factor, and importance factor.

(2) Zone Factor

Zone factor shall be dependent on the seismic zone map shown in Figure 6.3.3.



Source: IRC: SP:114-2018

Figure 6.3.3 Seismic Zone Map

Although Nepal is not in Figure 6.3.3, Zone V has been applied since Nepal is near the area categorized as Zone V. Table 6.3.3 shows the corresponding zone factor for each zone number.

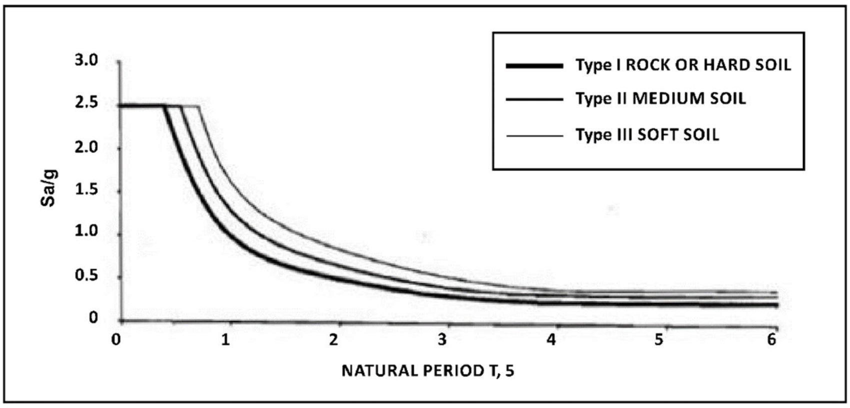
Table 6.3.3 Zone Factor

Zone No.	Zone Factor
V	0.36
IV	0.24
III	0.16
II	0.10

Source: IRC: SP:114-2018

(3) Natural Period (Design Acceleration Coefficient)

The design acceleration coefficient shall be determined based on the natural period, as shown in Figure 6.3.4.



Source: IRC: SP:114-2018

Figure 6.3.4 Spectra for Elastic Acceleration Method

(4) Response Reduction Factor

Applicable response reduction factor shall be determined based on structure type as shown in Table 6.3.4.

Table 6.3.4 Response Reduction Factor

Bridge Component	Response Reduction Factor
Masonry / PCC Piers, Abutments	1.0
RCC Wall Piers and abutments transverse direction	1.0
RCC Wall piers and abutments in longitudinal direction	3.0
RCC Single Column	3.0
RCC/PSC Frame	3.0

Source: IRC: SP:114-2018

(5) Importance Factor

The importance factor shall be determined based on seismic class, as shown in Table 6.3.5. Since the project site is within the city area, the seismic class of the project is Important Bridges.

Table 6.3.5 Importance Factors

Seismic Class	Illustrative Examples	Importance Factor
Normal Bridges	All bridges except those mentioned in other classes.	1.0
Important Bridges	a) River bridges and flyovers <u>in the cities</u> b) Bridges on national and state highways c) Bridges serving traffic near ports and other center of economic activities. d) Bridges crossing two existing/proposed railway lines (Future lines shall not be considered as proposed railway line.)	1.2
Large Critical Briges in all Seismic Zones	a) Long bridges more than 1 km length across perennial rivers and creeks b) Bridges for which alternative routes are not available. c) Bridges crossing more than two existing/proposed railway lines	1.5

Source: IRC: SP:114-2018

(6) Design Horizontal Seismic Coefficient

The design horizontal seismic coefficient depends on the zone factor, design acceleration coefficient, response reduction factor, and importance factor. It is used to calculate the horizontal force caused by an earthquake multiplied by the dead load.

$$Ah = \frac{\left(\frac{Z}{2}\right) x \left(\frac{Sa}{g}\right)}{\left(\frac{R}{I}\right)}$$

Where.

Ah: Design Horizontal Seismic Coefficient
Z: Zone Factor
Sa/g: Design Acceleration Coefficient
R: Response Reduction Factor
I: Importance Factor

6.4 Control Points for Route Setting and Road Design

6.4.1 Basic Approach to Control Points in Route Setting

Table 6.4.1 summarizes the policies for control points (C/Ps) in route setting.

