

2016/17 KSP Policy Consultation III : Establishment of Basic Plan to Strengthen the Connectivity of the Traffic Network of Kandy, Sri Lanka



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Project Title	Establishment of Basic Plan to Strengthen the Connectivity of the Traffic Network of Kandy, Sri Lanka
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List of Abbreviations

AAG	Average Annual Growth Rate
ADB	Asian Development Bank
ADT	Average Daily Traffic
BRT	Bus Rapid Transit
CBD	Central Business District
DS Divisio	Divisional Secretariats Division
EDCF	Economic Development Cooperation Fund
GIF	Global Infra Fund
KSP	Knowledge Sharing Program
MDB	Multilateral Development Bank
O/D	Origin/Destination
ODA	Official Development Assistance
RDA	Road Development Authority
SCDP	Strategic Cities Development Plan

Summary

1. Project Background and Objectives

Kandy City is the largest city in Sri Lanka, which is listed as a World Heritage Site by UNESCO. However, due to its geographical restriction and problems in historical zone preservation, the road network in Kandy has been unsystematically constructed. In addition, the traffic congestion in the city has been becoming more and more serious recently because of the economically active population rapidly being concentrated in the CBD (Central Business District). To respond to the changes in the traffic pattern in the future, the accessibility between the northern and eastern parts of Kandy should be first secured. However, relevant researches have not been sufficiently conducted so far.

Therefore, this research intends to share the traffic network expansion experiences of Korea with the Sri Lankan government and to suggest a basic plan of strengthening the accessibility between the northern and eastern parts of Kandy by analysing Korean cities that share similar characteristics with the former.

2. Current Status Survey and Future Prospect

Kandy City, the second largest city in the central province of Sri Lanka, is a high-density area with a population density of 5,558 people/km² and a population of about 150,000. It is geographically located at a high altitude of over 500 m and it has a basin-shaped terrain surrounded by mountains. Historically and culturally, it is an ancient capital of Sri Lanka and a center of tourism with many cultural heritages. Because of these characteristics, there are restrictions on road openings and expansions.

To solve these problems, a circular road network plan has been established. However, it is a passive road network plan limited to supplementation of existing road network, and a mid- to long-term road network plan needs to be established to solve the root cause of traffic

congestion. In addition, there is also a plan for a Central Expressway adjacent to Kandy City. However, because of Kandy City's inaccessibility, there is a need for a connectivity that can maximize the use of the expressway.

As a result of estimating the 2022 traffic volume on the routes passing through the city center that connect the northern Yatiwawala area, the main target area of this project, with the southeastern Dambawela area according to each alternative, it was analyzed that a basic alternative that connects both areas through construction can process the largest traffic volume (16,766 cars/day).

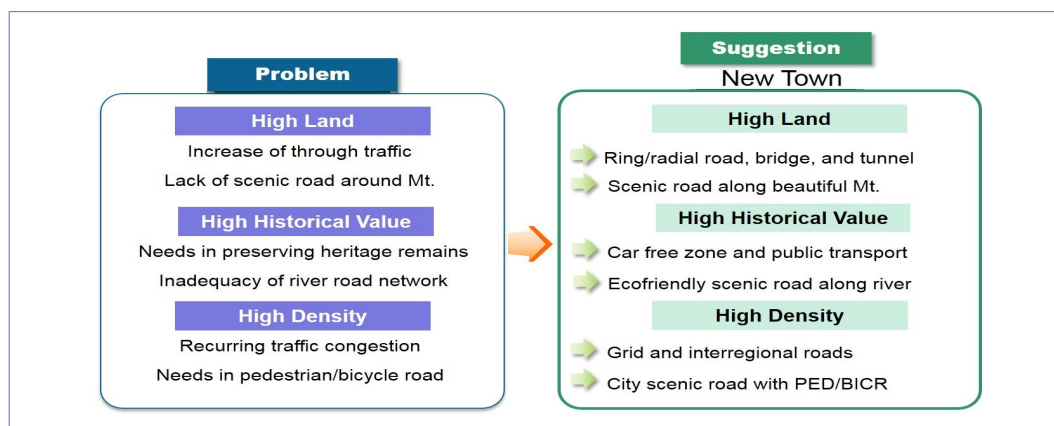
Table summary-1 | Result of future traffic volume estimation

Traffic Volume	Basic Alternative	Alternative 1	Alternative 2	Alternative 3
Traffic volume in 2022 (number of cars/day)	16,766	14,927	14,904	13,556

3. Analysis of Korean Cases

To solve the problem of traffic concentration in Kandy City center, the applicability of Seoul's riverside roads and circular roads was examined. In addition, Kandy City was divided into ancient city, high-altitude city, and high-density city, and the Korean city cases (Gyeongju, Wonju, Guri, etc.) with similar characteristics were analyzed according to each characteristic and their implications were deduced as shown in Figure 2.

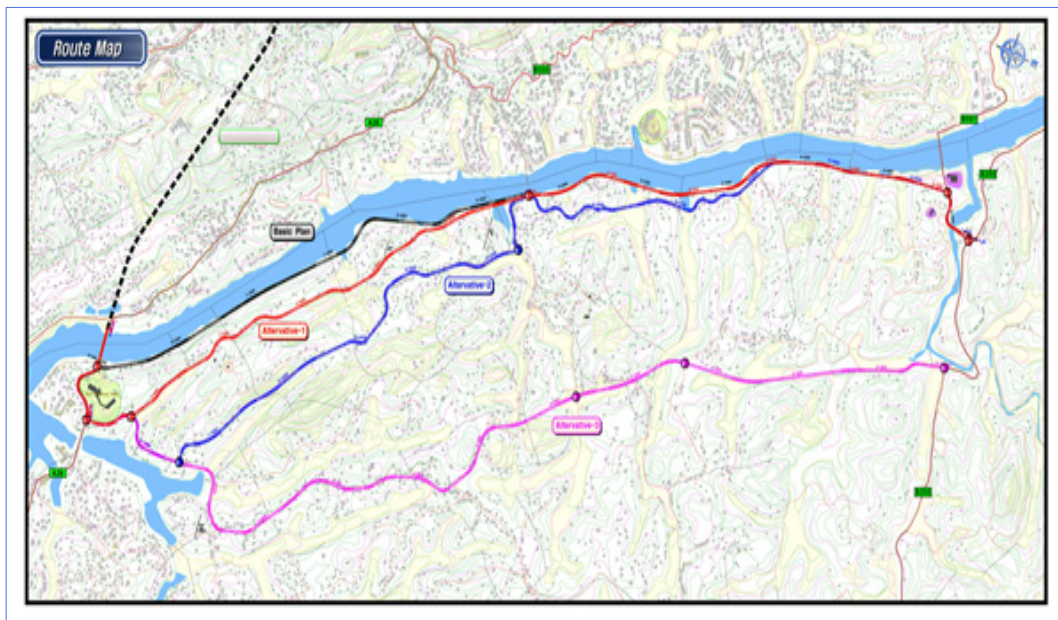
Figure summary-1 | General implications



4. Suggestion for Traffic Network Improvement

To construct a bypass road between the northern and southeastern areas of Kandy, a total of four connection routes between the two areas were selected as alternative routes, and their constructability, economic efficiency, environment, and migration compensation were examined. As a result of the review, it was found that alternative 1 (red line in Figure 3) was considered as the optimum alternative because it can be most easily expanded and serve as the outer ring road of Kandy in the future and it also yielded excellent results in terms of geographical, environmental, and migration compensation aspects.

Figure summary-2 | Route map of alternatives



I . Project Overview

1. Project Background and Objectives

1.1. Project Background

Kandy is located 116 km northeast of Colombo, the capital of Sri Lanka; it is the second largest city in Sri Lanka and has been designated as a World Heritage Site. Kandy is a basin-shaped city located at an altitude of more than 500 m above sea level and is surrounded by high mountains and the Mahaweli River. The entire city has been designated as a cultural heritage site, with worship places such as the Temple of the Sacred Tooth (Sri Dalada Maligawa) attracting thousands of tourists yearly. Because of its geographical constraints in urban expansion caused by geographical characteristics of the highland and the problem on historical district preservation, the road network of Kandy has been constructed in an unsystematic way.

Kandy City's road network has been formed in a radial system that connects the east, the west, the north, and the south areas of central Sri Lanka, and traffic congestion in the city center is getting more serious because of the combination of transit traffic and internal traffic. Recently, the rapid concentration of an economically active population in the Central Business District (CBD) also aggravates the traffic congestion in the city.

The development of Kandy City is a core national task of the Sri Lankan government, and various projects to improve the transportation infrastructure in Kandy are currently under way. Because of its mountainous terrain, there are no bypass roads in the southern part of Kandy. To supplement this situation, the Kandy Tunnel Project, a part of the bypass road network construction project, is being carried out with active support of Korea, and the bypass road construction project at the northern part of Kandy is also becoming a reality through support from the World Bank. However, although the accessibility between the northern and southeastern parts of the city should be improved to effectively cope with the present traffic situation and the traffic patterns that are expected to intensify in the future, relevant studies

have not been sufficiently conducted so far.

Accordingly, the Sri Lankan government and the Ministry of Strategy and Finance of Korea have agreed to support the improvement of the overall living environment of Kandy City through KSP construction and infrastructure policy consulting projects.

1.2 Project Objectives

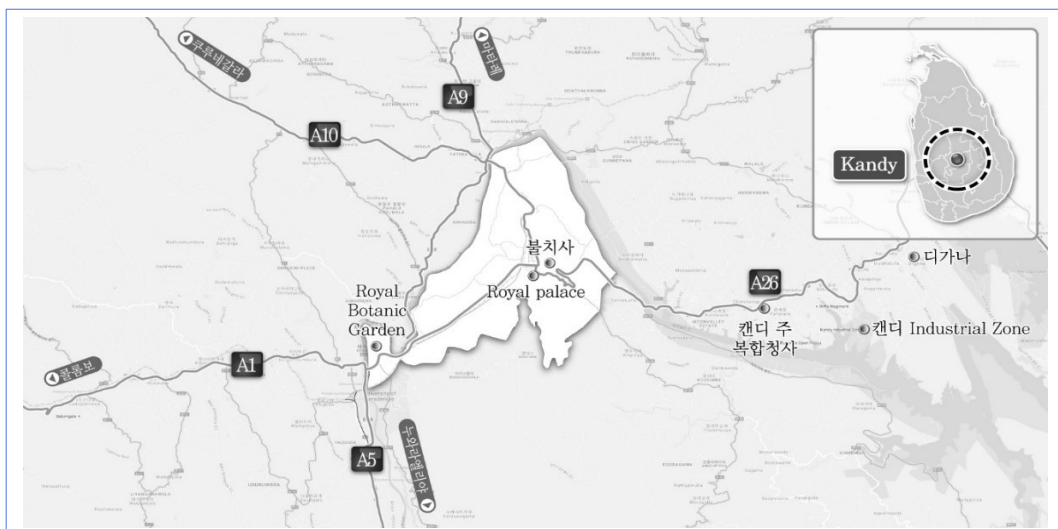
The purpose of this research is to share the traffic network expansion experiences of Korea with the Sri Lankan government, as well as to suggest a basic plan of strengthening the connectivity between the northern and eastern parts of Kandy through the analysis of Korean cities that have similar characteristics as the former.

2. Project Activities and Expected Results

2.1. Project Activities

As for the spatial range, the Central Province of Sri Lanka and Kandy City are direct areas of this project, and surrounding areas that have an impact on the traffic volume of Kandy City are indirect areas.

Figure I - 1 | Spatial range



The contents include the current situation of and the traffic forecast in Kandy City, the development of implications through a case study on the traffic network development in Korea and the development of cities with similar characteristics as Kandy City, the improvement of traffic connectivity between the northern and eastern parts of Kandy City, and the transfer of know-how on Korean traffic policy through the training of policy staff

2.2. Project Expected Results

2.2.1. Domestic

Through the performance of this research, projects from various fields in Sri Lanka can be developed, and the cornerstone for cooperation can also be arranged. In addition, the technical market can be also developed by identifying the traffic network design trend in Sri Lanka and the surrounding Asian nations, thus producing the effect of participation and market entry possibility of Korean companies. If the project is successfully completed, the national image of Korea would be improved, and the status of Koreans living in Sri Lanka can also be enhanced.

2.2.2. Project Nation (Sri Lanka)

Through the efficient traffic network construction experience, the improvement of the technology in the relevant field and the revitalization of the city can be promoted. Moreover, the philosophy in cultural asset preservation and traffic plan in economic development would be shared. In addition, through the establishment of a realizable plan, an economic road network system could be constructed, and a synergistic effect connected with a future development plan can be expected through the traffic network project that took in consideration the internal and external parts of the city.

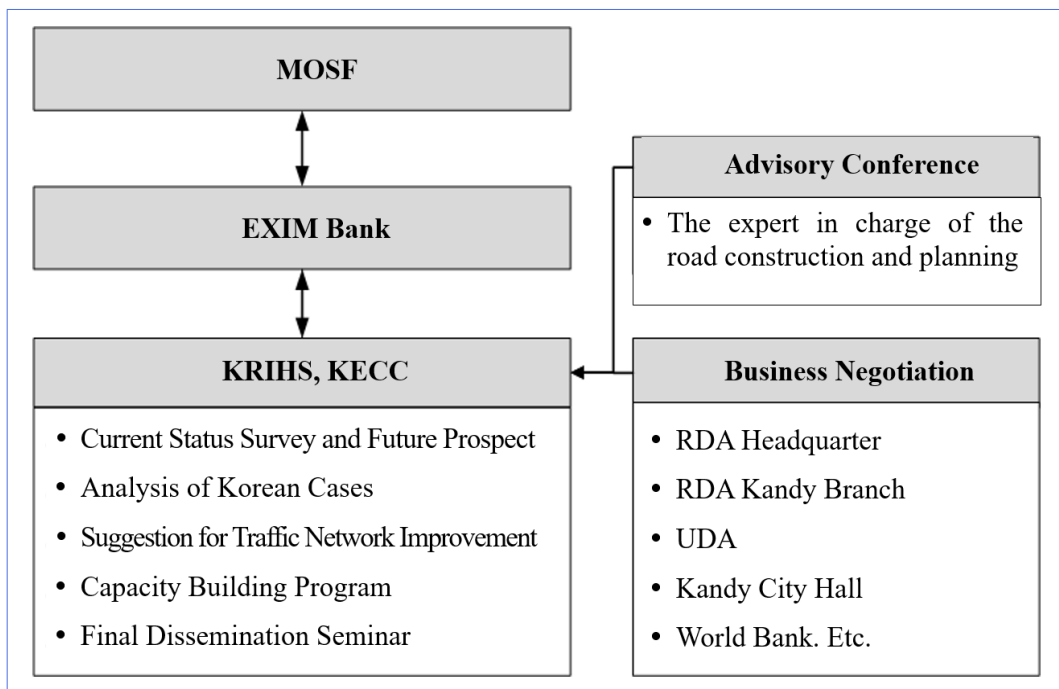
If the traffic network is successfully constructed based on the basic plan of this research, the chronic problem of traffic congestion will be improved. Also, its status of a culture and tourism city would be enhanced through the reduction of social expense and transportation time between the tourist sites and CBD.

Through a training of the policy staff, in-depth knowledge from the experience in Korean city traffic network construction will be obtained, and the effect of cooperation improvement between the two nations is also expected.

3. Project Promotion System and Methodology

The Ministry of Strategy and Finance is the department responsible for the KSP project, and the Korea Export-Import Bank has conducted management and monitoring for an effective progress of the project. The Korea Research Institute for Human Settlement and the Korea Engineering Consultants Corporation formed a consortium and promoted this project through discussions and consultations with the officials in charge of the road construction and planning, such as the officials from the Road Development Authority, Urban Development Authority of the Sri Lanka government, and Kandy City Hall.

Figure 1 - 2 | Project promotion system



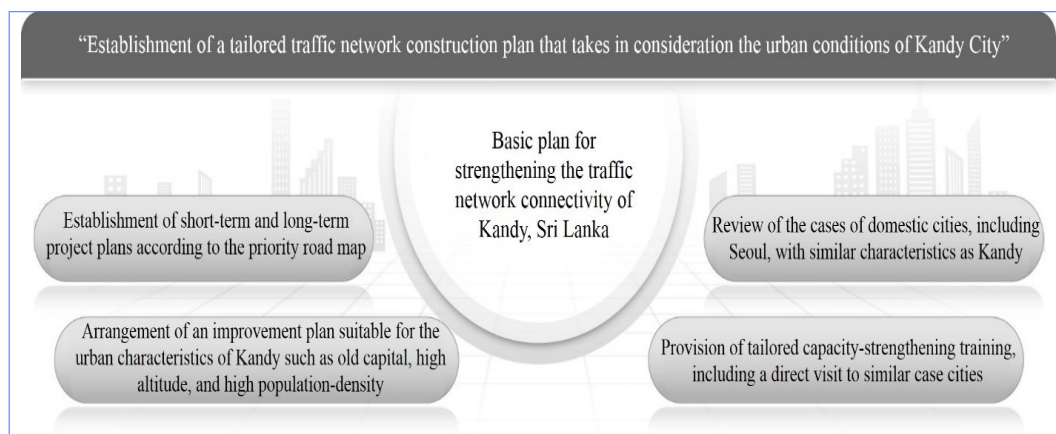
This research will be carried out for the purpose of establishing a tailored traffic network construction that takes in consideration the urban conditions of Kandy. For the production of reliable research results, relevant data will be collected from similar projects of the Korea Research Institute for Human Settlements ((Joint Consulting Project with ADB) Better Transport Data for Sustainable Transport Policies and Investment Planning, 2016) and through an advance survey, which will be immediately supplemented by the RDA staff (on-site coordinator).

During the analysis of the Korean traffic network development case, implications of the traffic network construction for Kandy will be suggested by reviewing the applicability of the Gangbyeon Expressway and the Circulation Road of Korea as well as suitable development cases of Korean cities with similar urban characteristics as Kandy such as high historical value, high altitude land, and high population density.

For the Kandy traffic network improvement plan, an efficient plan that simultaneously took in consideration environment-friendly road improvement to minimize the damage to cultural assets and environments, strengthening the connectivity with expressways for detour processing of transit traffic, changes in urban structure by arranging a linkage plan between the northern and eastern parts to respond to the changes in urban conditions, and existing road plans will be suggested.

Training of policy staff was conducted in a specialized and customized manner such as a visit to Korean cities with similar characteristics as Kandy City, and the construction and management of roads by hierarchy, etc.

Figure I - 3 | Project goal



II. Current Situation of Project Area

1. Current Situation of Project Nation

1.1. General Situation

Sri Lanka is an island country in the south-eastern part of India with a population of 22.05 million (Ministry of Foreign Affairs and Trade, July 2015); its capital is Colombo. The Sinhalese account for about three-fourths of the total population, and the Tamils and Moors exist as ethnic minorities. Approximately 70% of the population has Buddhism as their religion, followed by Hinduism, Islam, and Christianity.

Table II-1 | General situation of the project nation

Classification	Contents
Name	• Democratic Socialist Republic of Sri Lanka
Capital	• Colombo
Population	• 22.05 million
Area	• 65,610 km ²
Ethnic Composition	• Sinhalese (74%), Tamils(18%), and Moors(7%)
Religion	• Buddhism (69%), Hinduism (11%), Islam (7.6%), and Christianity (7.5%)
Language	• Sinhalese, Tamil, and English

Source: Ministry of Foreign Affairs and Trade, 2015

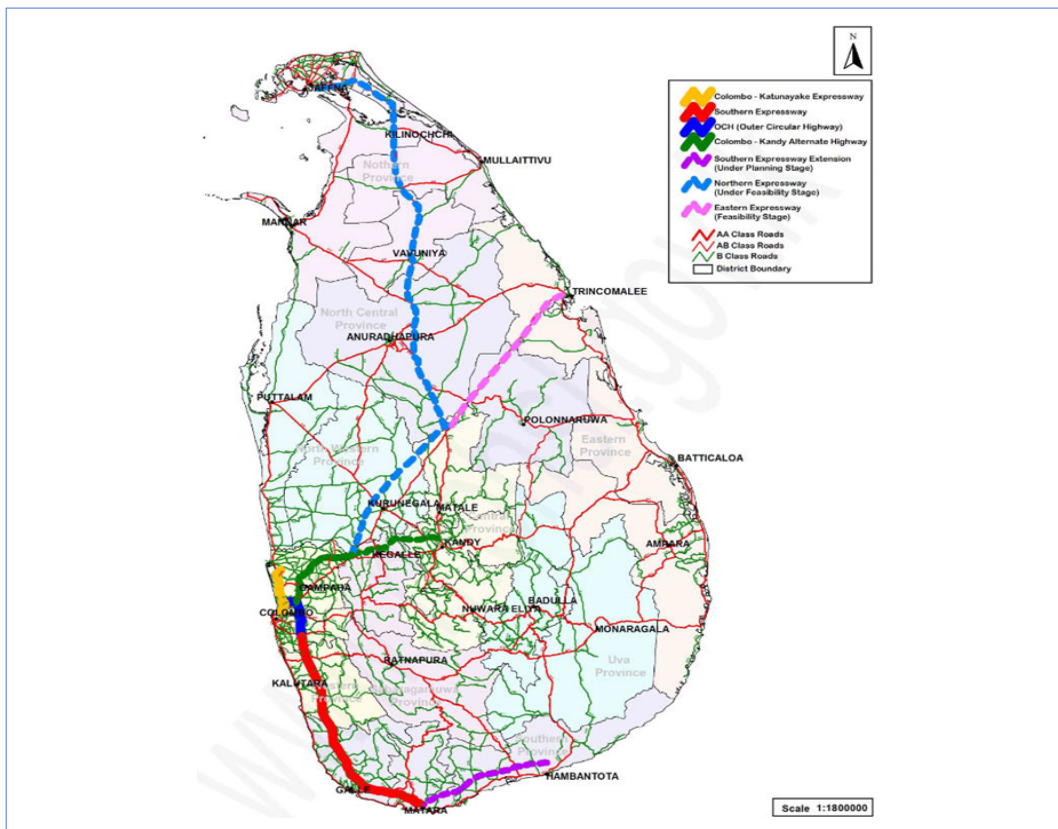
1.2. Road Network

1.2.1. Current Status of Expressway Network

Sri Lanka only has three operating expressway routes around its capital. It is operating the Southern Expressway linking Colombo and the southern Galle, the Outer Circular Highway bypassing the eastern part of Colombo, and Colombo-Katunayake Expressway connecting Colombo and the airport.

The expressway network in Sri Lanka has been constructed mainly on the North-South axis, so the connectivity between the east and west is comparatively weak. In addition, the utilization rate of the expressway is low because of insufficient connectivity between major points and expressway.

Figure II - 1 | Current status and plan of expressway network



Source: Ministry of Higher Education & Highways homepage in Sri Lanka (<http://www.mohsl.gov.lk>)

Table II-2 | Length of highway

Classification (Figure 1)	Road Name	Length (km)
E001 (Red)	Southern Expressway	124.08
E002 (Blue)	Outer Circular highway	19,245
E003 (Yellow)	Colombo-Katunayake Expressway	25.80
Sum		169.13

Source: RDA in Sri Lanka (<http://www.exway.rda.gov.lk>)

1.2.2. Current Status of National Roads Network

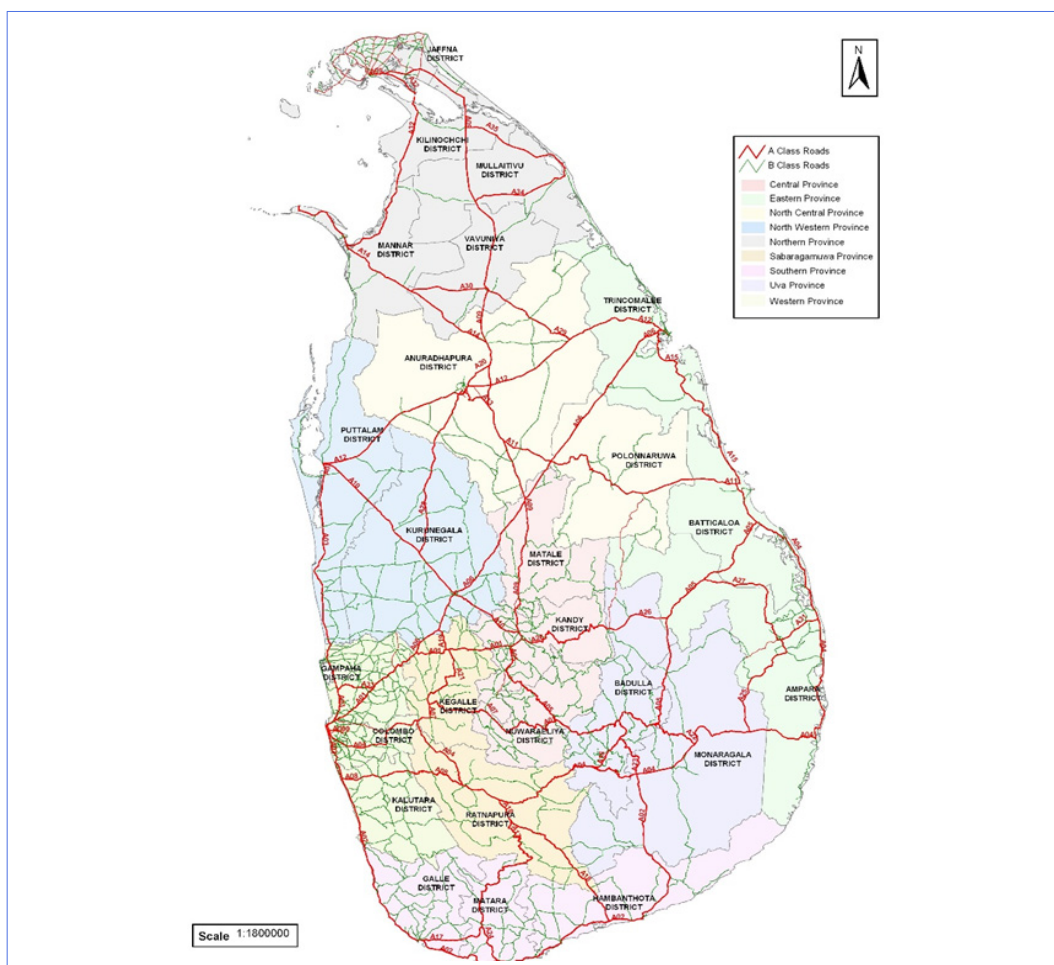
Sri Lanka's national roads are divided into two grades (A and B) and the total road extension is 12,210 km based on grades A and B. Grades A and B are managed by RDA and grades C and D belonging to the provincial roads are managed by local authorities. Because national roads are operating as two-way, two-lane roads, with the exception of some areas, they have difficulty handling the rapidly increasing traffic volume in Sri Lanka.

Table II-3 | Length of national roads

Class	Length (km)	Class	Length (km)
A	4,217.42	C	12,230
B	7,992.94	D	6,165
Sum			30,605.36

Source: RDA in Sri Lanka (<http://www.exway.rda.gov.lk>)

Figure II - 2 | Current status road network



Source: Inside data of RDA in Sri Lanka

2. Local Situation

2.1. General Situation

Kandy City, the second largest city located in Central Province at the central part of Sri Lanka, has a population of about 0.17 million with a high population density of 5,558/km². Moreover, it is one of the major cities of Sri Lanka with a floating population of 0.32 million, including tourist population. Located at an altitude of about 500 m and above, the urban expandability of Kandy is restricted due to its basin-shaped geographical characteristics and

being surrounded by mountains. It was also the old capital of ancient Sri Lanka, and is the mecca of tourism with many cultural assets such as the Temple of Tooth and the Royal Palace as well as the Royal Botanical Garden, the largest garden in Sri Lanka that receives more than 2 million visitors every year.

Figure II - 3 | Kandy position

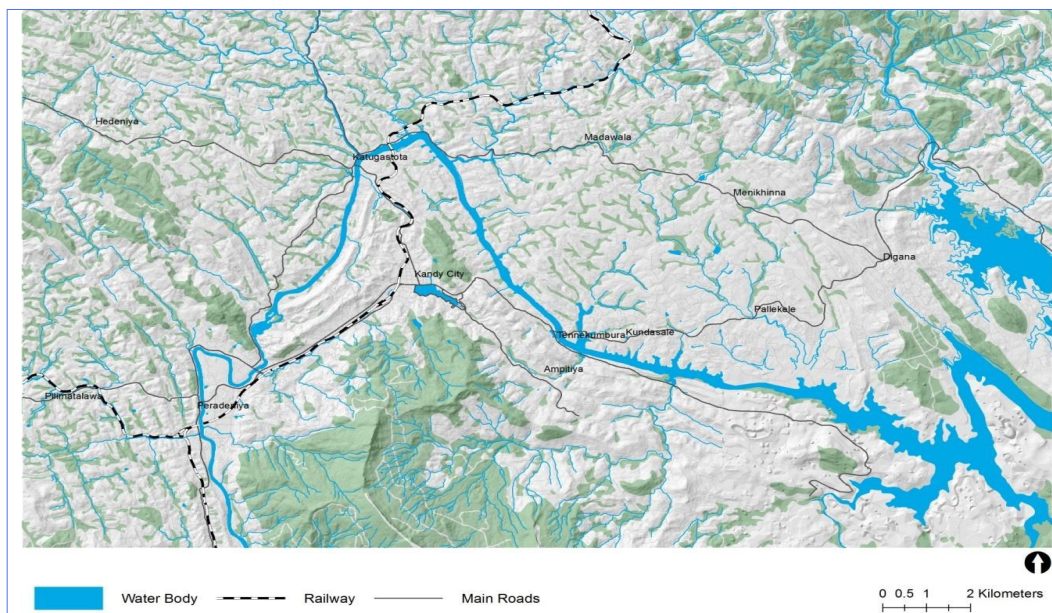


Source: Worldatlas(www.worldatlas.com)

2.1.1. Location and Terrain

Kandy City is located at an average of 488 m above sea level and is formed in a triangular shape because of mountainous terrains, including the Mahaweli River, Knuckles Mountain Range, and the Hantana Range. Because of its basin-shaped geographical condition surrounded by mountains, the exit points from the city to the outside are limited, and it has a radial road system from the center of the monocentric city to the outskirts of the city. The exit points from the outside are equivalent to the vertex of the triangular city structure, and vehicles pass through these points to go to the outside of the city. As for the major points in the outskirts with altitudes above sea level, the National Road A10 point in the north is located at 450 m above sea level; the National Road A1 point to Colombo is located at 530 m above sea level; and the National Road A26 point, which is directly related to this project, is located at 520 m above sea level.

