Chapter 4 Strategic Environmental Assessment

4.1 Legal and Institutional Framework of Environmental Considerations

The legal and institutional frameworks regarding environmental considerations in Bolivia are established as follows. Under the Law of Environment, the regime of environmental impact assessment and the efforts for the implementation of strategic environmental assessment are ongoing.

4.1.1 Law of Environment (Law No. 1333 of 1992)

The Law of Environment deals with the environmental issues in Bolivia comprised of environmental management, prevention and control of environmental pollution, the ruling of activities handling hazardous substances, and the management of solid waste.

The objective of the Law is the protection and conservation of the environment and of natural resources and the promotion of sustainable development to improve the population's quality of life. Consequently, the Law created the former National Secretary for Environment (SENMA), which subsequently became the Ministry of Environment and Water (MMAyA) engaging its implementation. Auxiliary, were created under MMAyA, the Department Secretariats of Environment, which must implement the environmental policy, plans and programs, and the enforcement of internal regulations in their jurisdictions.

The Law establishes as tools of environmental planning the following legal instruments:

- Inclusion of environmental issues in the formulation of national-, departmental-, and local administration plans, programs and projects;
- Formulation of spatial plans based on carrying capacity of the ecosystems, location of human settlements, and the conservational needs of environment and natural resources;
- Integrated management and sustainable exploitation of the resources administrated by watershed units and other important geographical features;
- Implementation of the environmental impact assessments;
- Establishment of mechanisms for inter-sectorial, inter-institutional, and inter-regional coordination and consensus;
- Establishment of a system for information management, inventories, and diagnosis; and
- Establishment of means for assessment, control, and monitoring of the environmental quality.

Under the Law was enacted the Supreme Decree No. 24176 of December 1995 (DS 24176), comprising the following regulations to enforce its stipulations:

- Regulation of General Management of the Environment,
- Regulation on the Matter of Air Pollution,
- Regulation on the Matter of Water Pollution,
- Regulation of Activities Handling Hazardous Substances,
- Regulation of Solid Waste Management, and
- Regulation of Environment Conservation and Control.

The Chapter IV of the Law stipulates on environmental impact assessments, which is regulated by DS 24176 in its Regulation of General Management of the Environment (called as RGGA).

4.1.2 System of Environmental Impact Assessment

Environmental impact assessment (EIA) is the instrument to identify and evaluate potential positive and negative impacts that may be caused by the future implementation, operation, maintenance, and abandonment of a project, work or activity. The purpose is to establish appropriate measures to prevent, mitigate or control negative impacts and enhance the positive ones. EIA applies to all works, activities, and projects, and public, private or mixed investment. EIA is applied before the implementation phase.

The Regulation of General Management of the Environment establishes the rules and regulations in environmental policy; namely, the administrative and juridical aspect; the competences of the environmental authority and the involvement of sector authorities; the public participation; the management of economic and financial resources; and the promotion of scientific and technological research.

The Regulation of Environment Conservation and Control sets the EIA concerned issues and the regulatory framework of environmental quality control. The Regulation establishes the methodology for EIA: the environmental license, competences of the environmental authorities, and screening. Environmental quality control concerns the control of all investments in the process of implementation, operation, maintenance or abandonment phase.

The competent national authority is the Vice-ministry of Environment, Biodiversity, Climate Change and Forest Development Management (VMABCCYDGDF). The Vice-Ministry depends on the Ministry of Environment and Water.

The approval of the environmental license is authorized by the competent environmental authorities: namely, VMABCCYDGDF and the local authority of one of the nine departments.

The concerned regulations establish the mandate and the functions exercised by the environmental authorities at different levels. In summary, the Local Governments are entitled to decide about environmental screening, EIA and dispensation certificates in their territorial jurisdiction. The municipal authorities have a role as advisor and supervisor during the process of elaboration of the technical report and supporting documents.

In the case of the Department of Santa Cruz, the Secretariat of Sustainable Development and Environment (SDSMA) reviews all projects before the submission of the environmental report to the Department Government. SDSMA informs all interested civilians and organizations of the contents of projects, especially of environmental issues including disturbance mitigation measures and contingent responses for unavoidable accidents and external forces. They also must inform all constraints and claims gathered from the affected people, calling responses for them.

The Law of Popular Participation (1994) gives a relative autonomy of public management towards urban and rural municipalities. The Law created “local community organizations” (OTBs). The OTBs can be organizations of neighborhoods, small farmers federations, rural communities or villages. The OTBs are entitled to propose, control and supervise the execution of projects and supervise the performance of public servants. The OTBs participate in the revision of the environmental form, elaboration of the EIA and monitoring and control.

4.1.3 Implementation of Strategic Environmental Assessment in Bolivia

The EIA legislative system establishes the possibility of implementing Strategic Environmental Assessment (SEA). The Regulation of Environment Conservation and Control stipulates that plans and programs formulated by the State be subject to SEA procedure. In 2007 the Vice-ministry of Biodiversity, Forestry, and Environment (in that period the National Environmental Authority) developed the Training Manual on Strategic Environmental Assessment (*Manual de Capacitación en Evaluación Ambiental Estratégica*). The process of SEA implementation resulted in the preparation of the SEA Regulation.

VMABCCYDGDF is continuing their effort for drafting the SEA regulations. The draft has been under development for several years. However, no agreement has been reached regarding the legal form of the regulations: if it should be a Ministerial decree or a Supreme Decree.

In the year 2008 were conducted nationwide training activities on the application of SEA in the process of formulation of policy, program, and plans for all sectors, using the Training Manual on the SEA, drafted with a technical assistance of Netherlands ODA; however, in practice, its application is almost null. As is published by the MMAyA, some preliminary approaches were just started in the country, and one of them is for the area of Madeira River basin focusing on energy sources development, taking into account the existing water rights.

In these circumstances, the Secretariat of Sustainable Development and Environment of Santa Cruz agreed on the idea to consider the SEA approach as one of the matters for the technical transfer of the Project, because this approach is a reference for the formulation of policy, programs, and plans in Santa Cruz regardless of the sector concerned.

4.2 Environmental Conditions

4.2.1 Baseline Survey

The baseline survey was conducted jointly with all members of Technical Working Groups and other officials of the six municipalities constituting the Metropolitan Area. The JICA Study Team also requested the collaboration with other stakeholders.

The requested data and information to all the groups are listed in below.

- General information: maps of isohyet, geology, hydrology, hydrogeology; locations meteorological stations and historical records of meteorological data; maps of ecoregions, landscapes, ecological systems, vegetation system; classification and zonation of forests including production forests with/without certification.
- Protection/conservation zones: distribution of protection/conservation zones and buffer zones including Ramsar sites; vulnerable and endangered species according to IUCN or Bolivian classification; existence of native communities depending on natural resources (firewood, food, medicine) in the protection/conservation and buffer zones; norms concerning allowed activities in protection/conservation and buffer zones.
- Air quality: Measured parameters and historical records (list of analytical laboratories with ISO 17025 certification); monitoring stations and mobile system of measurement; cadaster of fixed emitters by type of emission (industrial, hospital, thermal generators, refineries of metals, gas, and petroleum, mines); inventory of greenhouse gas emissions.
- Water resource: Measured parameters and historical records (list of analytical laboratories with ISO 17025 certification); monitoring stations and historical records of river water level; monitoring stations and historical records of surficial waters and cadaster of wells

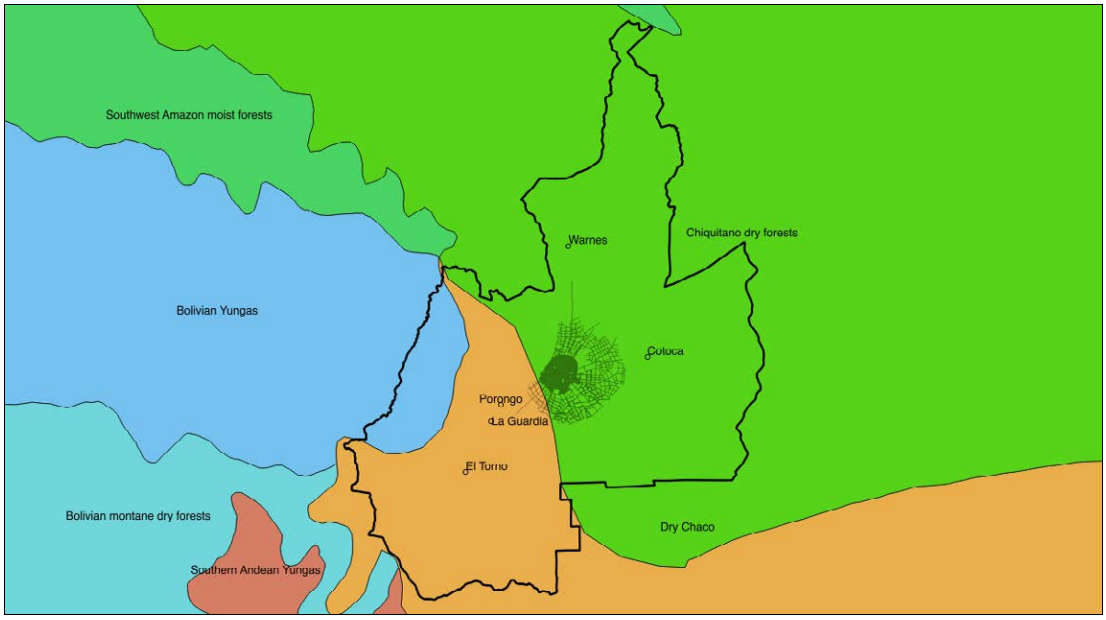
for industrial and domestic use (with data of depth and intake volume); location of water intake points for human consumption and intake rate; network of water supply system; regime and cadaster of water use right (agricultural, industrial, commercial); location of residual water drainage points (industrial, sewerage system, refineries of metals, gas and petroleum, mines).

- Soil quality: soil type (classification according to Bolivian norms for pedological taxonomy or based on usage aptitude); contaminated and eroded sites.
- Solid waste: generation of solid waste per capita and its composition; primary and secondary collection routes, and locations of transference stations; location of large generators of solid waste; list of authorized enterprises for special waste (infectious, toxic, radioactive, etc.) collection, treatment, including incineration, and disposal; location of solid waste treatment plants, including incinerators and recoverable materials classification, and final disposal sites.
- Sewerage system: sewer collection network and location of septic tanks; location of sewage treatment plants and drainage flow-rate.
- Legislation: current laws, regulations, norms, and standards on environment, air quality, water quality, noise, vibration; norms on environmental authorizations over projects: environmental impact assessment, categorization, evaluation process, public consultation, monitoring plan; regime for environmental consultancy (RENCA); and Municipal ordinances with respect of SEA and EIA.

4.2.2 Baseline Data

(1) Ecoregions of Santa Cruz Metropolitan Area

Ecoregions are relatively large units of land containing distinct assemblages of natural communities and species, with boundaries that approximate the original extent of natural communities before the major land-use change. According to Olson, D.M. *et al*. 2001. Terrestrial Ecoregions of the World: A New Map of Life on Earth (Bioscience November 2001 / Vol. 51 No. 11), the Santa Cruz Metropolitan Area is distributed in three ecoregions said, Chiquitano Dry Forests, Bolivian Yungas, and Dry Chaco.



Source: JICA Study Team based on data from WWF-Olson, D.M. *et al*. 2001.

Figure 4.2-1 Ecoregions of Santa Cruz Metropolitan Area

As shown in the Figure, the Chiquitano Dry Forest covers in fully Warnes and Cotoca and most of Santa Cruz de la Sierra; whereas Dry Chaco (in light brown): Porongo, La Guardia, and El Torno, including a small section of the southwestern area of Santa Cruz de la Sierra.

The ecoregion Bolivian Yungas encompasses western rural areas of Porongo and El Torno.

A description of each ecoregion is listed in below Table.

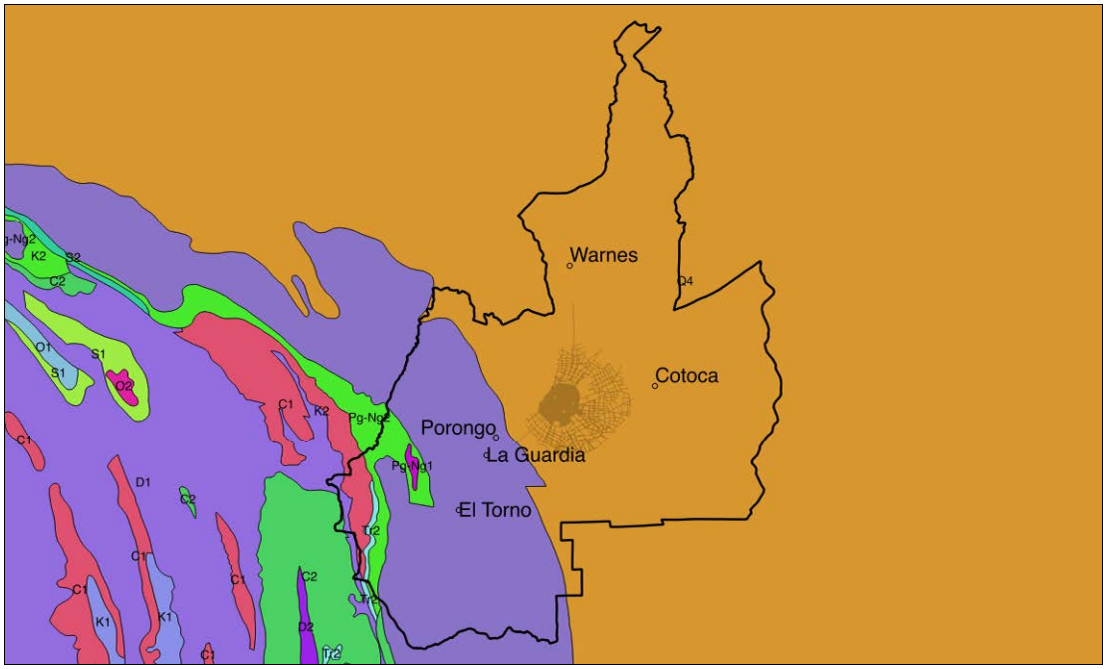
Table 4.2-1 Features of Ecoregions of Santa Cruz Metropolitan Area

Ecoregion	Physical features	Flora	Fauna	Threats
Bolivian Yungas (Western rural areas of Porongo and El Torno)	The ecoregion occurs at elevations ranging from 400 to 3,500 m on the eastern slopes of the Andes in Bolivia. It forms a transition zone between the Southwest Amazon moist forests to the northeast and the Central Andean Puna and wet Puna to the southeast.	Epiphytes are abundant and include bromeliads, orchids, and tree-ferns (*Cyathea*). Chusquea bamboo is an indicator species of the ecoregion.	Mammals found in this ecoregion include the spectacled bear (*Tremarctos ornatus*), Geoffroy's cat (*Leopardus geoffroyi*), lowland tapir (*Tapirus terrestris*), jaguar (*Panthera onca*), pacarana (*Dinomys branickii*), and brocket deer (*Mazama chunyi*).	Extensive land clearing, agricultural conversion, and logging (all intensified by road building and colonization) severely threaten the region. Certain game species from the Bolivian Yungas are threatened by over-harvest for protein and/or the wild bird trade.
Chiquitano Dry Forests (Warnes, Cotoca, and most of Santa Cruz de la Sierra)	Most of the Chiquitano forest lies within the eastern lowlands of Santa Cruz, Bolivia, with smaller patches extending into western Mato Grosso, Brazil. Although without rainfall and leaves for certain parts of the year, these dry forests still contain the abundance of life including many endemics.	These forests are dominated by *soto*, *curupau*, *cuchi*, *cuta*, *ajo-ajo*, *tajibo*, and *tuseque* trees. Flooding and fires are both common in this region, so many of these trees can withstand temporary flooding or have fire-resistant bark.	This unique forest shelters a critically endangered reptile, the broad-snouted caiman (*Caiman latirostris*); an endangered bird, the black- and-tawny seedeater (*Sporophila nigrofufa*), and at least three mammals, the giant armadillo (*Priodontes maximus*), maned wolf (*Chrysocyon brachyurus*) and giant otter (*Pteronura brasiliensis*). Selected species include the barefaced curassow (*Crax fasciolata*), puma (*Felis concolor*), jaguar (*Panthera onca*), and the lianas (*Bignoniaceae*).	Pollution, wildlife exploitation, agricultural expansion, burning, and grazing together constitute major threats. Habitat degradation is also significant, partly due to the Paraguay-Parana Hidrovia Dam project and uncontrolled logging. The third major threat is habitat fragmentation with improved and new access ways promoted by multinational energy companies (pipelines, power lines, and electricity generation) and the transportation sector (roads, ports).
Dry Chaco or Gran Chaco	This ecoregion is mainly filled with grasslands and thorn forests.	Tropical and subtropical dry broadleaf forests.	Dry Chaco spreads habitats that support a diversity of wildlife, including pampas deer, *Chacoan peccaries*, jaguars, pumas, and other large mammals, as well as little thornbirds, greater rheas, southern boas, horned frogs, and many other species.	Agricultural expansion, largely driven by soy, is the biggest threat to the natural ecosystems of the Gran Chaco. Growing market demand, coupled with innovations such as genetically modified crops, zero-tillage, and other technological changes, have made cultivation in drier and less productive areas more viable.

Source: JICA Study Team based on data from WWF. Terrestrial Ecoregions., GAD Santa Cruz. 2008. *Evaluación de la fauna silvestre y comunidades ecológicas del departamento de Santa Cruz.*

(2) Geology and Soil Physiology of Santa Cruz Metropolitan Area

The geology of Santa Cruz Metropolitan Area pertains mainly on quaternary sedimentary rocks (Q4: light-brown area of the Figure below) known as Chaco-Beniana Plain and tertiary sedimentary rocks (Pg-Ng2: purple area of the Figure below), the Chiquitano Cristalino Shield.



Source: Department of Santa Cruz Secretariat of Sustainable Development and Environment, processed by JICA Study Team.

Figure 4.2-2 Geology of Santa Cruz Metropolitan Area

From the north, Warnes, Cotoca, and Santa Cruz de la Sierra belong to the former Chaco-Beniana Plain; whereas, Porongo, La Guardia, and El Torno to the latter Chiquitano Cristalino Shield.

Quaternary fluvio-lacustrine sediments form the Chaco-Beniana Plain. They are deposits of detritus and sediments filling a pit of 5,000 m depth. Posterior weathering scattered sandy-flats. The lithology of the zone shows consolidated sediments of Quaternary sands, clayed mudstones, limonite, and limestone conglomerated with Devonian, Carboniferous, Silurian, Permian, Cretaceous sediments.

Whereas, the Chiquitano Cristalino Shield consists of a formation of Precambrian, Cambrian, Devonian, and Silurian rocks, predominantly by primary minerals such as granite, basalt, metamorphic rocks-gneiss, para-gneiss, granodiorite, micaceous shale, and some presence of sandstone, mudstone, lateritic minerals with calcareous rocks.

Soil physiology surveys were conducted by the Department of Santa Cruz during 2011, and their results had been compiled in three volumes report "*Fisiología y aptitud de uso del suelo en el departamento de Santa Cruz*".

The methodology used in the surveys followed parameters of Food and Agriculture Organization of the United Nations (FAO) for soil classification and aptitude of soil-use; and as results of these surveys, maps on soil physiology and aptitude of soil-use for the Department of Santa Cruz were achieved.

Main parameters used for the composition of soil physiology map were geological features,

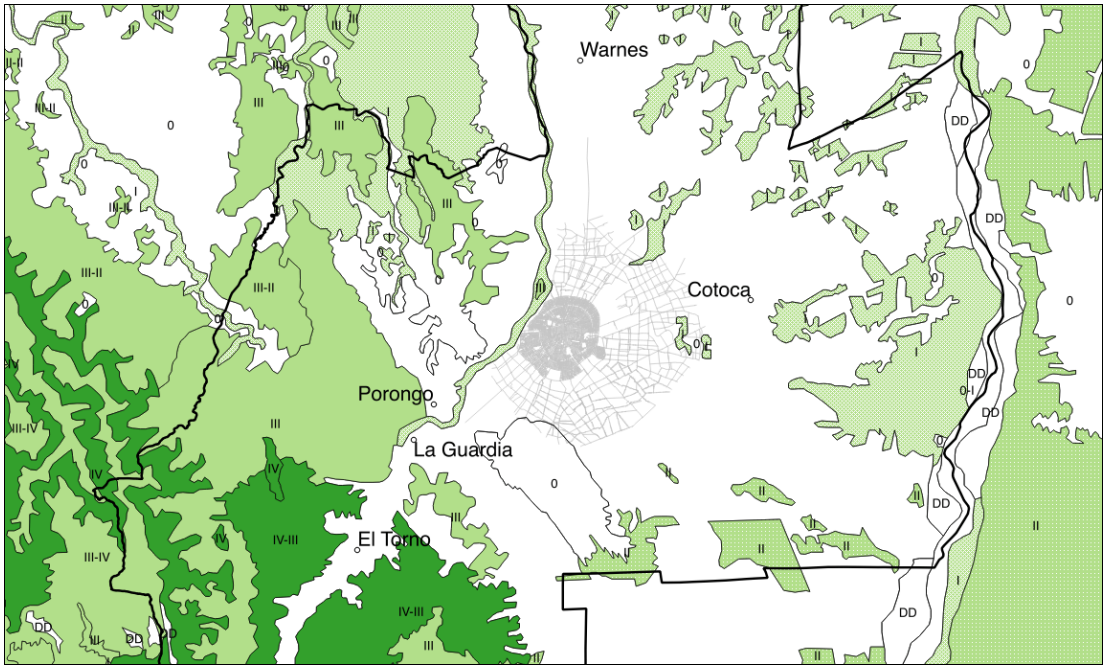
geomorphology, meteorological behavior, biological actions, among other relevant factors.

(3) Vegetation of Santa Cruz Metropolitan Area

The Department of Santa Cruz had made a potential map for forest development based on soil physiology and existing vegetation, classifying the zones as follows:

- Zone 0: potentiality inexistent for forest resources or anthropic zones;
- Zone I: very low potentiality for forest resources;
- Zone II: low potentiality for forest resources;
- Zone III: medium potentiality for forest resources;
- Zone IV: high potentiality for forest resources; and
- Zone V: very high potentiality for forest resources.

The following Figure shows the distribution of potential zones for forest resources of the Santa Cruz Metropolitan Area.



Source: Department of Santa Cruz Secretariat of Sustainable Development and Environment, processed by JICA Study Team.