Table 6.4.1 Policy for Control Points in Route Setting

Control Points (C/P)	Considered Items at Each Stage		Basic Approach	Remarks
	Route Setting	Outline Design and Detailed Design		
Obstacle Limitation Spaces	O	O	Completely follow	These items are essential in setting horizontal and vertical alignments and deeply related to project cost.
Existing Pedestrian Bridge	O	O	Avoid as much as possible	
Existing Bridge	O	O	Avoid as much as possible	
Airport Land and Facility	O	O	Completely avoid	
Private Land	O	O	Avoid as much as possible	
Private Building	O	O	Avoid as much as possible	
Private Building around Jadibuti IS in the south	O	O	Completely avoid	
Religious Facility	O	O	Avoid as much as possible	
Right of Way	O	O	Fully utilize	
Bus Stop	-	O	These C/Ps will be considered at the outline and detailed design stages to secure the current function by adding or relocating necessary facilities as much as possible.	These items can be addressed during preliminary and detailed design stages.
Monument	-	O		
Connecting Road*	-	O		
Access Road*	-	O		
Frontage Road*	-	O		
Truck Terminal	-	O		
Traffic Safety Facility	-	O		
Existing Retaining Wall and Drainage	-	O		
Underground Utility	-	O		

Note: Connecting roads: Legs connecting to the project intersections (Tinkune, Koteshwor and Jadibuti I/S)
Access roads: Minor roads giving access to a major road (project road)
Frontage roads: Service roads running parallel to a higher-speed, limited-access road.
Source: JICA Survey Team

6.4.2 Obstacle Limitation Spaces

Chapter 3 describes the details of the obstacle limitation spaces.

6.4.3 Control Points on Project Site

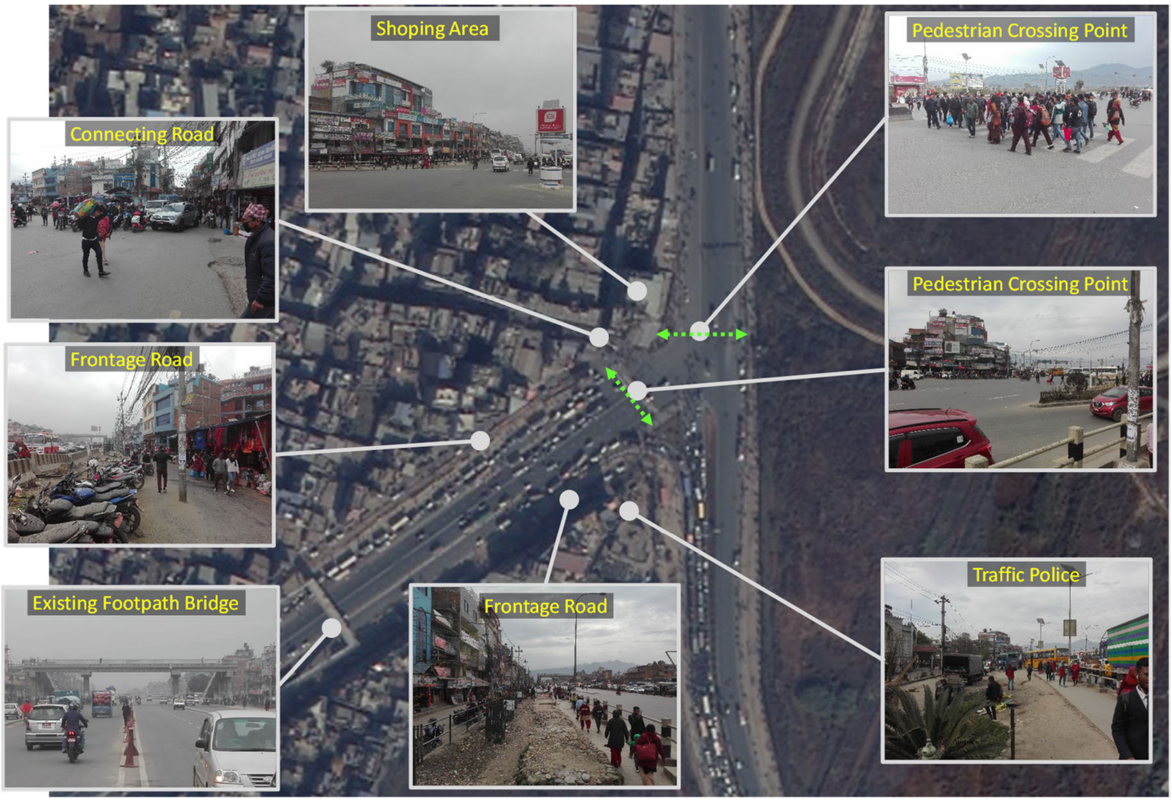
Figure 6.4.1 to Figure 6.4.6show the control points on the project site.