Figure II - 4 | Topographic in Kandy



Source: Ministry of Urban development, Water Supply and Drainage, 2015 : *Kandy City Region Strategic Development Plan-2030*, Uni Consultancy Services, University of Moratuwa

2.1.2. Cultural Heritage

Kandy is an ancient city of the 14th century Sri Lanka with over 600 years of history, and was designated as a World Heritage Site by UNESCO in 1988. While Colombo is the largest city in Sri Lanka as a trade and administrative center, Kandy City is Sri Lanka's first cultural center with rich historical relics.

King Wickramabahu III established Kandy as the first city in Sri Lanka, and King Senasammata Wickramabahu, who ruled Sri Lanka in the 15th century, developed the city into a new capital.

In Kandy, there are many historic buildings constructed during the Kandyan Dynasty and the colonial era, and some of them are currently being used for other purposes. Important historical sites in Kandy include the site of the Royal Palace of Sri Wickrama located at the north side of the artificial lake, and the Temple of the Sacred Tooth (Sri Dalada Maligawa). Vehicle traffic is prohibited in these sites so detour roads along the south side of the lake are being used for east-west transportation, which is the main reason for traffic congestion. In addition, many temples, including the Sri Dalada Maligawa, make urban development and road construction in the city difficult.

1) The Temple of Sacred Tooth (Sri Dalada Maligawa) and Surrounding Areas

The Sri Dalada Maligawa and the royal palace in its vicinity were erected in the 18th century by King Narendra Sinha and the kings before him. Also, during the reign of King Sri Vikrama Rajasinha, a moat connected to Kandy Lake and an octagonal Paththirippuwa were additionally erected. The Sri Dalada Maligawa is a place where religious ceremonies are held to enshrine the Buddha's teeth. The Esala Perahera festival is also held there for about 10 days in July or August. In this historical site, there is a royal palace, an Audience Hall, Mahamaluwa, a park located in front of the Sri Dalada Maligawa, and four sathara maha Devala temples. This area was bombed in 1995, but it was completely restored later.

Figure II - 5 | The Sri Dalada Maligawa



2) The Malwatta and Asgiriya Monastery Complex

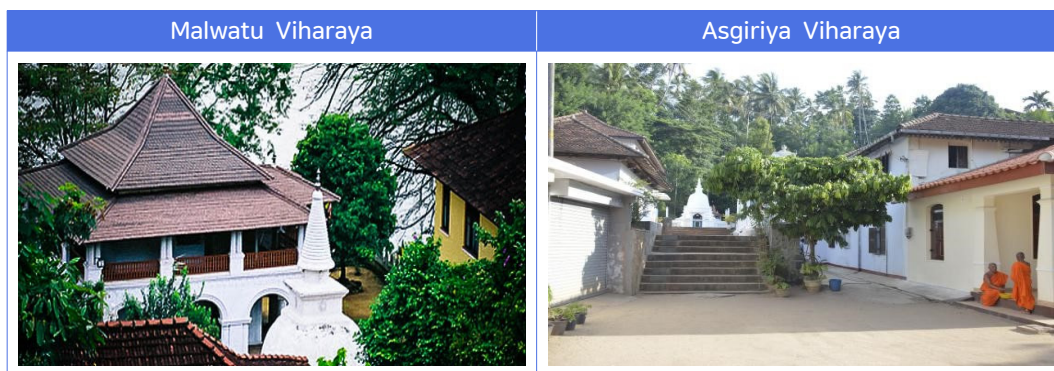
The Malwatta Monastery Complex is located beneath the Rajapihilla Mawatha at the Kandy Lakeside, facing the Sri Dalada Maligawa. This complex is composed of Uposatha Viharaya, known as Poyamalu Viharaya, and Pushparama Viharaya, recently built in octagonal form and known as Malwatu Viharaya.

The Asgiriya Monastery Complex was erected by Siriwardhana (1305–1335) during the reign of King Parakramabahu IV in the Kurunegala era. This complex is located in Asgiriya area, west of Kandy City, and includes a monastery for Asgiri priests. This site has many small temples and historic buildings that have been operating for centuries.

The annual religious ceremonies and major events related to the Sri Dalada Maligawa are held under the supervision of the chief priests of the Malwatta and Asgiriya Monasteries. These

two temples now play an equal role in religious events related to the Sri Dalada Maligawa.

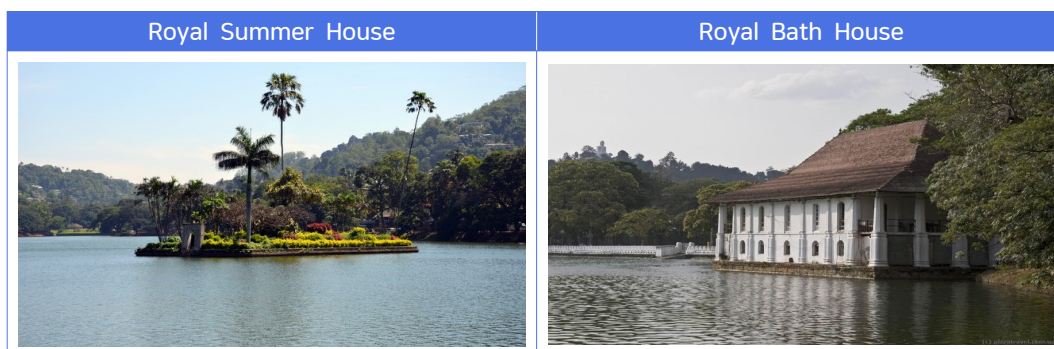
Figure II – 6 | The Malwatta and Asgiriya Monastery Complex



3) Kandy Lake and its Surrounding Area

Around the Kandy Lake, about 630 m of a decorative wall called Walakulu Bamma (cloud wall) is installed along the lake. In the middle of the lake, there is an artificial island with Seema Malaka (Royal Summer House), and at the opposite side of the Sri Dalada Maligawa, there is Ulpangeya (Royal Bath House), which was used as a bathhouse for the queen and the other concubines. The British added an additional floor for use as a library. There are also historical buildings and monuments, such as the Royal Spout, along the lake border.

Figure II – 7 | Kandy Lake and its surrounding area



4) Royal Botanic Garden

Located in Peradeniya, about 5 km from the center of Kandy to the west, it is the largest

botanical garden in Sri Lanka and boasts of more than 2 million visitors every year. It has more than 4,000 species of tropical plants and also houses the Sri Lanka National Plant Specimen Center.

Figure II - 8 | Royal Botanic Garden



5) Royal Palace Park

The Royal Palace Park is also called Wales Park, Wace Park, or Rajawasala Park. The park is located on top of a small hill in the center of Kandy City, overlooking the Kandy Lake and most of the city center. The park was built by King Sri Vikrama Rajasinha and was renamed as Wales Park by the UK in commemoration of the Prince of Wales. In the Royal Palace Park, there are many historical monuments, including Japanese field guns, donated by Mountbatten, the commander of the allied forces in Burma back then, from the Second World War in Southeast Asia. This park is a major attraction for both local and foreign tourists because of its breathtaking views.

Figure II - 9 | Royal Palace Park

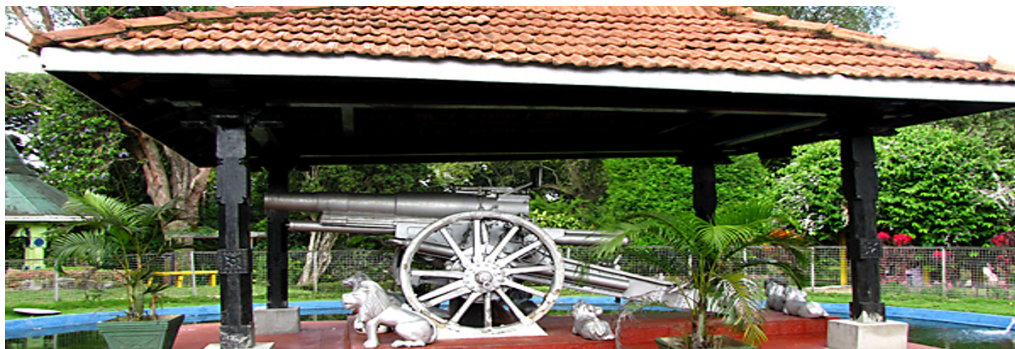
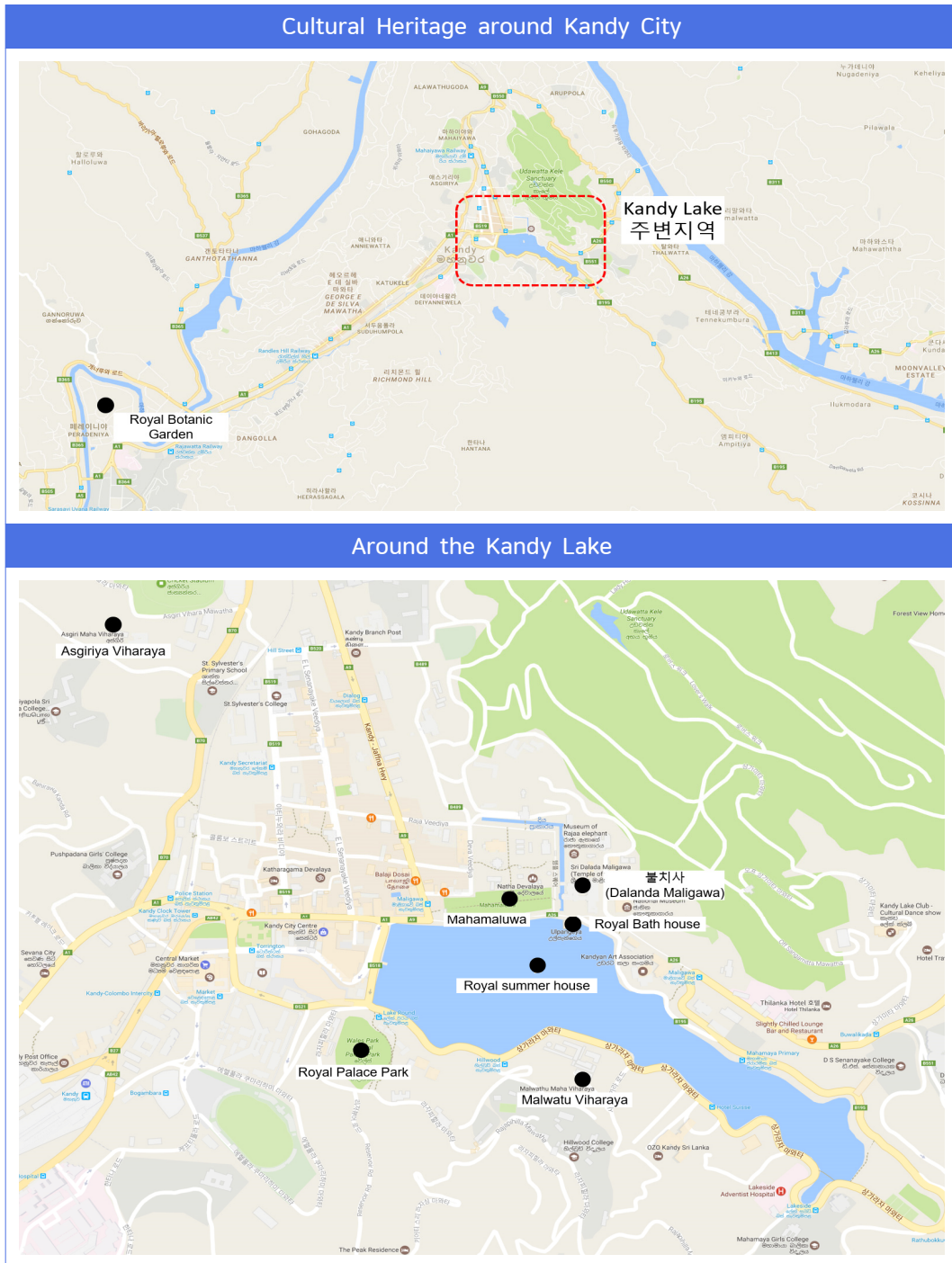


Figure II - 10 | Location of major historical sites



2.1.3. Population

The total population of the Kandy district was 1,370,000 in 2011 and 1,416,000 in 2015, with a relatively low annual growth rate of about 0.8%.

In terms of the population of the DS division unit, it is concentrated around Gangawata Kolare, the project area, among DS divisions. The most populated area was Gangawata Kolare, where about 160,000 people lived in 2015, accounting for 11.5% of the total population of the Kandy district. The next populated area was Kundasale with about 130,000 residents, followed by Uda Nuwara and Yatinuwara, with about 110,000 and 100,000 residents, respectively, which indicates that about 520,000 residents accounting for 36.5% of the total population are concentrated in four DS divisions around Gangawata Kolare.

Figure II - 11 | Population of Kandy district

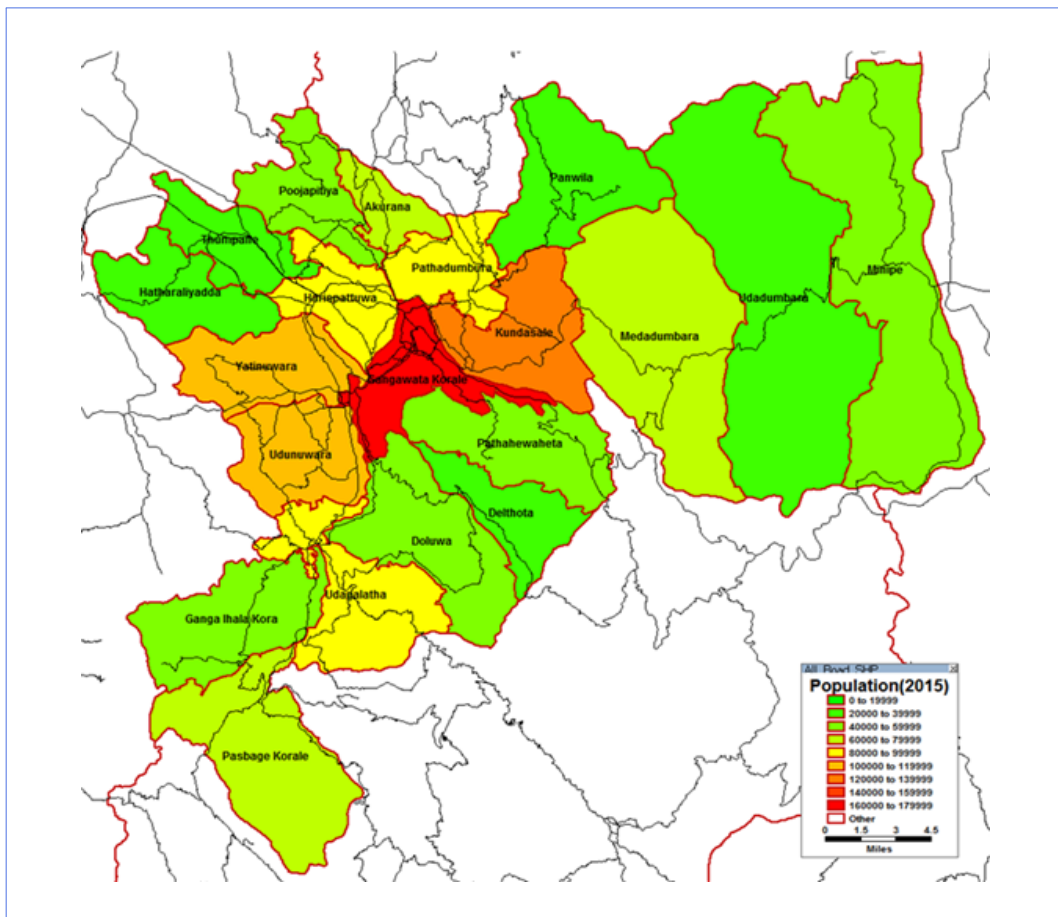
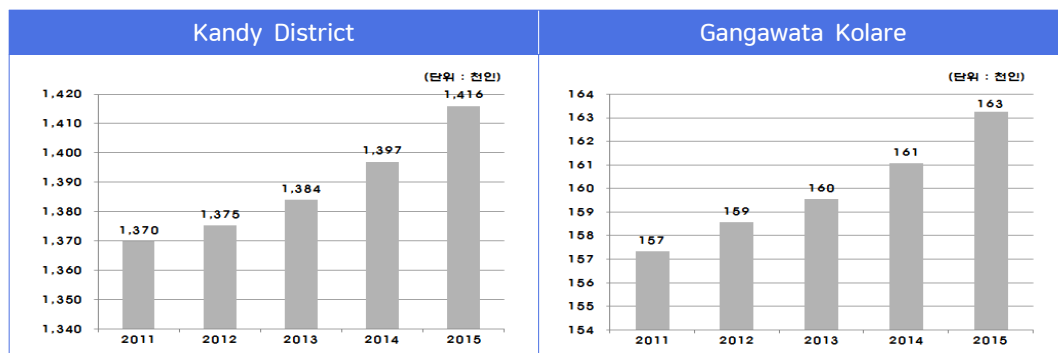


Table II-4 | Population of Kandy district

DS Division	Population (person)					Annual Growth rate
	2011	2012	2013	2014	2015	
Thumpane	37,356	37,642	37,875	38,234	38,754	0.92%
Poojapitiya	57,879	57,914	58,280	58,824	59,624	0.75%
Akurana	63,195	63,397	63,798	64,393	65,269	0.81%
Pathadumbara	88,599	88,725	89,285	90,120	91,345	0.77%
Panvila	26,186	26,294	26,463	26,707	27,071	0.83%
Udadumbara	22,408	22,505	22,643	22,859	23,170	0.84%
Minipe	51,577	51,883	52,200	52,698	53,415	0.88%
Medadumbara	60,783	61,034	61,419	61,993	62,836	0.83%
Kundasale	127,278	127,070	127,866	129,067	130,823	0.69%
Gangawata Kolare	157,330	158,561	159,546	161,054	163,244	0.93%
Harispattuwa	88,002	88,177	88,732	89,563	90,781	0.78%
Hataraliyadda	29,866	29,986	30,175	30,457	30,872	0.83%
Yatinuwara	105,962	106,027	106,687	107,694	109,158	0.75%
Udunuwara	110,232	110,905	111,592	112,648	114,180	0.88%
Doluwa	49,480	49,842	50,147	50,625	51,314	0.91%
Pathahewaheta	58,031	58,188	58,549	59,103	59,906	0.80%
Delthota	30,169	30,345	30,539	30,822	31,241	0.88%
Udawalatha	91,230	91,716	92,303	93,158	94,425	0.86%
Gangalhalala Korale	54,674	55,254	55,598	56,122	56,886	1.00%
Pasbage Korale	59,662	59,917	60,304	60,859	61,686	0.84%
total	1,369,899	1,375,382	1,384,001	1,397,000	1,416,000	0.83%

Source: Department of Census and Statistics, 2015, District Statistical Handbook Kandy, Department of Census and Statistics

Figure II - 12 | Population change of Kandy district



2.1.4. The Number of Registered Vehicles

The number of registered vehicles is a major socioeconomic indicator used to judge the current traffic characteristics and the direction of future traffic volume increase in the relevant analysis area. First, in terms of composition, motor bicycles and three-wheelers can be mostly seen in the Kandy district, which accounted for 34.8% and 30.4%, respectively, in 2015. These two types turned out to be major transportation means in the Kandy district, accounting for about 65% of total number of vehicles.

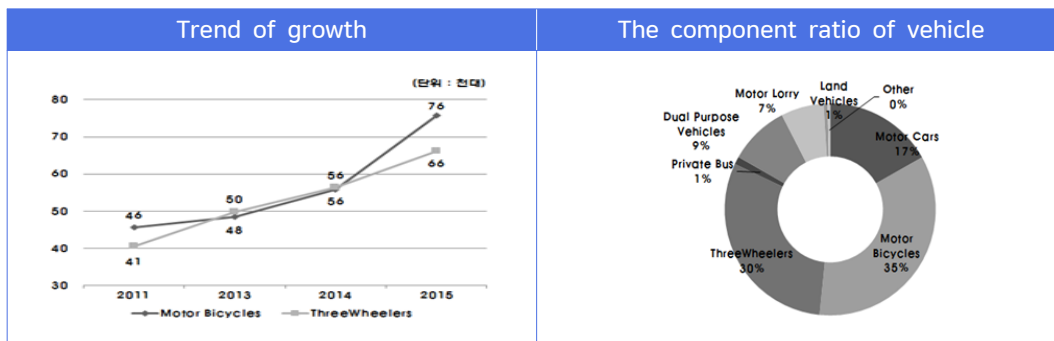
Since 2011, the annual average growth rates for motorbikes and three-wheelers were 13.5% and 13%, respectively, exceeding the annual average growth rate of 9.7% for all vehicle types, which indicates that the dependency on these types of vehicle has intensified.

Table II-5 | Trend of the number of registered vehicles by types in Kandy district

Type of vehicle	2011		2013		2014		2015		Annual Growth Rate
	Vehicle	Proportion	Vehicle	Proportion	Vehicle	Proportion	Vehicle	Proportion	
Motor Cars	24,283	16.2%	25,967	16.5%	29,381	16.5%	36,608	16.8%	10.8%
Motor Bicycles	45,643	30.4%	48,397	30.7%	55,772	31.3%	75,687	34.8%	13.5%
Three Wheelers	40,533	27.0%	49,825	31.6%	56,340	31.7%	66,198	30.4%	13.0%
Private Bus	1,920	1.3%	2,599	1.6%	2,780	1.6%	2,579	1.2%	7.7%
Dual Purpose Vehicles	16,653	11.1%	16,114	10.2%	17,846	10.0%	20,033	9.2%	4.7%
Motor Lorry	13,424	8.9%	12,941	8.2%	13,735	7.7%	14,219	6.5%	1.4%
Land Vehicles	1,358	0.9%	1,430	0.9%	1,457	0.8%	1,353	0.6%	-0.1%
Other	6,432	4.3%	457	0.3%	642	0.4%	867	0.4%	-39.4%
Total	150,246	100.0%	157,730	100.0%	177,953	100.0%	217,544	100.0%	9.7%

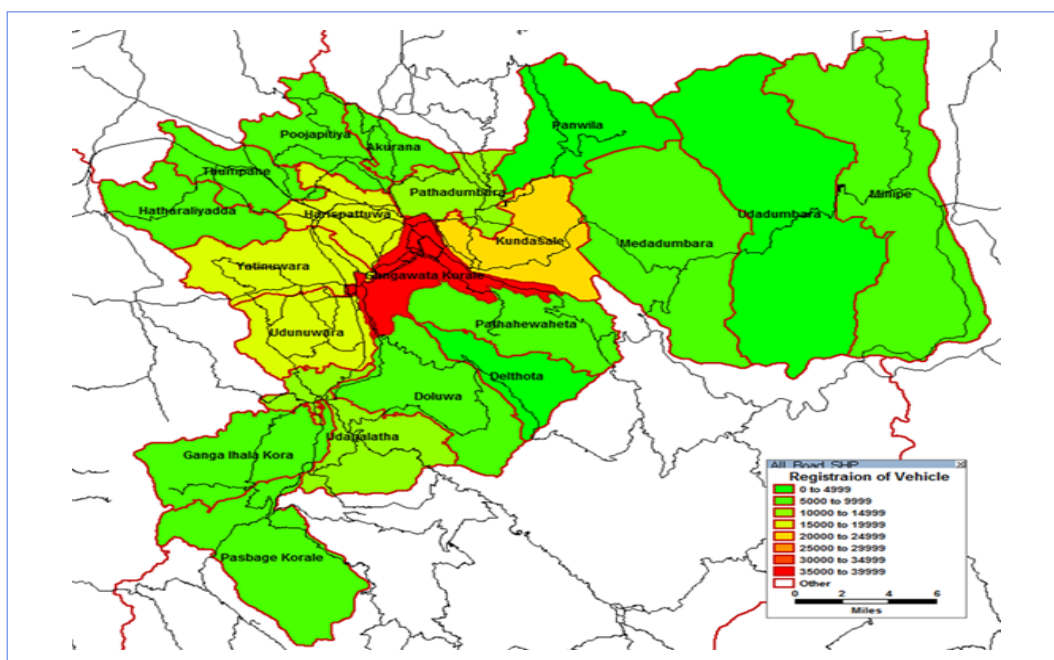
Source: Department of Census and Statistics, 2015, *District Statistical Handbook Kandy*, Department of Census and Statistics

Figure II - 13 | Characteristic of the number of registered vehicles by types in Kandy district



In terms of the number of registered vehicles in each DS division in Kandy district, it has been found that Gangawata Kolare, the project area, also had the most number of registered vehicles like the population. The number of registered vehicles in Gangawata Kolare was about 36,000, accounting for 16.7% of the total Kandy district. As of 2015, 23,000 vehicles, 19,000 vehicles, and 17,000 vehicles were registered in nearby Kundasale, Yatinuwara, and Udu Nuwara, respectively, which indicates that about 44.4% of the total vehicles in Kandy district is concentrated in these areas.

Figure II - 14 | The Number of registered vehicles in Kandy district



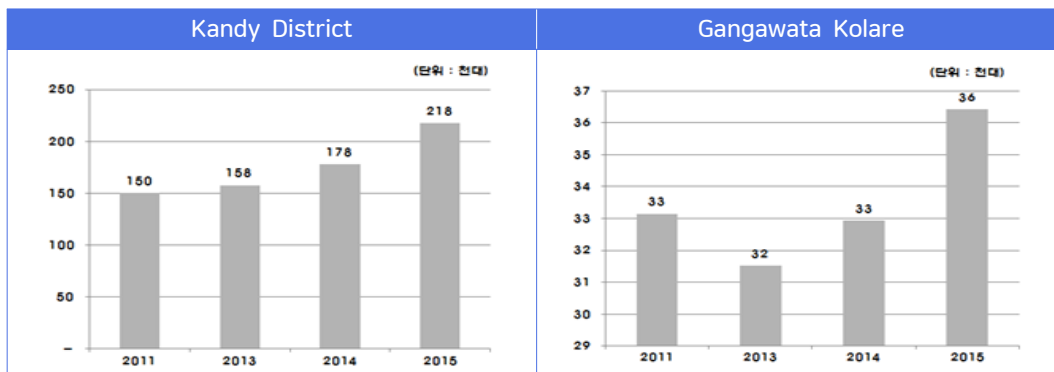
However, the vehicle growth rate in Gangawata Kolare and Kundasale was only about 2.4%, respectively, which is 9.7% lower than the overall vehicle growth rate in the Kandy district.

Table II - 6 | The Number of registered vehicles per capita in each DS division of Kandy district

DS Division	2011	2013	2014	2015	Annual Growth Rate
Thumpane	3,965	4,703	5,069	6,546	13.35%
Poojapitiya	2,893	6,570	7,187	9,280	33.83%
Akurana	4,145	6,380	6,770	8,066	18.11%
Pathadumbara	9,078	10,579	11,350	11,350	5.74%
Panvila	1,202	1,575	1,797	2,291	17.50%
Udadumbara	1,505	2,273	2,515	2,471	13.20%
Minipe	4,982	6,620	7,485	9,275	16.81%
Medadumbara	4,545	5,817	6,350	8,433	16.71%
Kundasale	21,418	18,931	18,965	23,541	2.39%
Gangawata Kolare	33,146	31,513	32,933	36,420	2.38%
Harispattuwa	11,829	11,402	12,176	15,235	6.53%
Hataraliyadda	2,897	3,726	3,971	5,558	17.69%
Yatinuwara	12,625	14,616	15,662	19,542	11.54%
Udunuwara	10,737	2,273	13,555	17,074	12.30%
Doluwa	3,540	4,483	4,483	6,245	15.25%
Pathahewaheta	5,378	6,588	7,230	8,923	13.49%
Delthota	1,446	1,928	1,481	2,777	17.72%
Udapalatha	7,717	8,472	8,873	12,122	11.95%
Gangalhala Korale	3,475	4,659	5,192	6,453	16.74%
Pasbage Korale	3,723	4,622	4,909	5,942	12.40%
total	150,246	157,730	177,953	217,544	9.69%

Source: Department of Census and Statistics, 2015, *District Statistical Handbook Kandy*, Department of Census and Statistics

Figure II - 15 | Vehicle registration number change in Kandy district(unit: thousand)



2.1.5. The Number of Registered Vehicles per Capita

To examine the level of urbanization and development of each DS division in the Kandy district, the number of registered vehicles per capita was analysed. It also turned out that Gangawata Kolare had the most number of registered vehicles per capita, which indicates that urbanization and economy are concentrated in the project area.