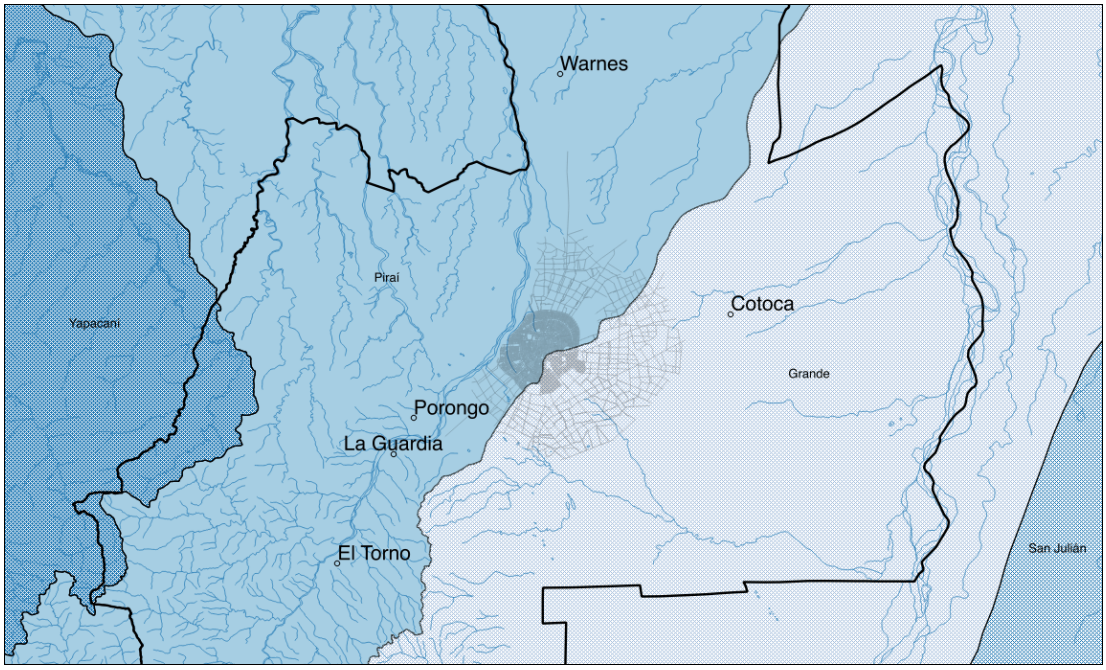
Figure 4.2-3 Forest development aptitude of Santa Cruz Metropolitan Area

As shown, the urbanized area of the Metropolitan Area is classified in Zone 0. It should be mentioned that along the riverine of the Pirai River the classification corresponds to Zone II "low potentiality for forest resources".

(4) Hydrography of Santa Cruz Metropolitan Area

The Department of Santa Cruz is distributed in its 80% on the hydrographic basin of Amazonas, and the rest, 20%, on the Plata basin. The aquifers pertain to Subandino, Chaco-Beniana, and Guaporé systems. The Province Andrés Ibáñez belongs to Chaco-Beniana system. The latter is encompassing variable ranges of extension among 50 to 1,500 m depth with medium-rate permeability.

The Santa Cruz Metropolitan Area is distributed in basins of the Pirai River and the Rio Grande. As shown in the Figure below, the western area is spread on the Pirai River Basin and the east on the Rio Grande Basin. Both rivers are tributaries of the Mamoré which is also one of the tributaries of Amazon River.



Source: Department of Santa Cruz Secretariat of Sustainable Development and Environment, processed by JICA Study Team.

Figure 4.2-4 Hydrography of Santa Cruz Metropolitan Area

The Pirai River has an extension of 457 km and is one the tributaries of Yapacaní River. The Pirai River flows crossing the city of Santa Cruz de la Sierra and is also limiting the border with Porongo. The stream also flows in El Torno, La Guardia, and Warnes.

The Rio Grande flows 1,438 km until its confluence with Mamoré River. Most of its extension is distributed in the Department of Santa Cruz; however, the upper stream is also the border of Chuquisaca and Cochabamba Departments.

A huge amount of riverbed sand is exploited in both banks of the Pirai River along El Torno, La Guardia, and Porongo, causing coastal erosion and high turbidity. Also, all the effluents from wastewater treatment plants of the Metropolitan Area are drained into its body attainting its quality.

The aquifer under Santa Cruz de la Sierra consists of an alluvial deposit with a lenticular shape of around 1,500 m depth in average with an extension of 1,000 km^2. The groundwater flow-path is principally from southwest to northeast and is recharged mainly from the rainfall and transmissions from the right bank of the Pirai River, left bank of the Rio Grande, and other tributaries of cordillera zone. Numerous clay layers of the zone restrict its vertical flow. However, the vertical flow is significant in the zones without notorious distribution of clay formations.

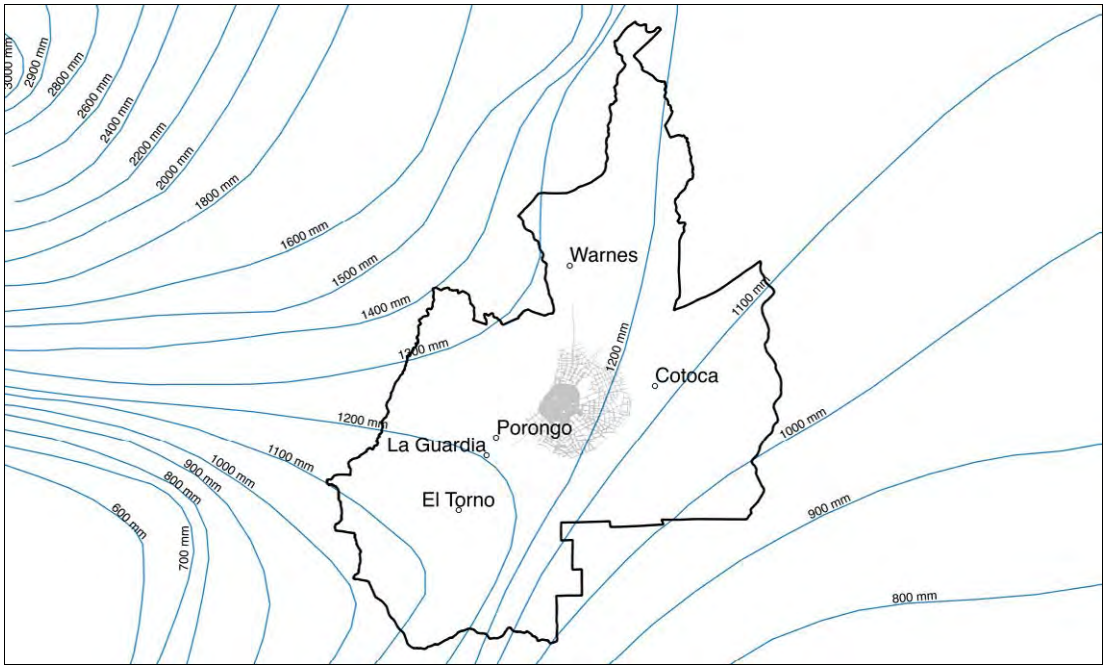
The transmissivity of the aquifer measured at some production wells of SAGUAPAC ranges between 1,100-1,200 m^3/day-m, almost uniformly in all its extension. The recharge from rainfall is seasonally high during January and March and from the surficial waters continues until September. However, a quantitative estimation of the water balance is still uncertain.

In 1979 the national government approved the request of the autonomous water council to become a cooperative. Since then, SAGUAPAC has become the largest urban water cooperative in Bolivia, with more than 180,000 water connections serving the equivalent of 1.2 million people, out of a total population of 1.6 million. All of SAGUAPAC's water comes from groundwater through 60 deep wells (360 m average depth), with an annual production of 64 million cubic meters. The water is directed to four storage tanks and pumped to the city through 3,370 km of primary and secondary networks. The collected wastewater is led to treatment plants where it is treated before being released into local rivers.

(5) Meteorological Behavior of Santa Cruz Metropolitan Area

The Bolivian region features several characteristics that influence the temporal and spatial behavior of precipitation. Geomorphologically, the area is dominated by the Andes Mountains, where the highest elevation is around 6,000 m above sea level (a.s.l). The Andes are divided into two meridional mountain ranges by a high-altitude basin, up to 4,000 m a.s.l., known as the Altiplano. During the summer (December-January), moisture from the Amazon is transported to the northwestern region of the continent by the low-level jet, which is blocked by the Andes and channeled to the eastern rim of the Andes near Santa Cruz de La Sierra. From there, the moisture moves toward northern Argentina or southeastern Brazil. Additionally, the 200-hPa Bolivian High, which is an upper tropospheric anticyclone formed by intense summertime convection and latent heating over the northern Amazon during the summer, is present.

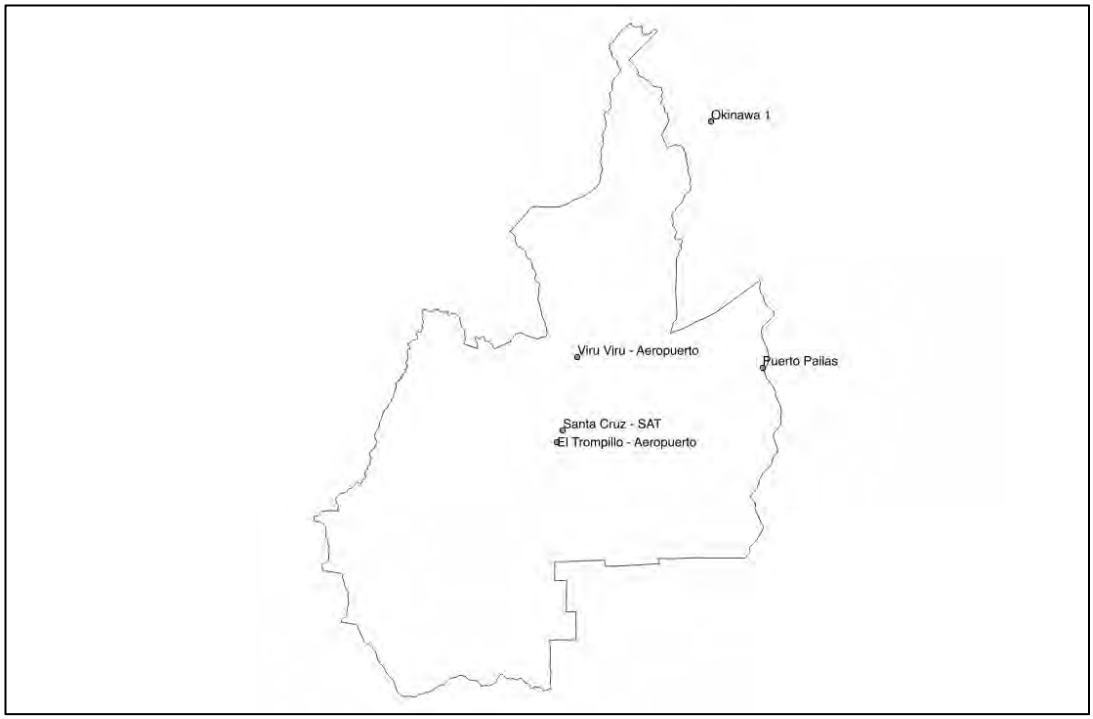
Rainfall in Santa Cruz Metropolitan Area ranges between 900 to 1,400 mm in average (see the Figure below). Most of Santa Cruz de la Sierra, Warnes, Porongo, and La Guardia encompasses the isohyet zone of 1,200 mm. Whereas, Cotoca and El Torno in the zones between 1,100 to 1,200 mm per year.



Source: Department of Santa Cruz Secretariat of Sustainable Development and Environment, processed by JICA Study Team.

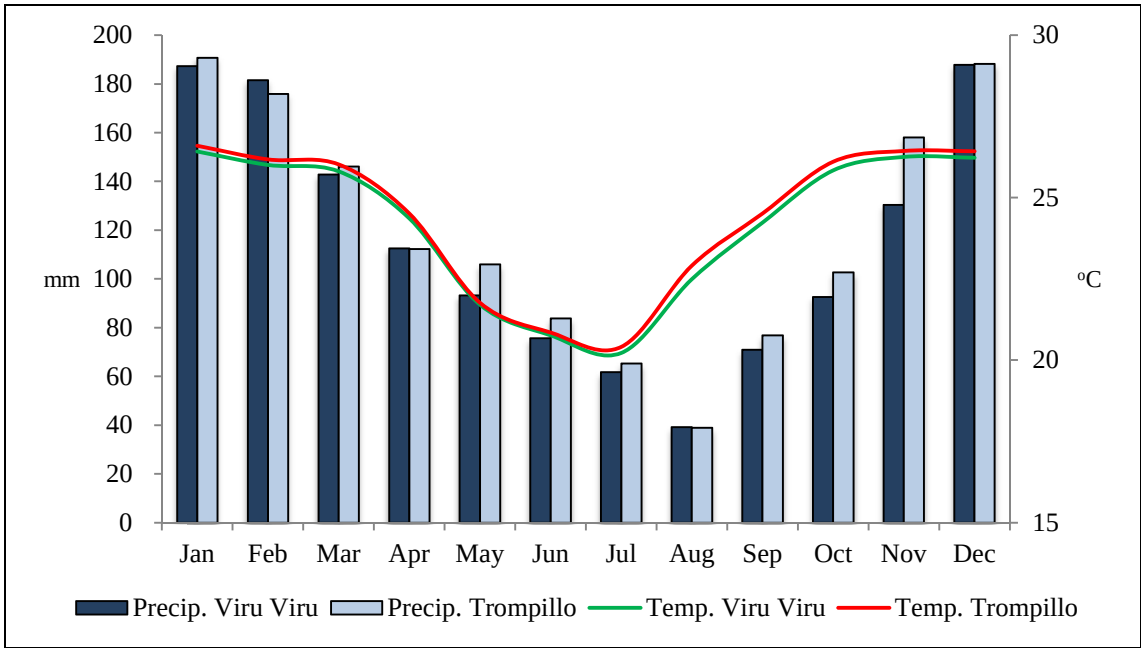
Figure 4.2-5 Isohyet of Santa Cruz Metropolitan Area

Data on meteorological stations were gathered from the Meteorological System (SISMET) of The National Service of Meteorology and Hydrography (SENAMHI). The locations of meteorological stations of influence on the Metropolitan Area are shown in the Figure below.



Source: JICA Study Team based on data from SENAMHI-SISMET.

Figure 4.2-6 Location of meteorological stations of influence



Source: JICA Study Team based on data from SENAMHI-SISMET.

Figure 4.2-7 Monthly average temperature (ºC) and Monthly Precipitation (mm)

Principal features of meteorology in the Metropolitan Area are described briefly in below.

- Temperature: The annual average temperature, of the last 30 years in the Department of Santa Cruz, oscillated from a minimum of 16.6 ºC at Vallegrande and a maximum of 26.6 ºC at San Matías; around the average of 24.7 ºC. In the same period, the absolute maximum and minimum were recorded at Okinawa 1, 40.0 ºC (December 6, 2011) and 0.8 ºC (July 6, 2007), respectively. Seasonality, for the station of Viru Viru and Trompillo, the locations of the most representative and relatively good availability of data for the

Metropolitan Area, is shown in the Figure below.

- Precipitation: Average annual rainfall, of the last 30 years in the Department of Santa Cruz, fluctuates from a minimum of 645 mm at Vallegrande and a maximum of 1,591 mm at Concepción; around the average of 1,175 mm.
- Wind speed and direction: Annual average wind speed is 16 km/h mainly toward NW direction. The maximum average recorded at Viru Viru was 21.7 km/h, and the minimum at Santa Cruz SAT was 9.7 km/h.

(6) Ecological Valuation of Santa Cruz Metropolitan Area

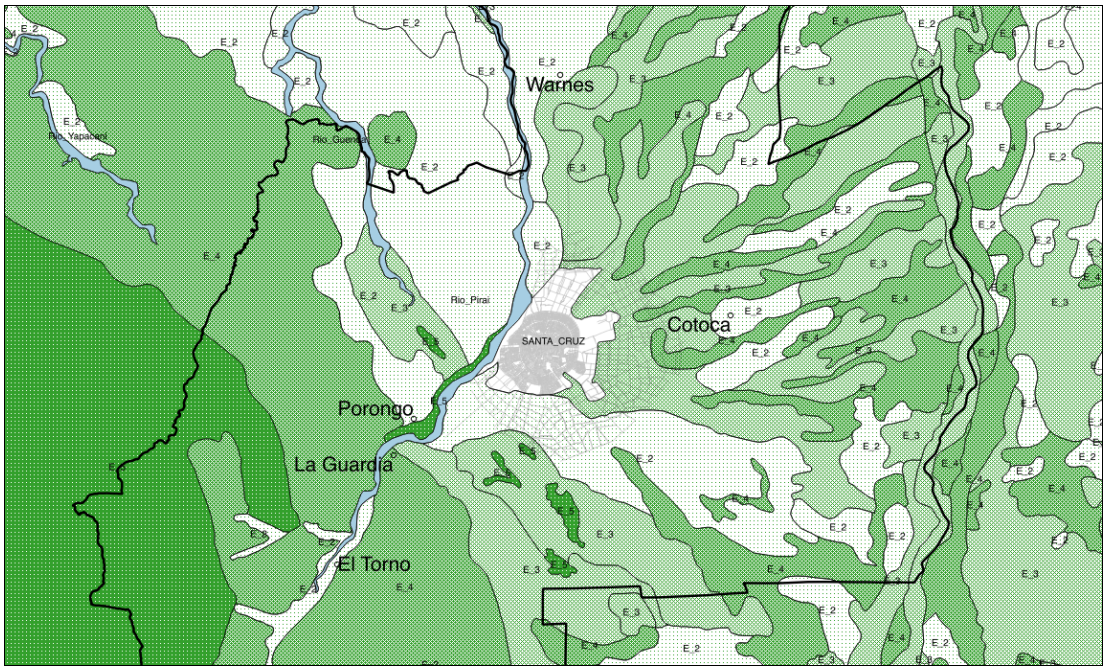
Based on the surveys on soil physiology and the ecoregion distribution, a map of the distribution of ecological values was obtained.

In addition to the soil physiology, factors such as flora and faunal forms of ecological units, and natural assets mater for tourism were considered for this valuation process. Also, were used following criteria which are consistent with PLUS-Santa Cruz, the spatial use plan of Santa Cruz formulated in 2009:

- The similarity to natural status without direct or indirect anthropological disturbance: the natural formations or quasi-like pristine forms with high ecological value.
- Rareness or singleness of geomorphology, vegetation or fauna of least occurrence: which should conserve or protect because of high ecological value.
- Biological diversity: zones with a vast variety of animal or plant species, which constitutes ecological niches of high ecological value.
- Areas that function as protection zones for other soils against floods or erosions.

From these criteria, a zoning map of ecological valuation was drafted classifying the ecological values in following five levels:

- E1: Very low ecological value; in which protection measures, the requirement of recovery nor rehabilitation are not justified.
- E2: Low ecological value; in which particular cases shall justify management recommendations, or particular exploitation norms without important restrictions on the use, restoration, or rehabilitation aiming its conservation.
- E3: Salient ecological value; in which particular cases shall justify management recommendations, or particular exploitation norms without important restrictions on the use, restoration, or rehabilitation aiming its conservation.
- E4: High ecological value; in which the management norms and use restrictions are foremost important, the protection of the unit shall be effective, and quasi-absolute limitation shall be practiced.
- E5: Very high ecological value; in which the conservation and protection shall be absolutely restricting all kind of use.



Source: Department of Santa Cruz Secretariat of Sustainable Development and Environment, processed by JICA Study Team.

Figure 4.2-8 Ecological valuation of Santa Cruz Metropolitan Area

Above Figure shows the map of ecological valuation of Santa Cruz Metropolitan Area as a result of the physiological and ecological analysis. As shown, the central zone of Santa Cruz de la Sierra has no classification under these valuation criteria, while the urban areas of the Warnes, Cotoca, Porong, and El Torno belongs to “low ecological value (E2)” zones. The outstanding situation for La Guardia shows that even its urban area is inner the “high ecological value (E4)” zone.

The eastern zone connecting Warnes with Santa Cruz de la Sierra is cataloged as “salient ecological value (E3)”, while it western area is E2.

The main part of Cotoca and Santa Cruz de la Sierra is E3 with partial zones classified as “high ecological value (E4)”.

The left-bank of the Pirai River between Porongo and Santa Cruz de la Sierra is cataloged as “very high ecological value (E5)”.

(7) Protected Areas of Santa Cruz Metropolitan Area

The regime of protected areas in the Department of Santa Cruz is normed by the Departmental Law No. 98 (*Ley de Conservación del Patrimonio Natural del Departamento de Santa Cruz*) enacted on May 21, 2015.

The regime encompasses conservational issues of natural ecosystems, habitats, biodiversity, genetic resources, water resources, natural goods, and ecosystem functions in the jurisdiction of the Department of Santa Cruz.

The Law aims conservation of fauna and flora with special interest on vulnerable, endemic, threatened, and endangered species. Furthermore, the conservation of geologic, speleological, archeological, and paleontological formations is considered. As those as, the conservation of natural landscapes and the scenic beauty of the Department is engaged.

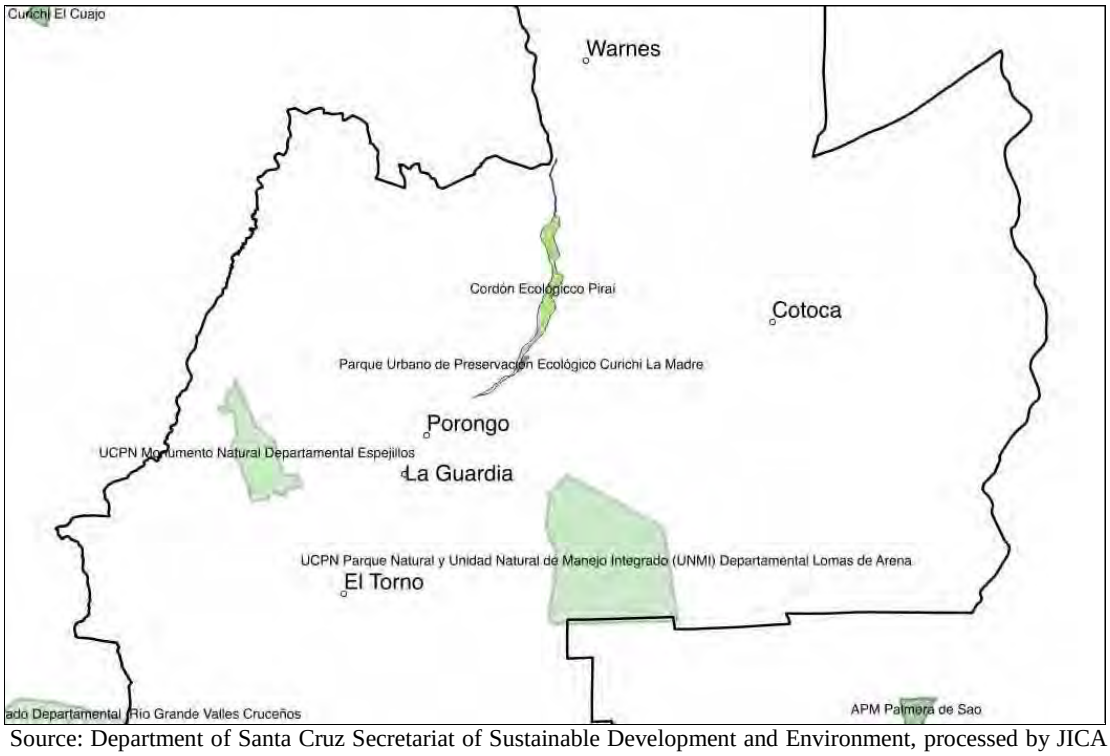
There are two protected areas in the Santa Cruz Metropolitan Area:

- Conservation Unit of Natural Asset (UCPN) and Natural Unit of Integral Management (UNMI) Lomas de Arena
- UCPN Department Natural Monument Espejillos

By the Municipal Ordinance 044/2007, the Municipality of Santa Cruz de la Sierra established the Urban Park for Ecological Preservation Curichi La Madre to conserve the natural resources, wild fauna, and native species, and also to establish the ecological equilibrium and to prevent pollution.

Similarly, throughout the Municipal Ordinance 150/2009 was delimited the jurisdictional area of Metropolitan Ecological Park Pirai correspondent to the Municipality of Santa Cruz de la Sierra. The conservation effort of the Metropolitan Ecological Park Pirai is an attempt initiated by the Law 2913 of November 18, 2004, instructed to the municipalities encompassing the riverine green belt along the Pirai River. However, by the date solely the segment corresponding to the Municipality of Santa Cruz de la Sierra was delimited and normed by Municipal Ordinance.