Source: JICA Survey Team

Figure 6.4.1 Control Points (around Tinkune Intersection)

Source: JICA Survey Team

Figure 6.4.2 Control Points (in the Tinkune – Koteshwor Intersection)

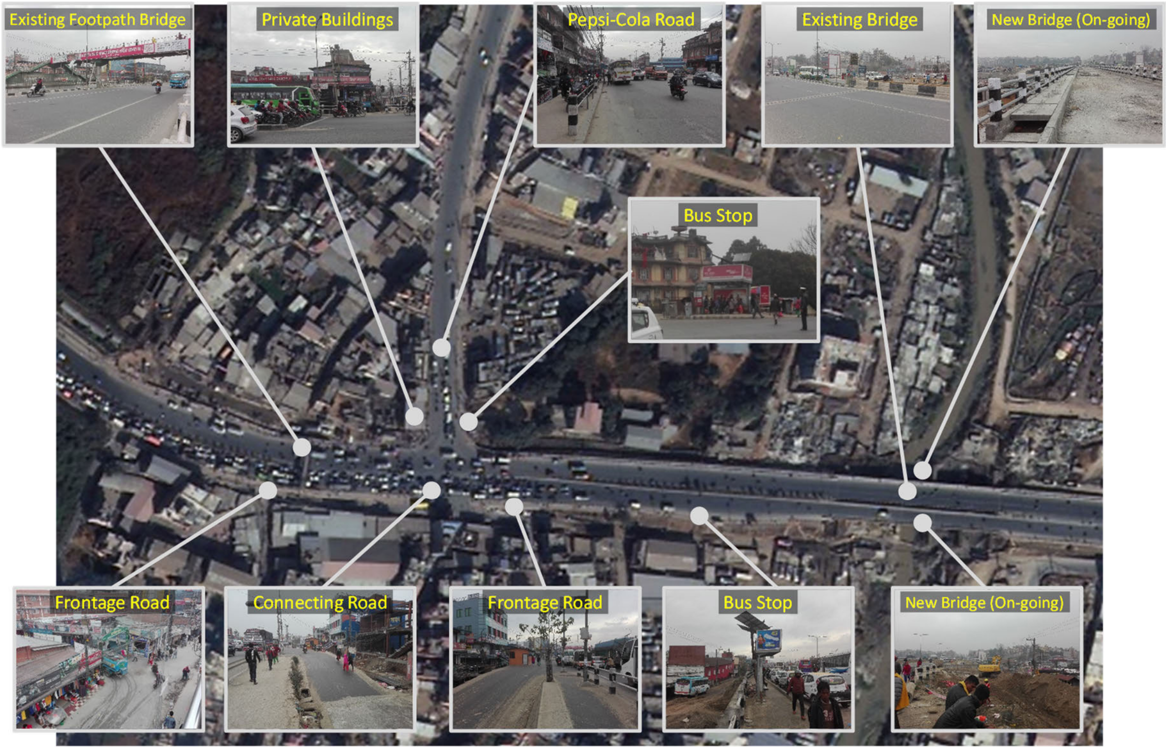


Source: JICA Survey Team

Figure 6.4.3 Control Points (around Koteshwor Intersection)

Source: JICA Survey Team

Figure 6.4.4 Control Points (in the Koteshwor – Jadibuti Intersection)



Source: JICA Survey Team

Figure 6.4.5 Control Points (around Jadibuti Intersection)

Source: JICA Survey Team

Figure 6.4.6 Control Points on the Project Site (East Jadibuti Intersection)