Figure II - 16 | The Number of registered vehicles per capita in Kandy district

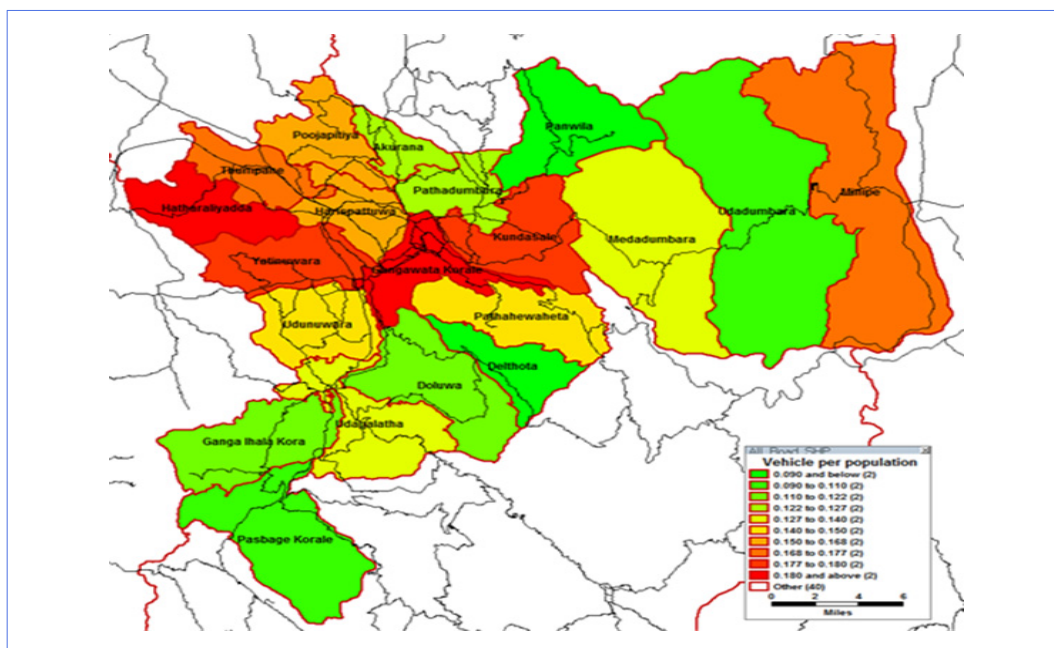


Table II - 7 | The Number of registered vehicles per capita in each DS division of Kandy district

DS Division	Vehicle per Capita			
	2011	2013	2014	2015
Thumpane	0.11	0.12	0.13	0.17
Poojapitiya	0.05	0.11	0.12	0.16
Akurana	0.07	0.10	0.11	0.12
Pathadumbara	0.10	0.12	0.13	0.12
Panvila	0.05	0.06	0.07	0.08
Udadumbara	0.07	0.10	0.11	0.11
Minipe	0.10	0.13	0.14	0.17
Medadumbara	0.07	0.09	0.10	0.13
Kundasale	0.17	0.15	0.15	0.18
Gangawata Kolare	0.21	0.20	0.20	0.22
Harispattuwa	0.13	0.13	0.14	0.17
Hataraliyadda	0.10	0.12	0.13	0.18
Yatinuwara	0.12	0.14	0.15	0.18
Udunuwara	0.10	0.02	0.12	0.15
Doluwa	0.07	0.09	0.09	0.12
Pathahewaheta	0.09	0.11	0.12	0.15
Delthota	0.05	0.06	0.05	0.09
Udapalatha	0.08	0.09	0.10	0.13
Gangalhala Korale	0.06	0.08	0.09	0.11
Pasbage Korale	0.06	0.08	0.08	0.10
total	0.11	0.11	0.13	0.15

Source: Department of Census and Statistics, 2015, *District Statistical Handbook Kandy*, Department of Census and Statistics

2.2. Characteristics of the Traffic Network System

2.2.1. Characteristics of the Road Network System

Because of the nature of being a city located in Sri Lanka, Kandy City acts as a traffic nodal point where major arterial roads cross each other. However, because Kandy City is located at high altitude, its road network is composed of a naturally occurring radial road network system. As the City is surrounded by the Mahaweli River and other nearby mountainous terrains, the amount of traffic is concentrated in the bridge section at the entrance of Kandy City. To disperse traffic volume, additional linkage roads to connect to the main points of the city or the city outside are required.

The main roads are A1 national road linking Colombo and Kandy City, A10 national road linking Kandy City and the north-western part, A9 national road linking Kandy City and the northern part, and A26 national road linking Kandy City and the eastern part, all of which form a major metropolitan arterial road network. Most of the roads are two-lane roads, but some sections of the AB42 national road, located parallel to the A1 national road, are made of four-lane roads.

A plan to connect the A10 national road with Central Expressway is under way. If the Central Expressway is completed, the major traffic flow will be processed by the A10 national road. To respond to this, a plan to expand the A10 national road, which is currently operated in two lanes, into a four-lane road is under way.

Although the bypass road is constructed as a two-lane road, some sections are operated without being divided into lanes or are operated in a nonstandardized form with no sufficient width. In addition, it is difficult to efficiently process the transit traffic volume because the roads have poor vertical and horizontal alignments because of the nature of the mountainous terrain.

In addition, there is no bypass road in the southern section because of the mountainous terrain. To compensate, the Kandy Tunnel project is under way as a part of the bypass road network construction project.

The inner section of the city is operated in the form of radial roads mixed with grid-shaped roads in the city center, and some sections of the city are operated in one-way roads. In some parts of the city, traffic congestion takes place because of street vendors and illegal parking. Bus bays were not installed at the bus stops and it is impossible to pass the bus when it stops, which is another reason for traffic congestion. As vehicle traffic is terrible at

the northern part of Bogambara Lake, where historical sites such as Sri Dalada Maligawa are located, vehicles need to pass through the Sri Sangaraja Mawatha road in the southern part of the lake, which still causes chronic traffic congestion on relevant roads.

Because of the rapid increase in the number of vehicles and a shortage in public transportation system, Kandy City has a high rate of passenger vehicles, believed to be one of the reasons that aggravate traffic congestion in Kandy City. In addition, because of the motorbikes and three-wheelers in Kandy, traffic flow shows unstable characteristics.

Figure II - 17 | Street network map in Kandy city

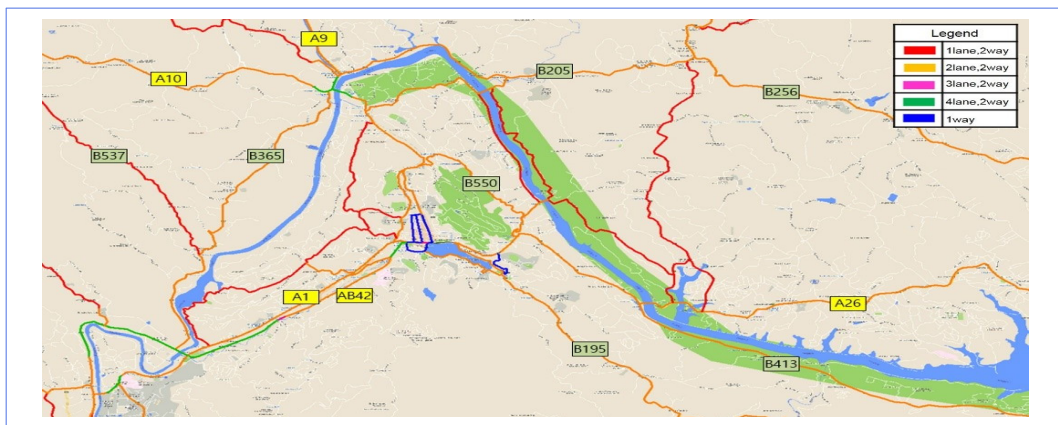
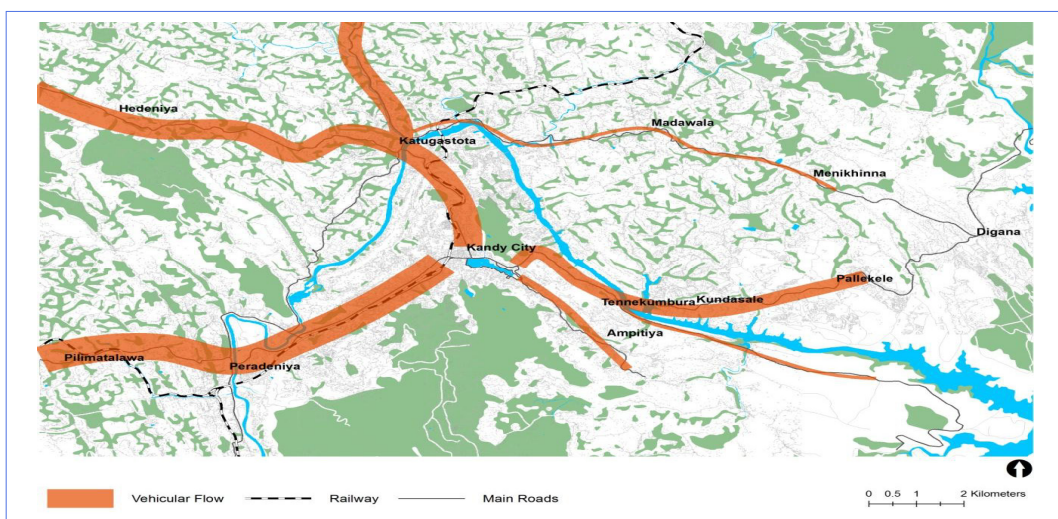


Figure II - 18 | Traffic pattern in Kandy city



Source: Ministry of Urban development, Water Supply and Drainage, 2015 : *Kandy City Region Strategic Development Plan-2030*, Uni Consultancy Services, University of Moratuwa

2.2.2. Vehicle Type Composition Ratio

Among the vehicles entering Kandy City, three-wheelers account for the largest percentage at 26.2%, and the motorbikes and passenger cars/jeeps/pick-up trucks account for 24% and 23.9%, respectively, which are close to the percentage of three-wheelers. These vehicle types account for the majority (about 75%) of vehicles entering Kandy City.

These vehicle types can only accommodate a small number of passengers. Therefore, it is necessary to replace them with high-capacity transportation vehicles such as buses to reduce traffic volume. The traffic volume to and from Kandy City increased by about 5% in 2015 compared to 2010. The three-wheelers, motorbikes, and passenger cars/jeeps/pick-up trucks increased by 9.6%, 8.0%, and 6.4%, respectively, which indicates that the increase rate of these three vehicle types accounting for majority of the traffic volume exceeds the average increase rate of all vehicles.

Table II-8 | Proportion of vehicle type in-out traffic Kandy district (conrdon Line)

Vehicle Type	ADT(2-way, 24Hour)				AAGR (2010~2015)
	2010		2015		
	Number	%	Number	%	
Cycles	513	0.5%	273	0.2%	-11.9%
Motor Bike	24,682	22.0%	36,309	24.9%	8.0%
3-Wheeler	24,203	21.6%	38,263	26.2%	9.6%
Car/Jeep/Pickups	25,614	22.8%	34,855	23.9%	6.4%
Pax. Van	11,469	10.2%	11,583	7.9%	0.2%
School Van	1,837	1.6%	1,723	1.2%	-1.3%
Non Route Bus	954	0.9%	597	0.4%	-9.0%
Route Bus	9,602	8.6%	10,333	7.1%	1.5%
Delivery Van	2,434	2.2%	446	0.3%	-28.8%
Light Goods(other)	2,984	2.7%	4,752	3.3%	9.8%
Medium Goods(2Axle)	6,990	6.2%	6,148	4.2%	-2.5%
Heavy Goods	676	0.6%	357	0.2%	-12.0%
Multi Axle	61	0.1%	92	0.1%	8.5%
Tractors	105	0.1%	99	0.1%	-1.2%
Carts	46	0.0%	1	0.0%	-53.5%
Total	112,170	100.0%	145,831	100.0%	5.4%

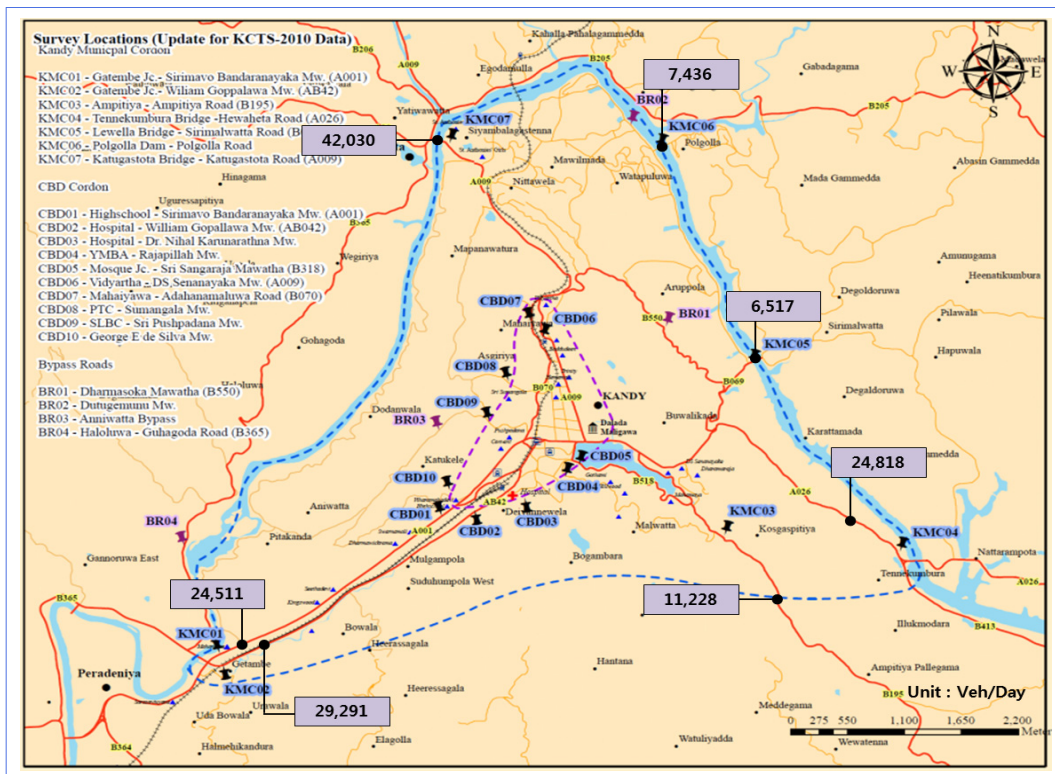
Source: Ministry of Urban development, Water Supply and Drainage, 2015, *Strategic Traffic Demand Management & Design Plan for Kandy*, Ministry of Urban development, Water Supply and Drainage

In terms of entry and exit traffic at major points in the outskirts of Kandy City, the number of vehicles entering and leaving Kandy through Gatenbe and Peradeniya areas, such as A1 and A5 national roads, from the southwest where the capital Colombo is located, was observed to be about 53,000/day, accounting for the largest percentage.

The number of vehicles entering and leaving Kandy through Katugastota via the A10 and A9 national roads in the northwest was observed to be about 42,000/day, and the number of vehicles entering and leaving Kandy from the southeast through the A26 and B195 national roads via Tennekumbura was observed to be about 35,000/day.

In terms of traffic volume leaving Kandy, the traffic to the capital Colombo accounted for the highest percentage at 37%, and in general, the traffic volume was more concentrated in the west. It is expected that a considerable number of traffic currently using the A1 and AB42 national roads will use the A10 national road when the construction of Central Expressway is completed.

Figure II - 19 | In-out traffic volume on cordon line

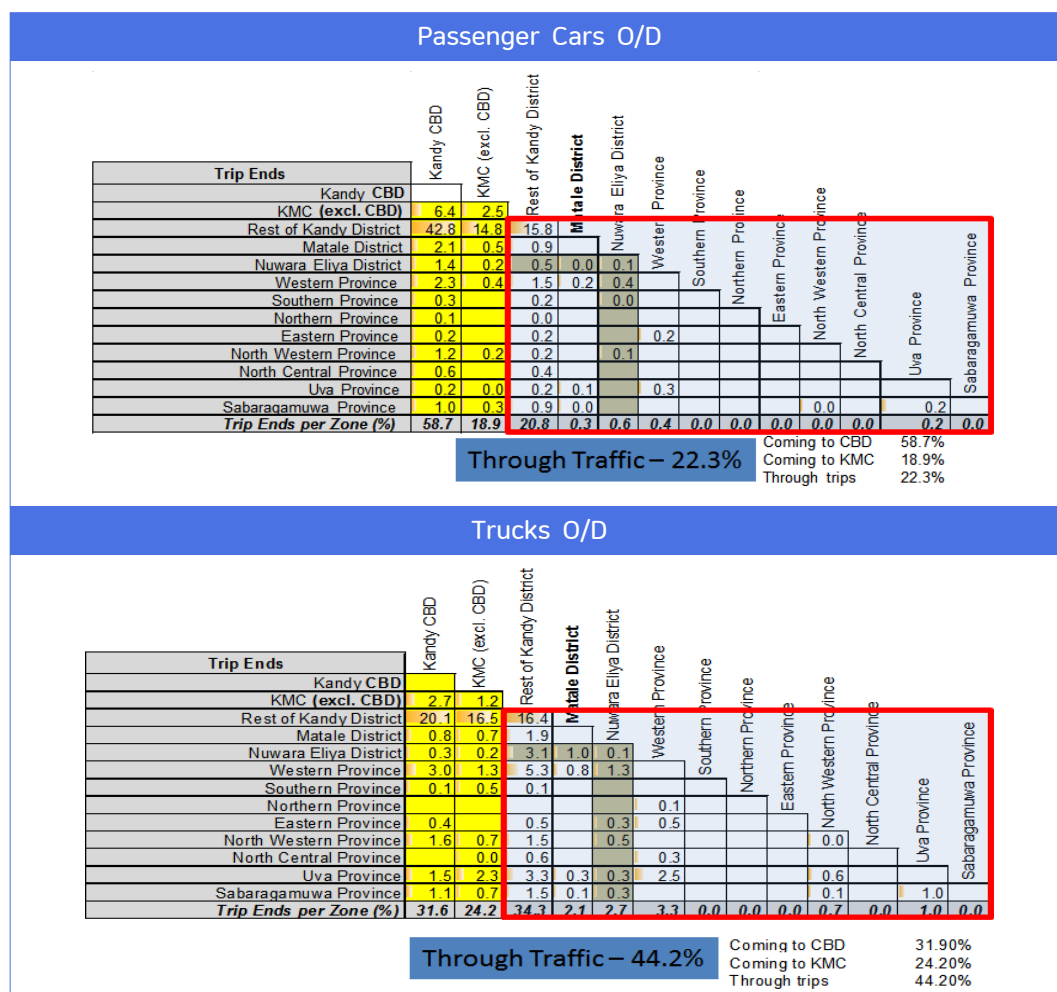


Source: Ministry of Urban development, Water Supply and Drainage, 2015 : *Kandy City Region Strategic Development Plan-2030*, Uni Consultancy Services, University of Moratuwa

2.2.3. O/D Distribution

Kandy City has been built in a monocentric radial road system, and because there is a shortage of bypass roads to process the transit traffic, the rate of traffic passing through the city center is relatively high. About 22% of the passenger cars approaching Kandy City is transit traffic, and the ratio of trucks in transit traffic was observed at about 44% (Strategic Traffic Demand Management Design Plan for Kandy, Sri Lanka, 2015), which is higher than passenger cars. This is because passenger cars with a relatively short travel distance have Kandy City as its destination, whereas cargo trucks with long travel distance merely pass through Kandy.

Figure II - 20 | O/D distribution of passenger cars and trucks in Kandy (cordon line)



Source: Ministry of Urban development, Water Supply and Drainage, 2015 : *Kandy City Region Strategic Development Plan-2030*, Uni Consultancy Services, University of Moratuwa

2.2.4. Travel Speed

The peak time for traffic entering Kandy City is 6:30–6:45 a.m., and the next peak time is at 8:00–8:15 a.m. The peak time for traffic leaving Kandy is at 7:30–7:45 a.m. The difference of these peak times is caused by the entry to the city center for school attendance (6:30–6:45 a.m.), leaving the city center after school attendance (7:30–7:45 a.m.), and entry to the city center for office attendance (8:00–8:15 a.m.).

The travel speed at peak time is 16.7 km/h, and the travel speed at normal hours is 25.7 km/h. On some congested roads with high traffic volume, the travel speed at peak time may be reduced to 4 km/h (Kandy Transportation Study, 2011), which is attributed to the decrease in road capacity caused by the traffic operation problems in Kandy City. The travel speed on the main roads is influenced by the concentration of traffic volume, whereas the travel speed on bypass roads or other subsidiary roads is influenced by poor terrain conditions and narrow road widths rather than traffic volume.

Table II-9 | Travel speed at the main points of Kandy

No	Road Name	Length (km)	Average Travel Time(s)		Average Speed (Km/h)	
			Peak	Off Peak	Peak	Off Peak
1	Wariyapola Sri Sumangala Mw.	0.763	755	176	4	16
2	SWRD Bandaranayake Mw.	1.132	819	191	5	21
3	Katugastota Road	2.928	1,706	402	6	26
4	D.S. Senanayaka Veediya	1.162	459	167	9	25
5	Kotugodalla Veediya	0.601	199	146	11	15
6	Colombo Veediya	0.555	180	126	11	16
7	George E. de Silva Mw.	1.533	388	265	14	21
8	Sangaraja Mw.	1.957	443	249	16	28
9	Yatinuwara Veediya	0.585	124	68	17	31
10	Ampitiya Road	0.398	76	57	19	25
11	Sirimavo Bandaranayake Mw	5.312	1,013	666	19	29
12	Dutugemunu Mw.	2.94	557	453	19	23
13	Matale Road	0.35	57	54	22	23
14	Dalada Veediya	0.799	128	99	22	29
15	Dharmasoka Mw.	3.043	485	358	23	31
16	Adahana Maluwa Road	1.09	164	137	24	29
17	William Gopallawa Mw.	3.655	484	326	27	40
18	Anagarika Dharmapala Mw.	1.18	145	136	29	31
19	Hewaheta Road	2.5	294	286	31	31
20	Guhagoda Road	7.2	800	741	32	35
21	Werra Madduma Bandara Mw.	1.02	87	76	42	48

Source: University of Morauwa and University of Peradeniya, 2011, *Kandy Transportation Study*, Road Development Authority

2.2.5. Problems in Kandy City's Road Network

Kandy City, the project area, is an area where about 11% of the population of the Kandy District resides and the demand for vehicle traffic is concentrated. However, because of limited road system, most of the traffic is concentrated in the CBD.

The bypass roads in Kandy City are mostly round-trip in two lanes, and composed of nonstandardized roads with poor vertical and horizontal alignments with no separate car lanes or constant lane width. As a result, traffic congestion caused by cargo trucks is extremely severe and 44% of these cargo trucks are simply transit traffic.

Most of the roads in Kandy City are round-trip in two lanes, and the noninstallation of bus bays also causes traffic congestion because the bus queue occurs behind the bus when it is stopped.

To solve road system problems, the Kandy Tunnel Project to connect the east and west of Kandy, and the Road Improvement Project supported by the World Bank are under way. However, these road plans are merely to improve the current road lines and expand the road width, and are unable to fundamentally solve the traffic congestion in Kandy City.

The Kandy Tunnel Project intends to disperse the transit traffic between the east and west of Kandy, but there are not enough connection routes to maximize the effect of the Kandy Tunnel construction.

The Central Expressway plan to connect Kandy and Colombo, and the A10 national road expansion plan have been established, but because of the lack of road project to connect the national road A10 expansion, the traffic congestion in Katugastota, the gateway area of the Central Expressway, can be intensified.

3. Traffic forecast

3.1. Establishment of Relevant Plans

As a national plan for the construction of the road network system, the National Road Master Plan (2007–2017) (RDA, 2007) was established, suggesting strategies for road development over the next 10 years. Based on this, the Central Expressway is being promoted to connect Colombo with the relatively underdeveloped central region.

The feasibility study of the Sri Lanka Kandy Tunnel construction project was carried out for the construction of a bypass road network in Kandy City. In addition, to find ways to improve Kandy City's urban infrastructure, the Strategic Cities Development Project plan was established in 2015 with funding from the World Bank.

The Central Expressway project is now under way to connect the national road A10 in the north-western part of Kandy City. Along with this, a plan is under way to extend the national road A10, currently a two-lane road, to the Katugastota Bridge.

The World Bank is promoting the Katugastota-Digana road extension project and Darmashoka mawatha-Lewella section extension project, which are parts of the road network improvement projects proposed in the Strategic Cities Development Project.

Table II-10 | Major relevant plans

Relevant Plans	Major Contents
National Road Mater Plan	<ul style="list-style-type: none"> • 10-year unit national road network plan of Sri Lanka
Strategic Cities Development Project	<ul style="list-style-type: none"> • Suggestion of improvement plan and enforcement plan for urban infra and public facilities of Kandy and Galle, the major cities of Sri Lanka
Kandy Transport Improvement Program	<ul style="list-style-type: none"> • Suggestion of comprehensive traffic improvement plans such as road improvement plan, public transportation improvement plan, traffic operation improvement plan, and pedestrian environment improvement plan • Suggestion of East - West direction detour roads for the improvement of traffic congestion
Feasibility study for the Sri Lanka Kandy Tunnel Construction Project	<ul style="list-style-type: none"> • Feasibility study to connect the East and West in the southern part of Kandy in order to spread the traffic volume and relieve the congestion in Kandy
Central Expressway Project	<ul style="list-style-type: none"> • Major expressway project suggested in the National Master Plan • Promote the economic revitalization and transportation convenience of tourists through the connection of the comparatively impoverished central north region and the capital, Colombo

3.1.1. National Road Master Plan

1) Goals and Overview

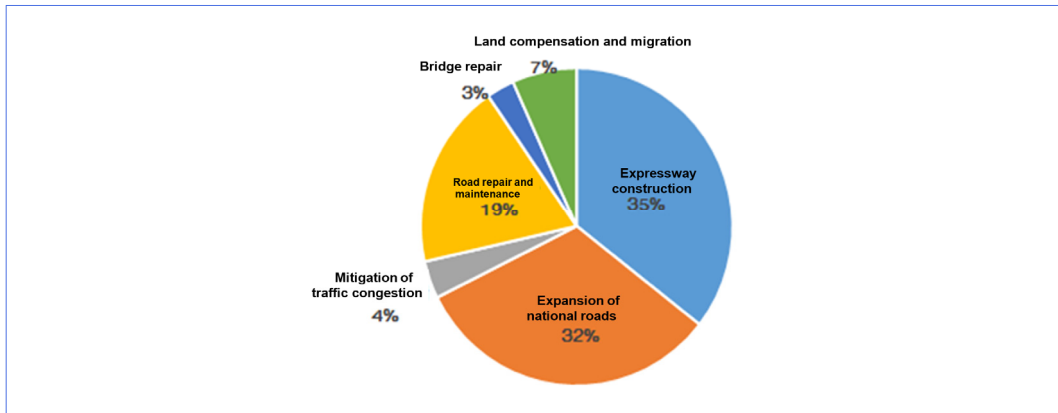
The Sri Lanka National Road Master Plan, a national road network plan that includes expressways, was established in 2007 with goals for welfare promotion, economy revitalization, poverty reduction, and social integration. The plan was established to achieve the following detailed goals through road planning, maintenance, and construction.

- Promotion of national economic development considering future development plans
- Mobility improvement, travel time reduction, travel cost reduction, and accessibility improvement
- Effective use of assets and investments through identification of demand for passenger and cargo
- Improvement of road quality and stability by using efficient and innovative design, construction, and maintenance technology
- Maintenance, repair, extension, and improvement of existing roads, and securing the road capacity through construction of new roads
- Promotion of institutional development of road management
- Conservation of environmental, social, and cultural values
- Activation of local civil engineering projects

2) Major Plans

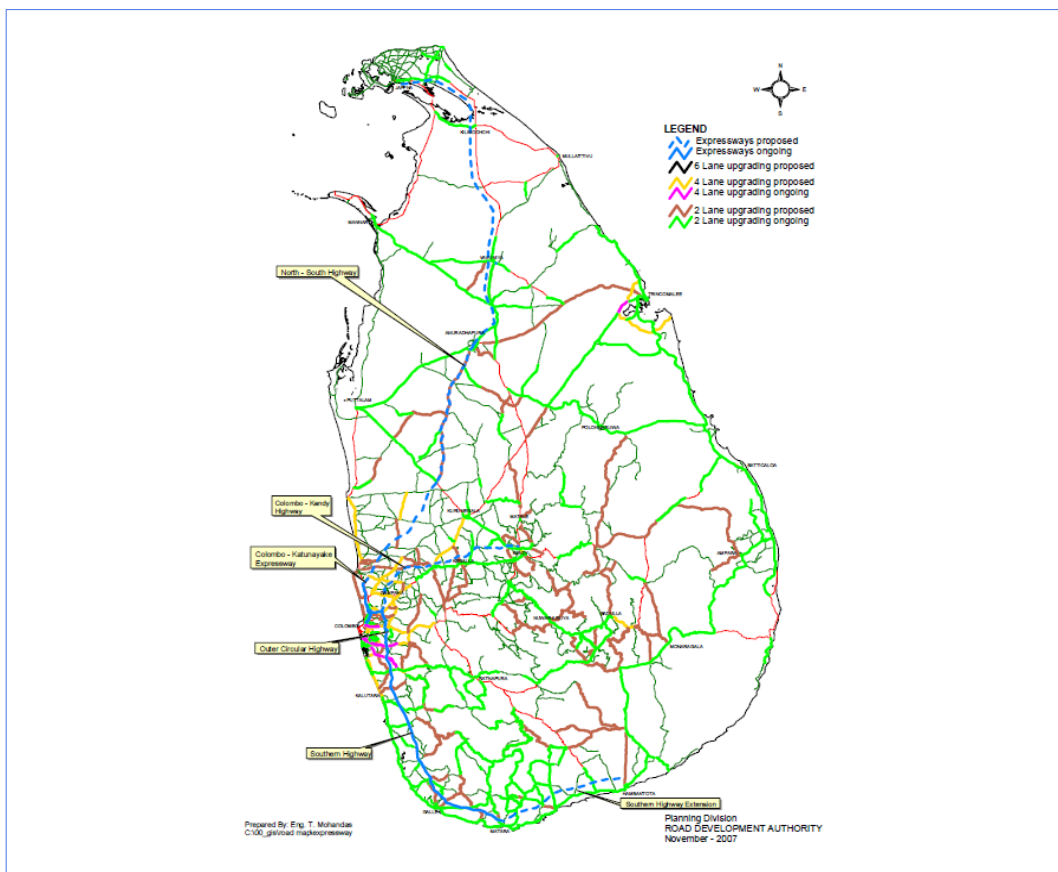
The major projects of the Sri Lanka National Road Master Plan include the expressway and national road construction projects that account for the largest portion (36%) of the total budget and the national road extension project that accounts for the second largest portion (32%). It also includes other projects such as overpass and intersection improvements, establishment of signal intersections, improvement of congestion points through bypass roads, and maintenance of roads and bridges. In particular, the Central Expressway Construction Project, which is expected to have a significant impact, was proposed through the Master Plan.