The location of these protected areas is shown in the Figure below.



Source: Department of Santa Cruz Secretariat of Sustainable Development and Environment, processed by JICA Study Team.

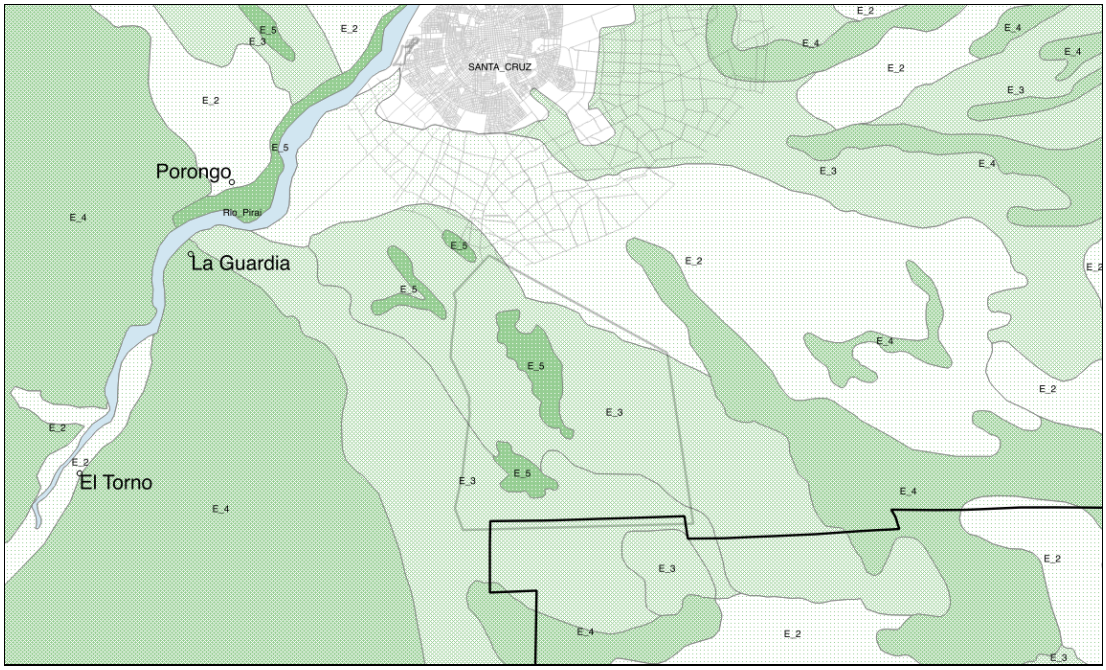
Figure 4.2-9 Protected areas of Santa Cruz Metropolitan Area

The Conservation Unit of Natural Asset (UCPN) and Natural Unit of Integral Management (UNMI) Lomas de Arena is in the jurisdiction of La Guardia. It was firstly established by the DS No. 22911 on September 25, 1991, with an extension of 13,326.6 hectares under a former national-tier regime. After several revisions, the latest on May 6, 2013, by the Resolution ADM 0011/2013, it was established over the current 14,075.97 hectares.

According to the definition of Law No. 98, UCPN is a territorial space for conservation with natural features, ecosystem functions, geological, historical, and cultural interest, with or

without human settlement in it. By the other hand, UNMI has an objective to make compatible the conservation of natural assets with the sustainable development of the local population. Its space contains predominantly natural pristine ecosystems; its management shall assure the protection for a long-term, and concomitantly, the conservation of biological diversity.

The DS No. 22911 established Lomas de Arena as a regional park and instructed to forbid land-use rights, sand extraction, burning of vegetation and forest logging, hunting and commercial fishing, sports and all kind of activities attainting the conservation of the park.



Source: Department of Santa Cruz Secretariat of Sustainable Development and Environment, processed by JICA Study Team.

Figure 4.2-10 UCPN and UNMI Lomas de Arena

The conservation status of the forest zone of Lomas de Arena is considered vulnerable, being the threats the deforestation and forest fires. Some traditional agriculture and animal husbandry is practiced in the area by private landowners impacting with progressive deforestation. The forest area preserves species of humid forest to natural savanna hosting animals, namely anteater, opossum, sloth, fox, monkeys, badger, bats, and migratory birds among 286 bird species. Moreover, circa 50 species of reptiles and amphibians are also recorded.

The fauna of the area encompasses 208 species of vascular plants, namely, the native species *torobochi*, *tajibo*, *curupaú*, *motacú*, *totaí*, and cactus.

The Figure below shows the situation of Urban Park for Ecological Preservation Curichi La Madre, which is considered in the central zone of Santa Cruz de la Sierra, in where the ecological valuation is not classified.

Source: Municipality of Santa Cruz de la Sierra Secretariat of Environment, processed by JICA Study Team.

Figure 4.2-11 Urban Park for Ecological Preservation Curichi La Madre

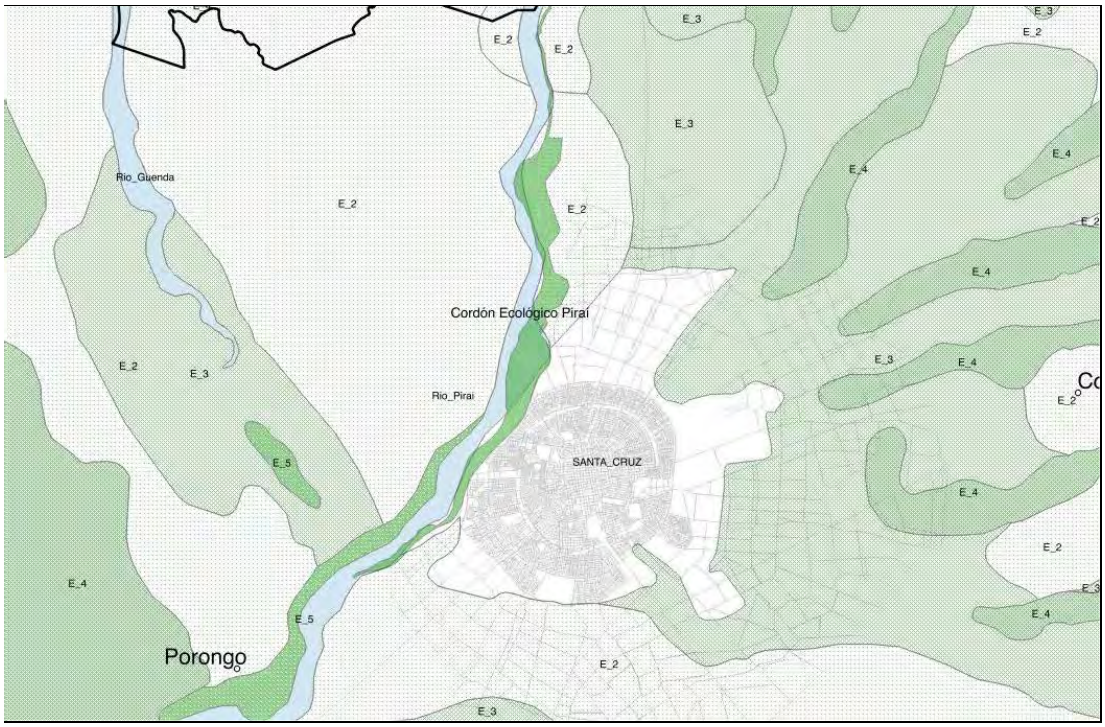
The jurisdictional area of Metropolitan Ecological Park Pirai correspondent to the Municipality of Santa Cruz de la Sierra, commonly known as *Ecological String Pirai*, lays at the right bank of the Pirai River inner the circumscription of the Municipality of Santa Cruz de la Sierra. As shown in the Figure below, it is distributed in E2 (low ecological value) and not classified zones. Nonetheless, it should notice that the left bank of the river on the jurisdiction of Porongo is classified as E5 zone (very high ecological value).

The Municipal Ordinance 150/2009 defined the *Ecological String Pirai* as Protection Forest establishing technical norms for adequacy of pre-existing households and usage of land, which comprise reforestation for protection purposes, wildlife protection activities, and other activities in a limited way such as recreational, social and cultural, accommodation, and some public institutional services.

By the other hand, the Municipal Ordinance forbids several activities such as mechanized movement of soil, tree-logging in unauthorized zones, land tenure, forestry concession, agricultural and farming, industrial, residence, and commercial activities. Whereas, architectural and civil works in the area of influence are allowed pursuing defined technical norms.

In the area are registered 51 families and 97 species of flora with high density (403 individuals per hectare). Eleven species of economic importance are recognized, namely Cacha (*Cyclolobium blanchetianum*), Tajibo amarillo (*Tabebuia impetiginosa*), Ochoo (*Hura crepitans*), Caqui (*Lonchocarpus guillemineanus*), and Curupaú (*Anadenanthera colubrina*). Fortunately, endangered species under the IUCN criteria are inexistent.

Faunal resources are also abundant counting by hundreds in the area with *circa* 46 species, among them 12 mammals, 30 birds, three reptiles, and one amphibian, are registered under CITES.



Source: Municipality of Santa Cruz de la Sierra Secretariat of Environment, processed by JICA Study Team.

Figure 4.2-12 Delimitation of Ecological String Pirai

The main threat over the area relies on shifts in land-use, deforestation, soil erosion, fragmentation of hydrologic system, growing of urbanizations, and construction of civil infrastructures.

(8) Air Quality of Santa Cruz Metropolitan Area

The management of air quality is governed by the Regulation on Matter of Air Pollution. The Ministry of Environment and Water (MMAyA), the competent sectorial institutions, the governors, and mayors shall conduct actions for preventing and controlling air pollution. According to the Regulation, allowed parameters of indicators for air quality is as listed in below Table.

Table 4.2-2 Allowed limits for air quality

Parameter	Concentration value	Period of statistic characterization
Carbon monoxide	10 mg/m^3	Eight hours average
	40 mg/m^3	One our average
Sulfur dioxide	80 µg/m^3	Annual arithmetic average
	365 µg/m^3	24-hour average
Nitrogen dioxide	150 µg/m^3	24-hour average
	400 µg/m^3	One our average
Total suspended particles	260 µg/m^3	24-hour average
	75 µg/m^3	Annual arithmetic average
PM10	150 µg/m^3	24-hour average
	50 µg/m^3	Annual geometric average
Ozone	236 µg/m^3	One hour maximum
Lead	1.5 µg/m^3	Trimester arithmetic average
Arsenic	50 ng/m^3	Annual arithmetic average
Cadmium	40 ng/m^3	Annual arithmetic average
Magnesium	2 µg/m^3	Annual arithmetic average
Mercury	1 µg/m^3	Annual arithmetic average
Vanadium	0.2 µg/m^3	Annual arithmetic average
Zinc	50 µg/m^3	Annual arithmetic average
Sulphydric acid	150 µg/m^3	24-hour average

Parameter	Concentration value	Period of statistic characterization
Fluor	50 mg/m^3	Annual arithmetic average
Chlor, Chlorhydric acid	100 µg/m^3	Annual arithmetic average
Dichloromethane	1 mg/m^3	24-hour average
Trichloroethylene	1 mg/m^3	24-hour average
Tetrachloroethylene	5 mg/m^3	24-hour average
Styrene	800 µg/m^3	24-hour average
Toluene	7.5 mg/m^3	24-hour average
Formaldehyde	100 µg/m^3	Half-hour average
Carbon disulfide	100 µg/m^3	Half-hour average

Note: Concentration values are referred to normal conditions (1 atm and 25 ºC)
Source: Annex 1 and 2 of Regulation on Matter of Air Pollution (DS 24176)

The Chapter III of the Regulation establishes environmental norms for prevention of air pollution by non-fixed sources named Technical Norms for Vehicular Emissions; while in Chapter V of the Regulation stipulates on noise and nuisance odors assessment and control. The Supreme Decree No. 28139 enacted on May 2005, also establishes for new vehicles emission limits for carbon monoxide, hydrocarbon and nitrogen oxides, and particle matter discriminated for gasoline and diesel vehicles based on European Directives and North-American Norms.

Following Tables list the allowed limits of emission quality of non-fixed sources.

Table 4.2-3 Allowed limits for emission of vehicles in circulation

Type of vehicle	Model year	Carbon monoxide (volume-%)	Hydrocarbons (ppm)	
			up to 1,800 m a.s.l.	from 1,800 m a.s.l.
Automobiles fueled by gasoline	up to 1997	6.0	600	650
	1998 - 2004	2.5	400	450
	from 2005	0.5	125	125
Automobiles fueled by natural gas	up to 1997	2.5	600	650
	1998 - 2004	2.5	400	450
	from 2005	0.5	125	125

Source: Regulation on Matter of Air Pollution (DS 24176) modified by DS 28139

Table 4.2-4 Allowed limits for motorcycles emission

Nominal engine capacity (cc)	Carbon monoxide (volume-%)	Hydrocarbons (ppm)
50 - 249	3.5	450
250 - 749	4.0	500
from 750	4.6	550

Source: Regulation on Matter of Air Pollution (DS 24176) modified by DS 28139

Table 4.2-5 Allowed limits for emission of new vehicles

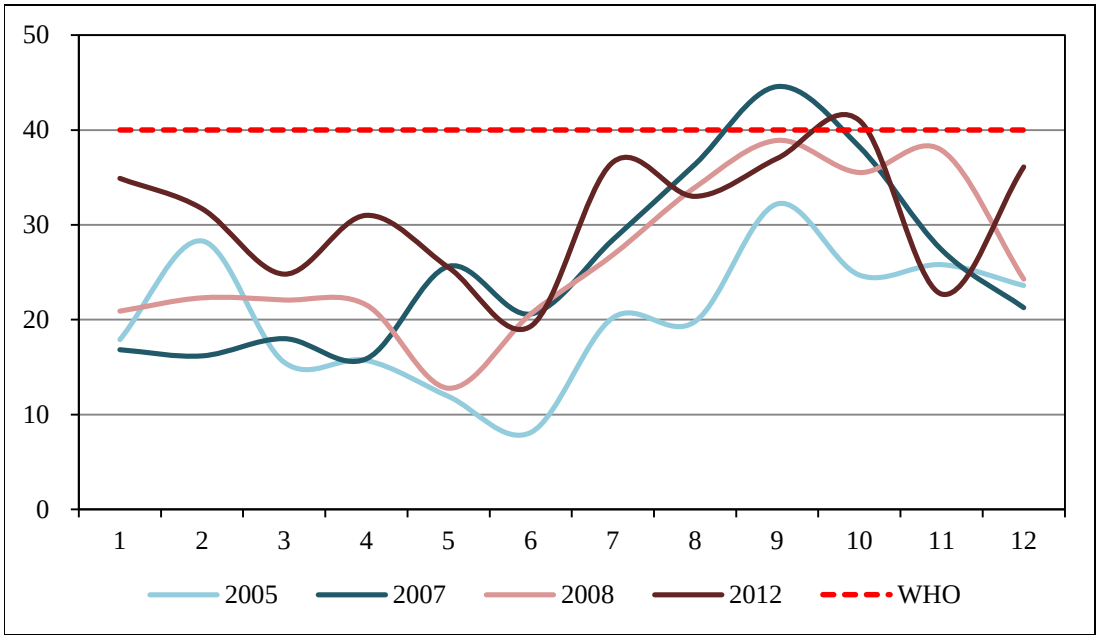
Light, and medium, weight vehicles							
Alternative 1							
Type	Reference weight (kg)	CO (g/km)		Hydrocarbon + NOX (g/km)		Particulate matter (g/km)	
		Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
≤6 passengers	≤2,500	2.72	3.16	2.72	1.13	0.14	0.18
>6 passengers	≤1,250	2.70	3.16	0.97	1.13	0.14	0.18
	<1,250 to ≤1,700	5.17	6.60	1.40	1.60	0.19	0.22
	>1,700	6.90	8.00	1.70	2.00	0.25	0.22
Alternative 2							
Type	Reference weight	CO (g/km)		Hydrocarbon (g/km)		NO_x (g/km)		Particulate matter (g/km)
		Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Diesel
≤12 passengers	Unspecified	2.13	2.13	0.26	0.26	0.63	0.63	0.13
GVWR≤6,000	LVW≤3,750	6.25	6.25	0.50	0.50	0.75	0.75	0.16

lb	lb							
	LVW>3,750 lb	6.25	6.25	0.50	0.50	1.60	1.60	0.08
GVWR>6,000 lb	LVW≤3,750 lb	6.25	6.25	0.50	0.50	0.75	0.75	0.16
	LVW>3,750 lb	6.25	6.25	0.50	0.50	1.60	1.60	0.08
Heavy vehicles								
Alternative 1								
Type	Reference weight (kg)	CO (g/kWh)	Hydrocarbon (g/kWh)	NO_X (g/kWh)	Particulate matter (g/kWh)			
>12 passengers	>3,500 (13-step cycle)	4.00	1.10	8.00	0.36			
Alternative 2								
Type	Cycle	CO (g/bHP-h)	Hydrocarbon (g/bHP-h)	NO_X (g/bHP-h)	Particulate matter (g/bHP-h)			
GVWR>3,860 kg	13 step cycle	15.50	1.30	5.00	0.07			

Source: Regulation on Matter of Air Pollution (DS 24176) modified by DS 28139

The vehicle sellers shall be compliant with the establishment of emission norms as stated by the Regulation on Matter of Air Pollution (DS 24176) modified by DS 28139 (enacted on May 17, 2005). However, the stipulations of the legislation are currently not applicable.

The Municipality of Santa Cruz de la Sierra started monitoring of air quality in 2004, installing 11 monitoring stations in the city, for the measurement of nitrogen dioxide (NO_2), ozone (O_3), and particulate matter under ten microns-size (PM10). PM10 is measured only in four stations. Below graphs show their historical records.



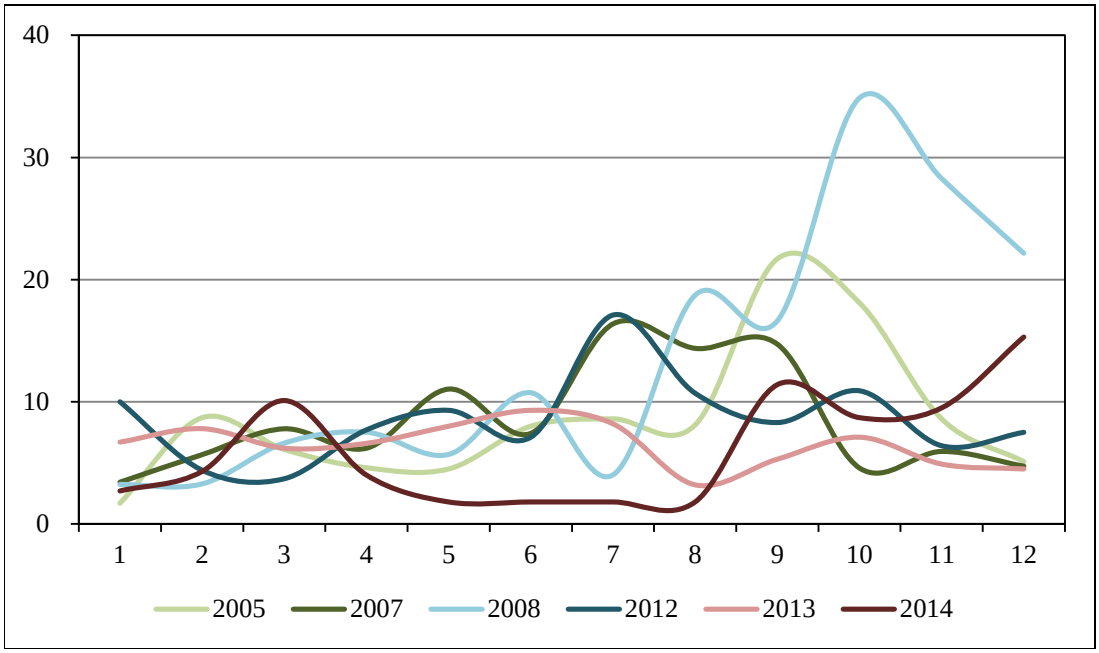
Source: Municipality of Santa Cruz de la Sierra Secretariat of Environment, processed by JICA Study Team.

Figure 4.2-13 NO_2 concentration (µg/m^3) in air in central zone of Santa Cruz de la Sierra

As shown in the graph, an increasing tendency from July to October is evident for NO_2. During these months, burning of grass and shrubs, named locally as "*chaqueo*", is widely practiced surrounding Santa Cruz. In turn, during the months without *chaqueo*, a yearly increase tendency can be shown. Based on the latter behavior can be inferred that quality of air correlates with the augmentation of automobile traffic.

Compared to the Bolivian Standards on air quality (150 µg/m^3 at 24-hour average) the reported

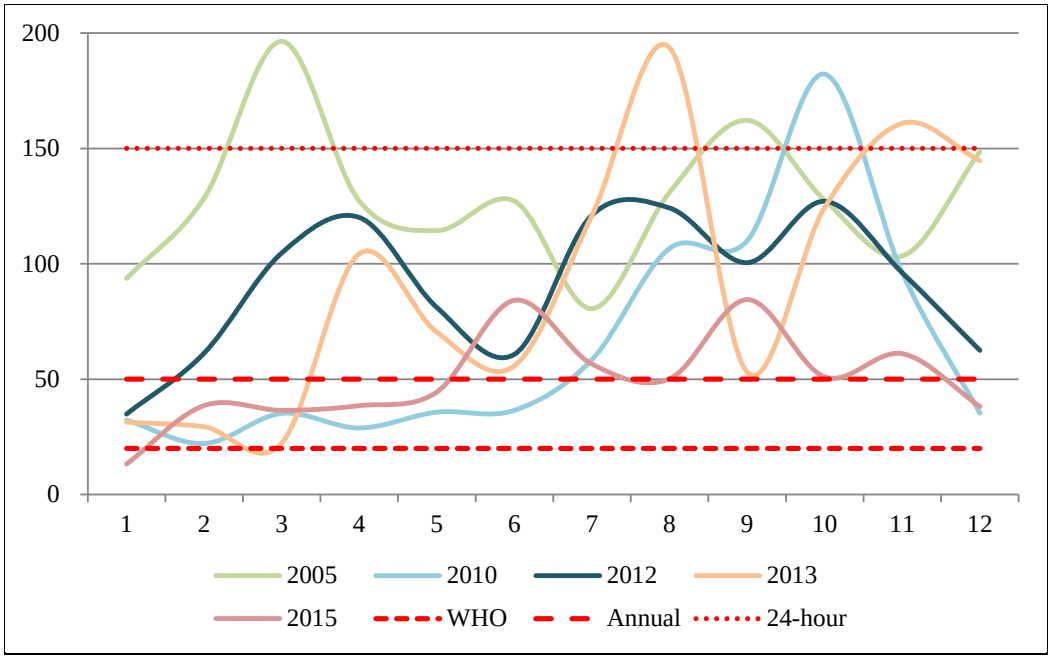
valued are compliant with it; however, according to the guidelines of World Health Organization (WHO), is partially surpassing the recommended guideline (40 µg/m^3 as annual mean).



Source: Municipality of Santa Cruz de la Sierra Secretariat of Environment, processed by JICA Study Team.

Figure 4.2-14 Ozone concentration (µg/m^3) in air in central zone of Santa Cruz de la Sierra

Similarly, to the behavior of NO_2, ozone showed lower concentration in periods without *chaqueo*; nevertheless, the values are lower also in comparison with WHO guidelines (100 µg/m^3 as eight-hour mean).