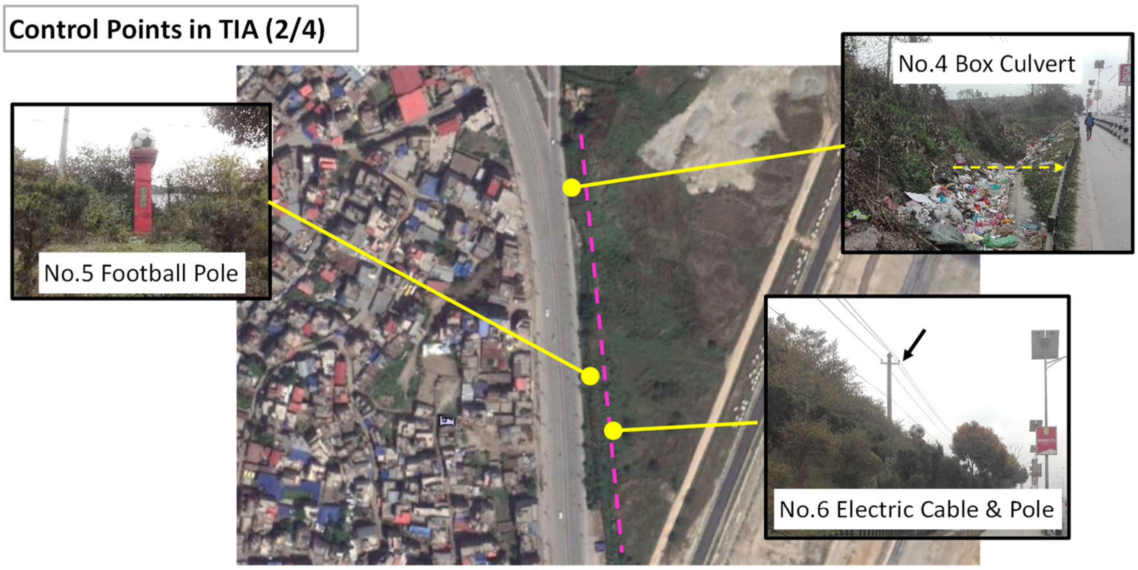
6.4.4 Control Points within TIA Land

Figure 6.4.7 to Figure 6.4.10 show the control points within the TIA land and the treating policies for them in road planning.

No.	Object	Policy in Road Planning
1	Contractor Camp	Avoid
2	Private Building	Avoid as much as possible (Relocate by DOR if affected)
3	Buildings	Avoid as much as possible (Relocate by DOR if affected)

Source: JICA Survey Team

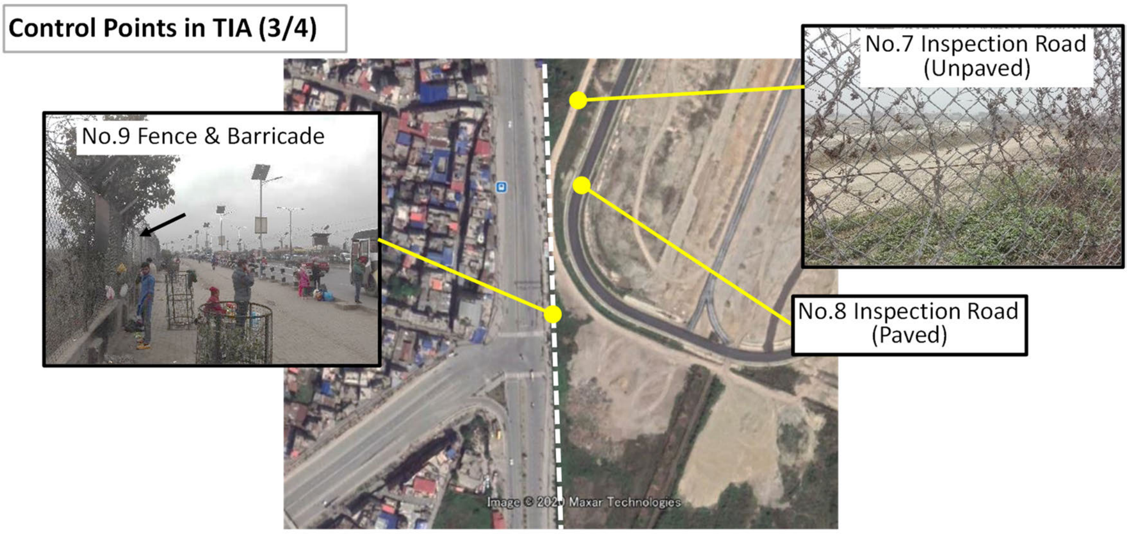
Figure 6.4.7 Control Points in TIA Land (1/4)



No.	Object	Policy in Road Planning
4	Box Culvert	Replace by DOR if affected
5	Football Pole	Relocate by DOR
6	Electric Cable & Pole	Relocate by DOR