Figure II - 21 | Ratio of investment in each project in the national road master plan



Source: Road Development Authority 2007, *National Road Master Plan*, Road Development Authority

Figure II - 22 | Sri Lanka national road master plan



Source: Road Development Authority 2007, *National Road Master Plan*, Road Development Authority

3.1.2. Strategic Cities Development Project

1) Contents of the Plan

The Strategic Cities Development Project is implemented by the World Bank and consists of three parts: the development plan for Kandy, the project area; the development plan for Galle area; and the implementation plan for each project. The improvement plan for each city is approached mainly from two aspects, which are enhancement of the functions of a city through basic service improvement of the city as a whole and enhancement of the charm of a city by strengthening its public functions.

The direction of Kandy City, the project area, focuses on improvement of traffic congestion, which is consistent with the project goal. Table II -11 shows the direction of the improvement of each city.

Table II - 11 | Improvement direction of each city in strategic cities development project

Kandy City Area	Galle City Area
<ul style="list-style-type: none"> • Traffic system improvement plan such as improvement of bypass road network and improvement of public transportation system and traffic operation method • Extension and supplementation of Kandy City's water supply system • Supplementation of sewage treatment facilities • Urban function improvement, including improvement of urban landscape, improvement of street environment, and restoration of public places, cultural heritage, and landmarks • Development of integrated master plan, system improvement, and capacity building program 	<ul style="list-style-type: none"> • Flood prevention measures, including the maintenance of canals and surface drainage facilities • Coastal erosion prevention measures • Urban function improvement, including improvement of urban landscape, improvement of street environment, and restoration of public places, cultural heritage, and landmarks • Development of integrated master plan, system improvement, and capacity building program

Source: World Bank, Sri Lanka Strategic Cities Development Project Appraisal Document, 2014, World Bank

2) Traffic Improvement Plan of Kandy City

Kandy City experiences traffic congestion because of its terrain, road conditions, and numerous transit traffics that do not have the city as their destinations. This traffic congestion not only affects the residents of Kandy City but also affects about 350,000 commuters who account for about 60% of public transportation users. To mitigate such traffic congestion and improve road efficiency, the center of Kandy City should not be affected by unnecessary transit traffic.

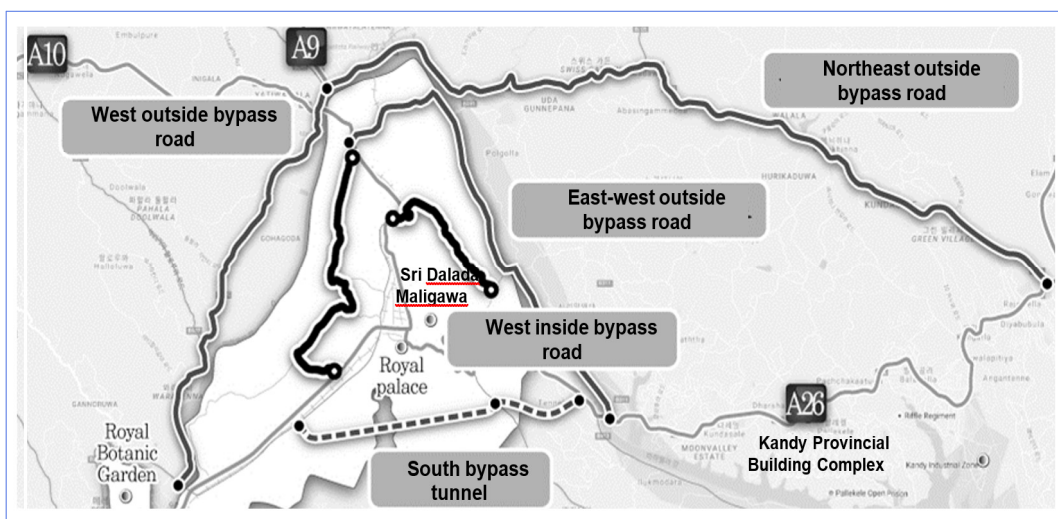
For this purpose, two implementation strategies have been established. The first is the separation of the traffic, which is not related to Kandy City, through the bypass roads; the second is the gradual relocation of the unnecessary traffic from inside Kandy City to the outside.

Through these strategies, the following major planning directions have been established:

1. Improvement of internal and external roads based on the analysis carried out by RDA based on the Kandy City Transport Study established in 2009
2. Improvement of the public transportation by relocating transfer facilities to a suitable point outside the city, to alleviate the phenomenon of bus overcrowding in the city
3. Introduction of traffic calming method, including the transfer of a street parking lot to off-street parking lot, for the convenience of pedestrians

Among the improvement directions above, the contents for the improvement of inner and outer bypass roads related to this project were suggested in the Kandy Transportation Implementation Program in detail. Figure II -23 shows the road improvement plan for the internal/external circular axis and the external axis suggested in relevant projects.

Figure II - 23 | Improvement method for the Kandy transportation implementation program



Source: Ministry of Defense and Urban Development, 2014, *Kandy Transport Improvement Program*, Ministry of Defense and Urban Development

3.1.3. Feasibility Study on Kandy Tunnel Construction Project

1) Background

Because of the mountainous terrain in the southern part of Kandy City, there is no bypass road network there and transportation between the east and west is made through the city center. As a result, traffic congestion is increasing in the city because of the entrance of transit traffic into the city center. To solve this problem, a feasibility study was conducted on a tunnel directly connecting the eastern and western parts of Kandy.

2) Project Contents

The purpose of the Kandy Tunnel is to construct the southern bypass road that runs across the mountainous region in the south of Kandy City to the east and west to eliminate traffic concentration and congestion in the city and to prepare for the increase of traffic volume in the future, considering the development of Kandy.

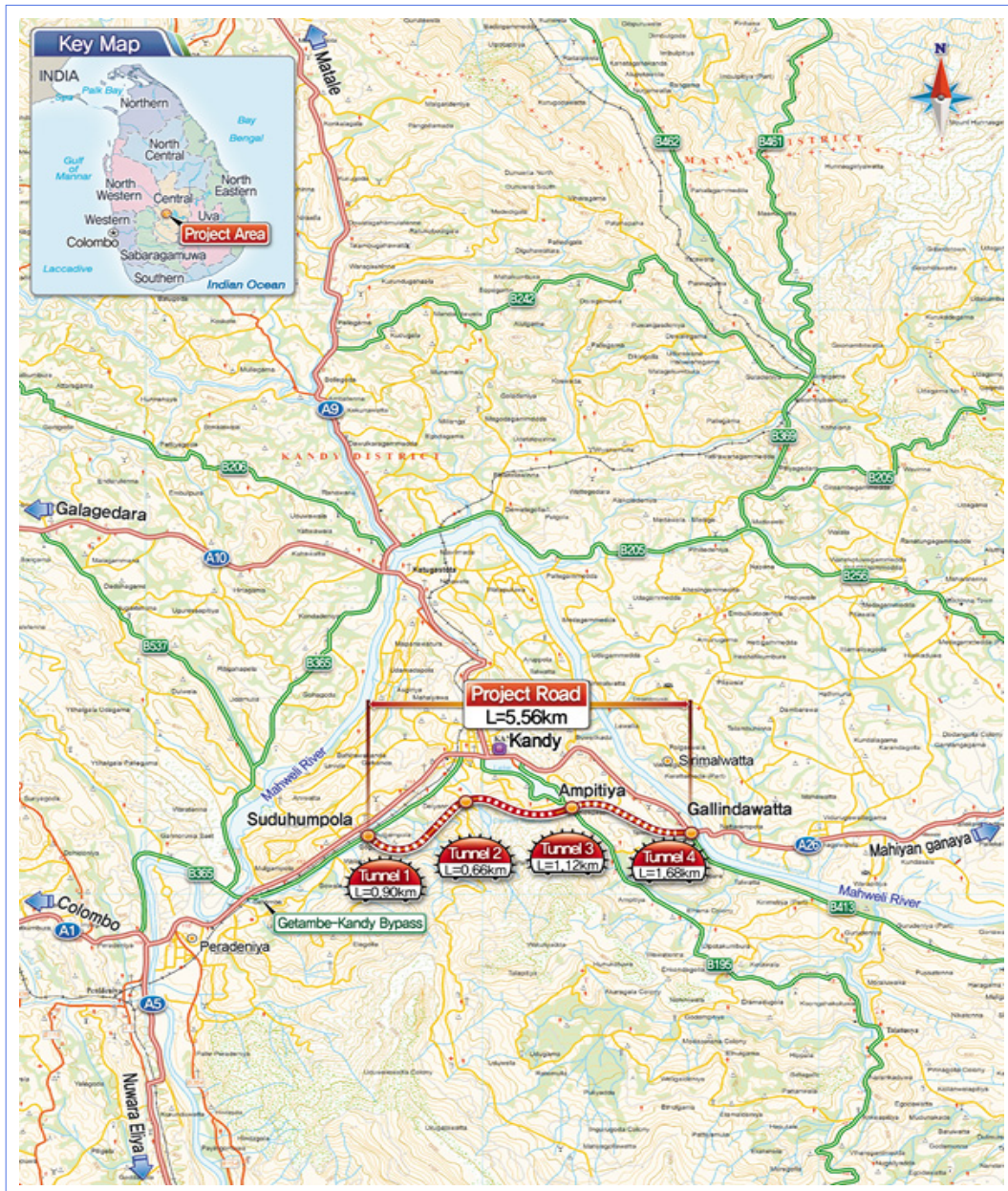
In this project, the feasibility of the Kandy Tunnel project was verified through economic and financial analysis such as traffic demand prediction and cost estimation. In addition, the transferable technologies in the tunnel and road sectors were transferred.

Table II-12 | Kandy Tunnel project contents

Item	Description
Project Name	Kandy Tunnel Construction Project Feasibility Study
Owner	Korea Exim Bank
Implementation Agency	Road Development Authority of Sri Lanka
Project Period	5 months (December 2015–June 2016)
Extension	5.56 km
Major Facilities	Four tunnels, four intersections, three bridges
Target Year	Completion year: 2022; Final target year: 2041
Design Speed	Main road: 70 km/h; Access road: 30 km/h
Pavement Material	Asphalt concrete
Construction Period	Four years (2019–2023)
Total Construction Cost	USD 253,000,000

Source: Korea Exim Bank, 2016, Feasibility Study on Kandy Tunnel Construction in Sri Lanka, Korea Exim Bank

Figure II - 24 | Kandy Tunnel route map



Source: Korea Exim Bank, 2016, *Feasibility Study on Kandy Tunnel Construction in Sri Lanka*, Korea Exim Bank

The design standard for the Kandy Tunnel was based on the Geometric Design Standard of roads (RDA, 1998) and a Policy on Geometric Design of Highways and Streets (AASHOTO, 2011, 6th Edition) as follows:

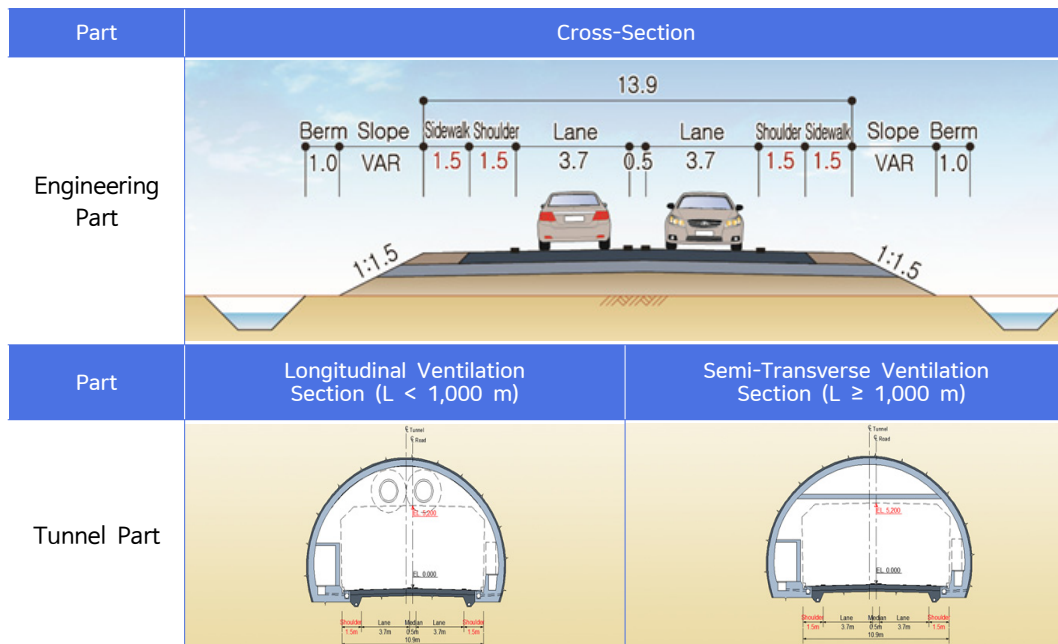
Table II-13 | Kandy Tunnel design standard

Item		Unit	Design Standard (RDA)	Applied Value
Road Class		-	A-E Class	B Class
Design Speed		km/h	-	70
Lane Width		m	3.1-3.7	3.7
Road Shoulder		m	0.6	1.5
Median Strip		m	0.5	0.5
Superelevation	Plain	%	6.0	6.0
	Hill	%	8.0	8.0
	Mountain	%	10.0	10.0
Minimum Radius of Curve	Main Road	m	185	600
	Subsidiary Road	m	25	25
Maximum Vertical Grade		%	9	7.0

Source: Korea Exim Bank, 2016, *Feasibility Study on Kandy Tunnel Construction in Sri Lanka*, Korea Exim Bank

The cross-section of the Kandy Tunnel was determined as follows after considering the characteristics and design standard of Kandy district and after discussion with RDA.

Figure II-25 | Cross-section of Kandy Tunnel



Source: Korea Exim Bank, 2016, *Feasibility Study on Kandy Tunnel Construction in Sri Lanka*, Korea Exim Bank

The Kandy Tunnel Project consists of a total of four tunnels and four intersections, and their locations are as follows:

Figure II - 26 | Locations of intersections and tunnels in Kandy Tunnel



As a result of the economic analysis of the Kandy Tunnel, alternatives 1 and 2 were analyzed as economically feasible and the B/C of alternative 1 and alternative 2 was 1.25 and 1.24, respectively.

Table II -14 | Result of the economic analysis of Kandy Tunnel

Item	Unit	Alternative 1	Alternative 2
B/C	-	1.25	1.24
NPV	USD 1 million	29.9	29.5
IRR	%	14.33	14.28

Source: Korea Exim Bank, 2016, *Feasibility study on Kandy Tunnel Construction in Sri Lanka*, Korea Exim Bank

3) Connectivity with this Project

This project is not to merely connect the Tennekumbura and Katugastota areas of Kandy City but to examine the eastern axis of Kandy City's external circular network in the future. So for the completion of the circular network, the tunnel should be constructed in advance. In addition, because Tennekumbura, the terminal point of the Kandy Tunnel, is also the starting point of this project, it is necessary to make effective connections by complementing each other when carrying out the projects in the future.

3.1.4. Central Expressway Construction Project

1) Background

For its effective development, the Sri Lankan government established the “National Road Master Plan” to strengthen overland infrastructure. In this plan, an expressway network, which considered economy and traffic demands, was suggested, and the Central Expressway is one of the important plans.

The Central Expressway is divided into two stages. Stage 1 is from Kadawatha through Kurunegala to Dambulla. To access Kandy City, an expressway plan, departing from Kumunagara in branch line and accessing Galagedara, about 10 km far from Kandy City, was established. In Stage 2, plans are under way to connect to the northeastern part of Sri Lanka.

Stage 1 of the Central Expressway was renamed from the previous Northern Expressway Project, and the first section will follow the linearity of Colombo–Kandy Expressway whose feasibility study was completed in 2001 from Kadawatha, located in the 3rd section of the circular expressway construction project in the outskirts of Colombo, to Gampaha, and the next section will follow the route established in the Northern Expressway Project. The Pothuhera–Galajidar section, which is linked to this project, belongs to Stage 3 of the Central Expressway Project.

Table II-15 | Central expressway project stages

Stage	Location
Stage 1	Kadawatha (0.0 km) to Meerigama (37.1 km)
Stage 2	Meerigama (37.1 km) to Kurunegala (76.8 km)
Stage 3	Pothuhera (0.0 km) to Galagedara (Kandy) (32.5 km)
Stage 4	Kurunegala (76.8 km) to Dambulla (137.1 km)

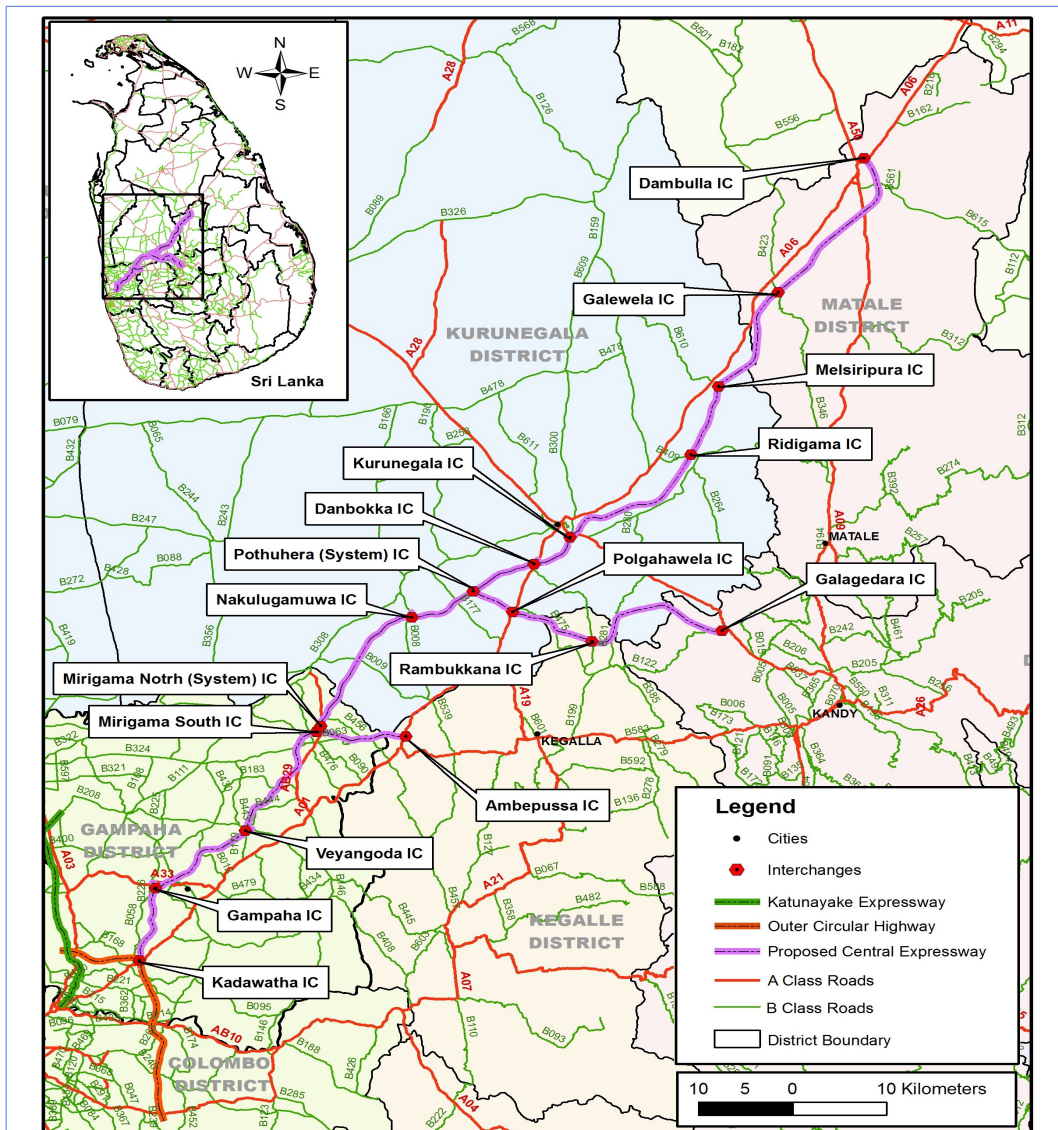
Source: Road Development Authority, 2016, *Official website of Central Expressway* (<http://www.cep.rda.gov.lk>).

2) Connectivity with this Project

The main traffic of Kandy City is the traffic flow to and from the capital Colombo through the national roads A1 and AB42, and traffic congestion also occurs around those roads. However, when the Central Expressway is completed, the traffic pattern of Kandy City will change around the national road A10 in the northwestern part where an IC is located to access the Central Expressway.

Because of this change in traffic patterns, the development potential of the northern and northwestern regions is expected to be improved. In addition, because the traffic congestion at the Kadawata intersection is expected to be intensified, the distribution of traffic volume through alternatives to be suggested in this project is necessary along with the connection with the northern part of Kandy City, which will be developed in the future, and eastern part of Kandy City, which was established as a future urban development axis.

Figure II - 27 | Location of central expressway



Source: Road Development Authority, 2016, *Official website of Central Expressway* (<http://www.cep.rda.gov.lk>)

3.2. Problems in Related Plans

A plan is under way to connect the Central Expressway with major cities and tourist sites such as Colombo, Kandy City, and Dambulla, but because of insufficient connectivity of the existing roads that can connect the expressway with Kandy City, the applicability of the expressway is reduced. Therefore, it is necessary to find a way to maximize the utilization of the expressway.

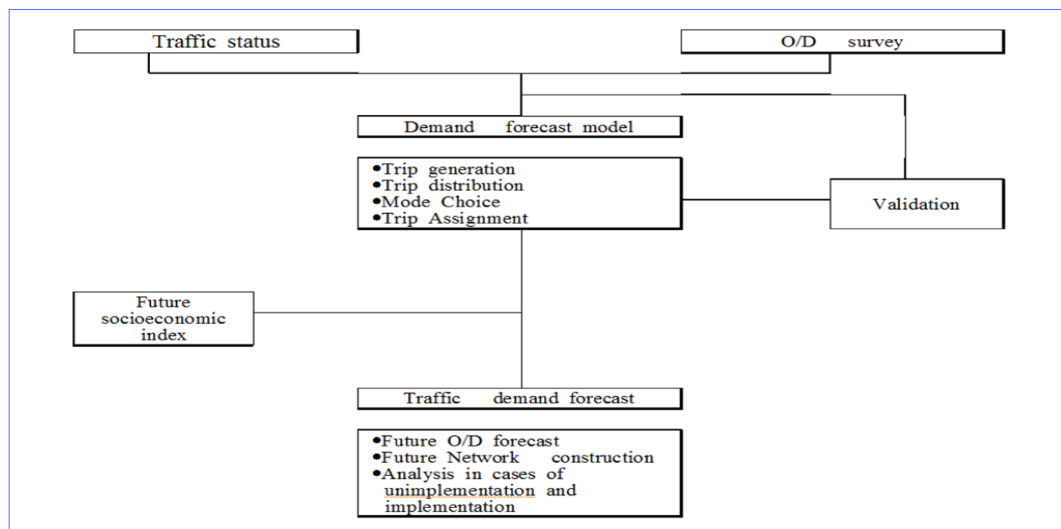
In the traffic improvement plan of Kandy City, a circular road network through supplementation of existing roads has been suggested. However, it is a passive road network plan focusing on supplementation of existing roads and it cannot sufficiently solve the fundamental cause of the urban traffic congestion. Consequently, establishing a road network system that can supplement the original plan is considered necessary.

4. Future Demand Analysis

4.1. Selection of basic data

In this study, a representative 4-stage method of forecast from among different methods of forecast of traffic demand was applied. It is a method with which traffic demand is forecasted sequentially through 4 stages such as trip generation, trip distribution, mode choice and trip assignment.

Figure II - 28 | Procedure of traffic forecast



The traffic demand analysis performed in this study used O/D and network of 「Feasibility Study on Kandy Tunnel Construction in Sri Lanka, 2016」 prepared recently as basic data.

Table II-16 | Overview of base data in traffic forecast

Division	Contents
Zoning system	• Kandy City and 17 zones of surrounding area
Area subject to the analysis	• Kandy City and its surrounding area
Reference year	• 2016
Final targeted year	• 2041

4.2. Setting of scope of analysis

4.2.1. Temporal scope

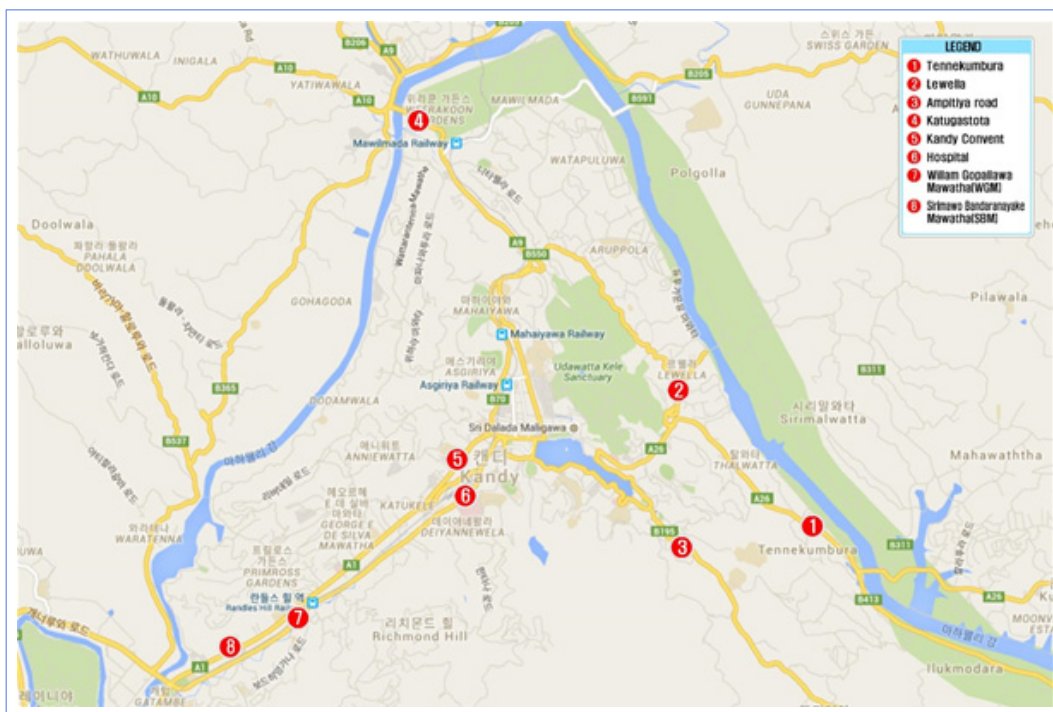
In this study, the year 2016 for which updated data are available and can be utilized was determined to be a reference year for estimation of traffic demand, and the public service start year is set as the year 2041, 20 years after opening.

- Reference year: 2016
- Year of initial analysis: 2022

4.2.2. Spatial scope

The area of influence which is considered as the spatial scope of the demand analysis includes Kandy City and its surrounding area where significant change of traffic pattern is expected to occur due to the project implementation.

Figure II - 29 | Spatial scope



4.3. Revision of Basic Data

4.3.1. Traffic Zone System

The traffic zone refers to a spatial range that serves as a basic unit of analysis and estimation on passengers and cargoes. We can identify the socioeconomic characteristics of each zone and perform analysis and estimation.

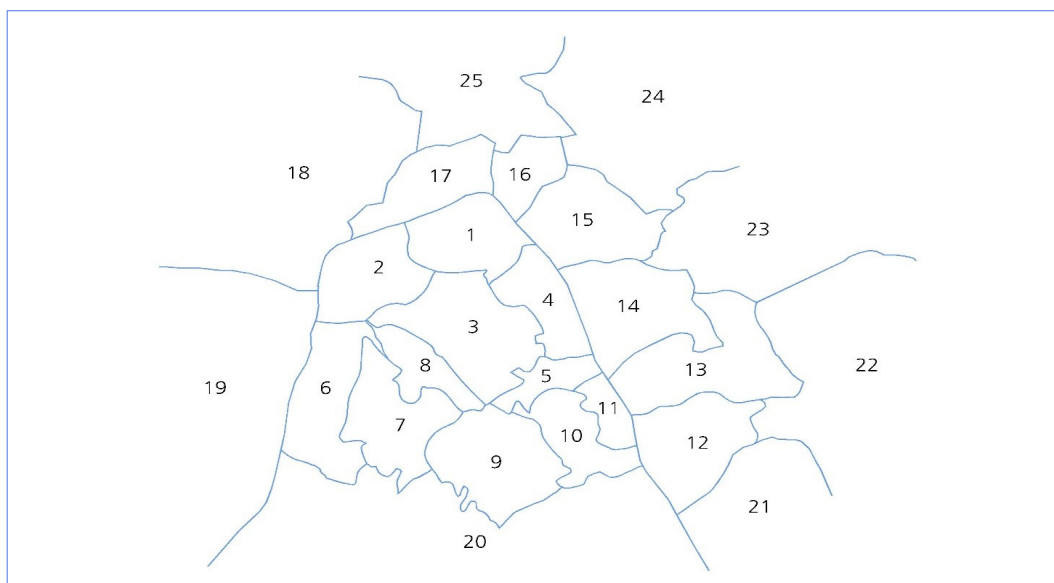
The criteria for traffic zone establishment should include the use of land with similar nature, matching the traffic zone with the administrative zone, if possible, matching the arterial roads and subsidiary arterial roads with zone boundary, and careful restructuring of traffic zone in surrounding areas around project routes.