Source: Municipality of Santa Cruz de la Sierra Secretariat of Environment, processed by JICA Study Team.

Figure 4.2-15 PM10 concentration (µg/m^3) in air in central zone of Santa Cruz de la Sierra

Particulate matter lower than 10 microns (PM10) is exceeding WHO guidelines (20 µg/m^3 as annual mean) almost all the year; also in comparison with Bolivian Standards is partially

exceeding the annual geometric basis of 50 μg/m^3 and the 24-hour average of 150 μg/m^3.

Out of 11 monitoring stations, one installed at the southwestern edge of the 1st Ring Road can register all the three parameters continuously. The rest of ten is equipped with samplers and is necessary to send the samples to a laboratory for quantitative analysis. Usually, they used the analysis service of UPSA (Private University of Santa Cruz).

Based on the information from the Secretariat of Environment of the Municipality of Santa Cruz de la Sierra, to fulfill with the recommendations of the guidelines of WHO, the monitoring of particulate matter lower than 2.5 microns (PM2.5) is under analysis for its implementation.

Monitoring data of oxide compounds of carbon (CO_X), oxide compounds of sulfur (SO_X), benzene-toluene-ethylbenzene-xylene (BTEX) or other constituents of volatile organic compounds (VOCs) are lacking. An approach with SO_2 was tried in the past, however, because of its extremely low detection amounts by that time, its continuance was dismissed.

A thesis in UPSA (Vaca, J.E.O. 2010. *Determinación de la cantidad de emisiones producidas por vehículos con motor de combustión interna en la ciudad de Santa Cruz de la Sierra*) inventoried several air contaminants, namely, carbon monoxide (CO), oxide compounds of nitrogen (NO_X), VOCs, SO_X, PM10, PM2.5, carbon dioxide (CO_2), and methane generated by vehicles in Santa Cruz de la Sierra.

Simultaneously, another thesis in UPSA (Gómez B.C.M. 2010. *Análisis de las emisiones generadas por fuentes estacionarias y de sistemas de control aplicados en la ciudad de Santa Cruz de la Sierra*) studied the emissions of fixed and diffuse sources in Santa Cruz de la Sierra, compiling self-monitoring data and inquiry survey of the industrial sector.

Reported data of Vaca and Gómez for the year 2008 are listed in Table 4.2-6.

Table 4.2-6 Annual emissions of air pollutants Santa Cruz de la Sierra in 2008

(Unit: metric tons)

Parameter	Vehicles (ton, %)		Fixed sources	Other sources	Totals
PM10	na		649	21	na
PM2.5	na		79	0	na
PM	518		na	na	na
CO_2	1,543,231	53%	1,310,097	48,656	2,901,984
CO	138,534	99%	1,009	150	139,693
Methane	12,501	99%	37	34	12,572
SO_X	88	31%	199	1	288
NO_X	12,019	91%	1,171	85	13,275
N_2O	121	81%	26	3	150
NH_3	288	33%	33	559	880
VOCs	3,420	30%	989	7,170	11,579
TOC	na	na	100	9,347	na

Source: UPSA Thesis: Vaca (2010), Gómez (2010), rearranged and recalculated by JICA Study Team.

The contribution of vehicle emissions to the air pollution is considerable, fluctuating between 30-99%, depending on the pollutant.

Noise and vibration are often cited as nuisances to people living in urban areas, but it is often the peak or unexpected noises that are most problematical. Vibration is caused by all vehicles, but it is heavy trucks that cause most intrusion, and this again affects sleep, increasing levels of stress and anxiety. Noises from horns are common in many cities, and car alarms also cause a nuisance to residents.

The Regulation on Matter of Air Pollution stipulates to measure noise levels caused by the

vehicles. The allowances of noise are normed in function of gross-weight of the vehicles as shown in the table below.

Table 4.2-7 Allowed limits of noise-level from non-fixed sources

Gross weight of vehicle	up to 3,000 kg	3,000 - 10,000 kg	Over 10,000
Maximum allowance in dB	79	81	84

Source: Annex 6 of Regulation on Matter of Air Pollution (DS 24176)

(9) Water Quality of Santa Cruz Metropolitan Area

The Regulation on the Matter of Water Pollution governs the management and control of water quality in Bolivia. The Chapter III of the Regulation stipulates the classification of water bodies as listed in Table in below.

Table 4.2-8 Classification of water bodies

Class	Features
A	Natural waters of the highest quality, qualified for human consumption without any pre-treatment, or with a simple bacteriological disinfection.
B	Waters of general use, which for the human consumption is necessary physical treatment and bacteriological disinfection.
C	Waters of general use, which for the human consumption is necessary a complete physical and chemical treatments and bacteriological disinfection.
D	The water of lowest quality, which for human consumption due to extreme public demand, requires initial pre-sedimentation because of high turbidity bearing high contents of suspended solids, later a complete set of physical-chemical treatment and bacteriological disinfection.

Source: Article 4 of Regulation on the Matter of Water Pollution (DS 24176)

The section of the Pirai River correspondent to the Municipality of Santa Cruz de la Sierra is classified as C, and the Los Sauces Creek as D, based on the establishment of Administrative Resolution SDSyMA/DITCAM/005/2012 (issued on April 18, 2012).

The Table A-1 of Annex A of the Regulation establishes the allowable limits of parameters for water quality for each category for water bodies classification listed in above Table as follows:

Table 4.2-9 Allowed limits for water quality of water bodies

Parameter	Unit	Class A	Class B	Class C
pH	-	6.0 to 8.5	6.0 to 9.0	6.0 to 9.0
Temperature	^oC	±3 ^oC of receiving body	±3 ^oC of receiving body	±3 ^oC of receiving body
Total dissolved solids	mg/L	1,000	1,000	1,500
Oil and fats	mg/L	absent	absent	0.3
BOD_5	mg/L	< 2	< 5	< 20
COD	mg/L	< 5	< 10	< 40
E-coli	MPN/100 mL	< 50 and < 5 in 80% of samples	< 1,000 and < 200 in 80% of samples	< 5,000 and < 1,000 in 80% of samples
Parasites	MPN/L	< 1	< 1	< 1
Color	mg/L	< 10	< 50	< 100
Dissolved oxygen	mg/L	> 80% saturation	> 70% saturation	> 60% saturation
Turbidity	TNU	< 10	< 50	< 100
Suspended solids	mg/L or mL/L	< 10 mg/L	< 30 mg/L or < 0.1 mL/L	< 50 mg/L or 1 mL/L
Aluminum	mg/L	0.2	0.5	1.0
Ammonium	mg/L	0.05 as NH	1.0 as NH	2 as NH
Antimony	mg/L	0.01	0.01	0.01
Arsenic	mg/L	0.05	0.05	0.05
Benzene	µg/L	2.0	6.0	10.0
Barium	mg/L	0.05	1.0	2.0
Beryllium	mg/L	0.001	0.001	0.001
Boron	mg/L	1.0	1.0	1.0
Calcium	mg/L	200	300	300

Parameter	Unit	Class A	Class B	Class C
Cadmium	mg/L	0.005	0.005	0.005
Cyanide	mg/L	0.002	0.1	0.2
Chloride	mg/L	250 as Cl	300 as Cl	400 as Cl
Copper	mg/L	0.05	1.0	1.0
Cobalt	mg/L	0.1	0.2	0.2
Chrome hexavalent	mg/L	0.05	0.05	0.05
Chrome trivalent	mg/L		0.6	0.6
1-2 Dichloroethane	µg/L	10.0	10.0	10.0
1-1 Dichloroethylene	µg/L	0.3	0.3	0.3
Tin	mg/L	2.0	2.0	2.0
Phenol	µg/L	1	1	5
Soluble iron	mg/L	0.3	0.3	0.1
Fluoride	mg/L	1.7	1.7	1.7
Total phosphates	mg/L	0.4 as orthophosphate	0.5 as orthophosphate	1.0 as orthophosphate
Magnesium	mg/L	100	100	150
Manganese	mg/L	0.5	1.0	1.0
Mercury	mg/L	0.001	0.001	0.001
Lithium	mg/L	2.5	2.5	2.5
Nickel	mg/L	0.05	0.05	0.5
Nitrate	mg/L	20.0	50.0	50.0
Nitrite	mg/L	< 1.0 as N	< 1.0 as N	< 1.0 as N
Total nitrogen	mg/L	5	12	12
Lead	mg/L	0.05	0.05	0.05
Silver	mg/L	0.05	0.05	0.05
Pentachlorophenol	µg/L	5.0	10.0	10.0
Selenium	mg/L	0.01	0.01	0.01
Sodium	mg/L	200	200	200
Floating solids		absent	absent	absent
Sulfate	mg/L	300	400	400
Sulfide	mg/L	0.1	0.1	0.5
Detergents	mg/L	0.5	0.5	0.5
Tetrachloroethane	µg/L	10	10	10
Trichloroethane	µg/L	30	30	30
Carbon tetrachloride	µg/L	3	3	3
2,4,6 trichlorophenol	µg/L	10	10	10
Uranium	mg/L	0.02	0.02	0.02
Vanadium	mg/L	0.1	0.1	0.1
Zinc	mg/L	0.2	0.2	5.0
Aldrin/Dieldrin	µg/L	0.03	0.03	0.03
Chlordane	µg/L	0.3	0.3	0.3
D.D.T.	µg/L	1.0	1,0	1.0
Endosulfan	µg/L	70	70	70
Heptachlor and Heptachloripoxide	µg/L	0.1	0.1	0.1
Lindane	µg/L	3.0	3.0	3.0
Metoxichlor	µg/L	30	30	30
PCB	µg/L	2.0		
PCB	µg/L		0.001	0.001
Toxaphene	µg/L	0.01	0.01	0.01
Demethon	µg/L	0.1	0.1	0.1
Gution	µg/L	0.01	0.01	0.01
Malathion	µg/L	0.04	0.04	0.04
Carbaryl	µg/L		0.02	0.02
2,4-D; herbicide: Chlorophenoxy	µg/L	100	100	100
2,4,5-TP; herbicide Chlorophenoxy	µg/L	10.0	10.0	10.0
2,4,5-T	µg/L	2.0	2.0	2.0
Alpha radiation	Bq/L	0.1	0.1	0.1
Beta radiation	Bq/L	1.0	1.0	1.0

Source: Table A-1 of Annex A of Regulation on the Matter of Water Pollution (DS 24176)

Whereas, the following Table lists the allowed limits for liquid discharge as stated in Annex A-2 of the Regulation.

Table 4.2-10 Allowed limits for liquid discharge

Parameter	Unit	Daily basis	Monthly basis
Copper	mg/L	1.0	0.5
Zinc	mg/L	3.0	1.5
Lead	mg/L	0.6	0.3
Cadmium	mg/L	0.3	0.15
Arsenic	mg/L	1.0	0.5
Chrome trivalent	mg/L	1.0	0.5
Chrome hexavalent	mg/L	0.1	0.05
Mercury	mg/L	0.002	0.001
Iron	mg/L	1.0	0.5
Antimony	mg/L	1.0	
Tin	mg/L	2.0	1.0
Cyanide free (mining sector)	mg/L	0.2	0.10
Cyanide free (hydrocarbon sector)	mg/L	0.5	0.3
pH		6 to 9	6 to 9
Temperature	^{o}C	±5	±5
Phenolic compounds	mg/L	1.0	0.5
Total suspended solids	mg/L	60.0	
Fecal coliforms	MPN/100 mL	1,000	
Oil and fats (mining sector)	mg/L	10.0	
Oil and fats (hydrocarbon sector)	mg/L	20.0	
BOD_5	mg/L	80.0	
COD (mining sector)	mg/L	250.0	
COD (hydrocarbon sector)	mg/L	300.0	
Ammonium	mg/L	4.0	2.0
Sulfur	mg/L	2.0	1.0

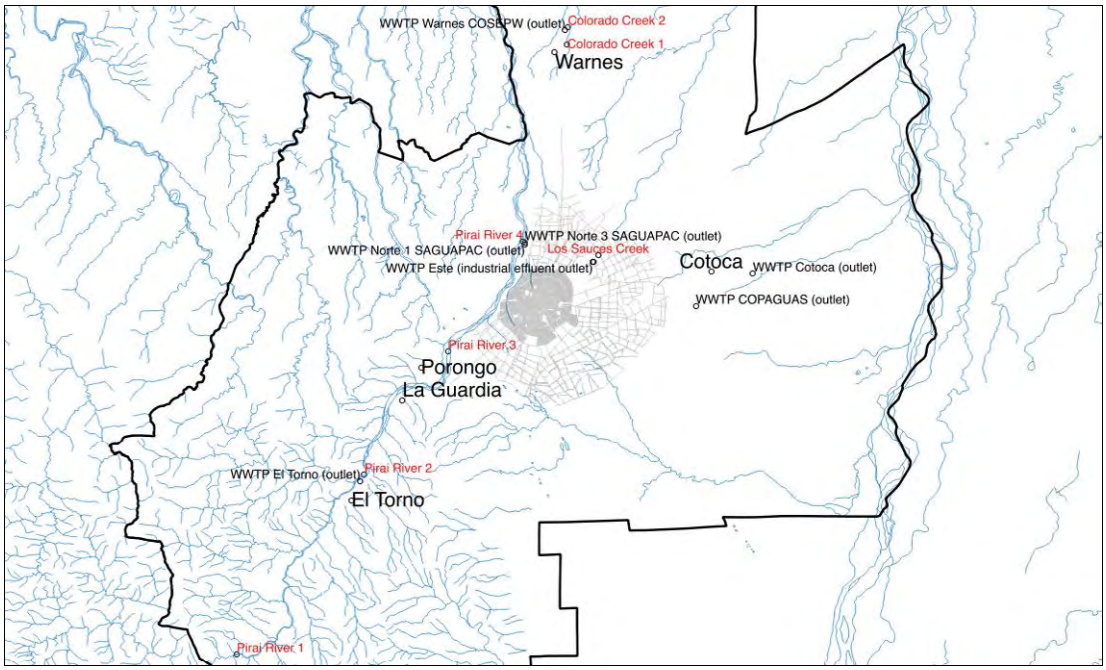
Source: Table A-2 of Annex A of Regulation on the Matter of Water Pollution (DS 24176)

According to the information from SAGUAPAC, diffuse contamination by nitrogen, increase in salinity, and high concentrations of organic carbon were found. Furthermore, derivatives of petroleum, industrially used solvents, organic compounds, and microorganisms were detected in shallow wells. Some private-owned shallow wells shown concentrations of nitrates and manganese higher than the values recommended by WHO.

SAGUAPAC also informed that all the recently excavated wells and existing shallow wells showed pollution by E-coli. Some of the polluted wells arising 50 m depth. The average values of total organic carbon (TOC) and chemical oxygen demand (COD) resulted in 2.3 and 5.5 mg/L respectively.

Based on the data, the principal risk of contamination is caused by untreated sewerage drainage; especially by numerous septic tanks existing in the zone. Runoffs and infiltration from roads and urban zones cause the pollution with organic compounds.

Between January 3rd and February 8th, 2013, spot sampling of water quality of surficial waters was conducted by the Department of Santa Cruz in locations shown in the Figure below.



Source: Department of Santa Cruz Secretariat of Sustainable Development and Environment, processed by JICA Study Team.

Figure 4.2-16 Sampling points for surficial water quality and discharge points of wastewater treatment plants of Santa Cruz Metropolitan Area

The sampling points Pirai River 2, Pirai River 4, and Colorado Creek 2 are located downstream of drainage points of wastewater treatment plants; and the Los Sauces Creek in the influence area of an industrial wastewater treatment plant. It is noticeable that wastewater treatment plants of Cotoca and COPAGUAS are located in the basin of the Rio Grande. The measured water quality is listed in the Table below.

Table 4.2-11 Water quality of surficial waters in Santa Cruz Metropolitan Area

Parameter	Pirai River 1	Pirai River 2	Pirai River 3	Los Sauces Creek	Pirai River 4	Colorado Creek 1	Colorado Creek 2
pH	7.4	7.7	7.9	7.8	8.1	7.9	7.7
Temperature (ºC)	24.6	27.3	24.9	30.0	32.0	26.5	28.0
Conductivity (µmhos/cm)	214	262	359	1,490	349	1,215	1,088
TDS (mg/L)	196	202	240	790	215	704	636
TSS (mg/L)	382	472	820	195	810	48	48
DO (mg/L)	8.4	8.1	8.3	4.1	4.2	4.1	4.9
BOD_5 (mg/L)	nd	nd	nd	66	nd	28	173
COD (mg/L)	57	41	53	407	44	145	255
NO_3 (mg/L)	4.0	6.1	6.4	7.8	2.0	4.4	nd
NO_2 (mg/L)	nd	nd	nd	9.4	nd	nd	0.7
N (mg/L)	nd	nd	nd	118.3	nd	21.0	25.6
Total P (mg/L)	0.2	0.3	nd	7.4	0.3	4.4	4.5

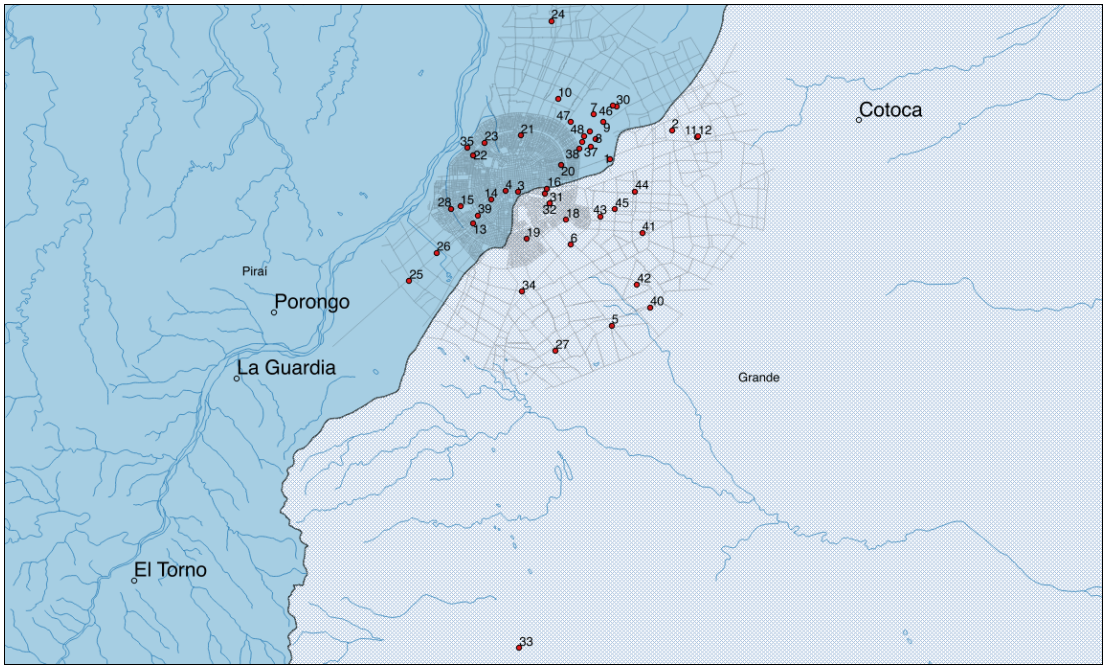
Note: Spot sampling January-February 2013

Source: Department of Santa Cruz Secretariat of Sustainable Development and Environment, reordered by JICA Study Team.

From the values listed in the Table, it is obvious the tendency of water quality degradation in the downstream direction, and the impact from drainage of treated wastewaters. The brown-colored values exceed the allowed limit for class C (see Table 4.2-9), and light-brown colored

values for class A.

The Municipality of Santa Cruz de la Sierra conducted a reconnaissance survey during the year 2016 on 48 observation wells. The locations of the observation wells are shown in the Figure below.



Source: Municipality of Santa Cruz de la Sierra Secretariat of Environment, processed by JICA Study Team.

Figure 4.2-17 Locations of observation wells in Santa Cruz Metropolitan Area

The measured water quality of these observation wells is listed in below Table.

Table 4.2-12 Groundwater quality in Santa Cruz Metropolitan Area

Well	Depth (m)	Turbidity (NTU)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	Fe (mg/L)	Cl (mg/L)	SO_4 (mg/L)	NO_3 (mg/L)	NH_3 (mg/L)
1	96	nd	101	16.0	8.4	0.05	13.0	7	3.6	Nd
2	140	nd	77	9.7	1.4	0.00	2.1	12	0.8	Nd
3	120	nd	54	8.9	1.4	0.00	2.2	29	0.5	Nd
4	65	nd	110	6.8	41.0	0.00	61.9	21	26.0	Nd
5	24	2.3	51	6.5	2.4	0.00	3.7	5	0.8	0.03
6	24	2.7	72	7.9	0.9	0.00	1.5	44	1.2	0.02
7	148	nd	73	12.0	1.6	0.00	2.4	15	1.4	Nd
8	114	nd	90	12.0	11.0	0.00	17.3	7	2.6	Nd
9	134	nd	59	11.0	0.0	0.00	0.0	6	0.6	Nd
10	55	2.8	139	26.0	24.0	0.10	36.3	44	9.9	Nd
11	130	nd	97	14.0	7.9	0.11	12.1	22	0.4	Nd
12	137	nd	73	11.0	1.1	1.81	1.7	8	0.5	Nd
13	56	nd	104	17.0	4.9	0.38	7.4	31	0.5	Nd
14	93	nd	92	17.0	13.0	0.14	20.2	38	0.9	Nd
15	124	nd	59	9.3	1.6	0.00	2.5	29	0.5	nd
16	120	nd	75	12.0	10.3	0.23	15.9	13	4.1	nd
17	55	nd	130	16.0	18.0	nd	27.2	51	6.7	nd
18	46	nd	110	17.0	12.0	nd	18.4	15	2.4	nd
19	22	nd	141	16.0	24.0	0.13	36.8	68	3.8	nd
20	161	nd	147	35.0	29.0	nd	44.4	57	2.5	nd
21	68	nd	123	18.0	12.0	nd	17.9	56	6.0	nd
22	50	nd	110	25.0	25.0	nd	38.1	53	1.4	0.31
23	100	nd	60	11.0	1.4	nd	2.2	21	0.5	0.13
24	80	nd	37	9.4	2.2	0.10	3.7	5	4.5	nd
25	80	nd	96	15.0	3.4	nd	5.9	28	2.8	nd

Well	Depth (m)	Turbidity (NTU)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	Fe (mg/L)	Cl (mg/L)	SO_4 (mg/L)	NO_3 (mg/L)	NH_3 (mg/L)
26	102	nd	104	26.0	5.3	nd	8.1	20	0.7	nd
27	37	nd	10	1.6	nd	nd	nd	nd	0.7	nd
28	26	nd	102	26.0	3.1	nd	4.7	35	1.0	nd
29	60	3.3	136	38.0	30.0	0.06	46.1	14	6.8	0.03
30	33	nd	37	7.4	3.8	0.05	5.8	7	1.7	0.02
31	80	1.6	71	12.0	5.8	0.09	8.9	8	2.2	nd
32	150	23.0	85	18.0	10.0	0.33	15.8	12	4.9	0.13
33	60	4.6	167	34.0	45.0	0.10	68.7	53	8.2	0.03
34	24	3.0	28	5.7	2.2	0.11	3.3	12	9.1	0.02
35	60	nd	51	11.0	12.0	0.13	19.0	12	0.7	0.02
36	138	nd	60	9.2	1.9	nd	3.0	5	1.3	nd
37	130	nd	89	15.0	5.7	nd	8.7	6	3.3	nd
38	186	nd	56	8.0	1.5	0.08	23.0	10	1.1	nd
39	75	nd	96	14.0	14.0	0.07	22.0	52	0.7	nd
40	126	nd	47	5.8	nd	nd	0.0	nd	0.9	nd
41	39	21.0	111	21.0	8.4	0.26	13.0	nd	1.4	0.40
42	280	nd	44	5.9	nd	nd	nd	10	0.6	nd
43	107	1.1	75	9.8	2.8	0.05	4.3	nd	1.8	nd
44	80	nd	72	18.0	10.0	nd	15.6	11	5.0	nd
45	45	1.0	96	24.0	4.7	0.06	7.2	nd	2.9	nd
46	3	nd	64	8.1	22.0	nd	34.5	105	10.0	nd
47	67	nd	136	43.0	29.0	nd	44.3	40	5.3	nd
48	90	nd	134	24.0	22.0	nd	33.5	200	3.1	nd

Note: Spot sampling January 1, 2013
Source: Municipality of Santa Cruz de la Sierra Secretariat of Environment, reordered by JICA Study Team.