Source: JICA Survey Team

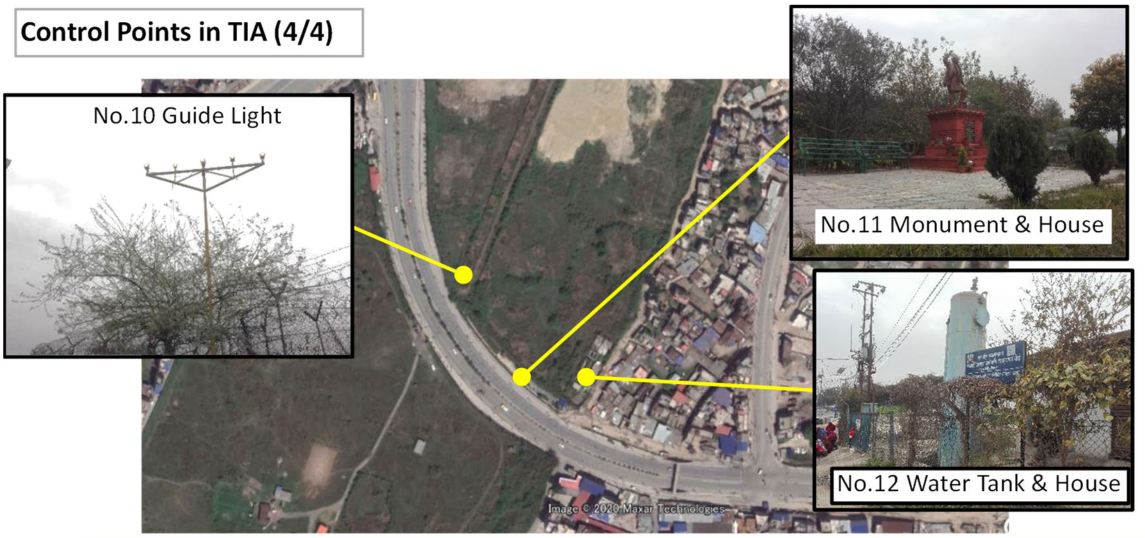
Figure 6.4.8 Control Points in TIA Land (2/4)



No.	Object	Policy in Road Planning
7	Inspection Road (Unpaved)	Relocate during construction by DOR
8	Inspection Road (Paved)	Relocate during construction by DOR
9	Fence & Barricade	Relocate during construction by DOR

Source: JICA Survey Team

Figure 6.4.9 Control Points in TIA Land (3/4)



No.	Object	Policy in Road Planning
10	Guide Light	Secure the present position by taking tentative measures during construction
11	Monument & House	Relocate by DOR
12	Water Tank & House	Relocate by DOR

Source: JICA Survey Team

Figure 6.4.10 Control Points in TIA Land (4/4)

6.5 Requirements of CAAN for the Project Route and Facility

In response to the clarification of the TIA land usage for the project by JST, CAAN issued the letter that clarified their requirements in designing the project route and facility within TIA land, as shown in Table 6.5.1.

Table 6.5.1 Requirements of CAAN for the Project Route and Facility within TIA

1. Since the project road alignment lies near to the landing/approach and takeoff zone of airport and close to the centerline of the extended runway, where is highly sensitive area of the airport, an open tunnel with U-shape structure shall be avoided.
2. Type of Structure and applicable area to be used.
   i. Underground/covered tunnel is proposed towards the north-western side of Koteshwor Junction/Extended runway centerline and it is understood to be located outside of the divergence line of approach surface
   ii. Some portion of the Project tunnel towards the south-eastern side of Koteshwor Junction/Extended runway centerline is allowable to use an open (U-shaped structure) and this portion lies inside the divergence line of the approach surface.
3. Hence, the Design/Estimate/Construction shall be done confirming that the tunnel/underpass in south-eastern side of Koteshwor/Extended Runway Centerline shall be covered at least up to the airport land boundary.
4. The earth cover above the tunnel shall be about 2 meter and shall be graded and leveled to ensure minimal or no loss during any accidents in those areas.
5. The Precision Approach Lights are vital for guiding and directing the aircrafts towards the runway of the airports. The design and development of the underpass or other infrastructure shall ensure to preserve the locations and heights of these approach lights during construction.
6. High Voltage Power Cables and Optical Fiber Cables are laid between the airport power houses via the proposed project area and upto the highly sensitive VOR/DME equipment, placed southward the highway, through various routes. If any damage to these cables may harm the landing/takeoff operation of aircrafts resulting to airport closure. Hence, utmost precaution shall be taken not to disturb these cables.
7. A parallel taxiway and bypass/exit taxiways are planned to commence their construction upto the end of the recently extended 300m of runway. The proposed underpass development being planned near to them, special care to be taken not to disturb their construction.
8. Since the proposed Project seem to damage the recently developed the perimeter road, an alternative temporary perimeter road shall be provided during the construction of the Project and the perimeter road shall be reinstated to original standard after the project is developed.
9. The spoil material as the result of excavation is useful for leveling the premises of the airport. Hence, the project shall dispose them in allocated space with proper levelling and compaction.
10. The concurrence for the underground tunnel construction can be given with the conditions set forth in 3 to 9 including compliance to other relevant safety standards.

Source: translated and compiled by JST

Chapter 14 details the requirements during construction of the project facilities as a result of a series of consultation between JST and CAAN.