Considering the change in traffic patterns when this project is implemented, the existing 17 zones in the Feasibility Study on Kandy Tunnel Construction in Sri Lanka (2016) were subdivided into 25 zones and used for demand prediction in this project.

Table II-17 | Zoning system

No	District, Division	No	District, Division
1	Mawilmada	14	Pallegunnepana South
2	Siyambalagasthenna	15	Polgolla
3	Nittawela, Watapuluwa	16	Balanagala
4	Mahaweli Uyana	17	Nawayalathenna
5	Watapuluwa South	18	To North West
6	Wattaranthenna	19	To West
7	Mapanawathura, Poorna Watta East	20	To South
8	Pitakanda Gama	21	To East South
9	Mahaiyawa	22	To East#1
10	Aruppala West	23	To East#2
11	Aruppala East	24	To East North
12	Sirimalwatte	25	To North
13	Pallegunnepana North	-	-

Figure II-30 | Zoning system



4.3.2. Network Revision

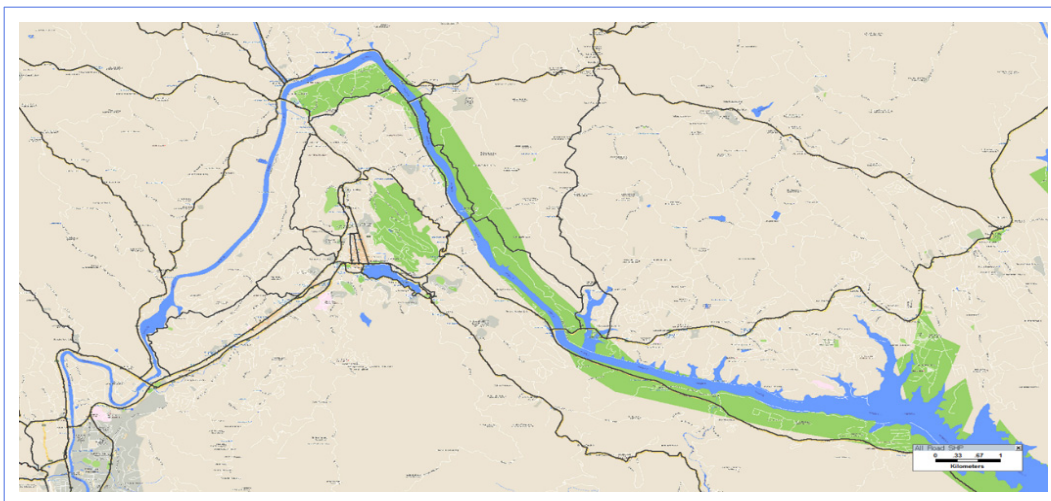
1) Base year network revision

In this project, the revision will be made by reflecting the reality of road network based on the network data of "Feasibility Study on Kandy Tunnel Construction in Sri Lanka, 2016." The number of cars, extensions, and property data on the roads of Kandy City and the surrounding areas, which are under the influence of this project, will be compared and examined through field surveys and various literatures. In addition, to properly distribute internal traffic, the number and location of centroid and centroid connectors will be revised.

To calibrate the current situation, it is necessary to compare the network used as the basic data with the actual network of the base year for revision. If a network error occurs in the impact zone, the travel time can be overestimated or underestimated, and unrealistic analysis results can be produced. Therefore, to prevent this and simulate a realistic traffic pattern, it is necessary to revise the base year network considering the following points:

- Whether the number of lanes or capacity of the network is miswritten
- Whether the routes in need of analysis in the impact zone are omitted
- Necessity of the addition or location adjustment of centroid connectors
- Necessity of link length adjustment
- Study on the relevance of link travel speed and delay at intersection
- Decision on zone size, traffic demand, and detailed network map according to observed traffic volume

Figure II - 31 | Base year network



2) Future Year Network Revision

For future network, the problems in basic network will be revised first and then the road network data, which are not reflected, will be supplemented and revised after reviewing the related plans.

4.4. Calibration of Transit Assignment Model

4.4.1. Precondition of Transit Assignment

The transit assignment will be performed using user equilibrium assignment that minimizes the travel time of each road user. In performing the transit assignment, the link cost function should be constructed so that the difference between link traffic volume obtained using O/D, network data, and base year 2016 data and actual traffic volume is within the error range. The assignment method, traffic delay function, and the network should be constructed so that the transit assignment model can sufficiently explain the current traffic patterns.

4.4.2. Calibration of Transit Assignment Model

To accurately predict the traffic demand of the future year, calibration of the base year as the basis of the analysis must be performed. In other words, the reality simulation ability of the model should be evaluated by comparing the actually observed traffic volume and the assigned traffic volume obtained from the traffic analysis.

4.4.3. Project Route Transit Assignment

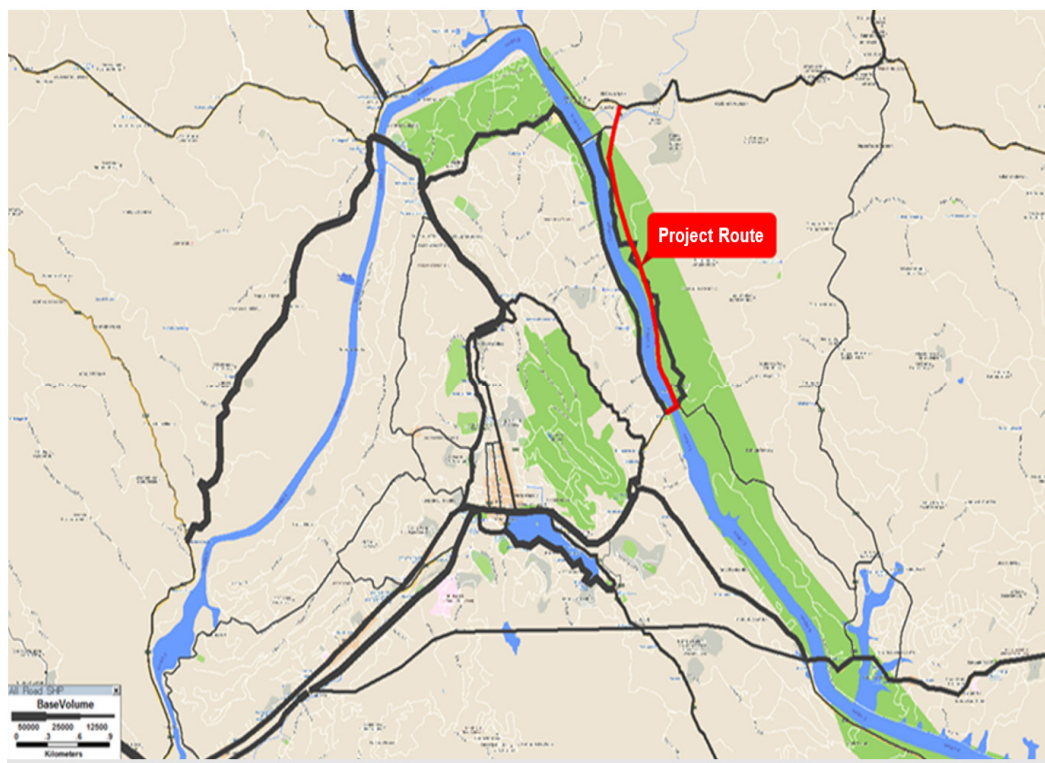
Kandy City, the target area of this project, is the center of traffic connecting major points. However, transit traffic frequently occurs between the major points of Kandy City, aggravating the traffic congestion in the city center. Therefore, the street network traffic volume was assigned on this project route so that the total system travel cost can be minimized.

The traffic volume of the A26 line and B195 line passing through the city center connecting Yatiwawala area in the northwest and Dambawela area in the southeast was assigned on this project route.

The future traffic volume in 2022, the final target year of each alternative, is estimated at 13,566–16,766 cars/day.

Figure II - 32 | Result of future traffic volume estimation

Traffic Volume	Basic Alternative	Alternative 1	Alternative 2	Alternative 3
Traffic volume in 2022 (number of cars/day)	16,766	14,927	14,904	13,556



III. Case study on Korea's experiences

1. Case Study of Arterial Road Network plan in Korea

Since the end of the Korean War in 1953, Korea has faced many problems before it became the stable economic state that it is today. To overcome various traffic congestion problems, Seoul, with a population of 10 million people, has attempted to solve traffic problems through bypass processing of urban traffic flow by constructing arterial roads, such as the Gangbyeon Expressway and Olympic Expressway, to facilitate traffic flow between the east and west and Inner/Outer Circular Expressway in a stepwise manner. Small- and medium-sized cities in Korea have also been faced with traffic problems, some of which have been solved whereas others have not been solved.

To solve the traffic concentration problem faced by Kandy City, we will seek for a way to construct an applicable arterial road network through an analysis of the spatial structure and a change in the street network of Seoul and small and medium cities in Korea, and will preempt any possible problem in the future.

1.1. Change of Spatial Structure and Street Network in Seoul

1.1.1. Change of Spatial Structure

Seoul was formed around the areas including five castle areas and Seongjeo 10-ri as its boundaries without a great change from the Joseon Dynasty until the Japanese colonial period. Like the other naturally-occurring cities, Seoul has been constructed in a type monocentric city where social and economic activities are concentrated around the city center formed in the past.

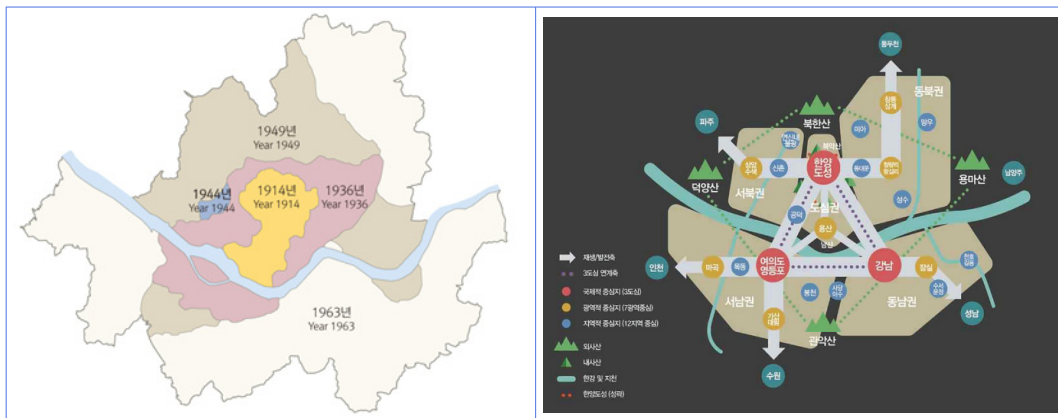
After the 1960s, Seoul started to be rapidly expanded due to the development of new city areas along with the incorporation of Yangju and Gimpo County of Gyeonggi Province and Gangnam area, except Yeongdeungpo and Noryangjin, into Seoul. Consequently, Seoul was

changed to poly-centric structure that expands and distributes the city function to the outskirts of Seoul.

In particular, compared to the existing city centers with vulnerable development conditions, the southeast life zones around Yeongdong sub-center with high development potential grew more actively. Currently, Seoul is operated in one center and five sub-center system, including the existing city center, the north-western life zone around the Sangam and Susaek area, the southwestern life zone around Yeongdeungpo, the southeastern life zone around Yeongdong, and north-eastern life zone around Cheongyangri and Wangsimni.

In the process of change in spatial structure of the city center in Seoul, Seoul has maintained the consistency of multi-centric structure since the 1960s. However, some changes occurred in other important development areas according to the city development.

Figure III - 1 | Change of administrative district and spatial structure of Seoul



Source: Seoul Metropolitan City, 2014, 2030 Basic Urban Plan for Seoul, Seoul Metropolitan City

1.1.2. Change of Arterial road Network in Seoul

The road network of Seoul is a mixture of radial-type, grid-type, and circular-type roads and this is related to the process of city formation.

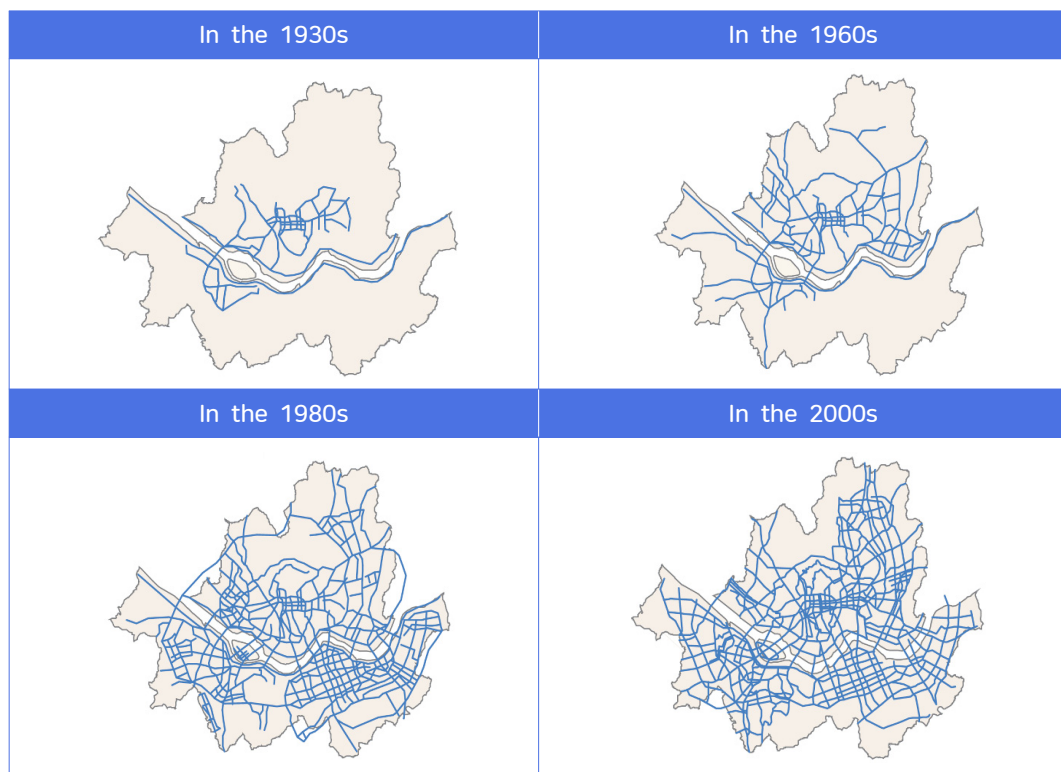
In the past, the traffic network of Seoul had a street network where grid type streets in four Great Gates were only connected with some peripheral areas such as Mapo and Yeongdeungpo. In the 1950~1960s, however, Gangbuk-centered road network project started to be carried out to improve the poor urban conditions. In particular, a new radial road that connected the city center with the outskirts of the city was constructed in the 1960s and a bridge maintenance project was also carried out to disperse the population of Gangbuk while

carrying out road expansion and improvement project in city centers to reduce the traffic congestion.

In the 1970s, a new town was constructed in Gangnam, the outskirts of the city, to respond to rapid population increase and bridges were also additionally constructed for the development of the southern part of the Han River. In the 1980s, access roads to Olympic Stadium were constructed to help attract world-famous sports events such as 86 Asian Games and 88 Olympic Games and road networks connected to subway stations were also constructed as the subway expansion projects started to be carried out in earnest. In addition, a grid-type road network developed in Gangnam area.

In the 1990s, the radial and circular type urban expressway network was constructed through the maintenance of arterial roads including urban expressways and the accessibility and connectivity between upper-level roads (urban expressway) and lower-level roads were improved. In addition, the low-cost and high-efficiency road capacity improvement projects, such as improvement of intersection structure and bottleneck sections, were promoted.

Figure III - 2 | Change of arterial road network in Seoul



Source: The Map of Seoul, Seoul Archive

1.2. Implications in the Process of Arterial Road Network Construction in Seoul

1.2.1. Problems in Existing Street Network Construction Process

1) Gangbyeon Road Plan that did not Consider Environmental Aspects

The Gangbyeon roads including the Gangbyeon Expressway connecting the east and west of Seoul and Olympic Expressway were installed for the purpose of flood damage prevention and improvement of traffic flow through the construction of roads using strengthened river banks.

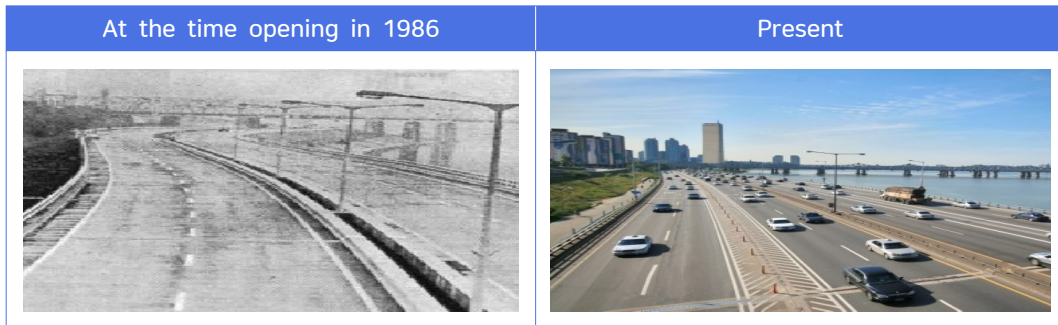
In the early years, they were intermittent roads mixed with four-lane and two-lane roads. However, due to the lack of road capacity and the risk of accidents according the increase in traffic demand such as the development of Gangnam new city and the Olympic Games, they became the freeway-type eight-lane roads exclusively for automobiles.

The Gangbyeon Roads contributed to the improvement of traffic flow as the multi-lane continuous type roads and major arterial road network of the city. However, the problem of the environment and the ecosystem damage by the construction of the bank road was raised during the road construction and people could access the waterfront of the Han River only through the limited access facility, making it difficult for them to freely use the waterfront spaces. In addition, the landscape of Han River was damaged due to the dimensional facilities for bridge connection and bridges for overcoming geographical conditions.

2) Dimensional Facility Plan Centered on Securing Road Capacity

Due to the population increase and the rapid increase of the number of automobiles in Seoul, the traffic volume was concentrated in the city centers and the road capacity increase plan was implemented through overpass construction and bridge covering works due to the limitation of new roads opening in existing city centers. In the past when the circular road network was not constructed and traffic was concentrated in the center of Gangbuk, these dimensional facilities were effective in improving the traffic flow. However, their functions gradually decreased when the old city center declined and the new city center Gangnam emerged along with the balanced development of the city and improvement of traffic systems such as road network and public transportation system. In addition, these facilities, along with the safety problems caused by their deterioration, started to obstruct regional development by damaging the urban aesthetics and causing the disconnection between the regions.

Figure III-3 | Olympic expressway's past and present

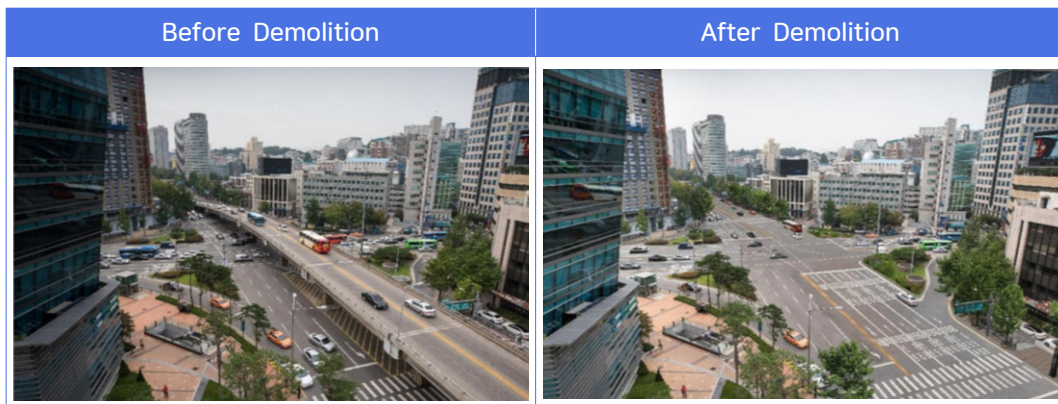


Source: The Economic Daily, News article on the opening of Olympic Expressway

1.2.2. Current Direction of Street Network Construction in Seoul

The transportation policy of Seoul, which started to be promoted in the 2000s, now changed its paradigm to the pedestrian/public transportation centered paradigm. As a part of this policy change, the covered roads and overpasses were removed and dedicated public transportation zones were constructed. The overpasses that supported the smooth access of cars to the city center in the past began to be demolished due to their deterioration, damage to urban view, and obstruction to regional development and public demand for demolition of overpasses increased greatly from 2003 when the Cheonggye overpass demolition project was successfully completed. In addition, in order to build pedestrian-centered traffic environment, dedicated public transportation zones started to be considered and plans are under way to gradually expand their range starting from the appointment of Sinchon dedicated public transportation zone in January 2014.

Figure III-4 | Before and after overpass demolition



Source: Dong-A Ilbo, 2015, News article on demolition of Seodaemun overpass

1.2.3. Application to This Project

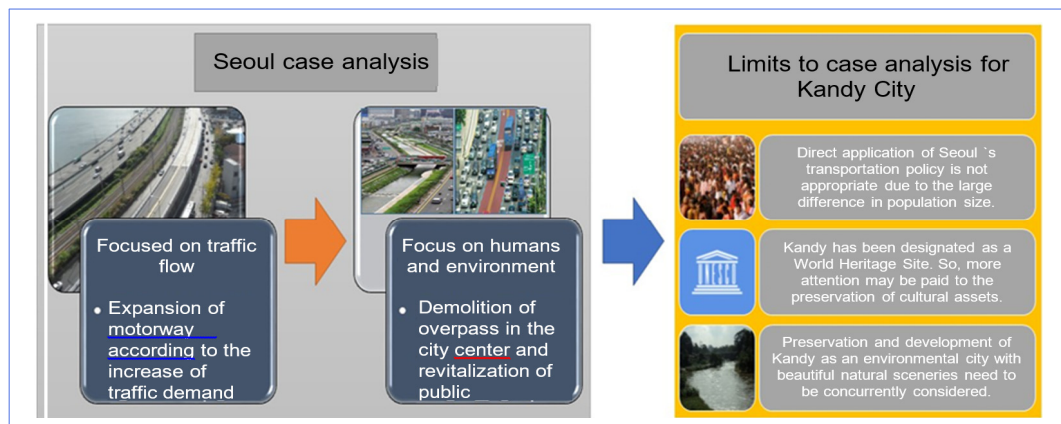
Seoul and Kandy City have similar traffic patterns in which traffic is concentrated in old downtown areas. Seoul developed the Gangnam area in the southern part of the Han River and Kandy City developed new areas in the eastern part of the Mahaweli River. Accordingly, it is expected that both cities will show similar urban development structure in the future.

However, because Seoul is a metropolitan city with a population of 10 million, the traffic policy of Seoul has been focused on securing a large-scale motorway and an urban traffic capacity suitable for such a large population size.

However, because Kandy City is a relatively small city with a population of 150,000, it is difficult to apply the traffic policy of Seoul as it is. In particular, Kandy City has been designated as a World Heritage Site and we should thus pay attention to the preservation of its environment and cultural assets. As such, it is difficult for Kandy to introduce the traffic policy of Seoul that focused on the facilitation of traffic flow.

Therefore, it is necessary to study a traffic network construction case that is more suitable for Kandy City by examining cases that are more similar to the latter: high-altitude, basin-shaped cities that are geographically similar to Kandy City; highly dense cities where population is also concentrated; and cities with a high historical value and have similar characteristics as Kandy City, a World Heritage Site. It is also considered necessary to review the road plans that are in line with the surrounding road network plans such as the Central Expressway Project that is currently being constructed, the road extension project, and the Kandy Tunnel Project funded by the World Bank.

Figure III - 5 | Limits in the application of case analysis on transportation policy in Seoul



2. Analysis of Similar Characteristics of a City Development Case

In Kandy City, an ancient city of Sri Lanka in terms of historical and cultural development, the road network system has been constructed in an unsystematic way for the preservation of the historical districts. In terms of geography and land use, it is a basin-shaped city located in a highland. Because of the nature of the highlands, the urban system has been constructed in a form of monocentric city and the transit traffic is concentrated in the city center, causing traffic congestion in the CBD. In terms of humanity, society, and environment, chronic urban traffic congestion occurs in Kandy because of high population density caused by urban population increase.

After selecting Korean cities with similar characteristics as Kandy, such as historical, cultural, geographical, land, humanistic, and social characteristics, we will suggest a traffic network improvement method tailored for Kandy by reviewing the cases to improve the problems according to each characteristic.

Table III-1 | Summary of similar characteristics city case analysis

Classification	In Terms of Historical and Cultural Development	In Terms of Geography and Land Use	In Terms of Humanity, Society, and Environment
Current state of Kandy	Repository of cultural assets designated by UNESCO as a World Heritage Site (1988)	Limited spatial structure of the basin-shaped terrain surrounded by steep mountains (500 m above sea level)	Highly overpopulated city (5,558/km ²)
Comparable Korean cities	A UNESCO-listed city that retains its rich cultural heritage and functions as a base for history and culture	A city where transit traffic is concentrated in the city center from all directions because of the geographical nature of the highlands	Comparable Korean cities with similar population and city area, and with largely the same population density
	Gyeongju (1995) Gongju (2015)	Wonju (300 m) Chuncheon(600m)	Guri (5,650/km ²) Osan (5,048/km ²)
Problems	Roads were unsystematically constructed for preservation of historical districts	Monocentric city where transit traffic is concentrated in the city center because of the nature of the highlands	Chronic traffic congestion during peak time

2.1. Aspect of High Historical Value City

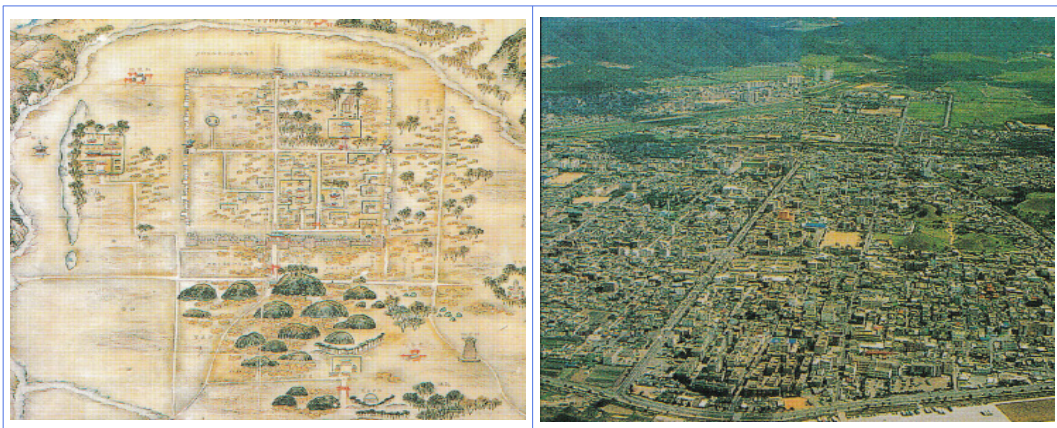
2.1.1. Gyeongju City

1) History and Culture

Gyeongju is operated in 1-center, 5-subcenter, and 5-zone system and it is promoting culture and tourism industry around its center and Gampo zone through the preservation and maintenance of various historical and cultural assets such as Bulguksa Temple and Hwangryongsa Temple. It was an ancient capital of Silla Dynasty for one thousand years and it has grown as a center of international tourism and as the birthplace of national culture. It is also known as the core place of Korean Buddhism as the source of the unification ideology that accomplished the feat of the unification of Three Kingdoms.

In the Silla Dynasty, Bakhukgeose, the founder, integrated six villages and named the country Seorabeol and named the capital Geumseong. During its peak period, there were 178,936 households in 1,360 districts. In the Goryeo Dynasty, it was named Gyeongju and Sadodokbu and Buseo Temple were established in there and East Capital, one of the three capitals, was also established but its name was changed to Gyerimbu in 1,308. In the Joseon Dynasty, it was named Gyeongjubu and the office of Gyeongsangjwado was established in there. In 1995, Gyeongju City and Gyeongju-gun were integrated into current Gyeongju City (Korea Planning Association, 2016).

Figure III - 6 | The past and present urban structure of Gyeongju



Source: Dae-A Engineering Co, 1998, 2016 *Basic Urban Plan for Gyeongju*, Gyeongju City

2) Problems of the Past Traffic Plan

a) Inadequate transportation infra due to mixed type of cultural remains and urban structure and improper development

It had a dual urban structure in which about 600ha of modern buildings were built on about 3,000ha urban structure of Silla cultural remains. The increase of the road was insufficient compared to the increase of the traffic volume and the image of cultural and historical city was gradually fading due to insufficient transportation infra.