As listed, some of the observation wells showed impaired situations with respect to class A quality; e.g., the well three located at the center of Santa Cruz de la Sierra resulted higher NO_3 at a depth of 65 m. Wells 12, 13 with iron at depths 137 m and 56 m, respectively. The wells 22 (50 m depth) and 23 (100 m depth) are impaired with ammonia. The well 32 of 150 m depth resulted impaired with respect to turbidity, iron, and ammonia; and the observation well 41 with turbidity and ammonia.

(10) Solid waste management of Santa Cruz Metropolitan Area

According to the General Directorate of Integral Management of Solid Waste under the Vice-ministry of Potable Water and Basic Sanitation (2011. *Diagnóstico de la Gestión de Residuos Sólidos en el Departamento de Santa Cruz*), the waste generated in 2010 in the urban areas of the Department of Santa Cruz was 1,344 ton/day, exceeding that of La Paz at 1,160 ton/day.

The services of street sweeping, waste collection and transportation, selective collection of sorted waste, treatment of waste, and final disposal of urban solid waste of the Municipality of Santa Cruz de la Sierra are provided by EMACRUZ, a municipality owned enterprise.

The waste collection services of EMACRUZ cover domiciliary waste, commercial waste, and hospital waste with direct transportation to the sanitary landfill for their confinement. Hospital waste is treated by chemical neutralization before confinement in separate cells.

The per capita generation of waste in Santa Cruz de la Sierra evolved from 0.68 kg to 0.82 kg in few years and is estimated to achieve 0.94 kg by 2018 (lifespan of the current sanitary landfill in Normandía Zone). Because more than 50% of the generated waste is composed of organic material, a five-hectare space closer to the current sanitary landfill is under analysis for making compost, which is processed in 40-60 days; however, the demand for the compost is uncertain.

The existing landfill is installed with leachate collection system connected to a system of

evaporation ponds with recirculation system to landfill; also gas exhaust system concentric with leachate collection pipes with burning devices at end-of-pipe.

The construction of a new sanitary landfill is under planning, waiting for approval from the Government Secretariat of Sustainable Development and Environment. The new landfill is expected to use by the Municipalities of Metropolitan Area, under the management of EMACRUZ. Based on their estimation, more than 90% of generation belongs to the Municipality of Santa Cruz de la Sierra and less than 10% to other municipalities. The use of incineration system was dismissed because of an enactment of a law prohibiting its application.

The daily per capita generation of other municipalities was estimated: Cotoca 0.63 kg, El Torno 0.50 kg, La Guardia 0.43 kg, Porongo 0.52 kg, and Warnes 0.48 kg (2011. *Diagnóstico de la Gestión de Residuos Sólidos en el Departamento de Santa Cruz, Cuadro No. 3*).

The provision of waste management services is made by local microenterprises in the municipalities of Cotoca (Microenterprise Tilichi) and Warnes (Microenterprises Macororó and Serere); whereas, El Torno, La Guardia, and Porongo have their municipal division in charge of these duties.

The final disposal of solid waste in the Municipality of Cotoca is conducted in an open damping site placed in a private-owned land, located 700 m from the center of the city, disposing of 81 tons per week. A new site for disposal of waste is under analysis, in a location named La Rinconada located 8 km southwest of the city.

The Municipality of El Torno established its open damping site crossing the Pirai River, two kilometers from the center of the city, which disposes of 7.5 ton of solid waste per week. The site is a former land for extraction of sand.

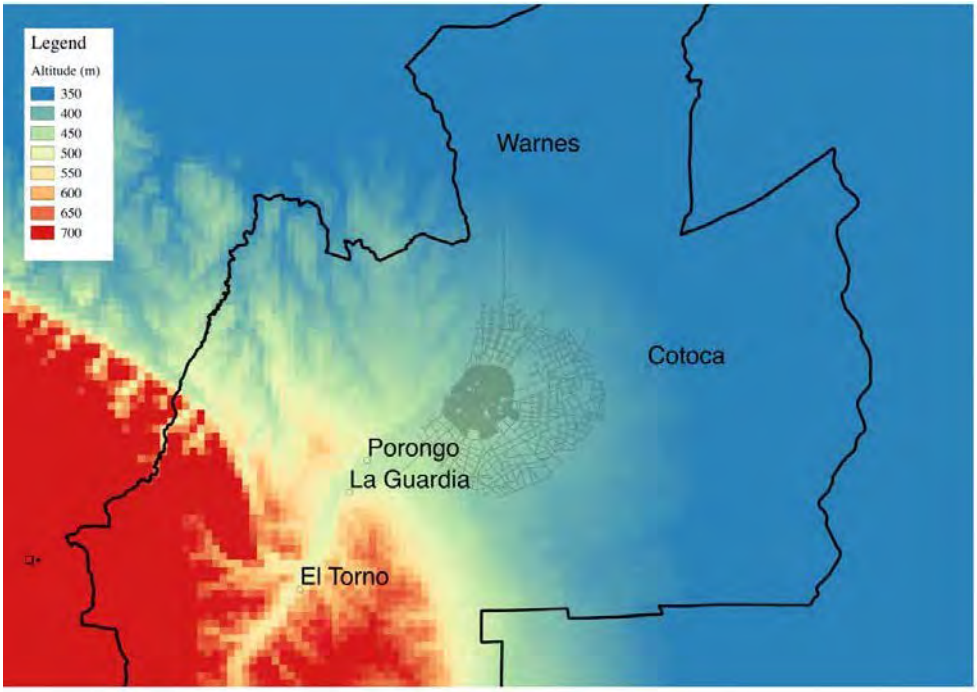
In La Guardia, a controlled dumping site is provided for the disposal of collected solid waste, located in the Barrio 23 de Octubre, El Carmen, 12 km from the center of the city. 24 tons per week is disposed of semi-mechanically.

An open damping site located 2.7 km from the center of the city, 700 m from the left bank of the Pirai River close to the edge of conservation area, is used in the Municipality of Porongo for their waste. 8.4 tons per week is disposed of.

The case of Municipality of Warnes is also an open damping site, located 2.5 km from the populated zone, disposing of 42 tons weekly.

(11) Geographical settings and risk vulnerability of Santa Cruz Metropolitan Area

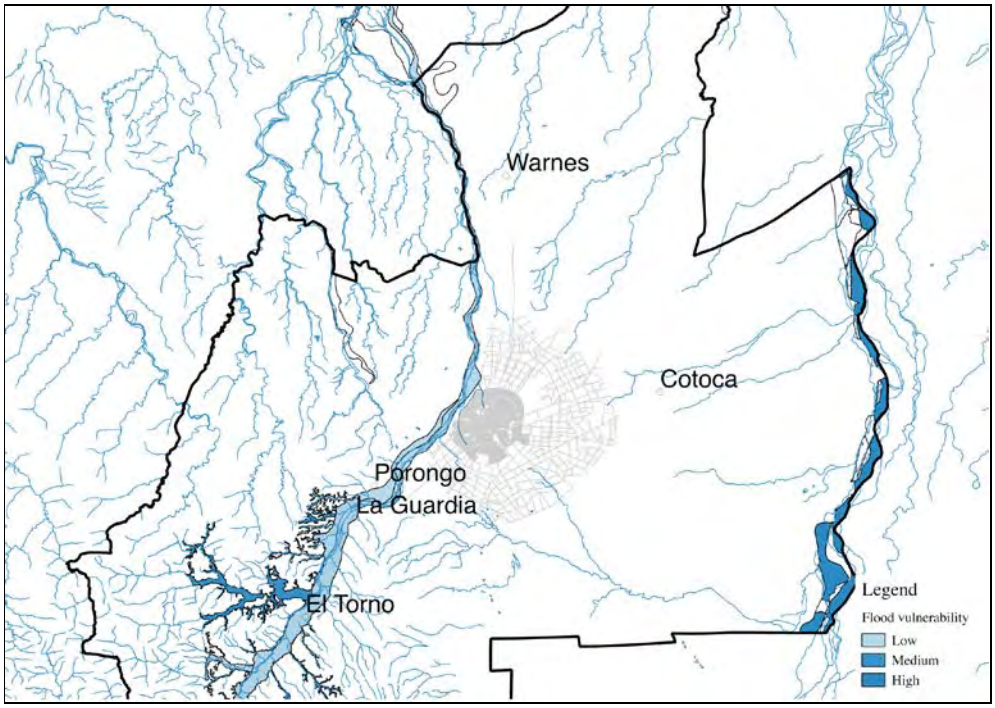
The topography declines relatively smoothly southwest to northeast. The altitude of capital cities varies from 528 m a.sl. of El Torno to 340 m a.s.l. of Warnes (La Guardia: 506 m, Porongo: 450 m, Santa Cruz de la Sierra: 416 m, and Cotoca: 350 m). The Figure below shows roughly the topographical distribution of Santa Cruz Metropolitan Area.



Source: WorldClim Version 1 alt_33, processed by JICA Study Team.

Figure 4.2-18 Topography of Santa Cruz Metropolitan Area

The Department Administration assessed the vulnerability of Santa Cruz Metropolitan Area against flood, landslide, and drought. The following Figure shows the vulnerability against flood in where is notorious highly prone situation along the Rio Grande. Medium level of risk at the Pirai River left bank tributary in El Torno was identified.

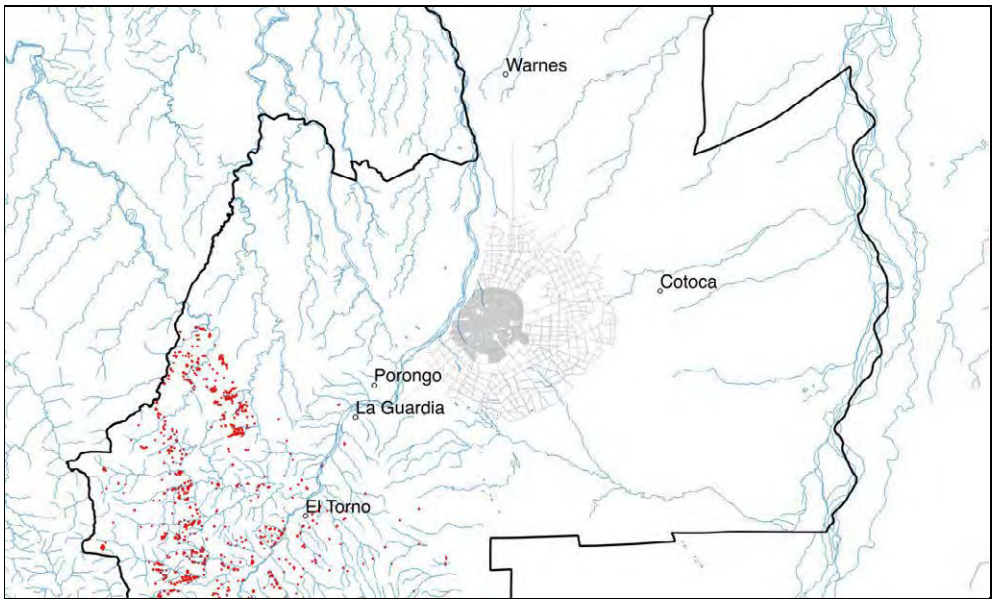


Source: Department of Santa Cruz Secretariat of Sustainable Development and Environment, processed by JICA Study Team.

Figure 4.2-19 Flood vulnerability map of Santa Cruz Metropolitan Area

The red bullets in the Figure below show the locations vulnerable to landslides. The locations

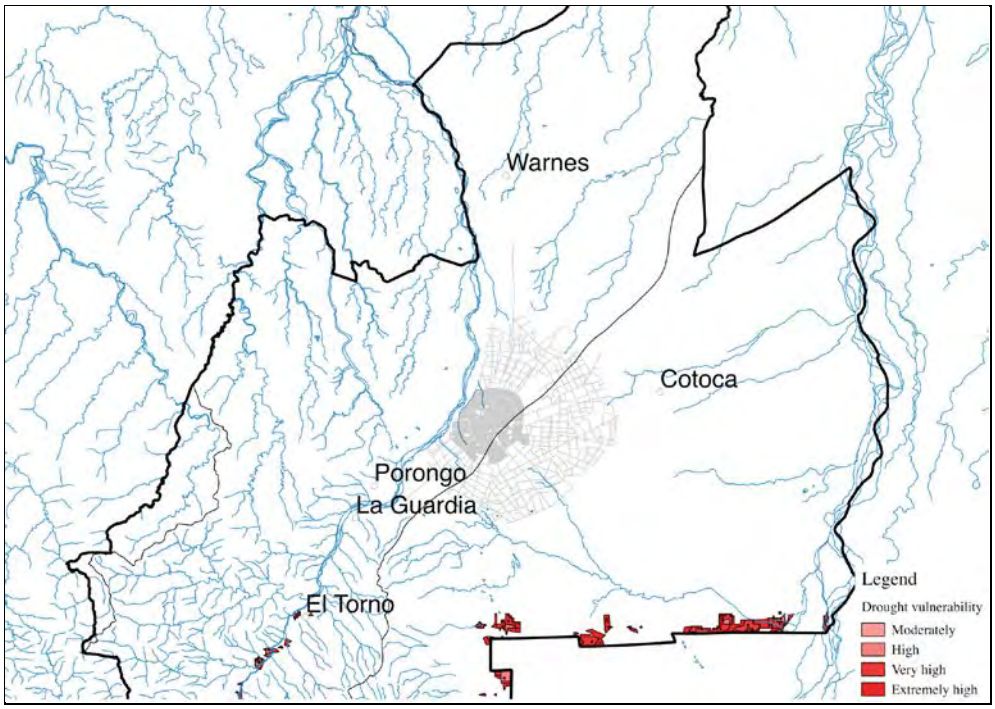
are scattered in highlands (over 600 m a.s.l.) of El Torno.



Source: Department of Santa Cruz Secretariat of Sustainable Development and Environment, processed by JICA Study Team.

Figure 4.2-20 Landslide vulnerability map of Santa Cruz Metropolitan Area

The Figure below shows the vulnerable zones of Santa Cruz Metropolitan Area against drought. Some zones in the south of the city of El Torno along the Pirai River and the borderline of Santa Cruz de la Sierra with the Municipality of Cabezas of Cordillera Province is identified.



Source: Department of Santa Cruz Secretariat of Sustainable Development and Environment, processed by JICA Study Team.

Figure 4.2-21 Drought vulnerability map of Santa Cruz Metropolitan Area

4.3 Scoping

The most common definition of scoping in SEA refers to a range of tasks that specifies the activities and objectives of the SEA-process. As a minimum, this stage should define the broad contents of the SEA target factors and the likely significant environmental effects to be considered. The SEA-process consists of the following activities and approaches.

- Collection of baseline data and information,
- Identification of Stakeholders,
- Consultation within and between public authorities,
- Description of principal inherent development initiatives,
- Significant environment effects to be considered,
- Involuntary resettlement issue, and
- Setting of evaluation criteria for alternative analysis.

4.3.1 Identification of Stakeholders

The default stakeholders of the current approach are constituted by the Municipal Administrations of the Metropolitan Area. Especially, the Secretariat, Department, and Divisions in charge of environmental issues.

Following entities also were identified as stakeholders:

- The staff in charge of the environment of the Directorate of Drainage of the Municipality of Santa Cruz de la Sierra have the duty to monitor the water quality at end-of-pipe of their drainage system at discharge points to water bodies. Under this work, they found some unpaired connections, especially from incompliant industries jointing effluents to pluvial channeling system. They are analyzing to implement measuring devices for to quantify water drainage flows.
- SEARPI (*Servicio de Encausamiento de Aguas y Regulación del Río Pirai*), an institution dependent on the Government of the Department of Santa Cruz, in charge of flood control and conservation of watersheds of the Department.
- EMACRUZ a Municipality of Santa Cruz de la Sierra owned enterprise for providing services of street sweeping, waste collection and transportation, selective collection of sorted waste, treatment of waste, and final disposal of urban solid waste. Waste collection services cover domiciliary waste, commercial waste, and hospital waste (hospital waste is treated by chemical neutralization before confinement in separate cells) with direct transportation to the sanitary landfill for their confinement.
- Private companies of water supply and sewerage service such as SAGUAPAC
- Representatives of organizations of public transportation service providers

Complementing the aforementioned entities, the Faculty of Engineering of UPSA (*Universidad Privada de Santa Cruz de la Sierra*) which is involved in the Red MONICA, a nationwide network for air quality monitoring, the Faculty of Environmental Engineering of UNE (*Universidad Nacional Ecológica*), a group of professionals for the conservation of environment and livelihood Plataforma por el Medio Ambiente y la Vida, and Fundación Amigos de la Naturaleza (FAN), a NGO working with the Secretariat of Sustainable Development and Environment under the Departmental Autonomous Government of Santa Cruz for the conservation of environment.

4.3.2 Consultation within and between public authorities

The first stage of consultation activities included gathering relevant data and information on development plans. The purpose of the consultation consisted on to identify development targets and associated potential environmental disturbances in respective jurisdictions.

Three stakeholder meetings (named *Foro Ambiental* in Spanish-language) were held. The first meeting conducted on July 26, 2016, at Center for Environmental Studies (CEA), where evaluation criteria for the alternatives of development scenarios and the methodology to monitor the chosen scenario were discussed. On November 23, 2016, the second stakeholder meeting was held at CEA, where the different alternatives of development scenario using the selected criteria and identifying the monitoring indicators for appropriate management among the stakeholders were analyzed.

The third stakeholder meeting was held on May 5, 2017 in CEA, sharing available indicators of selected criteria as much as possible in the quantitative method. The necessity of collaboration mechanism for sharing relevant data and responsibilities of stakeholders on the monitoring duties were discussed and encouraged to continue their effort during the implementation of the Master Plan activities.

An additional technical workshop was held on May 12, 2017, to enhance local capacities for using remote sensing techniques for a group of indicators for the selected criteria, namely for heat island effect, air quality, and vegetation indexes.

4.3.3 Description of principal inherent development initiatives

(1) Development plans

The 2030 Agenda for Sustainable Development under the United Nation's approach established (September 2015) the Sustainable Development Goals and targets, taking into account different national realities, capacities and levels of development and respecting national policies and priorities.

Each government shall decide how these targets should be incorporated into national planning processes, policies and strategies. Furthermore, the link between sustainable development and other relevant ongoing processes in the economic, social and environmental fields is imperative.

The Sustainable Development Goal 11 aims to “Make cities and human settlements inclusive, safe, resilient and sustainable”, establishing the following indicators:

- 11.1: By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums;
- 11.2: By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons;
- 11.3: By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries;
- 11.4: Strengthen efforts to protect and safeguard the world’s cultural and natural heritage;
- 11.5: By 2030, significantly reduce the number of deaths and the number of people

affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations;

- 11.6: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management;
- 11.7: By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities;
- 11.a: Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning;
- 11.b: By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels; and
- 11.c: Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials.

Under the circumstance, the Santa Cruz Departmental Plan 2025 states five principal components for development as follows:

- Enhancement of capacity and fostering of sustainability as the principal producer of food for the country,
- Improvement of road infrastructure aiming continental connectivity,
- Correction of uncontrolled consumption of groundwater,
- Solution to irregular settlement and deficit of private properties, and
- Improvement of sewerage system coverage.

At the level of Municipality, current Municipal development plan (PDM) and spatial plans named PLOTs states as priority development goals the items as listed in the following Table.

Table 4.3-1 PDM/PLOT priorities at Municipal level

Municipality	Priorities
Cotoca	• Strengthening of agricultural and stockbreeding sectors consequent with soil aptitudes • Strengthening of brick and pottery sectors in clay-rich areas • Fostering of fishing-tourism at the Rio Grande • Fostering of stockbreeding at Cotoca and Quitachiyú Creeks
El Torno	• Strengthening of agricultural and stockbreeding sectors • Fostering of artisan and small, and medium, sized enterprises (SMEs) • Improvement of production infrastructure • Improvement of transportation system • Fostering of tourism sector • Development of local market
La Guardia	• Adequacy of spatial use • Improvement of water supply system • Improvement of energy supply system • Improvement of health services • Improvement of education system • Improvement of civilian security

Municipality	Priorities
	• Fostering of private investment through improvement of infrastructure, financial system, and market facilities
Porongo	• Improvement of road system to be runnable in rainy season • Construction of vicinal roads • Improvement of agricultural techniques • Provision of financial mechanisms for the agricultural sector • Support for the tourism sector
Santa Cruz de la Sierra	• Pavement of roads • Construction of roads • Establishment of markets and distribution system • Improvement of transportation service • Improvement of draining system • Decentralization of the city • Improvement of health services
Warnes	• Improvement of road system to be runnable in rainy season • Establishment of cadaster system for property procedures of real estates • Improvement of solid waste management • Strengthening of control capacity for the supervision of effluents from industrial and animal husbandry sectors • Establishment of mechanism for forest conservation activities

Source: Municipalities PDMs/PLOTs

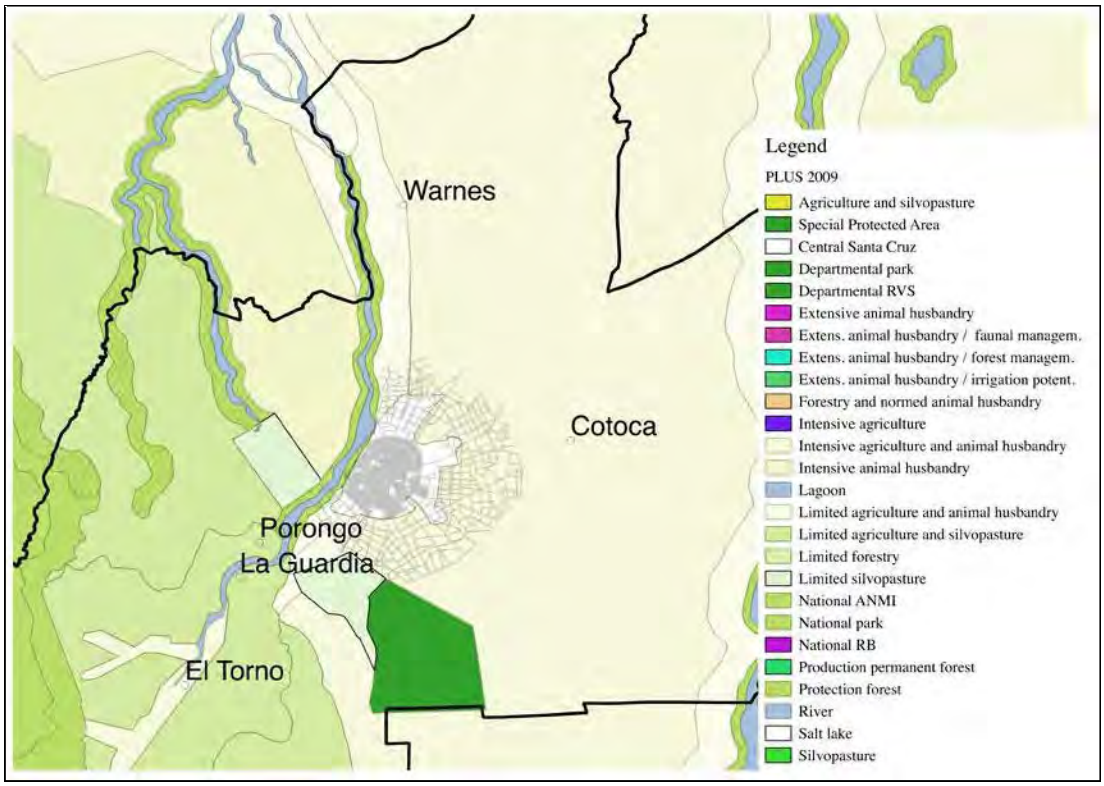
(2) Spatial plans

The Department of Santa Cruz counts with a Departmental Plan of Soil Use named PLUS-Santa Cruz. The first version of PLUS-Santa Cruz was approved by the Supreme Decree No. 24124 on September 21, 1995. Posterior updates achieved on the current PLUS-Santa Cruz 2009.

The principal soil use under PLUS-Santa Cruz categorization was established as follows:

- Soils for intensive agriculture and animal husbandry,
- Soils for extensive agriculture and animal husbandry,
- Soils for agricultural and silvopasture use,
- Soils for forestry use,
- Soils of limited use, and
- Protected natural areas.

The following Figure shows the Santa Cruz Metropolitan Area with soil use sub-categorization.



Source: GAD Santa Cruz. PLUS-2009.

Figure 4.3-1 Soil use plan for Santa Cruz Metropolitan Area

As shown in the Figure, the Central Santa Cruz (white zone) had not been categorized under PLUS criteria. Most of the surrounding zone of Santa Cruz de la Sierra, Warnes, Cotoca, and La Guardia is placed on zone categorized for intensive agriculture and animal husbandry.

It is noticeable that along the Pirai River both riverbanks are categorized as protected forest and beyond the protected zone, the zone of limited agriculture and animal husbandry up to western zone of Warnes.

A part of Porongo and La Guardia is in the zone of limited silvopasture.

The dark-green zone at Southeast of La Guardia categorized as Departmental park coincides with the UCPN and UNMI Lomas de Arena (See for details Section 4.2.2 (7) Protected Areas of Santa Cruz Metropolitan Area).

Furthermore, the Santa Cruz Metropolitan Area counts with its Spatial Plan named PDOT (*Plan Departamental de Ordenamiento Territorial*). Principal actions on PDOT were established as follows:

- Definition of principal aptitudes of the urban centers to plan houses densification and the complimentary services needed;
- Definition of urban infrastructure prioritizing projects for integration, such as highways for connecting Cotoca - Warnes, Cotoca - La Guardia, and Porongo - Buena Vista, to improve the freight corridors and traffic, impeding the traffic of large trucks from entering the urbanized zone of Santa Cruz de la Sierra;
- Definition and establishment of intermodal centers for freights in Warnes and La Guardia;
- Definition of guidelines and locations for waste disposal sites with integrated management of waste to mitigate water and soil pollution, throughout the installation of

facilities for pre-treatment of solid waste and leachate treatment;

- Definition and promotion of industrial parks and processing centers based on the aptitudes of each municipality;
- Definition of areas for conservation in the basin of the Pirai River establishing the Park Pirai River along its riverine in the Metropolitan Area, for recreational and sports usage with enforcement of norms on sand extraction; and
- Definition and identification of risks upon soil, geology, and hydrology of the Metropolitan Area with the aim to assign technical norms and criteria for all types of buildings and civil works, updating codes of urbanism and construction.

(3) Air quality management

The National Program of Air Quality Management (*Programa Nacional de Gestión de Calidad del Aire*) was established at a national-tier to manage and disseminate the MONICA Network nationwide.

The Program aims by the year 2025 to establish an integrated management of air quality monitoring in collaboration with local governments and relevant institutions.

The objective of the Program consists on to recognize the air quality of most populated urban centers in the country to use the situational information for decision makings on environmental approaches consequent with the improvement of the quality of life of the population.

The specific objectives of the Program consist of:

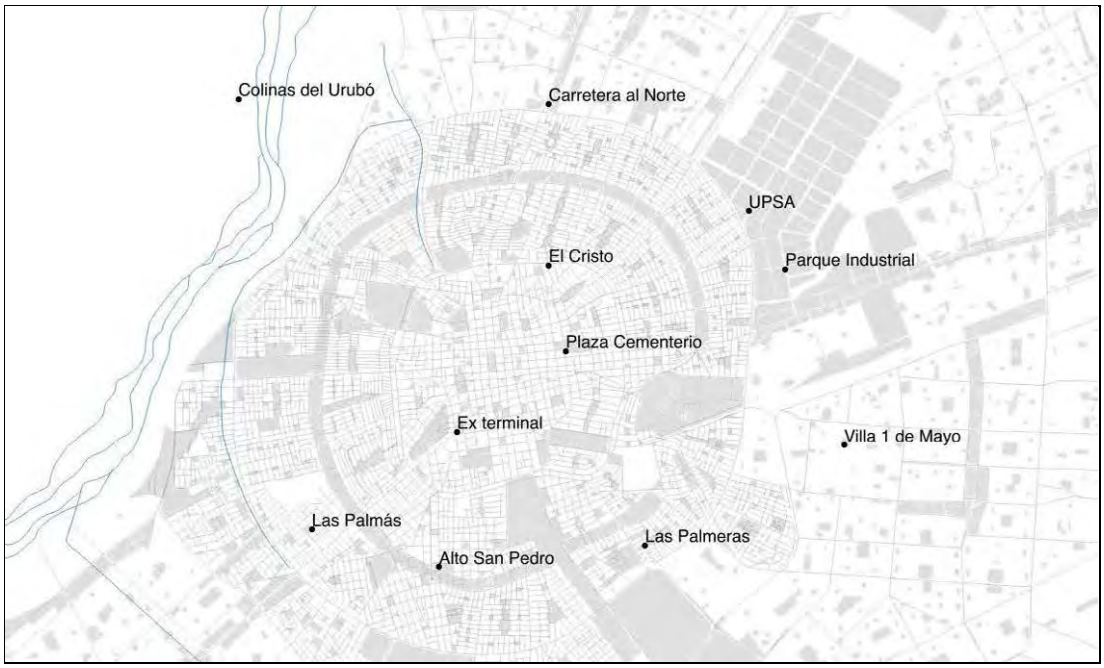
- Strengthening of MONICA Network;
- Improvement of the quality of life of the population throughout the implementation of an integrated management of air quality in Bolivia; and
- Provision of reliable data and information on air quality to the population.

The Program initiated its implementation in June 2012, assisted technically by the Switzerland cooperation, and is composed of the following main approaches:

- Management of air quality: strengthening of local administration to implement a plan or strategy for the management of air quality involving relevant aspects and the foremost contaminant activities in the jurisdiction, based on an initial diagnosis, such as inventory of emissions;
- Monitoring of air quality: strengthening of local administration to be capable of monitoring continuously during all the seasons of the year, especially during special events such as San Juan holiday and periods of slash-and-burn "*chaqueo*", comparing with the quality standards;
- Technical inspection of vehicles: strengthening of local administration in order to be capable to add inspections of vehicle emission in the procedure of vehicular technical inspection (*Ley 195 de Transporte promulgada el 16 de agosto de 2011*) and the emission norms (*Norma Emisiones Atmosféricas Euro II a Euro IV Sistema Nacional de Revisión Técnica Vehicular*); and
- Urban mobility: strengthening of local administration to implement municipal programs of transportation (PROMUT), taking into account the demand of the population on mobility, efficiency on the use of public spaces, and sustainability of the transportation sector.

In fact, a prohibition of fireworks during the San Juan holidays (22-24 of June) was instructed by the Ministerial Resolution No. 178 (enacted on June 8, 2016).

As part of MONICA Network, the Municipality of Santa Cruz de la Sierra established since 2004, monitoring stations in eleven places surrounding the city (See for locations in the Figure below).



Source: Municipality of Santa Cruz de la Sierra Secretariat of Environment. Processed by JICA Study Team.

Figure 4.3-2 Locations of MONICA stations under the Municipality of Santa Cruz de la Sierra

The parameters of air quality handled are particulate matter lower than 10 microns, nitrogen dioxide, and ozone.

(4) Water quality management

As an approach to the Departmental policy for the integral management of water resources, an agreement among the municipalities of Santa Cruz de la Sierra, Cotoca, El Torno, La Guardia, Montero, Porongo and Warnes was achieved to establish a network for the monitoring of groundwater quality (*Red de Monitoreo de Calidad de Aguas Subterráneas*).

The objective of the agreement consists on to generate and provide permanently updated information on the quality of groundwater at different depths, installing observation wells, to use the information for the alert system, protection of health, and the use of water resources in a sustainable manner.

The main specific objectives of the Agreement consist of:

- Monitoring of groundwater resources recognizing their seasonal, geographic, and qualitative tendencies;
- Identification of possible sources of contamination gathering periodically data on physical-, chemical-, and microbiological parameters; and
- Provision of reliable information on groundwater quality to the public, throughout the System of Information for the Monitoring and control of Water Quality (SIMCA: *Sistema de Información para el Monitoreo y Control de la Calidad de las Aguas*).

With the collaboration of private water supply companies and the Environmental Laboratory of the Autonomous University of Gabriel René Moreno, a first reconnaissance survey was conducted during May 3-6, 2011.

(5) Management of protected areas

The Department of Santa Cruz had implemented an approach for the strengthening of management capabilities for the control and monitoring of its protected areas. The objective consisted on to contribute to the conservation and protection of natural resources, based on effective planning, administration, supervision, and implementation of an integrated management of protected areas. The approach focuses on the local stakeholders' participation, aiming better quality of the inhabitants.

The main specific objectives of the approach consist of:

- Implementation of the Departmental Strategy of Conservation of Protected Areas and Conservation Units of Santa Cruz, developing the legal framework of Departmental System of Protected Areas (SDAP: *Sistema Departamental de Areas Protegidas*), focusing on the importance of conservational issues and sustainable use of the resources, adopting mechanisms for the compliance with the stipulated norms;
- Reduction of at least in 30% of illegal activities that cause degradation of vegetation coverage, loss of biodiversity due to habitat fragmentation, as those as recovery of traditional local knowledge of the communities associated with sustainable management of natural resources; and
- Strengthening of awareness of the society regarding the protected areas of the Department, promoting the active participation of stakeholders in the actions inherent to management, protection, and conservation of the assets.

The Program for Sustaining the Corridor Santa Cruz, Puerto Suarez, is an integral action Plan for the development of protected areas, was implemented to establish a strategy for solving problems facing therein. Financial plan and monitoring system are proposed.

(6) Waste management

The Departmental policy on the management of solid waste includes the following technical and environmental issues:

- Characterization of waste generated in each municipality in terms of its physicochemical composition, taking into account the consumption of imported goods, to identify the necessary treatments prior their disposal;
- Minimization and re-utilization of waste, based on systematic and sustainable educational approaches; introduction of waste sorting practices at source and in final disposal sites, involving private recycling entities;
- Identification of appropriate locations for disposal of waste in the Metropolitan Area where installation of sanitary landfills is expected in view of the environmental and biophysical factors. In this process of identification, shall consider the establishment of a Center for Valuation of Municipal Solid Waste;
- Utilization of transformation techniques for organic waste to produce soil conditioners or fertilizers; and
- Formulation of a Department Plan for the Management of Urban and Municipal Solid Waste, adopting requirements of each municipality.

(7) Adaptation to climate change

The policy of the Department of Santa Cruz on mitigation and adaptation to climate change encompasses following actions:

- Formulation of an action plan against adverse effects of climate change, including fostering of sustainable use and conservation of forest resources, neutral effect on industrial sector emission of greenhouse gases (GHG), decrease of deforestation rate and prevention of forest fires and slash-and-burn practices;
- Dissemination of knowledge of impacts and consequences of climate change at departmental and municipal tiers;
- Fostering of formation of strategic alliances between public organizations and local and foreign private entities, promoting initiatives and projects for the obtainment of financial and technical resources for effective reduction of GHG;
- Fostering of development of technologies based on renewable energy sources, such as wind power, hydraulic, biofuels, and solar energy;
- Development of programs on integrated watershed management, establishing baselines for deforestation, degradation, biodiversity, and emissions; recognizing the background situation to monitor the evolvement of those parameters in the Department; and
- Inventorying of GHG at departmental and municipal tiers per type of GHG and classified by type of activity.

The Government of the Department of Santa Cruz agreed with FAN to conduct a pilot program regarding adaptation to climate change, taking into account the Fourth IPCC evaluation which estimated 10-30% of decrease on water resources and 20-30% loss of biodiversity in the region.

The Agreement with FAN, a pilot program regarding adaptation to climate change, has an objective to develop and promote adaptation strategies against climate change, assuring the food safety, the conservation of biodiversity, and the steadiness of hydrologic cycle.

By the date principal achievements of the pilot programs are:

- FAN had implemented a regional model PRECIS (Providing Regional Climate for Impact Studies) covering 2.6 million square kilometers with a resolution of 25 km/pixel regarding climate tendencies up to the year 2100. Currently, is performing a new model BRAMS with more fine resolution (5 km/pixel);
- Risk analysis with impacts on water resources, agriculture and farming productions, and on the equilibrium of ecosystems, making simulations of hydrologic processes in the basins of Pirai, Quirusillas, and Comarapa with the hydrologic model SWAT (Soil & Water Assessment Tool); and
- Awareness raising activities on climate change adaptation in critical zones of the Department of Santa Cruz (communities of Municipality of Postrevalle). Furthermore, FAN had trained the officials of the Department of Spatial Planning regarding classification of soil for its categorization used in the reformulation of PLUS.

4.3.4 Significant environment effects to be considered

The Table in below lists the environmental constraints and disturbances recognized at Municipal level.

Table 4.3-2 Environmental constrains and disturbances at Municipal level

Municipality	Priorities
Cotoca	• Groundwater pollution by infiltration of septic tanks • Soil and water pollution by textile and meat industrial effluents • Soil erosion due to extraction of clay • Deforestation due to development of land for animal husbandry
El Torno	• Insufficient capacity for the management of natural resources • Lack of local ordinances for the environmental conservation and protection • Environmental degradation due to improper management of solid waste • Deforestation at riverine fringes
La Guardia	• Low level of concern on environmental issues of agricultural and SMEs • Lack of capacity for monitoring the environmental behavior and supervision for pollution control
Porongo	• Soil erosion and loss of biodiversity due to deforestation • Environmental degradation due to improper management of solid waste • Insufficient management capacity for the conservation of the National Park Amboró • Deforestation due to use of wood for fire to cook
Santa Cruz de la Sierra	• Environmental degradation due to deficient management of solid waste • Water pollution by anthropic activities • Air pollution by vehicles exhaust gas, waste burning, and bush firing • Noise and landscape degradation due to commercial sector • Ecosystem degradation by urbanization growth
Warnes	• River water contamination by industrial and stockbreeding effluents • Environmental degradation due to improper management of solid waste • Insufficient management capacity for forest conservation

Source: Municipalities PDMs/PLOTs

Particularly, for a development of new roads and improvement of existing roads, the Secretariat of Sustainable Development and Environment of Santa Cruz is aware of the amount of deforestation and affection on hydrogeological regime due on the pavement of current unpaved roads. In turn, they expect positive impact such as decrease of air pollution as the effect of less gas-emission because of traffic efficiency.

4.3.5 Involuntary resettlement issue

The Bolivian legislation does not stipulate the involuntary-resettlement concerned matters explicitly. In turn, the Law on Municipalities (Law No. 2028 of 1999) regulates on land expropriation procedures, based on an old law, on expropriation in pursue of public utility, enacted in 1884. Consequent with this legal framework, the Municipality of Santa Cruz de la Sierra enacted a local ordinance (GAMSCS No.84/2015) on Municipal expropriations, administrative limitations, and compulsory purchase of properties.

The Municipal ordinance is allowed for land expropriation in the following cases among others:

- Implementation of Municipal plans, programs, and projects;
- Construction and improvement of urban and rural public infrastructures;
- Construction of roads, highways, flyovers, bridges, tunnels, and other facilities for transportation;
- Construction of parks, and other infrastructure for recreation purpose;

- Construction of drainage channels, regulating ponds, dams, embankments, etc.;
- Construction of hospitals, schools, sports camps, and other facilities for communal benefits;
- Conservation of cultural sites, buildings, archeological or historical monuments;
- Preservation of natural areas spreading native vegetation, and ecologically-interest areas;

The procedure initiates with deliberation on the necessity of land expropriation by the Municipal Council, based on the technical and legal reports on the related plan, program or project, requiring approval by at least two-thirds of the Council members. The Municipal Council decision shall be enacted as a Municipal ordinance, which is published once through nationwide communication media.

A concept of "*justiprecio* (fair price)", is applied to the valuation of the property matter of expropriation, in which a registered architect or civil engineer provide the pecuniary value of the land based on the topography, state of existing buildings and facilities, current land use, real estate taxation regime, among other valuation factors. This fair price should be used as a reference for the Municipal budgeting process regarding the relevant plan, program or project.

In practice, around 40 cases of land expropriation were proceeded during the last decade, estimated that *circa* 90% was conducted satisfactorily with the former landowners. Recent cases were an expropriation for the construction of Municipal markets, and construction of drainage system for flood control.

4.3.6 Setting of evaluation criteria for alternative analysis

The vast tracts of impervious roads, sidewalks, driveways, parking lots, roofs, and walls alter the surface energy budget and the hydrologic cycle. The most prominent characteristic of the urban climate is the urban heat island, by which the air temperature in cities can be several degrees warmer than that of rural landscapes. The heat island arises due to the reduced emission of long-wave radiation by the city surface, much of which is trapped by tall buildings, reduced latent heat flux and increased sensible area, and from the storage of heat in urban materials during the day that is released at night. Cities also generate more runoff compared with rural landscapes because of the greater impervious surface area.

While, the main environmental disturbances of the transportation sector consist on air pollution caused by the exhaust gas, soil and groundwater pollution by oil drops from the vehicles to the soil, and precipitation of volatile organic compounds, contained also in the exhaust gas, driven by rainfall.

Under the scenario, the first stage of environmental considerations focused on to figure out the current situation of climate, air quality and water quality of the Metropolitan Area. The second stage was focused on to establish monitoring indicators capable of measuring the tendencies of relevant parameters quantitatively. Furthermore, qualitative tendencies of non-measurable parameters were also analyzed.

An alternative analysis of the development scenarios described in Chapter 3 was conducted in the Second Stakeholder Meeting based on the following evaluation criteria:

(1) Increase of temperature

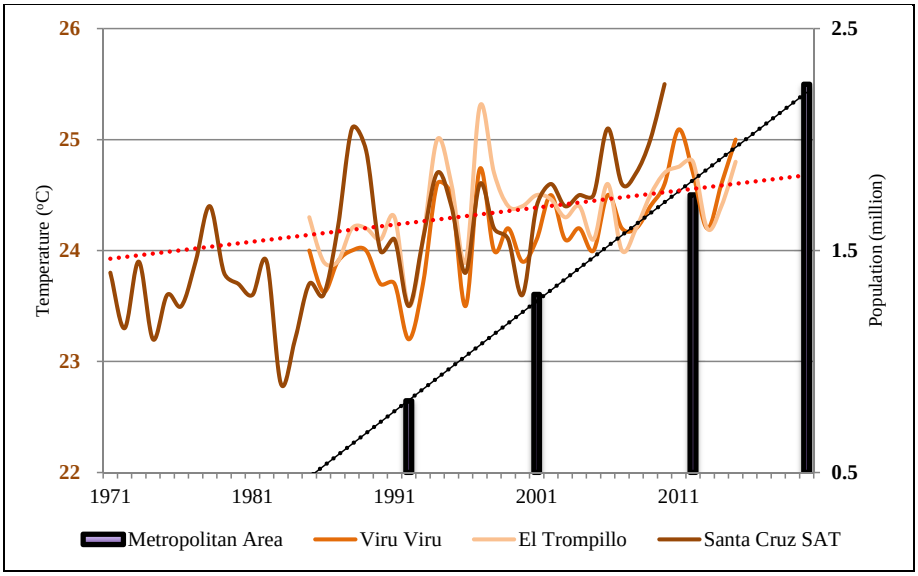
The expansion of cities and road constructions cause a phenomenon called heat island effect. The changes in heat fluxes because of asphalt and building construction over natural soil is the reason. As a result, the temperature increases, especially at night times when the heat absorbed

by the asphalt and buildings dissipates into the atmosphere.

FAN had conducted a field survey to elucidate the heat island effect in Santa Cruz de la Sierra choosing the zone surrounding Urban Park for Ecological Preservation Curichi La Madre, covering natural forest zone and urbanized zone. FAN applied remote sensing methodology using satellite images for the estimation of surficial temperature and vegetation index. Field measurement of ambient temperature was conducted on August 23, 2014, in two transects of the chosen zone.

The result of FAN survey concluded a biased behavior between the natural zone and urbanized zone; fluctuating from 25 to 28 ºC in the former, while building standing zone up to 6 ºC higher.

The following Figure shows the evolution of average temperature recorded by the meteorological stations of Viru Viru, El Trompillo, and Santa Cruz SAT, and the evolution and estimation of the population of Santa Cruz Metropolitan Area.



Source: SISMET 1971-2015; INE. Census 1992, 2001, 2012 (including a projection for 2020), processed by JICA Study Team.

Figure 4.3-3 Evolution of average temperatures (ºC) and population

Inferring from the above Figure, the population growth and its consequent spread of urbanized zone, is affecting with temperature increase in Santa Cruz Metropolitan Area, similarly with other cities worldwide.

(2) Decrease of aquifer recharge capacity

Groundwater is of major importance in providing municipal water supply and for private domestic and industrial use in many urban centers. Due to its relatively low cost and high quality, groundwater has often been the preferred source for reticulated public water supplies and is also widely exploited for private domestic and industrial uses. The specific case of Santa Cruz Metropolitan Area fits in these premises.

In the process of urbanization, soils are often compacted and covered by impervious surfaces such as roofs, roads, and sidewalks resulting in increased runoff from the developed area into drainage ways and ephemeral channels.

Meanwhile, the same asphalt and buildings cause a decrease of aquifer recharge capacity because usually, they are much more impervious than the natural soil under them. The increase

of asphalt and buildings extension results in a reduction of infiltration capacity of meteoric waters to the aquifers and increases run-off to surficial waters. The latter also affects the increase in flood, if it exceeds the capacity of the drainage system.

In contrast with surface runoff, the effect of urbanization on groundwater systems is dependent on the geological and hydrogeological setting and the adopted stormwater management practice.

Where groundwater abstraction is heavy and concentrated, such that it greatly exceeds average rates of local recharge, aquifer water levels may continue to decline over decades, provoking an expensive and inefficient cycle of well deepening or even premature loss of investment through the abandonment of wells.

An understanding of how urbanization may impact the timing of groundwater recharge and its quality is a prerequisite for mitigating water scarcity and identifying vulnerability to contamination. Where surface water-groundwater interactions are important processes controlling catchment hydrology particular care has to be taken to understand this interaction before determining urban water management strategies for new urban developments.