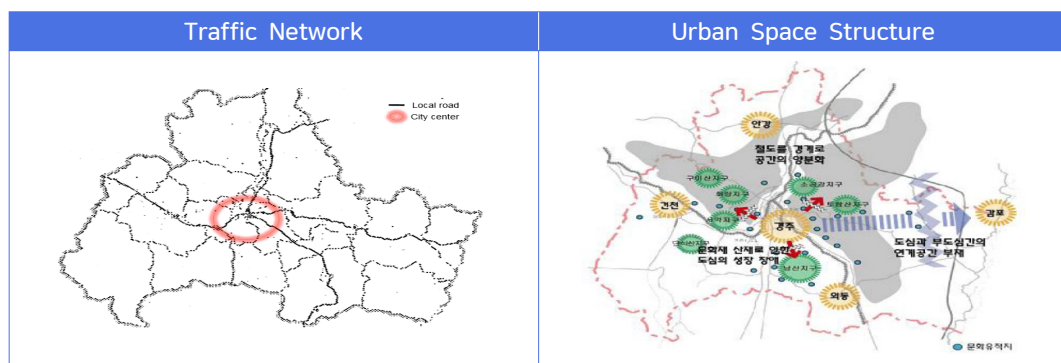
b) Disruption of city center space due to transit traffic such as transit roads and railways

The transit transportation from surrounding cities was obstructing the integration of urban spaces and due to Central Line and Donghae Nambu Line passing through the city center, the west and east side of Gyeongju Station were designated as different purpose districts, not achieving the balance with urban development.

c) Deepened urban traffic congestion due to inadequate arterial road system inside and outside the city

Due to intercity arterial roads traffic flowing into the city area, the urban traffic congestion was increasing and because the cultural remains were distributed throughout Gyeongju, the capital city of the Silla Dynasty, the urban arterial road system was inadequately constructed. In addition, the urban circular road network system to improve the accessibility between individual life zones and the connection between individual tourist spots was also inadequately constructed and it was necessary to secure a systematic pedestrian space in the city and to prevent the vehicle entry around the commercial districts in the city centers.

Figure III - 7 | The traffic network and urban space structure of Gyeongju in the 1970s



Source: 1) Dae-A Engineering Co, 1998, *2016 Basic Urban Plan for Gyeongju*, Gyeongju City
 2) Korea Planning Association, 2004, *2020 Basic Urban Plan for Gyeongju*, Gyeongju City

3) Current Direction for Establishment of Traffic Plan

a) Appointment of surrounding area as Car Free Zone and construction of pedestrian space

For development of cultural asset preservation city suitable for historic city, Gyeongju appointed the areas around historic sites as traffic control districts and it is constructing large public parking lots and transit traffic facilities at the outskirts of the city. At the same time, Gyeongju is promoting a plan to secure pedestrian space by constructing the area around historic sites as Silla cultural asset streets.

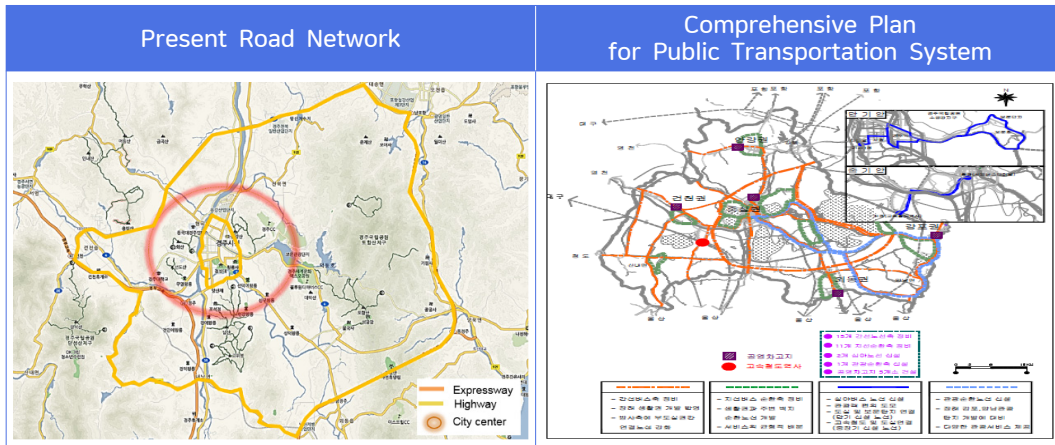
b) Change of public transportation use pattern for sustainable preservation of cultural assets

In order to construct a public transportation system suitable for characteristics of Gyeongju, the bus route system is being reorganized and bus information system is being constructed step by step. In order to improve the satisfaction and convenience of the passengers who use existing expressway bus and intercity bus terminals at the outskirt of the city, integration and expansion of the bus terminals into modern multi-purpose terminals are also underway. In addition, in order to promote the use of bicycle transportation that can supplement the pedestrians' means of transportation, the bicycle transportation system is being constructed in connection with the buses.

c) Promotion of the construction of circular road network and improvement of urban arterial roads and district roads

The transit traffic passing through the city center is bypass-processed by constructing bypass roads that form circular road network in connection with National Highway Route 14 and 20. In addition, improvement of urban roads in each district near the arterial roads is being carried out to secure spaces for safety facilities, parking lots, and road pavement works and to improve their performance. Gyeongju is also promoting the expansion of lane widths of arterial roads and construction of traffic facilities for major arterial roads in urban areas and it is also effectively adjusting the frequency of traffic signal operations.

Figure III - 8 | Present road network of Gyeongju and comprehensive plan for public transportation system



Source: 1) Gyeongju, 2016, Naver Map
2) DGI, 2007, *Gyeongju Long-term Development Plan*, Gyeongju

2.1.2. Gongju City

1) History and Culture

Based on Geum River in east-west direction, Gongju is largely divided into Gangnam life zone, where historical sites are distributed, and Gangbuk life zone, a new town area. As the center of Baekje history and culture as important as Silla cultural areas, it repeated growth through development and preservation of Baekje cultural remains and development of tourist sites and it grew into a central city of Chungcheongnam-do Province.

Historically, Baekje, one of the three kingdoms, moved its capital to Gongju during the reign of King Munju and played the role of center of Baekje culture for 64 years until the fifth King Seong. During the Joseon Dynasty, Gongju played the pivotal role of local administration as one of the four major divisions of the Chungcheong Province. During the reign of King Seonjo, it served as the center of the local government of Chungcheong Province that had 27 counties under its jurisdiction. In 1995, Gongju City and Gongju County were integrated in current Gongju City (Dongbu Engineering, 1998).

Figure III - 9 | The past and present urban space of Gongju city



Source: 1) Haewol, 2013, *Looking at the old map of Gongju*, Express news
 2) Ahn Do-Seong, 2013, *Integration of Gongju City and Sejong City*, Civilian Committee for Integration of Gongju and Sejong City

2) Problems in the Past Transportation Plan

a) Circular road network and access roads that connect major Baekje cultural and tourist sites need to be expanded

Gongju's transportation system is mainly a car-based on-land transportation system with five national roads and six provincial roads forming a radial transportation network around Gongju but there were few circular roads and access roads connecting major tourist sites.

b) City center oriented transportation system makes the traffic congestion worse and worse

Gongju has X-type arterial road network and major traffic facilities are located around city center, forming city center oriented road network system. Therefore, the problems such as disconnection of urban space structure and concentration of transit traffic were occurring.

c) Systematic road network has been inadequately arranged and in particular, the road network near waterfront has been insufficiently improved.

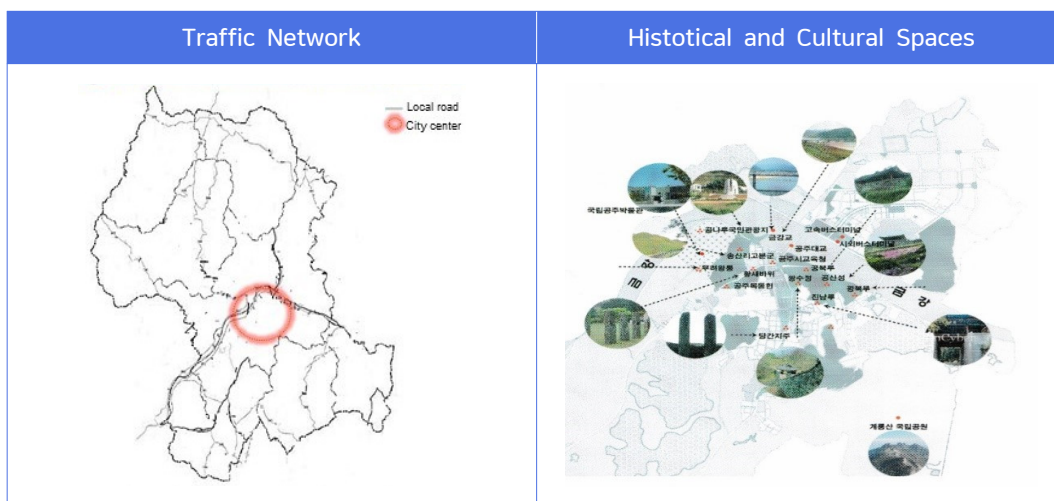
The linear form of arterial roads was inadequate and district roads were directly connected with the arterial roads. Therefore, smooth traffic flow was not achieved because the access

3) Current Direction for Establishment of Traffic Plan

a) Gradual construction of urban traffic system effective in preservation of history and culture

For preservation of history and culture, Gongju changed its traffic system into public transportation-oriented transportation system and it is introducing eco-friendly and efficient transportation system such as BRT (Bus Rapid Transit), comprehensive transfer center, and high-speed railway system. It is also promoting the revitalization of bicycle transportation through the construction and maintenance of bike roads linked to bus stations and the expansion of unmanned bicycle rental facilities. In order to reduce the traffic volume in Gangnam where cultural assets are scattered, Gongju installed a public parking lot that can concentrate the road side parking space in the outskirts of the city and it is introducing a traffic reduction program such as carpool system and operation of commuting buses in cooperation with companies.

Figure III-10 | Traffic network and historical and cultural spaces of Gongju in the 1970s



Source: 1) Dongbang Construction Co, 1994, *2011 Basic Urban Plan for Gongju*, Gongju City
2) Dongmyung Engineering Corporation, 2013, *2020 Basic Urban Plan for Gongju*, Gongju City

b) Expansion of road network inside and between the districts and strengthening of accessibility between the tourist sites

To improve the connectivity between the towns and villages, Gongju is expanding the local roads and pavement rate and it is carrying out road linearization project. In addition, it is scattering the traffic volume in semi-circular road network (tentatively called "horseshoe-shape road network") and strengthening the accessibility between the tourist sites. It is also planning to construct additional outer circular roads.

c) Strengthening city center access and transit function by improving circular road network

Gongju is building a semi-circular road network using the Geum River waterfront and developing the city in the multi-centric form divided into old city center (cultural assets preservation) and new city center (residence and living center). In addition, it is constructing and improving the roads connecting Yugu - Gangnam - Banpo life zones and enhancing the traffic flow function and life zone connection function through bypass processing of traffic volume passing through city centers. It is also trying to increase the communication and connection functions between the regions by expanding the connection road between Daejeon - Banpo - Gongju - Sejong.

Figure III-11 | Present road network and scenic roads in Gongju



Source: Gongju City, 2016, Naver Map

2.2. Aspect of High Altitude Land City

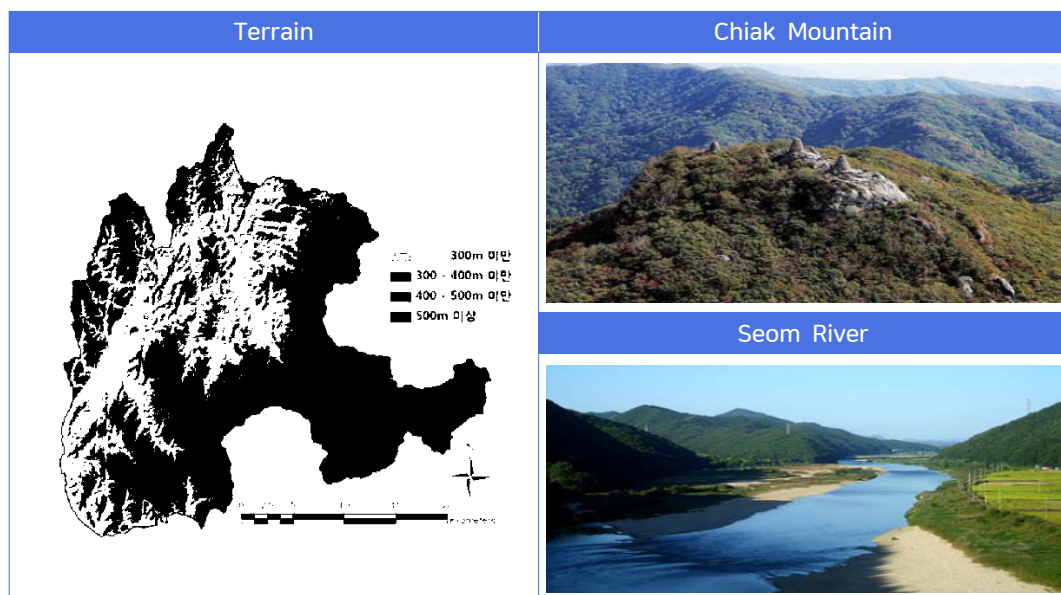
2.2.1. Wonju City

1) Geography and Land

Wonju City is a mixed urban and rural city formed from the basin terrain of the South Han River where the Seom River originating from Taegi Mountain (1,258 m) in Hoengseong County and Yeongwol River originating from Odae Mountain (1,563 m) join with each other. Most of the plains where the Seom River runs are formed in farmlands and the total area of Wonju is 867.4 km² (Extension distance: 41.9 km between East and West, 41.1 km between South and North) and it is composed of 631.7km² forest and 125.7km² farmland (Dongbang Construction, 1974).

Wonju has east-high and west-low terrain. At the eastern part of Wonju, the Chiak Mountain (1,228 m), a branch of Taebaek Mountains, is projected high, making Socho-myeon and Sinlip-myeon mountainous regions. The Taebaek Mountains gradually become lower till it reaches Baekun Mountain (1,087 m) and Mireuk Mountain (461 m) and forms hilly regions and plains when it reaches Munmak-eup, Heungup-myeon, Jiseong-myeon, and Buron-myeon (Gangwon Development Research Institute, 1996).

Figure III-12 | Geography and land use in Wonju city



Source: 1) Wonju Vision 21 Committee, 2000, *Wonju Vision 21 Basic Plan*, Wonju City
 2) Saman, 2014, *2030 Basic Urban Plan for Wonju*, Wonju City

2) Problems in the Past Traffic Plan

a) Difficulty in efficient management of land use due to the nature of highland

The difficulty of development due to the rugged mountains around Wonju and the geographical characteristics of the basin has acted as constraints on urban growth including road construction. Due to sporadic urban development that lacks long-term and comprehensive plan, the urban space structure for construction of urban traffic system has not been sufficiently arranged and due to concentrated distribution of medical and convenience facilities, the problems of unnecessary and concentrated traffic volume have occurred along with inconvenience of people who use the facilities.

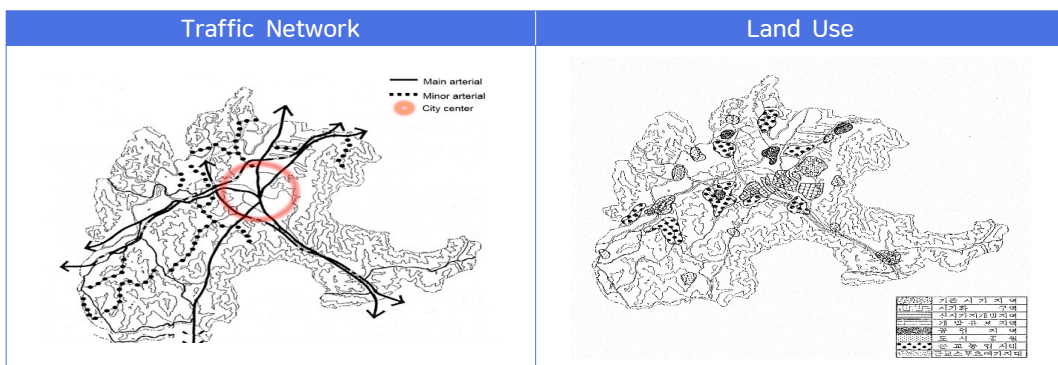
b) Increase of transit traffic volume in the city center due to the characteristics of mono centric city in highland

Wonju's street network is in grid-type system but the railroad passed through the city area and bypass roads were insufficient. Furthermore, the width of roads was narrow and the pavement was poorly conducted. Military vehicles and excessive transit traffic were increasing the traffic congestion in the city because Wonju is an important military point and the lack of circular street network resulted in weakened accessibility of the whole area.

c) Inadequate transportation facilities and lack of traffic connectivity

Compared to the north-south axis, the roads in the east-west direction and the pedestrian sidewalk were insufficiently constructed. It was necessary to expand the road network for smooth processing of traffic between the regions and the traffic in the city and some adjustments to the arterial road network was also necessary along with the dualization and linearization of railway lines. The Central Line was passing through the south-eastern part of Wonju and due to the disadvantage of the geographical condition; there was almost no road connection between the regions.

Figure III - 13 | Road network and land use in Wonju city in the 1970s



Source: Gangwon Development Research Institute, 1996, *General Construction Plan for Wonju*, Wonju City

3) The Current Direction of Traffic Plan Establishment

a) Implementation of road plan that reflects the land use pattern

Wonju is planning to minimize unnecessary traffic volume on the roads by considering the correlation with the land use. In addition, in order to reinvigorate various city activities and prevent traffic congestion, Wonju is establishing the road network system according to the functional allocation of roads and promoting a plan to give a hierarchical order according to the traffic routes and transportation means. Furthermore, the government supports the construction of innovation cities through the relocation of public institutions in terms of balanced regional development. After the governmental approval of the Wonju Innovation City Development Plan in 2007, 13 public institutions, including the Korea ROAD Traffic Authority, completed the relocation.

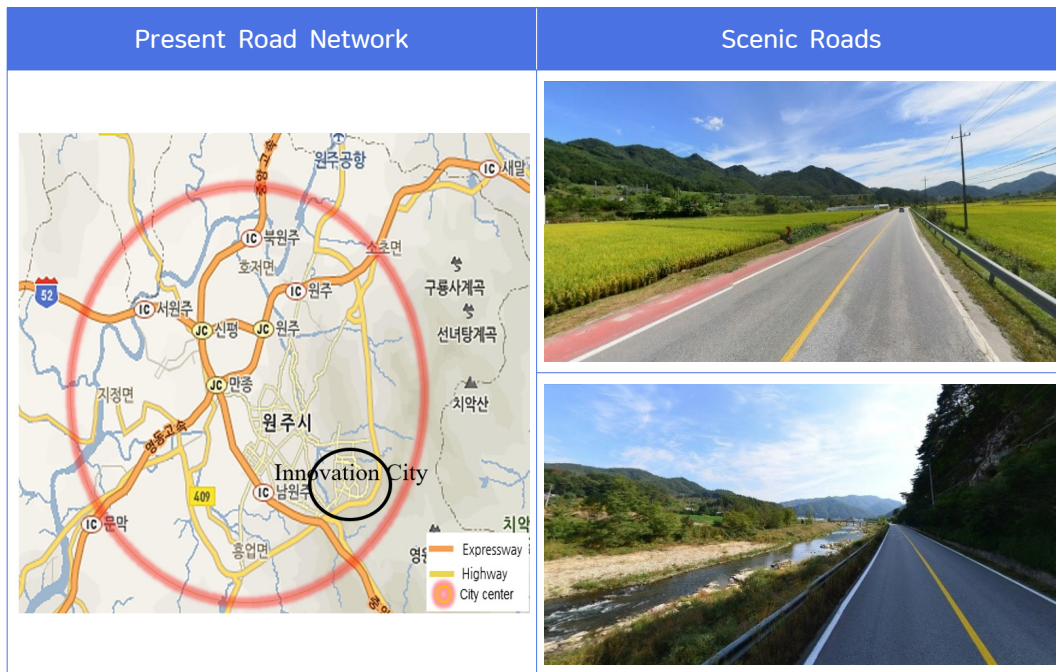
b) Construction of arterial road network and circular urban traffic system considering the expansion of access roads and their accessibility

To guarantee balanced development of urban and rural areas and to give convenience and residential living rights to the residents, Wonju is expanding the arterial road network linking tourist sites, agricultural complexes, and various life convenience facilities. In addition, Wonju is strengthening the connectivity between the transportation means by constructing traffic network system such as smooth transfer system in linkage with metropolitan traffic network and railway network. To suppress the traffic volume passing through the city center as much as possible, Wonju constructed circular road network.

c) Construction of tourist road network system connected to beautiful natural scenic areas

Wonju is constructing tourist road network system that is connected to beautiful scenic areas around Seom River and Chiak Mountain (Wolsong~Oksan~Socho, Haenggu~Bangok~Geumdae) and it is improving and constructing the roads considering the connection between government-supported local roads and national road replacing bypass roads.

Figure III-14 | Present road network and scenic roads in Wonju



Source: Wonju City, 2016, Naver Map

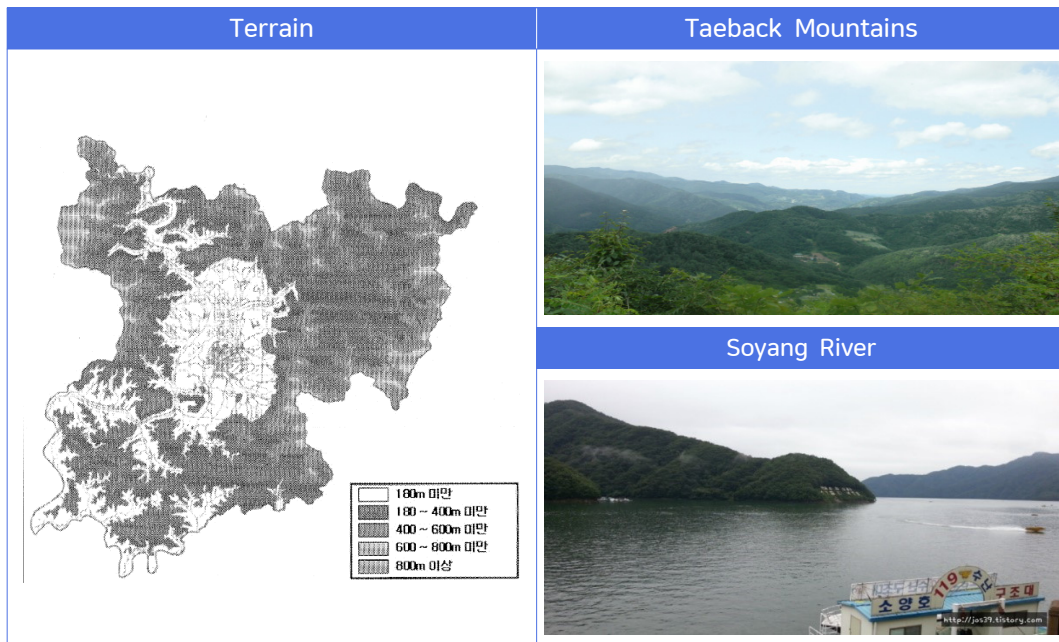
2.2.2. Chuncheon City

1) Geography and Land

Chuncheon City is located in the basin-shaped lowland where the North Han River running southward between the Gwangju Mountains and Charyeong Mountains and Soyang River meet with each other. Chuncheon City is located in a mountainous basin with an elevation of 600 m above sea level that extended from the Taebaek Mountains. The city center forms an urban area at an altitude of 75 ~ 100 m. However, the eastern, western, southern, and northern areas in the outskirts of the city are mostly mountainous regions and they are forming a terrain of average 400~800 m above sea level (Woobo Engineering, 1998).

Urban areas (residential, commercial, industrial, green area) with less than 15% of the slope that can be developed by Chuncheon City are 332.9 km², 29.2% of the Chuncheon basic urban plan area. The other agriculture and forest area is 482.6km², accounting for 43.3%, while the natural environment preservation area is 184.3 km², accounting for 16.5% (Dongil Engineering, 2015).

Figure III-15 | Terrain and land use of Chuncheon city



Source: Dongil Engineering, 2007, 2020 Basic Urban Plan for Chuncheon, Chuncheon City

2) Problems in the Past Traffic Plan

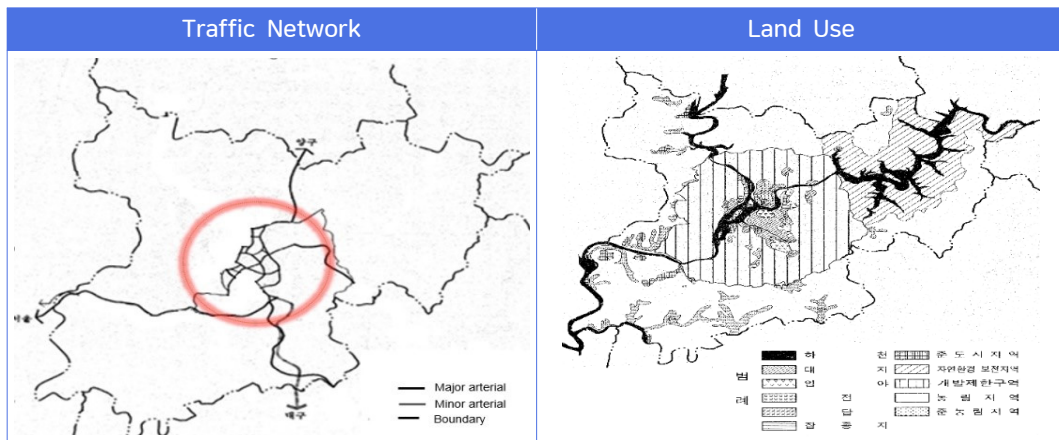
a) Occurrence of traffic congestion sections in the city center according to city center focused development due to basin characteristics

The road network was disconnected due to the passage of the Gyeongchun Line Railway and it was acting as a constraint factor in the land use and the connection system in the city and between local regions was inadequately operated because the development was concentrated in the city center. In addition, due to the concentrated development of the city center, traffic congestion sections occurred because of the disconnected sections between the city center and the city bypass roads.

b) Concentration of life convenience facilities and educational/cultural facilities in the city center

The vulnerable connection roads between six life zones of city limited the growth of the city and the hierarchy of the life zone became vulnerable because of the concentration of life convenience facilities and educational/cultural facilities in the city center.

Figure III-16 | Road network and land use in Chuncheon city in the 1970s



Source: Woobo Engineering, 1998, *2016 Basic Urban Plan for Chuncheon*, Chuncheon City

3) Current Direction of Traffic Plan Establishment

a) Improvement of road structure through re-improvement of city center, Strengthening connectivity between districts

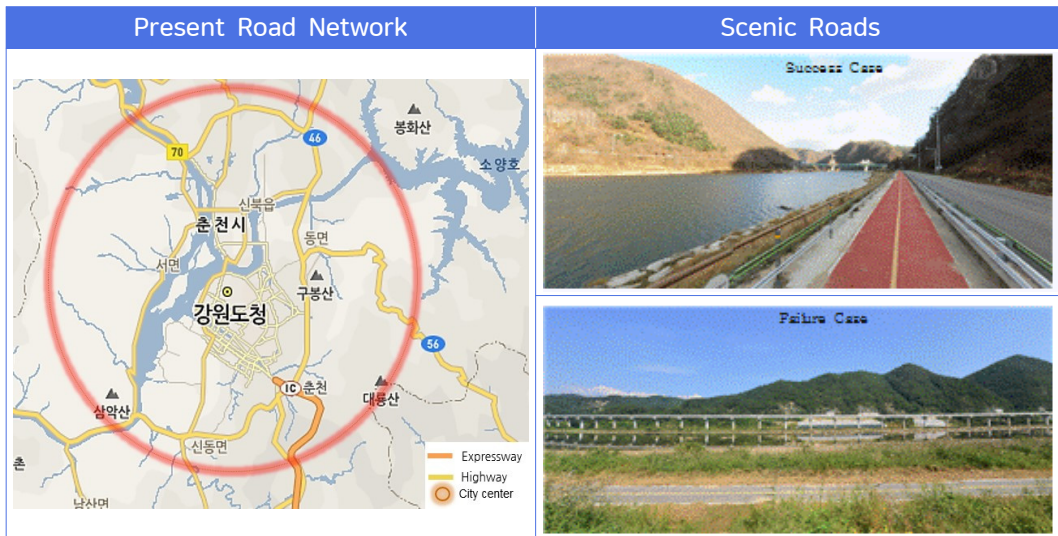
Because the traffic congestion areas are caused by the excess of traffic capacity according to the urban development focusing on existing city center, Chuncheon has constructed two roads for improvement of disconnected section in the city center and it is constructing connection system between outer road system in the city center and arterial road network through the improvement of existing roads of 4 routes. In addition, Chuncheon expects that regional connectivity will be strengthened through the construction of Central Expressway and Hanam-Chuncheon Expressway and regional cooperation and win-win growth will be made possible through the expansion of cultural and economic exchange with neighboring regions.

b) Construction of circular road network to reduce the transit traffic volume eco-friendly scenic roads

Chuncheon is improving the urban road network system connected to outer circular roads while constructing road network in circular radial type in Gangnam district, the existing city center, and constructing road network in grid-type in Gangbuk district. In addition, in order to reduce the traffic congestion in the city center caused by national roads passing through the city center, national bypass roads are being planned or under construction. Chuncheon plans to reduce the traffic congestion in the city center and between districts and enhance the accessibility through the expansion of circular road network connecting the outskirts of

the city. During the construction of beautiful scenic roads around Soyang Lake, there were success cases of harmony with the surrounding environment along with the failure cases of destroyed waterfront space.