There is increasing concern about the ongoing reduction in water supplies in the tropical Andes due to climate change effects such as glacier/snow melting resulting from rising air temperatures. Also, extreme events and population growth are already directly affecting life and water renewability in the country.

(3) Degradation of air quality

Large quantities of chemical compounds are emitted to the atmosphere by anthropogenic and biogenic processes. In the atmosphere, these trace gases are subject to various transport mechanisms and complex physicochemical transformations, the latter being responsible for the formation of secondary pollutants.

In the transport sector, the exhaust gases of combustible-use vehicles generate toxic gases and particles, as those as emissions of greenhouse gases (GHG), affecting air quality and global warming. The combustion of combustibles produces toxic gases such as nitrogen oxides, and proportional to the impurities in the combustibles additional toxic gases such as sulfide oxides and volatile organic compounds. Furthermore, in case of low performance of vehicle engines, an incomplete combustion produces carbon monoxide and soot.

Population growth in large cities leads to air quality degradation at the local and regional scale, among other problems. Toxic trace gases emitted into the troposphere and their oxidation products represent a direct human health risk. In developing countries, this problem is generally aggravated by the age of the vehicle fleet, as well as intensive use of fossil fuels rather than low emission energy sources in both industry and the transport sector.

The production of elevated near-surface levels of ozone is particularly worrisome. Clinical studies have related high ozone concentrations with reduced lung function, and its phytotoxicity can compromise agricultural productivity and affect forest areas.

The noise and vibration increase in proportion to the growth of transportation system are also the constraints to be monitored.

(4) Degradation of water quality

The degradation of water quality relies on the expansion of cities without proper management

of sewerage system and the precipitation of contaminants generated by the vehicles. In the case of the Metropolitan Area, a huge amount of septic tanks and untreated sewerage system is disturbing surficial waters and the aquifers. Simultaneously, toxic compounds such as oil drops and precipitation of contaminants bearing the exhaust gas can infiltrate to the soil and consequently transported to the groundwater; in that way, sourced by urban storm runoff, recharge waters may transport anthropogenic contaminants to groundwater systems.

Is very common that high concentrations of metals like zinc, copper, lead, and nickel can originate from urban material decomposition associated with vehicular traffic, pavement aging and wind-blown dust. Runoff from industrial and residential areas has been shown to contain lead, copper, zinc, and nickel; however, storm runoff solute concentrations are highly variable across land use types. Increasing variability in the amount and type of metals present in urban run-off reduces the ability to track groundwater contamination. The migration of metals through the vadose zone is further complicated by variable soil surface properties, organic matter content, redox potential and pH.

Also, fecal indicator bacteria, such as *Escherichia coli*, originating from human and animal waste, is often used to assess levels of groundwater contamination and associated risks to public health.

Furthermore, rapid rises in the water table resulting from episodic recharge events can also trap excess air (air above equilibrium solubility), which may contain pollutants, and cause an increase in groundwater concentrations.

Localized septic systems can also be significant sources of groundwater contamination. Also, leaking water infrastructure and sewer exfiltration have also been shown to provide substantial recharge in urban centers and may contribute to elevated groundwater contamination.

While, landfills and manufacturing plants have been identified as anthropogenic point sources of contaminants such as volatile organic compounds (VOCs) associated with disposal of aerosols, paint remover, dry cleaning agents, foam blowing agents and refrigerants. E.g., the release of VOCs associated with landfills and industrial areas has resulted in groundwater contamination in many cities worldwide.

Whereas, agricultural irrigation practices and the application of pesticides have been shown to be sources of groundwater contamination.

(5) Degradation of landscape

It is obvious that the expansion of the cities affects the visibility of the surrounding nature to the living citizen; and in the specific case of the Department of Santa Cruz, the fragmentation of areas with priority for conservation is mainly caused by the construction of transportation infrastructure, is one of the appointed awareness.

United Nations Food and Agriculture Organization definitions of deforestation and degradation are widely used. Deforestation is defined as “the conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10% threshold.” Degradation is defined as “changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and/or services.”

Getting spatially and timely accurate information about the land cover change is essential as a change in forest cover is likely to affect aspects of the biosphere such as carbon cycle and biodiversity. Remote sensing, especially in recent years, with a large amount of data becoming

freely available offers great opportunities to monitor forest at the relatively high spatial resolution and systematically and objectively. However, there is a challenge that consists of extracting the desired information from large amounts of spatiotemporal data containing natural variability (seasonality and exceptional events such as droughts) and noise.

In addition to being widely available at no cost, Landsat data, thanks to their spatial (30 m resolution) and temporal characteristics (16 days revisit period) are well suited to monitor processes such as deforestation and forest degradation.

(6) Mitigation of public constraints on transportation

The increasing mobility experienced in cities all over the world brings enormous benefits to society and provides the essential means by which a city can function effectively. The increasing urban mobility is manifested in three major forms: an increase in the number of trips made, an increase in the length of each trip, and an increasing motorization of urban people and goods movement. However, the traffic congestion created by unsustainable transportation systems is responsible for significant economic and productivity costs for commuters and goods transporters.

The transportation sector is also responsible for many other challenges that do not necessarily get solved by the construction of new infrastructure. It is, e.g., responsible for a large proportion of the greenhouse gas emissions that lead to climate change. Furthermore, road traffic accidents are among the main causes of premature deaths in most countries and cities. Likewise, the health effects of noise and air pollution caused by motorized vehicles are a major cause for concern. In some cities, the physical separation of residential areas from places of employment, markets, schools and health services force many urban residents to spend increasing amounts of time, and as much as a third, and sometimes even more, of their income, on public transport.

While those among the urban populace that have access to a private car, or can afford to make regular use of public transport, see traffic jams and congestion as a major concern; this is a marginal issue for people living in “transport poverty”. Their only affordable option for urban transportation is their own feet. Persons with low household incomes form the bulk of those characterized as living in transport poverty.

By the other hand, community severance divides and fragments communities, and is often a result of heavily used transport infrastructure forming a barrier so that people cannot cross the road or rail track. It adversely affects the quality of life, the level of activities on the street and the amount of social interaction within communities.

There is also evidence that traffic congestion can impair “health, psychological adjustment, work performance and overall satisfaction with life”. Job satisfaction and commitment decline with increased road commuting distance, and that perceived traffic stress are associated with both lower general health status and depression.

(7) Positive and negative socio-economic effects

For more than half a century, most countries have experienced rapid urban growth and increased use of motor vehicles. This has led to urban sprawl and even higher demand for motorized travel with a range of environmental, social and economic consequences. In that sense, the impact on economic growth expected by the development scenario, and the enhancement of social welfare due to transportation efficacy and efficiency should also consider as an indicator for decision-making. Also, the involuntary resettlement, bearing the construction of new access roads or the wide expansion of existing roads, shall be considered

as a factor of evaluation.

One of the most powerful justifications for the disproportionate funding of private motorized transport is that it saves time. This, in turn, leads to the evolution of urban transport policies that promote extensive reliance on ever more mobility to solve the urban congestion and access problems. In fact, much of the treatment of urban transport as an economic good focuses on its mobility value, usually measured as travel time saved.

Because time spent in motion is such a relatively straightforward concept to understand and to measure, it provides a powerful basis for valuing transport improvements.

Whereas, the direct and indirect contributions of transport spending to overall productivity and employment creation are also valuable. Thus, it is important to create transport systems that are as efficient and effective as possible regarding both their monetary and social costs.

In addition to being a major factor of production and urban consumption, urban transport is a major source of employment. Direct employment by public transport operators is the gross source, and others are involved in the provision of goods and services to public transport operators and authorities. However, the transport in the Santa Cruz Metropolitan Area is primarily characterized by the informal sector. In turn, the costs associated with road traffic accidents are often overlooked in the context of transport economics but should always be accounted for in policy-making.

4.4 Alternative Analysis

The objective of the SEA is “to provide a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programs to promote the sustainable development”.

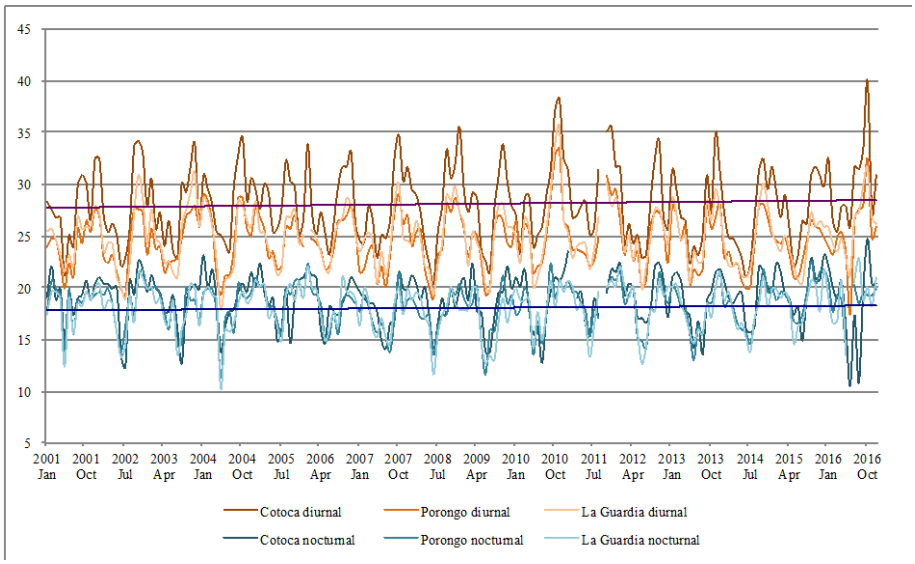
An attempt was conducted in setting representative indicators regarding evaluation criteria for alternative analysis. Following is described the development of these attempts.

(1) Increase of temperature

Land surface temperature (LST) available from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard NASA's Terra and Aqua satellites covering the Santa Cruz Metropolitan Area was used to recognize the behavior of temperature in it.

The measurements shown in Figure 4.4-1 represent the temperature of the “skin” (or top one millimeter) of the land surface, including bare land, and cropland or forest canopy for the cities of Cotoca, Porongo, and La Guardia.

The red line represents the linear regression of LST diurnal and the blue one the nocturnal. It can be shown positive gradients regardless of the short period of 15 years. This behavior infers, the phenomena of urban heat island in the Metropolitan Area, evident.



Source: Terra/Aqua satellites: Land Surface Temperature (January 2001-December 2016), processed by JICA Study Team.

Figure 4.4-1 Evolution of LST (ºC) of Cotoca, Porongo, and La Guardia

Correlation between the population growth and this set of LST data was conducted to estimate the effects of future development scenarios. The Table in below lists the best fits of non-linear LST-population model and the estimation of LST for each development option.

Table 4.4-1 Estimation of LST (ºC) in function of population (P) by development scenario

Municipality	Correlation model	Development scenario	2020	2025	2030	2035
Cotoca	$27.090 \times {}^{3.881\times10^{-2}} - 12.928$	1	29.63	30.21	30.66	31.03
		2	29.28	29.77	30.17	30.51
		3	28.69	28.86	29.03	29.18
		4	29.24	29.72	30.10	30.44
El Torno	$24.083 \times {}^{3.2843\times10^{-2}} - 9.335$	1	25.25	25.30	25.36	25.42
		2	25.25	25.29	25.33	25.37
		3	25.29	25.36	25.43	25.50
		4	25.26	25.31	25.36	25.41
La Guardia	$49.111 \times {}^{9.6844\times10^{-3}} - 30.16$	1	24.87	24.92	24.98	25.03
		2	24.90	24.98	25.05	25.12
		3	24.94	25.04	25.12	25.20
		4	24.90	24.98	25.05	25.11
Porongo	$37.286 \times {}^{2.0711\times10^{-2}} - 20.887$	1	25.84	26.21	26.49	26.72
		2	25.63	26.02	26.32	26.55
		3	25.03	25.18	25.31	25.44
		4	25.52	25.89	26.16	26.39
Santa Cruz de la Sierra	$14.869 \times {}^{6.4947\times10^{-2}} - 9.8896$	1	27.83	28.00	28.16	28.32
		2	27.89	28.08	28.27	28.45
		3	27.98	28.23	28.47	28.70
		4	27.88	28.06	28.24	28.41
Warnes	$54.374 \times {}^{1.0364\times10^{-2}} - 33.475$	1	28.26	28.42	28.55	28.66
		2	28.21	28.34	28.46	28.56
		3	28.13	28.21	28.29	28.37
		4	28.26	28.42	28.56	28.67

Source: LST: Terra/Aqua satellites: Population estimates: JICA Study Team.

In the Table, for highest values of LST, the table-cells were colored in red; while, the lowest in green. A simple punctuation “plus one” for the favorable, and “minus one” for the unfavorable makes the Scenario 2 as the best scorer accounting “plus one”.

(2) Decrease of aquifer recharge capacity

Neither reliable data nor information were found to elucidate the state of aquifer recharge capacity. Thus, until having the concerned data an indicator based on pressure (negative factor affecting the recharge capacity of the aquifer) to correlate the variable is recommended to use.

The population density by the municipality was used because it is directly related to the growth of impervious surfaces and water abstraction.

The Table in below lists the population density behavior estimated by JICA Study Team.

Table 4.4-2 Estimation of population density by development scenario

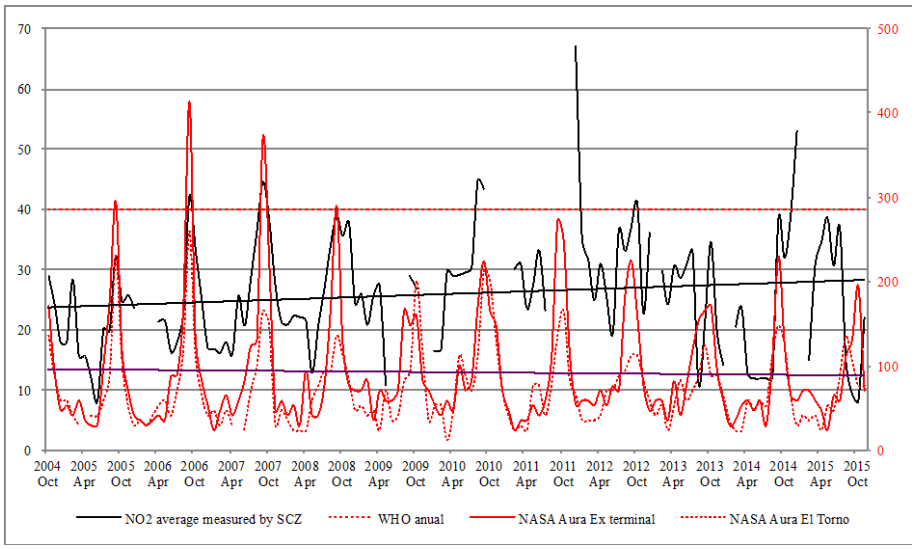
Municipality	Development scenario	2020	2025	2030	2035
Cotoca	1	1.84	2.60	3.39	4.23
	2	1.49	2.01	2.55	3.12
	3	1.03	1.15	1.27	1.40
	4	1.45	1.94	2.44	2.98
El Torno	1	0.64	0.67	0.70	0.74
	2	0.64	0.66	0.68	0.71
	3	0.66	0.70	0.74	0.79
	4	0.64	0.67	0.70	0.73
La Guardia	1	1.31	1.46	1.61	1.77
	2	1.41	1.62	1.85	2.09
	3	1.50	1.81	2.12	2.46
	4	1.40	1.62	1.84	2.08
Porongo	1	0.57	0.84	1.12	1.41
	2	0.46	0.69	0.93	1.19
	3	0.25	0.29	0.33	0.38
	4	0.41	0.60	0.80	1.01
Santa Cruz de la Sierra	1	13.36	14.28	15.24	16.25
	2	13.69	14.80	15.96	17.18
	3	14.17	15.70	17.30	18.99
	4	13.61	14.65	15.73	16.88
Warnes	1	1.61	2.05	2.51	2.99
	2	1.48	1.83	2.19	2.57
	3	1.30	1.49	1.69	1.89
	4	1.60	2.06	2.54	3.05

Source: JICA Study Team.

In the Table, for highest values of population density, the table-cell were colored in red; while, the lowest in green. A simple punctuation “plus one” for the favorable, and “minus one” for the unfavorable makes the Scenario 2 as the best scorer accounting “plus one”.

(3) Degradation of air quality

The Aura satellite measures tropospheric column density of nitrogen dioxide (NO_2). The Figure below shows the evolution of NO_2 average measured by the Secretariat of Environment of the Municipality of Santa Cruz de la Sierra as part of MONICA Network and the values of NO_2 column density registered by Aura in the area of Ex-terminal at the center of Santa Cruz de la Sierra and the city of El Torno.



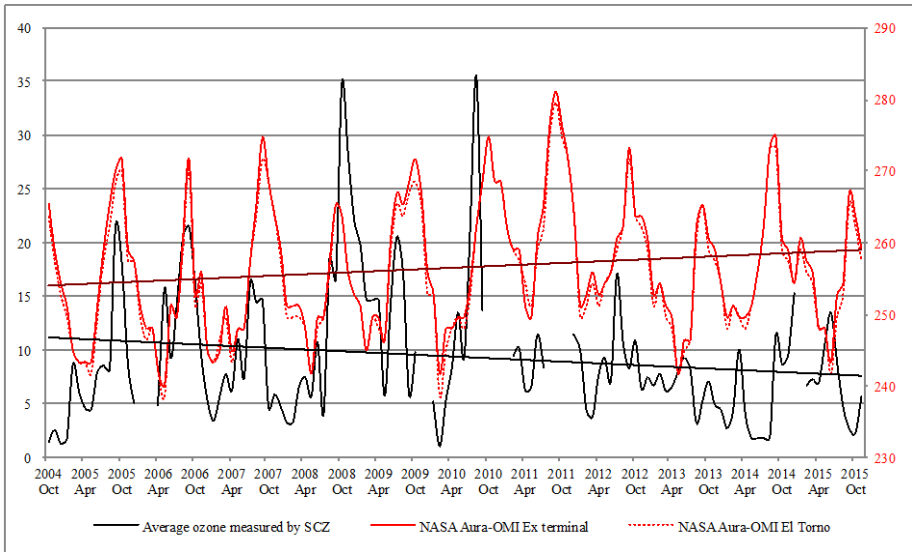
Source: Red MONICA-Santa Cruz de la Sierra, Aura satellite: Nitrogen Dioxide (October 2004-November 2015), processed by JICA Study Team.

Figure 4.4-2 Evolution of NO_2 concentration (µg/m^3) and column density (10^9 molecules/mm^2)

Figure 4.4-2 also shows the value of NO_2 annual mean concentration recommended by WHO (dotted red line of 40 µg/m^3). The red line represents the linear regression of NO_2 average concentration measured by the Municipality's Secretariat of Environment and the black one for the NO_2 column density recorded by Aura to show their tendencies.

Ozone Monitoring Instrument (OMI) on board of NASA's Aura satellite provides daily measurements of ozone. OMI measures total column ozone, which is how much ozone is present in a column of the atmosphere stretching from the surface to the top of the atmosphere, including both ground-level and stratospheric ozone.

Ozone column density is measured in Dobson Units (DUs). A Dobson Unit is the amount of ozone that would be required to create a layer of pure ozone 0.01 millimeters thick at the Earth's surface, at a temperature of zero degrees Celsius and a pressure of one atmosphere.



Source: Red MONICA-Santa Cruz de la Sierra, Aura satellite/OMI: Ozone (October 2004-November 2015), processed by JICA Study Team.

Figure 4.4-3 Evolution of ozone concentration (µg/m^3) and column density (Dobson units)

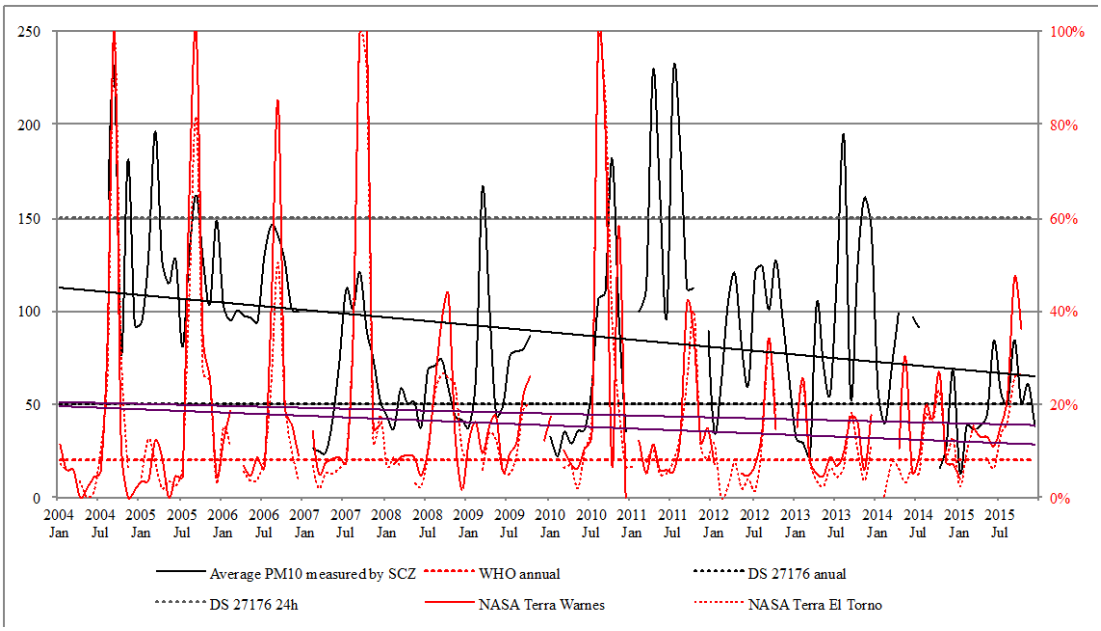
Figure 4.4-3 shows both the evolution of average ozone concentration and the values of ozone

column density at the center of Santa Cruz de la Sierra and the city of El Torno.

Figure 4.4-3 also shows the linear regressions of both parameters. The red line represents the linear regression of average ozone concentration measured by the Municipality's Secretariat of Environment and the black one for the ozone column density recorded by Aura/OMI to show their tendencies.

MODIS aboard NASA's Terra and Aqua satellites is used to monitor aerosol optical thickness, proportional to the total aerosol loading, and size distribution, integrated on the vertical column of the ambient aerosol. Aerosol accounts solid, liquid, and plasmatic particles bearing the atmosphere, thus includes PM10 measured by the Secretariat of Environment of the Municipality of Santa Cruz de la Sierra.

The Figure below shows both, the evolution of average PM10 and the values of aerosol column density at the center of Santa Cruz de la Sierra and the city of El Torno.



Source: Red MONICA-Santa Cruz de la Sierra (October 2004-November 2015), Terra satellite/MODIS: Aerosol (January 2004-December 2015), processed by JICA Study Team.

Figure 4.4-4 Evolution of PM10 concentration (μg/m^3) and aerosol column density (%)

The graph also shows the value of the annual mean concentration of PM10 recommended by WHO (20 μg/m^3) and the values (50 μg/m^3 for 24-hour average and 150 μg/m^3 correspondent to annual mean) of Bolivian norm (Supreme Decree No. 24176). The red line represents the linear regression of average concentration of PM10 measured by the Municipality's Secretariat of Environment and the black one for the aerosol column density recorded by Aura to show their tendencies.