Figure III-17 | Present road network and scenic roads in Chuncheon



Source: Chuncheon City, 2016, Naver Map

2.3. Aspect of High Population Density City

2.3.1. Guri City

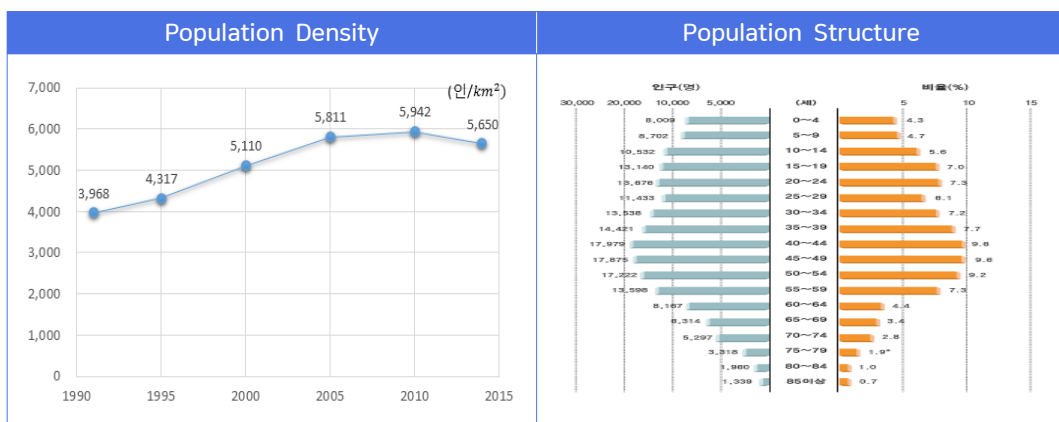
1) Population Density

Because the Guri City has been developed as a planned satellite city for residential purpose to disperse the population concentration of Seoul during the rapid urbanization process of Seoul in the 1960s-1970s, a grid-type road network was constructed from the first urban planning stage.

The population density of Guri is 5.650 people/km² in 2014, 4.6 times higher than the average population density of 1.218 people/km² in Gyeonggi-do. The annual population density growth rate of the past 23 years (1991~2014) is in a slightly higher level of 1.5% (Guri City, 2015).

The population structure of Guri city in the 2010s shows the trend of low birthrate and low death rate, with the number of youths (aged 0~14) stagnating while the number of productive population (aged 15~64) and the number of older population (over 65 years of age) ever increasing. Therefore, such transition of population structure will reduce the cost for youth support but the cost for the elderly support will continue to increase and the continuous increase of the elderly population will require the qualitative and quantitative expansion of the elderly welfare facilities (Gyungho Engineering, 2009).

Figure III-18 | Population density of Guri city



Source: Guri City, 2015, *Guri Statistics e-book*, Guri City

2) Problems in the Past Traffic Plan

a) Chronic traffic congestion in the city center during the commuting hours

Guri City has a good access condition due to the developed transportation network between the east and west and the north and south. However, there are chronic traffic congestion areas in the vicinity of Guri Station and National Highway No. 6 section because the transit traffic and urban traffic are mixed with each other. In addition, the road connection between Galmae-dong and existing city center was inadequately arranged.

b) Lack of eco-friendly road facilities and insufficient road hierarchy system

Dedicated pedestrian roads and eco-friendly road facilities were insufficiently constructed and the hierarchy of the main and minor arterial roads in the city and their organic connection system were not sufficiently arranged.

3) Present Direction of Traffic Plan Establishment

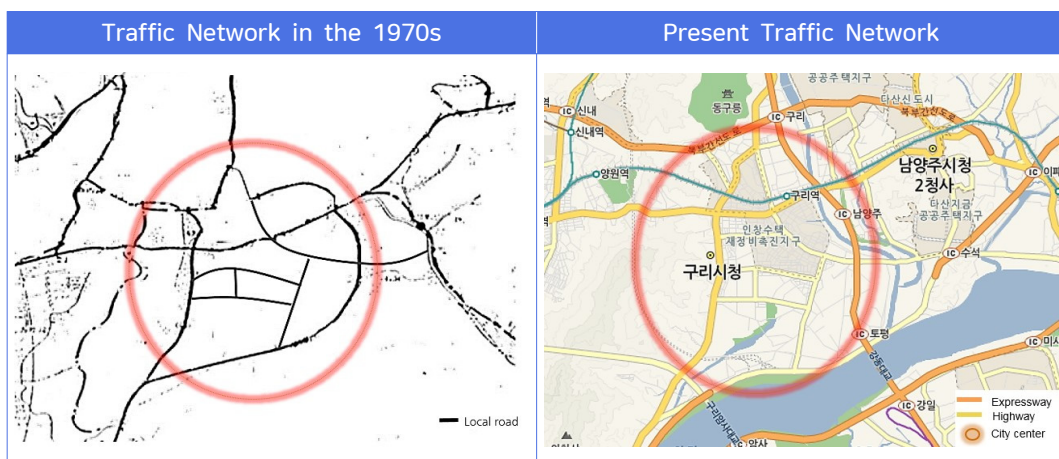
a) Improvement of arterial road network and construction of connection system with the life zones

The BRT is being operated to eliminate the traffic congestion in National Highway No. 6 and to promote the use of public transportation. In addition, Guri is improving the traffic system around Guri Station and constructing/expanding the arterial roads from Guri IC to Namyangju. Guri plans to construct a subsidiary arterial road that crosses the city area to the east and west and the south and north. In addition, it is promoting the extension of Seoul outer ring road to establish the connection system between life zones around the existing national roads.

b) Construction of urban scenic roads and establishment of hierarchy system between access roads

Guri is promoting a circular-type urban scenic roads that include motorway, bicycle road, and pedestrian roads using natural scenery. In addition, it plans to enhance the connectivity between the circular road network and high traffic density areas by establishing road hierarchy system of the arterial roads in each district and life zone.

Figure III - 19 | Traffic network of Guri city in the 1970s and present



Source: 1) Dongmyung Engineering, 1995, *1995 Basic Urban Plan for Guri*, Guri City
 2) Guri City, 2016, Naver Map

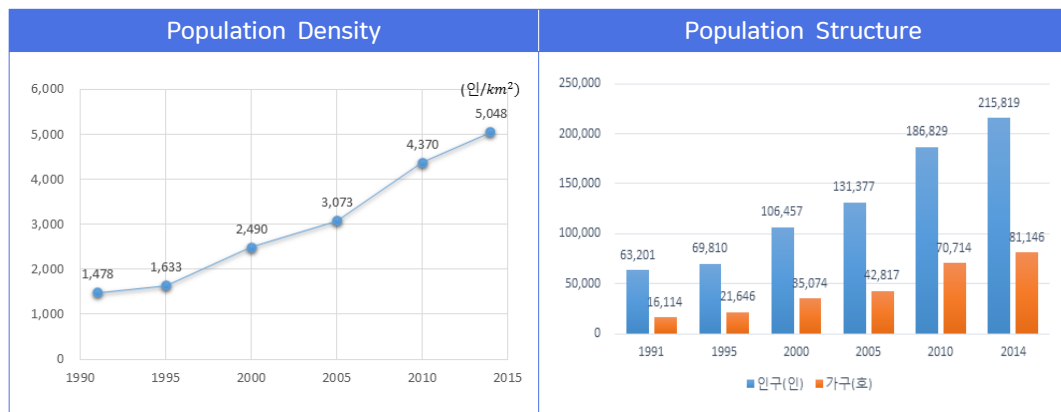
2.3.2. Osan City

1) Population Density

Like Guri City, Osan City is a planned satellite city for residential purpose to alleviate the population expansion of Seoul. The population density of Osan is 5,048 people/km² in 2014, 4.1 times higher than the average population density of 1,218 people/km² in Gyeonggi-do. The annual population density increase rate in the past 23 years (1991~2014) shows a higher level of 5.4% (OsanCity, 2015).

Osan City has grown into a midsize city with a population of more than 200,000 in 23 years through the continuous population increase since the city was upgraded to a city from Osan town (population of about 50,000) in 1989. As of 2014, Osan has 215,819 registered inhabitants in 81,146 households. The population in their 30s accounts for the greatest percentage compared to other age groups. It seems that the recent development of housing complex in Segyo 1 district, expansion of LG Electronics Pyeongtaek plant and construction of AMORE PACIFIC factory caused the population increase in Osan. In addition, the population growth of Osan is expected to continue because people in adjacent cities are looking for a school in Osan City due to childcare policy and innovation education of Osan (Kim Jong-sik, 2012).

Figure III-20 | Population density of Osan city



Source: Osan City, 2015, Osan City Statistics e-book, Osan City

2) Problems in the Past Traffic Plan

a) Inflow of transit traffic into city center due to lack of east-west metropolitan road network

Due to the absence of east-west metropolitan road network connected with Hwaseong and Yongin City, there occurred a concentration of traffic volume in existing government-supported local road No. 82 and extreme traffic delay and congestion in city center due to lack of alternative roads and bypass roads. In addition, the lack of a circular road network to control vehicle entry into the center of Osan caused the deterioration of traffic environment in urban areas.

b) Malfunction of arterial roads and inefficiency of signal operation frequency around crossroads

There occurred too many disconnected sections on the arterial roads and the inefficient allocation of traffic signal time around crossroads in some sections made the optimized signal operation necessary according to the change of traffic volume.

3) Present Direction of Traffic Plan Establishment

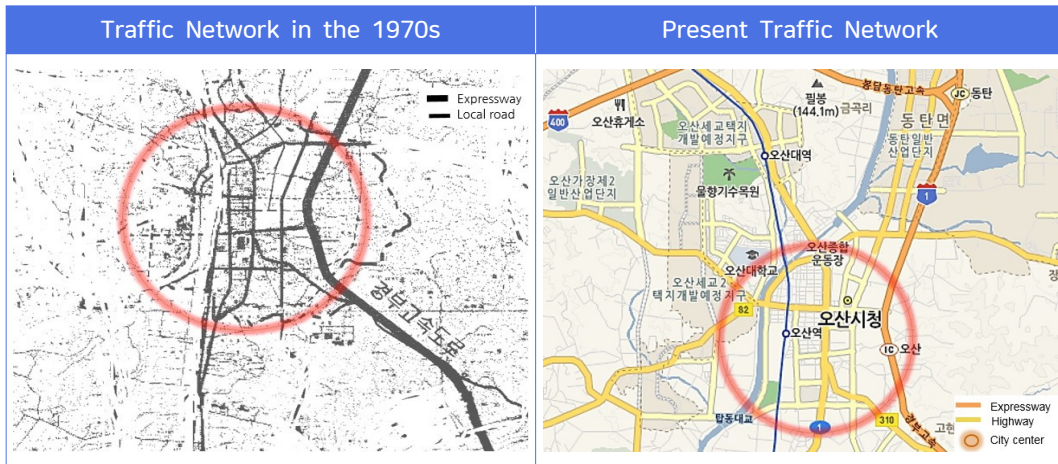
a) Expansion of metropolitan traffic system and construction of circular road network

The accessibility between districts will be improved through the expansion of metropolitan traffic network system (arterial road between Songsan-Dongtan, Bongdam-Dongtan highway, bypass road of National highway No. 1, etc.) and major arterial roads passing through the planned areas. In addition, Osan is planning to construct bypass road network to make the bypass/distribution processing of the traffic volume possible through the construction of circular road network and grid-type road system.

b) Securing the sustainability of arterial roads and improvement of signal operation system

In order to solve the bottleneck phenomenon on National Highway No. 1 connecting Suwon and Pyeongtaek, Osan is promoting the improvement of road functions by widening the road width and it is also constructing roads in disconnected arterial road sections. In order to improve the continuity of the traffic flow, Osan is continuously adjusting the signal time allocation and frequency of the unreasonable signal operation system.

Figure III - 21 | Traffic network of Osan city in the 1970s and present



Source: 1) Namwon Construction & Engineering, 2002, *Mid-Term Plan for Urban Traffic Improvement for Osan*, Osan City
 2) Osan City, 2016, Naver Map

2.4. Implications

2.4.1. In Terms of High Historical Value City

The problems of the previous traffic plans of Gyeongju City were that its image of a cultural and historical city has faded because of the lack of traffic infrastructure caused by the thoughtless and mixed form of development of cultural heritage and urban structure. Moreover, the urban space was destroyed by the increase in transit traffic. However, Gyeongju City has designated the surrounding areas as traffic management districts and constructed a large public parking lot and transfer facilities in the outskirts of the city to transform traffic usage patterns into public transportation usage pattern, and made efforts to create pedestrian-centered space and construct cultural assets street. In addition, for the bypass processing of the transit traffic in the downtown area, it is currently constructing a circular road network and carrying out maintenance work on the arterial roads and service roads in the city center.

In Gongju City, smooth traffic flow is not possible because service roads are directly connected to arterial roads, and most of the arterial roads constructed in two to four lanes reached the limit of traffic capacity and repair of the road network between important historical sites near Geum River waterfront was not well conducted. However, Gongju City constructed a semi-circular road network using the Geum River waterfront, and it is now developing the city to be a dual-centric structure: a historical and cultural preservation district in the south of the Geum River, and a residential district in the north of the Geum River.

2.4.2. In Terms of Highland City

The problems regarding previous traffic plans of Wonju City were that transit traffic increased in the city center because of the nature of the monocentric city located in the highlands, the transit traffic aggravated the traffic congestion in the city center, and that accessibility to the whole area was weakened because of the lack of the circular-type street network. However, Wonju City is strengthening the accessibility between transportation means by constructing a traffic network system, such as a smooth transfer system to link the metropolitan traffic network and reduce transit traffic by constructing a circular road network to restrict the transit traffic in the city center as much as possible. In addition, Wonju City has established a tourism road network system linking the scenic areas around Seom River and Chiak Mountain, carrying out preservation and development at the same time.

In Chuncheon, the convenience, educational, and cultural facilities were concentrated in the city center because the city was developed as a basin-terrain city. In addition, traffic flow difficulty sections occurred because some bypass roads were disconnected from the city center. Therefore, Chuncheon City is improving the roads connected to outer ring roads and the road network system in the city through the construction of an annular radial- / lattice-type street network; to reduce the traffic congestion and improve the accessibility between the city center and local regions, a circular road network connected to the outskirts of the city will also be constructed.

2.4.3. In Terms of High-Population Density City

In Guri City, chronic traffic congestion sections were formed because the transit traffic and internal traffic were mixed with each other in the vicinity of Guri Station and in the National Road 6 section. However, Guri City promoted linearity expansion of the Seoul Ring Expressway by constructing subsidiary arterial roads crossing the city inside to the east, west, north, and south, and it is strengthening the connection system of each living zone around existing national roads.

In Osan, traffic volume concentration phenomenon occurred because of the absence of the east-west axis metropolitan road network linking Hwaseong City and Yongin City, and the traffic situation in the city worsened because of the absence of a circular road network to suppress vehicle entry into the city center. Therefore, Osan City is improving the accessibility between the regions through the expansion of the metropolitan traffic network system and constructing a bypass road network so that the traffic volume can be diverted and distributed through the construction of a circular road network and lattice-type street network.

Table III-2 | Past problems and current measures related with the traffic plan in each city with similar characteristics

Similar Characteristic	Case City	Problems with Previous Traffic Plans	Direction of Current Traffic Plan Establishment
High Historical Value City (History, Culture)	Gyeongju	<ul style="list-style-type: none"> - Thoughtless development mixed with cultural heritage preservation and urban development - Destruction of downtown space by transit traffic - Intensified traffic congestion on the streets because of insufficient arterial road system 	<ul style="list-style-type: none"> ▶ Designation of surrounding areas as traffic management districts and construction of pedestrian space ▶ Transformation of current traffic system into public transportation system for sustainable preservation of cultural assets ▶ Construction of circular road network and maintenance of arterial roads and service roads
	Gongju	<ul style="list-style-type: none"> - Circular road network and access roads between major historical sites are necessary - Intensified traffic congestion because of city center-oriented traffic network system - Insufficient road network maintenance because of the lack of a systematic road network 	<ul style="list-style-type: none"> ▶ Gradual construction of an urban traffic system that is effective in the preservation of cultural assets ▶ Expansion of road network in the city or between local regions and reinforcement of accessibility between tourist sites ▶ Reinforcement of city center access and passage function through the maintenance of circular road networks
High-Altitude City (Geography, Land)	Wonju	<ul style="list-style-type: none"> - Inefficient management of land use because of the nature of highlands - Increase of transit traffic in the city center because of the nature of monocentric city in highlands - Poor traffic facilities and insufficient traffic network connectivity 	<ul style="list-style-type: none"> ▶ Implementation of a road plan that reflected land use pattern ▶ Construction of an urban circular system that considers access to road expansion and connectivity ▶ Construction of a tourism road network system linking the scenic areas
	Chuncheon	<ul style="list-style-type: none"> - Occurrence of traffic flow difficulty section in the city center because of the nature of a basin-terrain city - Concentration of convenience, educational, and cultural facilities in the city center 	<ul style="list-style-type: none"> ▶ Improvement of a road structure through maintenance of the city center and promotion of road construction and maintenance ▶ Construction of a circular road network and eco-friendly scenic roads
High-Population Density City (Humanity, Society)	Guri	<ul style="list-style-type: none"> - Occurrence of chronic traffic congestion sections in the city center during rush hours - Shortage of eco-friendly road facilities and insufficient road hierarchy system 	<ul style="list-style-type: none"> ▶ Improvement of an arterial road network and construction of roads connected to living zones ▶ Construction of urban scenic roads for pedestrians and bicycles
	Osan	<ul style="list-style-type: none"> - Entry of transit traffic into the city center because of the absence of east-west axis metropolitan road network - Reduction of arterial road function and inefficiency of signal operation cycle 	<ul style="list-style-type: none"> ▶ Expansion of a metropolitan traffic network system and construction of a circular road network system ▶ Securing the continuity of artery roads and improvement of signal operation system

2.4.4. General Implications

A total of six case cities possessing similar characteristics with Kandy City of Sri Lanka as High Historical Value, High Land, and High Density were analyzed. In terms of cultural and historical city, the High Historical Value City had extreme traffic congestion in the past around cultural heritage sites and the maintenance of road network adjacent to waterfront spaces was very poorly conducted. To solve these problems, Gongju City and Gyeongju City have reorganized the urban space structure into a dual-centric city where preservation and life are separated, and urban growth, cultural assets, and environment are preserved at the same time by constructing scenic roads harmonized with waterfront spaces.

In the case of High Land City, the volume of transit traffic increased in the past because of the nature of highland monocentric city and the roads connected with natural scenery were insufficiently constructed. However, Wonju City and Chuncheon City are currently constructing eco-friendly circular/radial road network, bridges, and tunnels, and diverting a considerable volume of transit traffic. They are also constructing scenic roads connected with beautiful mountains in the vicinity where people can enjoy natural landscapes.

Lastly, in the case of High Density City, overpopulated cities, such as Guri and Osan, are trying to minimize the occurrence of chronic traffic congestion sections in the city center during the rush hours by constructing lattice-type and metropolitan road networks. In addition, they are planning a human-centered traffic network system through the construction of infrastructure for pedestrians and bicycles.

Table III-3 | General implications

Problems	Direction of Improvement
High Historical Value <ul style="list-style-type: none"> • Serious traffic congestion around historical sites • Insufficient road network maintenance in the areas adjacent to waterfront spaces 	High Historical Value <ul style="list-style-type: none"> • Transition to dual-centric city where preservation and life are separated from each other • Construction of scenic roads harmonized with waterfront spaces
High Land <ul style="list-style-type: none"> • Increase of transit traffic due to highland mon-centric city • Insufficient road construction connected to highland natural scenery 	High Land <ul style="list-style-type: none"> • Construction of circular/radial roads, bridges and tunnels • Construction of scenic roads connected to beautiful mountains
High Density <ul style="list-style-type: none"> • Occurrence of chronic congestion areas in the city center during rush hours • Insufficient pedestrian and bike-centered infra construction 	High Density <ul style="list-style-type: none"> • Construction of grid-type/metropolitan roads • Construction of pedestrian and bike-centered scenic roads

IV. Suggestion of Traffic Network Improvement Method

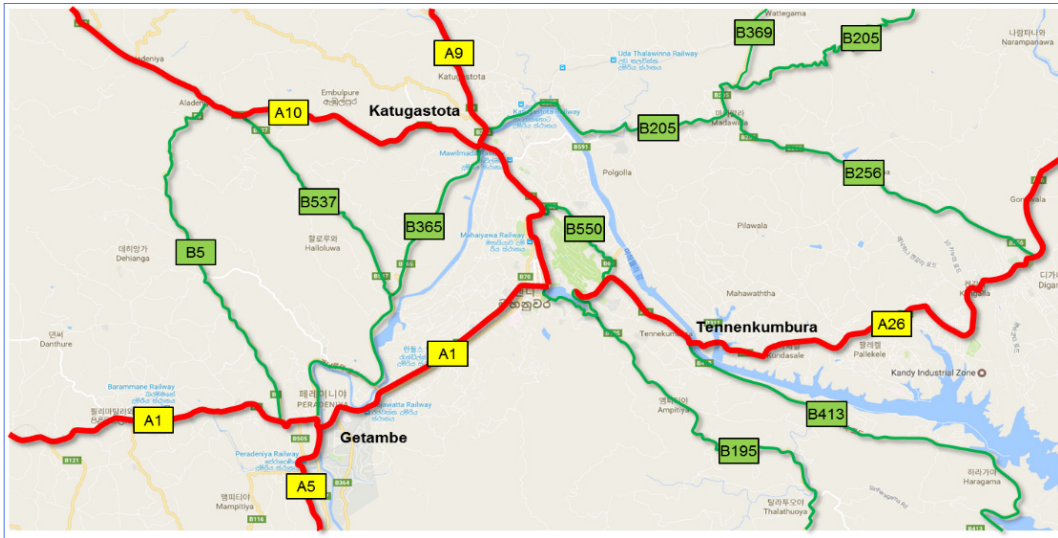
1. Conceptual plan for Optimal Road Network

Kandy City is currently operating a southwest access system around National Road A1, a northwest access system around A10, a north access system around A9, and an east access system around A26. In general, vehicle entry and exit is made to the outskirts of the city from each vertex of the triangular areas surrounded by Mahaweli River. As a bypass road axis supplementing this, the National Road B365 is located in the west and the National Road B205 and B256 connected to Digana are located in the east. As such, Kandy City has very limited road system where the traffic is concentrated in CBD because of its historical, geographical, and socioeconomic characteristics.

Because of these characteristics, the opening or expansion of roads is very limited. Nevertheless, it is necessary to design an optimal road network system suitable for Kandy City to preempt the impact of the urban expansion and the opening of an expressway in the future.

When planning the optimal road network system, various plans considered to have a great influence on the traffic pattern of Kandy City were examined. Among them, the Central Expressway is a project to construct an expressway that can connect the capital Colombo and Kandy. When the expressway is constructed, the main traffic access direction will be changed from A1 road to A10 road. Therefore, a method for maximizing the effect of the national road A10 expansion plan connected with this project was examined and a route line that can construct an efficient bypass road network that links with Kandy Tunnel was also examined. At the same time, a current road plan promoted by RDA was examined and a comprehensive study was also conducted on the urban development conditions of Kandy; its geographical, historical, and cultural limitations; and the land available for development in the vicinity.

Figure IV-1 | Metropolitan road network system of Kandy



1.1. Conceptual plan for Kandy's Road Network

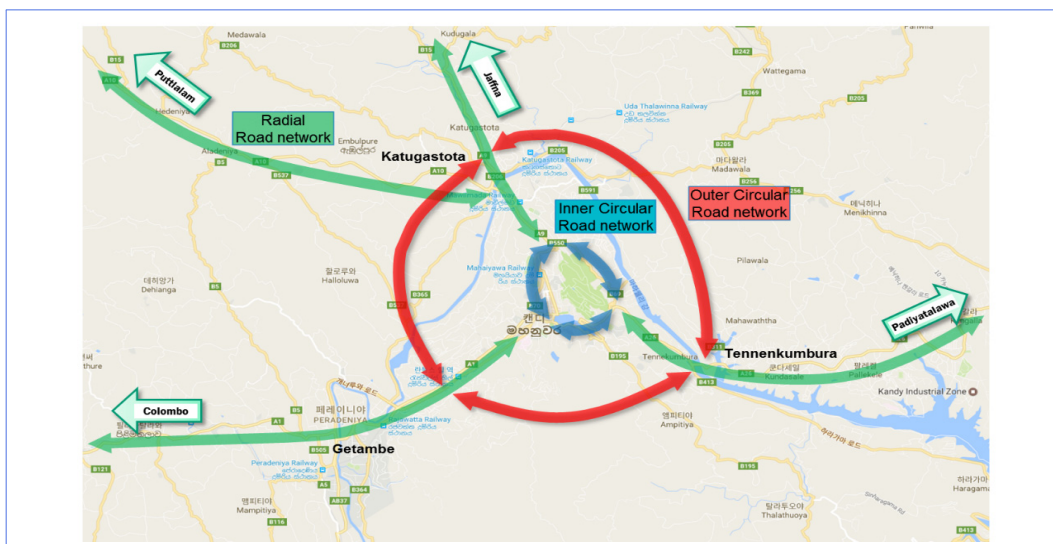
As a mono centric city, Kandy has a radial road system because of its geographical conditions. As a result, considerable amount of transit traffic passes through the city center and causes traffic congestion in the CBD. The bypass roads are operated in two-lane or first-lane roads and they are not efficiently processing the transit traffic volume.

In order to alleviate such traffic congestion, Kandy is planning to reduce the amount of transit traffic passing through the city center by improving bypass roads and public transportation system. We tried to propose optimal road network for Kandy by examining Kandy's plan and direction of urban development.

To fundamentally solve the traffic congestion problem in the CBD of Kandy, we aimed to construct efficient and effective bypass road network in Kandy. For this purpose, we proposed a radial/circular type road network system composed of external circular network for bypass processing of transit traffic from the inside of the city and internal circular network for smooth access of the traffic approaching city inside.

For optimal road network, our plans were divided into mid-term road plan that utilizes the existing road network as much as possible and long-term road that plan that utilizes the new roads. Our final goal is to construct circular road network connecting the west part of Kandy and Digana.

Figure IV-2 | Conceptual idea for Kandy's road network



1.1.1. Mid-term Plan

Currently, to move to Katugastota in the north and to Tennekumbura in the east part of Kandy, people use the route A9-B550-A26 passing through the center of Kandy and the route B205-B311-A26 along the Mahaweli River.

However, because the route A9-B550-A26 passes through the B550 road with poor road structure, it is very congested because of the access traffic in the city center and user's convenience is reduced. The route B205-B311-A26 does not have great traffic volume because it does not pass through the city center. However, the road width is narrow and the linearity is not good so new bypass roads are necessary.

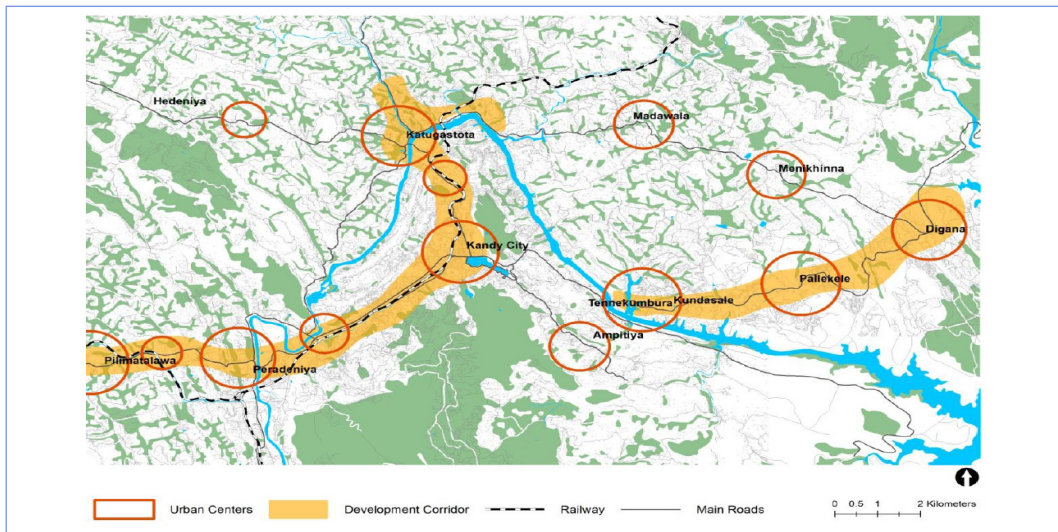
Therefore, this task proposed an alternate route connecting Katugastota in the north and Tennekumbura in the east as a traffic axis bypassing the eastern part of Kandy.

In addition, because Kandy has no road network that bypasses the south, we proposed constructing bypass road axis in the south through prompt construction of Kandy Tunnel.

We also proposed constructing western bypass road network in connection with B205 Katugastota-Digana road improvement project and B365 Getambe-Katugastota road improvement project that are currently carried out.

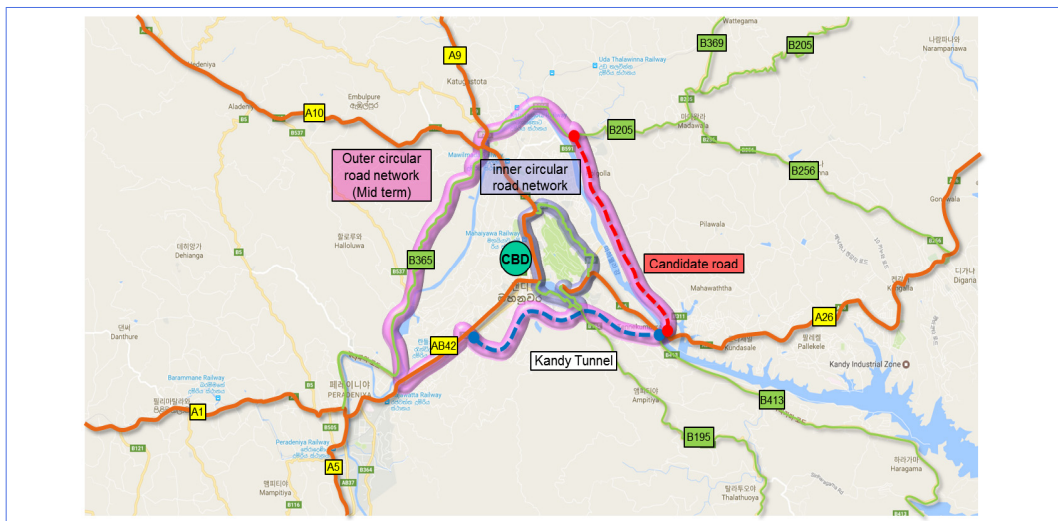
Through this, we plan to bypass-process the traffic flow coming from the direction of Colombo in the southwestern part of Kandy and going to the northeastern part of Kandy using Kandy Tunnel and this task routes and to propose efficient connection axis between Tennenkumbura and Pallekale on A42, one of main development axes, and Katugastota, a hub district located in the northern part of Kandy.

Figure IV-3 | Urban development axis of Kandy



Source: Ministry of Urban Development, Water Supply and Drainage, 2015, *Kandy City Region Strategic Development Plan-2030*, Ministry of Urban Development, Water Supply and Drainage

Figure IV-4 | Kandy road network plan - mid-term plan



1.1.2. Long-term Plan

In order to respond to Central Expressway construction project and the urban expansion of Kandy, our long-term plan proposed outer ring road network mainly composed of new routes.

Katugastota in Kandy is the area where the traffic volume from Highway A9, A10, B205 is concentrated, causing congestion in Katogastota Junction. In addition, on A9 Highway connecting the northern part and CBD of Kandy, congestion is taking place in the direction of the city center due to the influence of traffic congestion in CBD in peak time. If the Central Expressway is constructed in the future, it is expected that a considerable amount of traffic from Colombo to Kandy will move from A1/AB42 to A10, which will access the Expressway, intensifying the traffic congestion.

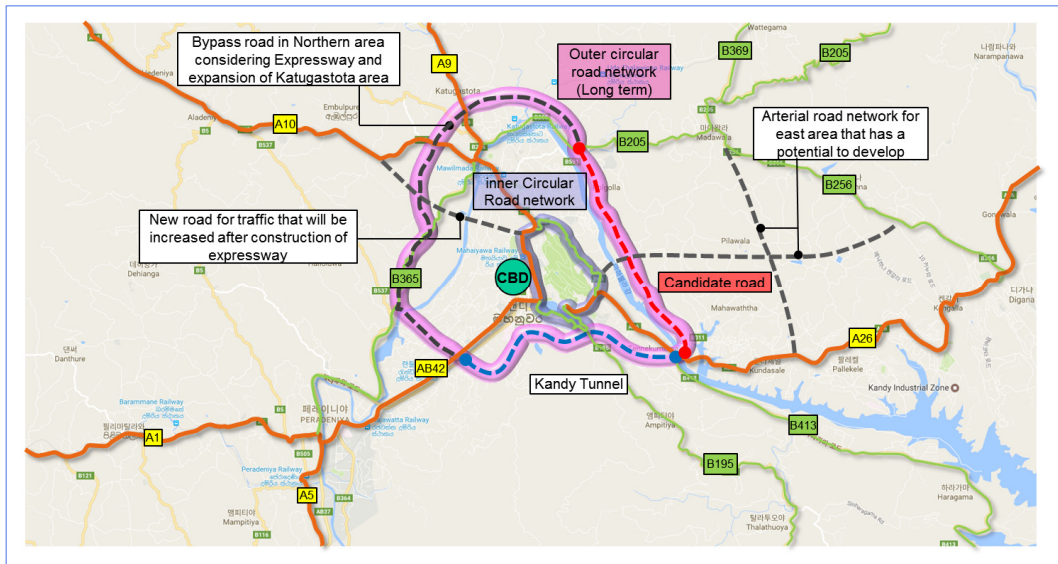
Therefore, a northern bypass road needs to be constructed to suppress the traffic concentration in Katugastota, where traffic congestion is currently taking place, and to respond to traffic increase which will be caused by Central Expressway in the future.

To this end, our long-term plan will propose a northern bypass road that extends this task route, based on Kandy Tunnel and this task route proposed in our mid-term plan. We proposed that the northern bypass route be freshly constructed to bypass Katugastota to the north and access B365 route.

In addition, in order to increase the efficiency of Kandy Tunnel, we proposed a road connecting AB42 line accessing Kandy Tunnel and B365, a western bypass road axis, and an outer road network.

To prevent Central Expressway traffic from concentrating on the Highway A9, we also proposed a bypass road accessing CBD from Highway A10 as an alternative plan and to increase the future development potential of the eastern part of Kandy, we also proposed a grid-type arterial road axis.

Figure IV-5 | Kandy road network plan - long-term plan



1.2. Selection of Alternative Route

1.2.1. Geographical Characteristics

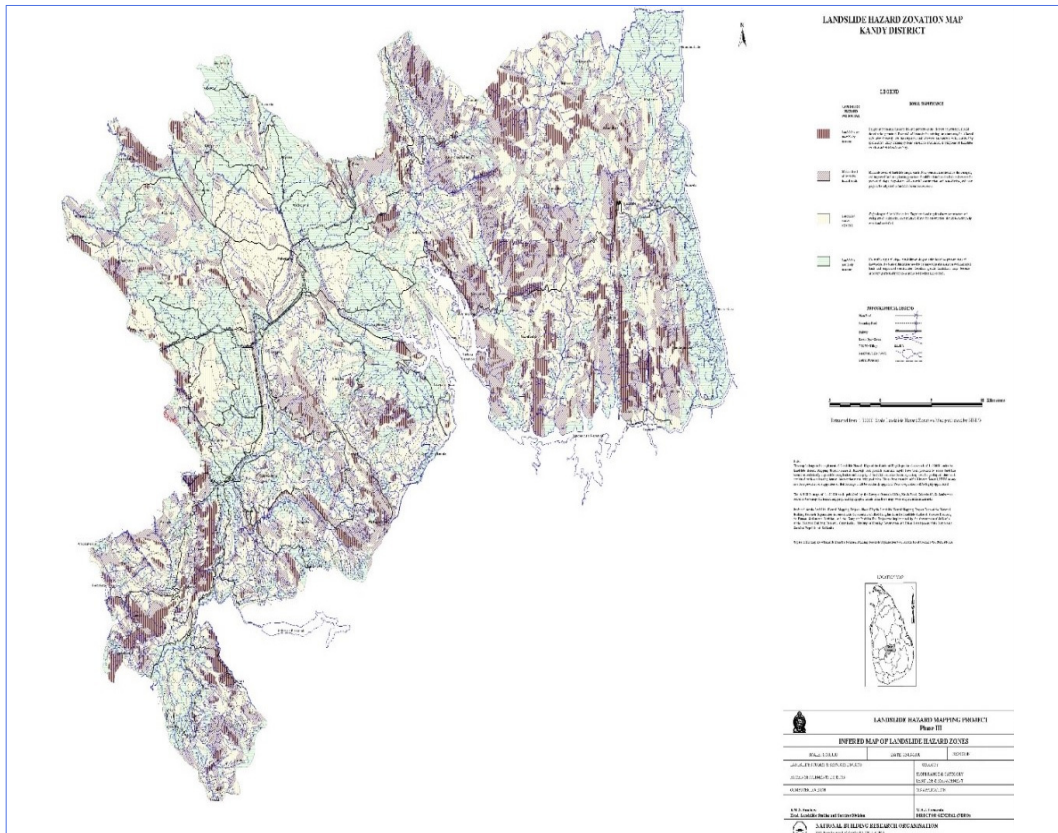
Kandy is a basin-type city and it is located between many mountains, including the Knuckles mountain range and the Hanthana mountain range.

As main geological features of Kandy, Kandy is surrounded by streaked marble composed of rough calcite crystals with the thicknesses ranging from 0.65 to 1.0 km. The major bedrock of Kandy is composed of biotite gneiss and the sand was generated by overflow of the Mahaweli River.

The average annual precipitation of Kandy is 2,085 mm (1953~2013) but the western region surrounded by mountain ranges records the precipitation of more than 1,500~3,000 mm during the concentrated heavy rains from September to January, a southwestern monsoon period. The rapidly urbanized areas within the Mahaweli river floodplain are exposed to flood hazards due to repeated flooding and they involve the risk of soil erosion and landslides due to steep slopes in the surrounding mountains and the exposed rocks in urban boundaries.

Due to such unique hydrological and geographical features, Kandy has a geographical disadvantage in establishing a sustainable urban development strategy.

Figure IV-6 | Landslide hazard zonation map of Kandy district



Source : National Building Research Organisation, 2017, *Landslide Hazard Zonation Map Kandy District*, National Building Research Organisation

1.2.2. Current Situation of Existing Roads

Kandy is an old city with residential and commercial facilities concentrated on both sides of the existing road. Most of the existing roads are non-standard roads and most roads have many sections where the profile grade is steep, the width of the road is narrow, and the road geometry is not good. In addition, the road users experience inconvenience due to the deterioration of the roads.

Three wheelers and motorcycles, which account for the majority of the traffic, are affecting the travel speed of the vehicles. The lack of bus facilities such as bus bay is causing serious traffic congestion in peak time when buses stop at bus stations.

The poor pavement condition of the roads and increase of damaged parts of the roads due to their deterioration are reducing the convenience of the users and causing the accidents. In most roads, road damages are frequently occurring due to the lack of drainage system during the rainy season. In addition, there are many sections with poor road geometry and there is a risk of accidents at night due to insufficient safety facilities.

Figure IV-7 | Current situation of road in Kandy



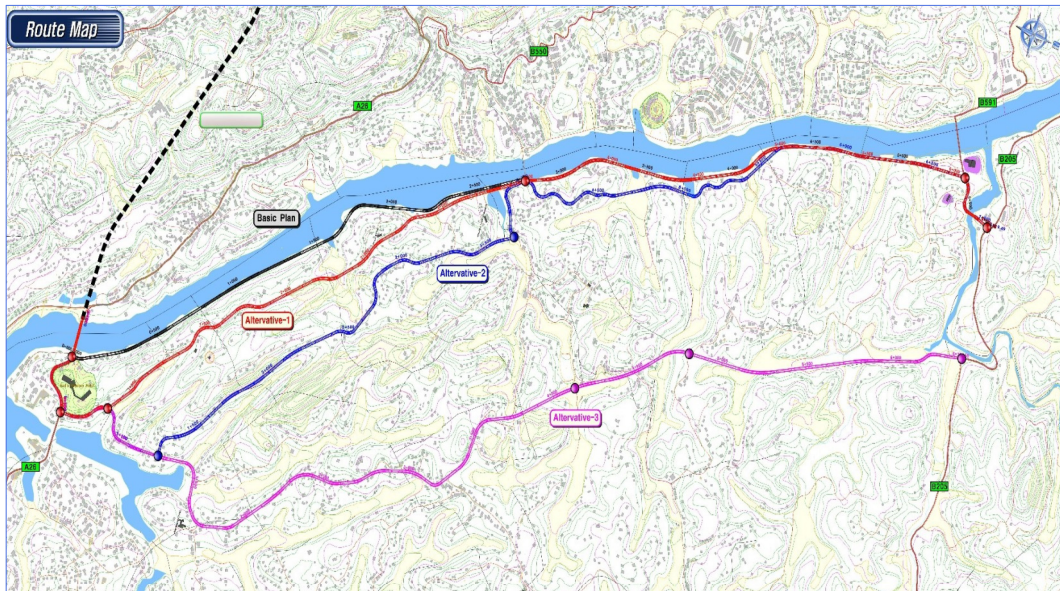
1.2.3. Selection of Alternative Routes

As a result of establishing and examining four alternatives to construct bypass roads in the northern and south-eastern part of Kandy, Alternative 1 turned out to be excellent in terrain, environment, civil affairs, migration and compensation, and at the same time, it was considered as the most easily expandable and able to act as an outer ring road for Kandy in the future.

Table IV-1 | Comparison of alternatives

Description	Basic Plan (along Riverside)	Alternative 1	Alternative 2	Alternative 3
Length	5.68km	6.39m	7.02km	6.38km
Constructability	Poor constructability because construction should be made on the rocky part of Mahaweli River	Good constructability because existing roads and buffered greens of Mahaweli River are used	Good constructability because the linearity of existing roads is improved and expanded	Good constructability because the linearity of existing roads is improved and expanded
Accessibility	Poor accessibility because construction is made along Mahaweli River	Good accessibility because existing roads are used	Good accessibility because existing roads are used	Good accessibility because existing roads are used
Geometric	Good	Good	Poor	Poor
Acquisition and Resettlement	Resettlement compensation cost can be minimized because it is new route	Resettlement compensation cost can be minimized because it is combination of existing road sections and new routes	Increase of resettlement cost because existing roads are expanded	Increase of resettlement cost because existing roads are expanded
At grade Intersection	4EA	5EA	7EA	7EA
Environmental	<ul style="list-style-type: none"> • Increase of environmental damage and damage to natural scenery because all sections are constructed in Mahaweli River waterfront space • Occurrence of river pollution because of non-point pollution source caused by roads • Necessity of scenery design 	<ul style="list-style-type: none"> • Minimization of environmental damage through the combination of existing road expansion and new sections, Excellent view 	<ul style="list-style-type: none"> • Excellent environmental aspect through the use of existing roads but increase of civil complaints 	<ul style="list-style-type: none"> • Excellent environmental aspect through the use of existing roads but increase of civil complaints
Connection	Occurrence of congestion because the starting point is near from hotel access road	The starting point accesses the end point of Kandy Tunnel and the end point accesses B205	The starting point accesses the end point of Kandy Tunnel and the end point accesses B205	The starting point accesses the end point of Kandy Tunnel and the end point accesses B205
Economical	It's the route along the Mahaweli River and the construction cost will be expensive because of the increase in bridge sections considering highwater level	As the combination of existing roads use and new road sections, the construction cost is considered reasonable to secure smooth linear combination and traffic flow	Construction cost can be minimized because existing roads are used but compensation cost is expected to increase	Construction cost can be minimized because existing roads are used but compensation cost is expected to increase
comment	<ul style="list-style-type: none"> ■ The Alternative 2 and 3 intend to use existing roads. However, as there are narrow road width sections with poor geometry, improvement and expansion of linearity are necessary and they are disadvantageous in terms of geometry and resettlement compensation. So increase of civil complaints is expected. In addition, they are disadvantageous when road expansion is requested due to increase of traffic volume in the future. ■ The Alternative 1 is considered as the optimal alternative considering geographical conditions, environmental conditions, civil complaint, and resettlement compensation. If traffic volume increase in the future, the roads can be the most easily expanded and it is excellent in terms of geometry. So, if it is operated in connection route and bypass in the future, it can be applied to outer circular road. 			

Figure IV-8 | Route map



2. Road Map for Top-Priority Project

The proposed route will form the eastern axis of the external circular network of Kandy City. To have this route play its role as an external circular network, linkage to related plans is necessary. The major projects considered to have an effect on this route include the Kandy Tunnel Construction Project and the Central Expressway Construction Project. In particular, the Kandy Tunnel, which is to be accessed from Tennekumbura, is directly related to this proposed route.

Therefore, this project should be implemented in consideration of the construction period of the Kandy Tunnel. If the time gap is large, each project function will be limited to the function of the local bypass road rather than to the external circulation axis function.

The economic feasibility of this project and its impact on surrounding conditions need to be further analyzed according to general procedures through a feasibility study as a follow-up task; the feasibility study should have a more detailed analysis of the traffic demand on the project route, an additional cost estimation on the terrain, and a list of obstacles on the project route. After the feasibility study is completed, basic and detailed designs should be carried out. In particular, during the detailed design phase, connection part problems in the Tennekumbura area and the Kandy Tunnel should be discussed, and continuity should be

ensured so that the two roads can serve as a single circular network.

The road completion period should be established in connection with the completion year of the Central Expressway so that the increase in traffic demand caused by the development projects can be effectively solved and the traffic congestion in Kandy City can be minimized, considering the increase in traffic volume in the north-eastern part of Kandy City following the opening of the Central Expressway.

The opening of this project route is expected to take eight years: one year for feasibility study, one year for basic design, one year for detailed design, and five years for construction.

Figure IV-9 | Road map for this project

Stage	Major Works	Considerations	Implementation Period
Feasibility study	<ul style="list-style-type: none"> Analysis of the project area Selection of rough routes Forecast of the traffic demand Cost estimation and economy analysis Analysis of environmental and social impacts 	<ul style="list-style-type: none"> Checking of the construction periods of the Kandy Tunnel and the Central Expressway Identification of detailed development plans and field survey around the project route 	<ul style="list-style-type: none"> Within one year after budget completion
Basic design	<ul style="list-style-type: none"> Decision for the road route Analysis of environmental impacts Preparation of an expected work schedule for road construction 	<ul style="list-style-type: none"> Checking of the route location and intersection type in the basic design stage of the Kandy Tunnel 	<ul style="list-style-type: none"> Concurrently with or after the basic design of the Kandy Tunnel One year after feasibility study
Detailed design	<ul style="list-style-type: none"> Suggestion of a detailed improvement plan Quantity and construction cost estimation 	<ul style="list-style-type: none"> Review of the detailed design of the Kandy Tunnel near Tennekumbura, and seeking for an effective linkage method 	<ul style="list-style-type: none"> Concurrently with or after the detailed design of the Kandy Tunnel One year after basic design
Construction	<ul style="list-style-type: none"> Construction 	<ul style="list-style-type: none"> Adjustment of the construction period in connection with the Kandy Tunnel 	<ul style="list-style-type: none"> Concurrently with the Kandy Tunnel Construction Project Five years after detailed design



V. Conclusion

1. Conclusion

Kandy City has been designated as a World Heritage Site and is a basin-shaped city located at an altitude of over 500 m above sea level, with geographical restrictions on urban expansion because it is located in a highland and it has to preserve its historical districts. In addition to the cultural and geographical restrictions, the road network of Kandy City, located in the central region of Sri Lanka, has been constructed in a radial system linking the east, west, south, and north. As such, the transit traffic passes through the city center and is mixed with the internal traffic, producing extreme traffic congestion.

With regard to traffic infrastructure improvement, a core national task of the Sri Lankan government, various projects, such as the Central Expressway Construction Project and Kandy Tunnel Construction Project, are being carried out in Kandy City. However, there is a lack of planning to connect the northern and eastern parts of Kandy to effectively respond to changes in traffic patterns in the future such as urban development and Kandy Tunnel construction in the eastern part of Kandy City.

In this project, the characteristics of Kandy were divided into three categories—High Historical Value, High Land, and High Density—and the direction of improvement was derived by analyzing two Korean cities with similar characteristics. To improve the characteristics of High Historical Value city, the transformation of the city into dual-centric by separating the preservation of cultural heritage and the living area from each other, and the construction of scenic roads harmonized with waterfront spaces were suggested. To improve the characteristic of High Land city, a method of bypassing the transit traffic volume through the construction of circular and radial road networks, bridges and tunnels, as well as a method to construct scenic roads connected to natural landscapes of the highlands were suggested. To improve the characteristics of High Density, methods to minimize the occurrence of chronic traffic congestion sections in the city center by constructing lattice-type and metropolitan road

network as well as a human-centered traffic network system through the construction of urban scenic roads for pedestrians and bicycles were suggested.

Based on these Korean cases, a mid- to long-term optimal road network was suggested to effectively solve the traffic congestion problem in the center of Kandy City. The optimal road network was suggested in two plans: the midterm plan that maximizes the use of the existing road network, and the long-term plan that uses new roads.

For the construction of bypass roads in the eastern part of Kandy City, four route alternatives were examined in terms of constructability, accessibility, terrain, migration compensation, environment, and economic efficiency. As a result of the examination, Alternative 1, which can achieve a smooth linear combination through the use of existing roads and new roads, was considered as the most appropriate alternative.

In this project, Korean experiences were shared to support the improvement of living environments in Kandy City, and efforts were made to construct an economic road network system through a practicable traffic network plan that considered internal and external development plans.

It is expected that the traffic network improvement plan proposed in this project will be able to produce an overall traffic environment improvement effect in Kandy, such as for the improvement of chronic traffic congestion and for the reduction of social cost.

2. Future Tasks

As suggested in the road map for top priority projects, the traffic network improvement proposed in this project should be carried out sequentially in the order of feasibility analysis, basic design, working design, and construction. Financing method, land expropriation, and migration measures, which are expected to be necessary for project promotion, are briefly proposed as follows.

2.1. Migration Measures

To construct the roads in the northeastern part of Kandy City, expropriation of project land and measures for the migration of indigenous people will be needed. In Korea, there is a relevant act, “Standards on the Measures for the Resettlement of Migrant Workers by Corporate City Development,” which includes the contents shown in Table 8.

Table V-1 | Table of contents of the act on migration measures

Chapter 1. General Provisions

Chapter 2. Migration Measures

Paragraph 1. Establishment of Migration Measures

Paragraph 2. People Subject to Migration Measures

Paragraph 3. Selection Criteria for People Subject to Migration Measures and Method of Identifying Relevant Facts

Paragraph 4. Supply of Housing Site for Migrants

Paragraph 5. Special Supply of Housing

Paragraph 6. Payment of Resettlement Cost and Residential Migration Expense

Chapter 3. Living Measures

Paragraph 1. People Subject to Living Measures

Paragraph 2. Selection Criteria for People Subject to Living Measures and Method of Identifying Relevant Facts

Paragraph 3. Method of Living Measures

Chapter 4. Others

Source: Ministry of Land, Infrastructure and Transport, 2013, *Standards on the Measures for the Resettlement of Migrant Workers by Corporate City Development*

More detailed contents can be found in “Expropriation and Compensation System of Korea” (MOLIT, 2014), a report on the economic development experience modularization project of KSP in 2013.

2.2. Financing Method

There are five types of overseas business support systems, and financial resources for the construction of roads between the northeastern parts of Kandy City (feasibility study, basic planning, construction, etc.) can be secured using these systems.

2.2.1. Infrastructure Master Plan Establishment Support Project

It supports a project that has the comparative advantage of Korean enterprises, such as transportation and city, finding a subsequent profitable business, and a great front-to-back connection effect. It supports the establishment of a master plan for the recipient country and also comprehensively supports the technology and finance of the country, if necessary.

Table V-2 | Infrastructure master plan establishment support project

Classification	Contents
Responsible Agency	Ministry of Land, Infrastructure and Transport
Support Area	Overall infrastructure
Major Support Contents	Support of technology and finance for the project
Project Scale	Maximum of KRW 1 billion for each project

Source: Ministry of Strategy and Finance, 2015, *Policy Consulting for Development of Both Banks of Red River, Hanoi, Vietnam*

2.2.2. Global Infrastructure Fund (GIF)

It supports investment and development projects (roads, harbors, power plants, airports, etc.) related to overseas social infrastructures and subsidiary projects (urban development, etc.) connected with social infrastructures. It is a policy to revitalize private investment in the field of overseas infrastructure development and to build the international competitiveness of investment and development-type overseas infrastructure projects of Korean companies.

Table V-3 | Global infrastructure fund

Classification	Contents
Responsible Agency	Ministry of Land, Infrastructure and Transport
Support Area	Overall infrastructure
Major Support Contents	Feasibility study cost and excellent project fund investment
Project Scale	Maximum KRW 0.5 billion for each project

Source: Ministry of Strategy and Finance, 2015, *Policy Consulting for Development of Both Banks of Red River, Hanoi, Vietnam*

2.2.3. Overseas Construction Market Development Support Project

It is a project to encourage the active market development of Korean companies by supporting the costs for new market development with high-risk burden for the long-term development of overseas construction projects.

Table V-4 | Overseas construction market development support project

Classification	Contents
Responsible Agency	Ministry of Land, Infrastructure and Transport / International Contractors Association of Korea
Support Area	MDB-led Infrastructure Development Project
Major Support Contents	<ul style="list-style-type: none"> • Project feasibility study support • Owner personnel and engineer training support • Field ordering and survey activity support • Dispatch of market survey team, market development activity support
Project Scale	KRW 0.2 billion for each project (feasibility study: KRW 0.3 billion)

Source: Ministry of Strategy and Finance, 2015, *Policy Consulting for Development of Both Banks of Red River, Hanoi, Vietnam*

2.2.4. Official Development Assistance (ODA)

Official Development Assistance (ODA) is a fund provided by public institutions, such as the central or local government of a country, aid execution agencies or international organizations to improve the economy and welfare of developing countries. ODA is divided into grant and loan depending on the repayment conditions of the support fund.

Table V-5 | Official development assistance

Classification	ODA Grant	ODA Loan (EDCF)
Support Condition	Free	Repayment
Support Limit	100%	Within 85% of total project cost (may be different for each project cost)
Interest Rate	-	0.1–2.5%/year
Repayment Period	-	Within 40 years
Support Project	All projects, except those with military purpose	Limited to the projects suitable for the development plan

Source: Economic Development Cooperation Fund (www.edcfkorea.go.kr), Korea International Cooperation Agency (www.koica.go.kr).

2.2.5. Special Accounts for Traffic Facility

The purpose of the special accounts for traffic facility system is to secure traffic social overhead capital (SOC) investment fund through self-financing projects. For the smooth expansion—as well as the efficient management and operation—of roads, railways, airports, and ports, the special consumption tax for gasoline and light oil was converted to traffic tax (special purpose tax) to establish special accounts for traffic facility with traffic tax as its major tax source. The traffic facility special account is covered by money transferred from traffic, energy, and environmental tax accounts, passenger car individual consumption tax and other accounts, such as property income, etc. wherein 80% of traffic, energy, and environmental taxes are allocated to special accounts for traffic facility through general accounting. From this, 40% to 50% of these taxes are used for road account.

Table V-6 | Act on Special Accounts for Traffic Facility

〈Act on Special Accounts for Traffic Facility〉

Article 1. The purpose of this Act is secure the smooth expansion of roads, railways, airports, and ports and their efficient management and operation.

Article 8. (Transfer from general accounting) In each fiscal year, the government shall transfer from general accounts the revenue budget equivalent to the amounts specified in each of the following paragraphs.

- ① Amount equivalent to 800/1,000 of traffic, energy, and environmental tax according to the「Act on Traffic, Energy, Environmental Tax」.
- ② Individual consumption tax amount imposed on passenger cars according to the「Individual Consumption Tax Act」.
- ③ Tariff imposed on vehicles and their parts and components, except for railway or track vehicles, according to the「Individual Consumption Tax Act」.

Source: Ministry of Land, Infrastructure and Transport, 2016.03.29, Act on Special Accounts for Traffic Facility

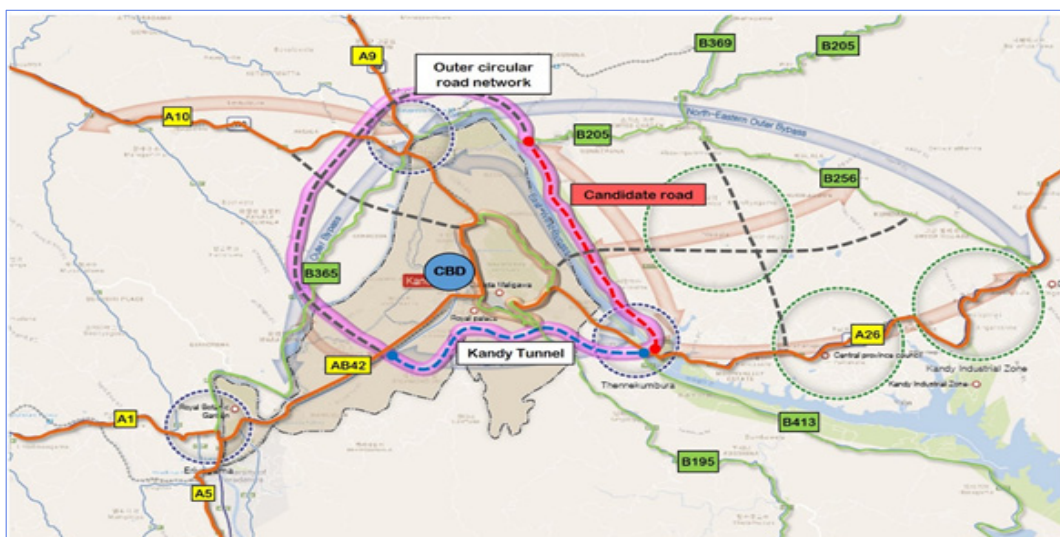
3. Follow-Up Tasks

As the Central Expressway has been planned for Kandy, along with the Greater Kandy Master Plan, a metropolitan urban development plan is thus being established. As such, change is expected in the future movement pattern of population, traffic demand, and travel pattern of the people. In particular, when the Central Expressway is finally opened, the main development axis of Kandy City and the traffic volume will be concentrated in the northwestern part of Kandy around route A10 where the highway will be located. Accordingly, there is an urgent need to find ways to maximize the effects of expressway construction at the northwestern part of Kandy, as well as to disperse traffic in the crowded northern region of Kandy. Based on the mid- and long-term plan, including the expressway construction plan proposed in this project, it is necessary to promote the construction of the external circular road network to process the traffic volume passing through Kandy City by sharing knowledge about road planning and construction in Korea.

In addition, to relieve the traffic congestion in Kandy caused by the unsystematic road network construction following natural urban expansion, it is necessary for Kandy to establish a systematic urban plan for newly developed areas, particularly for the northwestern region, which is expected to be directly affected by the Central Expressway, through the transfer of experiences and knowledge for the development of new cities around Korean expressways.

Therefore, it is necessary to perform follow-up tasks in order to maximize the efficiency of this project, as well as promote the detailed external road network for the processing of transit traffic passing through Kandy and the city's systematic urban development.

Figure V-1 | Network plan



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