The data of carbon monoxide (CO) are collected by MOPITT (Measurements of Pollution in The Troposphere) sensor on NASA's Terra satellite. Concentrations of CO are expressed in parts per billion by volume (ppbv). Data of Active Fires are collected by MODIS aboard on Terra and Aqua satellites. Active Fires provide information on the location of a fire, its emitted energy, the flaming and smoldering ratio, and an estimate of area burned.

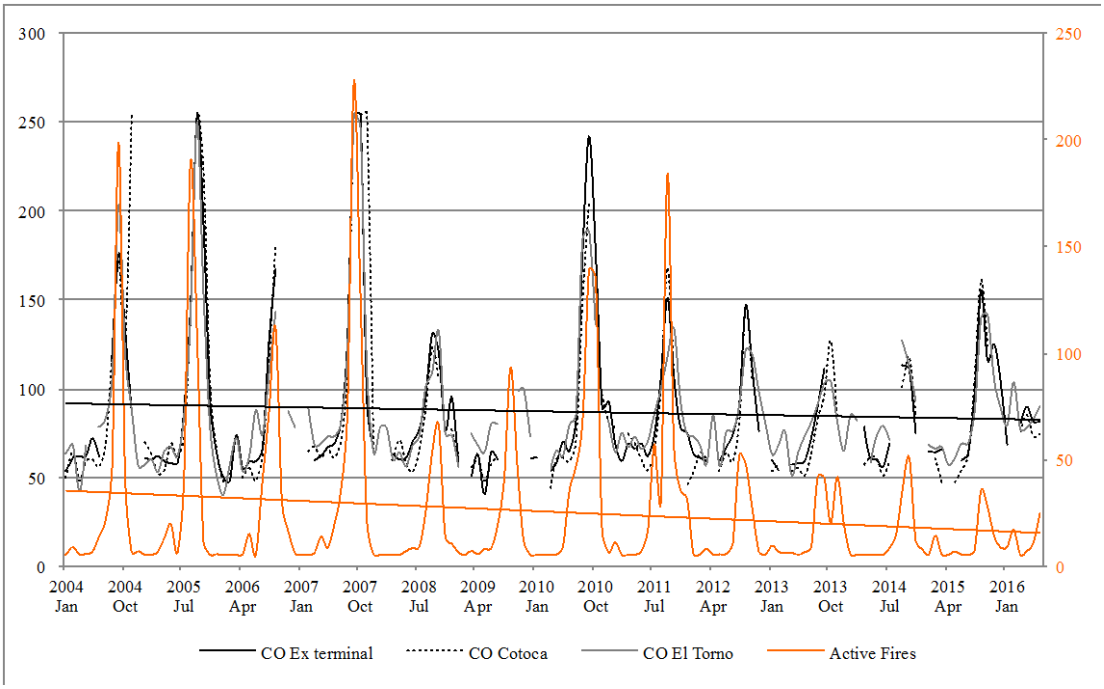
Colorless, odorless, and poisonous, carbon monoxide is one of the major air pollutants. When carbon-based fuels, such as coal, wood, and oil, burn incompletely or inefficiently, they produce carbon monoxide. The gas is spread by winds and circulation patterns throughout the

lower atmosphere (troposphere). CO plays a major role in atmospheric chemistry and affects the ability of the atmosphere to cleanse itself of many other polluting gases. It also takes part in the formation of toxic, lower-atmospheric ozone and urban smog.

The release of chemically reactive gases during biomass burning strongly influences chemical processes within the troposphere. In tropical regions, biomass burning has strongly influenced regional and global distributions of tropospheric ozone and has been related to acid deposition. Furthermore, intensive biomass burning associated with naturally occurring forest fires, deforestation practices, and savanna land management is a major source of trace gases such as nitric oxide, carbon dioxide, CO, ozone, methane, and various gases containing nitrogen, sulfur, and other non-methane hydrocarbons. Fire is also an abundant source of aerosols.

Concluding from the air quality parameters, it can be simplified to monitor CO solely as a representative parameter, to monitor air quality associated with the transportation sector.

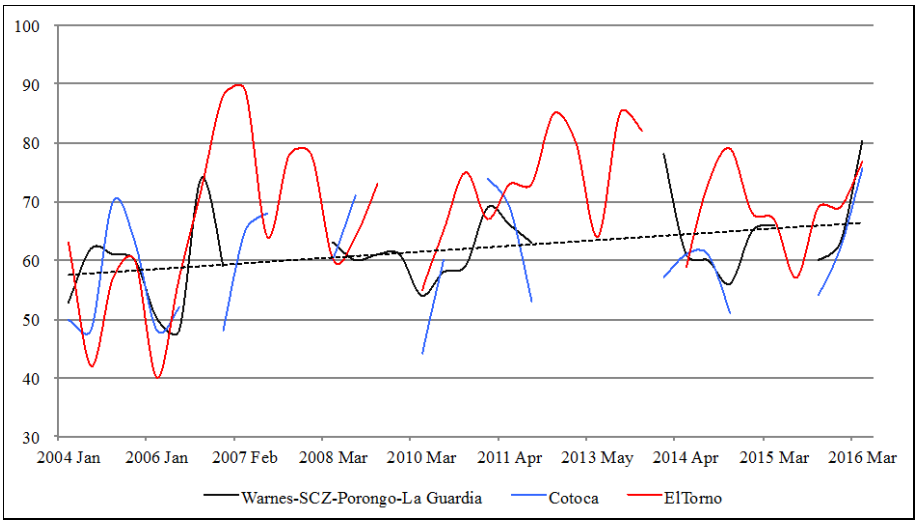
The Figure below shows both, the evolution of CO at the center of Santa Cruz de la Sierra and the cities of Cotoca and El Torno and the values of Active Fires.



Source: Terra satellite/MODIS: CO, Active Fires (January 2004-June 2016), processed by JICA Study Team.

Figure 4.4-5 Evolution of CO (ppbv) and active fires (pixels/1,000 km^2)

The reddish-yellow line represents the linear regression of average concentration of active fires and the black one for the CO concentration to show their tendencies. It shows that both have negative gradients, inferring that slash-and-burn practice inner Metropolitan Area is decreasing.



Source: Terra satellite/MODIS, processed by JICA Study Team.

Figure 4.4-6 Evolution of CO (ppbv) in the absence of slash-and-burn practice

The Figure above shows the evolution of CO in the urbanized areas within months with the absence of slash-and-burn activities inner the Metropolitan Area.

The black dotted line represents the linear regression of CO concentration in the urbanized areas of Warnes, Santa Cruz de la Sierra, Porongo, and La Guardia, which infers air quality degradation driven by the transportation sector.

Correlation between the population growth and this set of CO data was conducted to estimate the effects of future development scenarios. The Table in below lists the best fits of non-linear CO-population model and the estimation of CO concentrations (ppbv) for each development option.

Table 4.4-3 Estimation of CO in function population of (P) by development scenario

Municipality	Correlation model	Development scenario	2020	2025	2030	2035
Cotoca	$23.779 \times {}^{0.11937} - 27.064$	1	68.4	72.4	75.6	78.3
		2	66.0	69.3	72.1	74.6
		3	62.0	63.2	64.2	65.3
		4	65.7	68.9	71.6	74.0
El Torno	$0.93627 \times {}^{0.41255} - 11.97$	1	76.2	78.0	79.9	81.8
		2	76.2	77.5	78.9	80.2
		3	77.4	79.8	82.1	84.5
		4	76.6	78.1	79.7	81.4
La Guardia	$0.86612 \times {}^{0.27992} + 42.378$	1	65.6	66.3	66.9	67.6
		2	66.0	67.0	67.9	68.8
		3	66.5	67.7	68.9	70.0
		4	66.0	67.0	67.9	68.7
Porongo	$0.68802 \times {}^{0.38245} + 35.549$	1	79.9	87.0	92.9	98.2
		2	76.4	83.3	89.1	94.3
		3	67.7	69.7	71.6	73.4
		4	74.7	80.8	86.0	90.7
Santa Cruz de la Sierra	$0.14451 \times {}^{0.40521} + 18.022$	1	66.2	67.5	68.8	70.1
		2	66.6	68.2	69.7	71.3
		3	67.3	69.4	71.5	73.5
		4	66.5	68.0	69.5	70.9
Warnes	$0.86709 \times {}^{0.26321} + 45.406$	1	67.2	68.7	69.9	71.1
		2	66.7	68.0	69.1	70.1
		3	66.0	66.8	67.5	68.2
		4	67.2	68.7	70.0	71.2

Source: CO: Terra/MODIS; Population estimates: JICA Study Team.

In the Table, for highest values of CO, the table-cell were colored in red; while, the lowest in green. A simple punctuation "plus one" for the favorable, and "minus one" for the unfavorable makes the Scenario 2 as the best scorer accounting "plus one".

(4) Degradation of water quality

Neither reliable data nor information were found to elucidate the state of degradation of water quality. Thus, until having the concerned data a pressure to correlate the variable is recommended to use.

In this case, it is proposed to use tendencies of population density, rely on that population density is directly related to the increase of sewage and also for precipitation of exhaust gases, and seepages of oil and grease of the transportation sector.

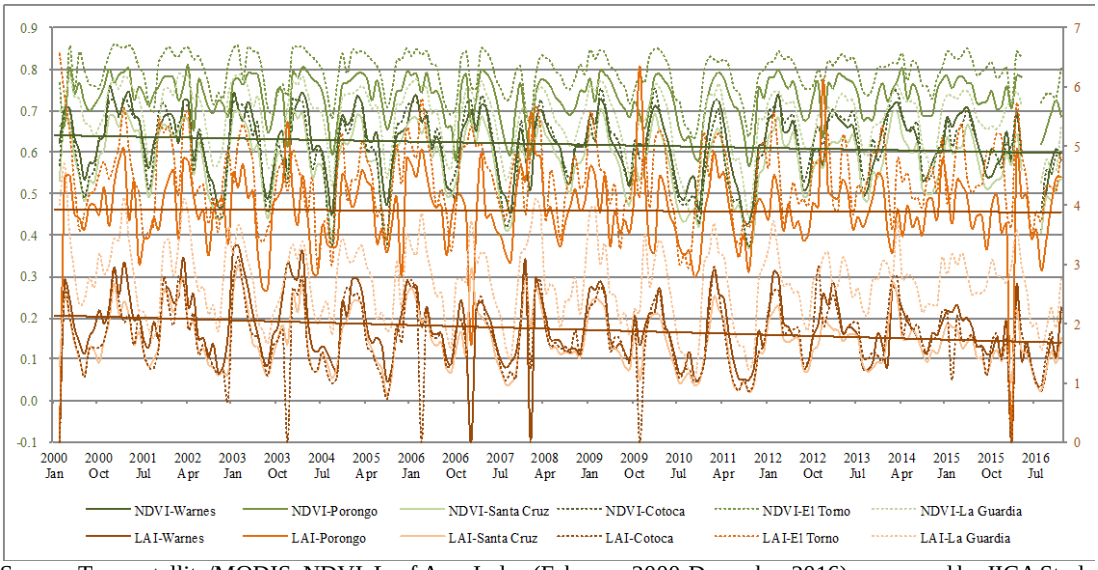
Similarly, a simple punctuation "plus one" for the favorable, and "minus one" for the unfavorable makes the Scenario 2 as the best scorer accounting "plus one".

(5) Degradation of landscape

The Normalized Difference Vegetation Index (NDVI), is produced using data collected by the MODIS aboard Terra satellite; while Leaf Area Index (LAI) is using data collected by the MODIS aboard Terra and Aqua satellites.

The values of NDVI are empirical measures of vegetation activity, photosynthetic vegetation activity, at the land surface or measure of the "greenness" of vegetation across landscapes. Whereas, LAI defines an important structural property of a plant canopy, the number of equivalent layers of leaves vegetation relative to a unit of ground area.

The Figure below shows both, the evolution of NDVI and LAI in the area of municipalities comprising the Metropolitan Area.



Source: Terra satellite/MODIS: NDVI, Leaf Area Index (February 2000-December 2016), processed by JICA Study Team.

Figure 4.4-7 Evolution of NDVI and LAI in Metropolitan Area

All linear regressions of NDVI and LAI showed negative gradients, denoting the decrease of vegetation in all municipalities comprising the Metropolitan Area.

Correlation between the population growth and this set of NDVI and LAI data was conducted to estimate the effects of future development scenarios. The Table in below lists the best fits of non-linear NDVI-population model and the estimation of NDVI for each development option.

Table 4.4-4 Estimation of in function of by development scenario

Municipality	Correlation model	Development scenario	2020	2025	2030	2035
Cotoca	$6.6936\times \ ^{-0.37651} + 0.49485$	1	0.578	0.568	0.561	0.556
		2	0.585	0.576	0.569	0.563
		3	0.599	0.595	0.591	0.588
		4	0.586	0.577	0.570	0.565
El Torno	$1.0831\times \ ^{-0.12665} + 0.51278$	1	0.781	0.779	0.778	0.776
		2	0.781	0.780	0.779	0.777
		3	0.780	0.778	0.776	0.774
		4	0.781	0.779	0.778	0.776
La Guardia	$141.28\times \ ^{-0.68294} + 0.61052$	1	0.657	0.654	0.651	0.648
		2	0.655	0.651	0.647	0.644
		3	0.653	0.648	0.644	0.641
		4	0.655	0.651	0.647	0.644
Porongo	$5.634\times \ ^{-0.4432} + 0.64968$	1	0.695	0.688	0.683	0.680
		2	0.699	0.691	0.686	0.682
		3	0.715	0.711	0.707	0.704
		4	0.702	0.694	0.689	0.685
Santa Cruz de la Sierra	$44.418\times \ ^{-0.3307} + 0.16196$	1	0.550	0.542	0.533	0.526
		2	0.547	0.537	0.528	0.519
		3	0.543	0.530	0.518	0.507
		4	0.548	0.538	0.530	0.521
Warnes	$106.43\times \ ^{-0.68985} + 0.57117$	1	0.594	0.590	0.588	0.586
		2	0.595	0.592	0.590	0.588
		3	0.597	0.595	0.593	0.591
		4	0.594	0.590	0.588	0.586

Source: JICA Study Team.

In the Table, for highest values of NDVI, the table-cell were colored in green; while, the lowest in red. A simple punctuation "plus one" for the favorable, and "minus one" for the unfavorable makes the Scenario 2 as the best scorer accounting "plus one".

(6) Mitigation of public constraints on transportation

Time invested per passenger to travel a determined distance shall be the best indicator for measuring the grade of public satisfaction with the transportation system.

Since this data was not ready at the time of the alternative analysis, an indirect measure was used transitorily, such as distance traveled per passenger as shown in Table 4.4-5.

Table 4.4-5 Distance traveled per passenger in the peak hour in 2035

Unit: km/person

Scenario	Option	Car	Bus	Car+Bus
1	A	9.8	9.8	9.8
	B	9.7	10.2	10.0
2	A	9.3	9.6	9.5
	B	7.6	9.7	9.0
3	A	9.4	8.8	9.0
	B	7.0	9.3	8.6
4	A	9.2	9.5	9.4
	B	7.5	9.5	8.9

Source: JICA Study Team.

The Option 3B shows the best performance. For passengers traveling in cars, the best performance can be achieved by the development Option 3B. In turn by bus the Option 3A.

(7) Positive and negative socio-economic effects

Similarly, as the criteria, cost of opportunity of time invested per passenger is a good indicator; thus the tendency is the same, the best performance could be achieved by the development Option 2B. In turn by bus the Option 2A; however, because of the option A requires high investment for infrastructure, the indicator performance shall be penalized.

(8) Greenhouse gas effect

The total emission of GHG was estimated using the data of "total distance traveled by vehicle" in the Table above.

The methodology instructed in Volume 2: Energy, Chapter 3: Mobile Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories was used.

The Table below lists the estimation of GHG for the development scenario options by the year 2035 during one-rush-hour traffic.

Table 4.4-6 Estimation of GHG emission at one rush hour of 2035

Scenario		1		2		3		4	
Option		**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Travelled distance (thousand km)	car	2,761	2,605	2,446	2,434	2,278	2,266	2,463	2,454
	bus	390	391	404	398	390	379	390	388
Caloric value (TJ/ thousand ton)	Gasoline	44.8							
	Diesel oil	43.33							
Efficiency (km/L)	Gasoline	10							
	Diesel oil	5							
Density (kg/L)	Gasoline	0.75							
	Diesel oil	0.9							
Emission factor CO_2 (kg/TJ)	car (Gasoline)	69,300							
	bus (Diesel)	74,100							
Emission of CO_2 (car)		643	607	570	567	530	528	574	571
Emission of CO_2 (bus)		225	226	233	230	226	219	226	224
Emission of CO_2 (kg)		868	832	803	797	756	747	799	796
Emission of CO_2 (kg)		868	832	803	797	756	747	799	796
Emission factor CH_4 (kg/TJ)	car (Gasoline)	33							
	bus (Diesel)	3.9							
Emission of CH_4 (car)		0.306	0.289	0.271	0.270	0.253	0.251	0.273	0.272
Emission of CH_4 (bus)		0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Emission of CH_4		0.318	0.301	0.284	0.282	0.264	0.263	0.285	0.284
Conversion factor CH_4 to CO_2-eq.		25							
Emisión CH_4-CO_2-eq. (kg)		8	8	7	7	7	7	7	7
Emission factor N_2O (kg/TJ)	car (Gasoline)	3.2							
	bus (Diesel)	3.9							
Emission of N_2O (car)		0.030	0.028	0.026	0.026	0.024	0.024	0.026	0.026
Emission of N_2O (bus)		0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Emission of N_2O		0.042	0.040	0.039	0.038	0.036	0.036	0.038	0.038
Conversion factor N_2O to CO_2-eq.		298							
Emisión N_2O-CO_2-eq. (kg)		12	12	11	11	11	11	11	11
Total CO_2-eq. (kg)		889	852	822	815	773	764	818	814

Source: JICA Study Team.

As listed in the above Table, the less emitting option is 3B, in turn, the most emitter option is 1A.

4.5 Stakeholder Meeting

4.5.1 First Stakeholder Meeting

The procedure of SEA requires that the public, and also the authorities likely to be concerned by the environmental effects of implementing the development plan, including the Master Plan, owing to their environmental responsibilities, are consulted as part of its process. The purpose of this is to contribute to more transparent decision-making and to ensure that the information supplied for the assessment is comprehensive and reliable. With this aim, stakeholder meetings are the form adopted.

A Stakeholder Meeting was held on July 26, 2016 at one the Auditoriums of Center of Environmental Studies (CEA), with the participation of representatives of the Government of the Department of Santa Cruz, the Municipal Administrations of the Metropolitan Area, and Faculty of Engineering of UPSA (Universidad Privada) which is involved in the Red MONICA and an environment conscious civil society group FAN.

A presentation from the JICA Study Team consisted on to explain concepts on possible scenarios for the development of the Metropolitan Area followed by a proposal for composing evaluation indicators based on Modified DPSIR linked method, and some initial indicators for heat island effect, decrease of recharge capacity of aquifers and air quality characterization.

Following Table lists the concept of each indicator type concept comparing the Modified DPSIR with its former version.

Table 4.5-1 Context of DPSIR and modified DPSIR

DPSIR	Modified DPSIR
D: Driving forces of environmental change	Pressures: indicators monitoring the extent and intensity of the threats to the environment that responses aim to address.
P: Pressures on the environment	
S: State of the environment	State: indicators tracking the condition of the environment.
I: Impacts on population, economy, ecosystems	Benefits: indicators measuring trends in the benefits and services that humans derive from the environment.
R: Response of the society	Responses: indicators measuring the implementation of policies or actions to prevent or reduce environment benefit loss.

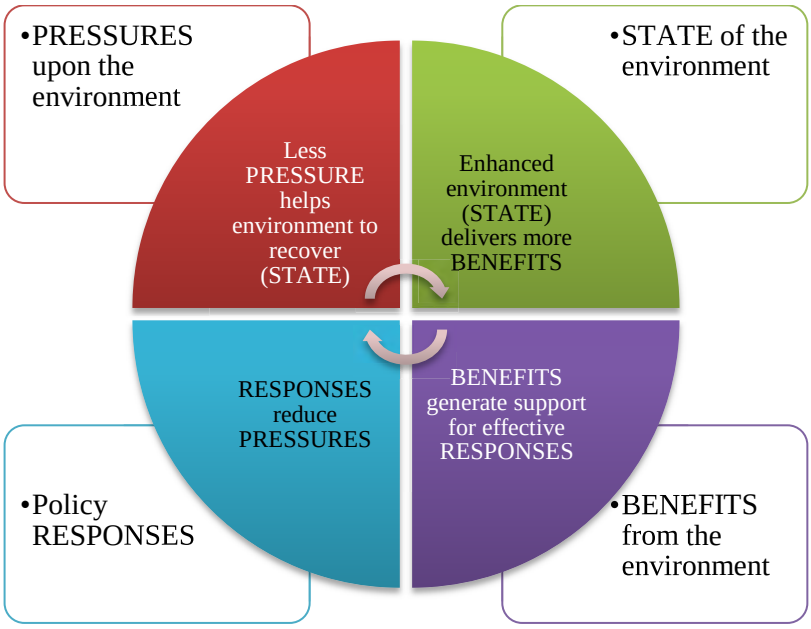
Source: JICA Study Team

An important function of indicators is to facilitate the informed assessment of progress towards targets. “Linked” sets of indicators provide a more logical and effective framework for this than do individual indicators on their own or as an unstructured set. Linked sets of environmental indicators help to develop a clearer understanding of relationships between policy actions, anthropogenic threats, the status of the environment and the benefits and services that people derive from it. Linking indicators of in these four categories clarify how policy responses are affecting change:

- Pressure on the environment (Category of Pressure): indicators monitoring the extent and intensity of the threats to the environment that responses aim to address;
- State of the environment (Category of State): indicators tracking the condition of the environment;
- Benefit from the environment (Category of Benefits): indicators measuring trends in the benefits and services that humans derive from the environment; and
- Policy responses (Category of Responses): indicators measuring the implementation of policies or actions to prevent or reduce environment benefit loss.

The mentioned categories of indicators have linked relationships as follows.

- Between Pressure and State category indicators: less pressure helps the environment to recover. Thus, the recovery can be expressed quantitatively regarding the environment state.
- Between State and Benefits category indicators: enhanced *status quo* of the environment, expressed regarding "state", deliver more benefits, expressed with related ecosystem services.
- Between Benefits and Responses indicators: benefits as explained above, regarding ecosystem services, generate support for effective policy responses.
- Between Responses and Pressures indicators: effective implementation of relevant policy responses derives in the reduction of pressures on the environment.



Source: JICA Study Team.

Figure 4.5-1 Linked relationship of evaluation/monitoring indicators

4.5.2 Second Stakeholder Meeting

The Second Stakeholder Meeting was held on November 24, 2016 at the Main Auditorium of CEA, with the participation of representatives of the Government of the Department of Santa Cruz, the Municipal Administrations of the Metropolitan Area, Faculty of Engineering of UPSA (*Universidad Privada de Santa Cruz de la Sierra*), UNE (*Universidad Nacional Ecológica*), FAN, and representatives of the public transportation sector.

Following to the presentations from the JICA Study Team consisted of the description of the alternatives of development scenarios and the analysis of those scenarios by the evaluation criteria, a debate with the participants was conducted.

The results of the analysis are listed in the Table below:

Table 4.5-2 Alternatives analysis of development scenarios

Option	Evaluation criteria	Estimated scenario
Option 1A Zero option	Increase of temperature due to urban heat island effect	Highly prone in overall Metropolitan Area rely on high asphalt and building constructions
	Decrease of groundwater recharge capacity	Highly prone in overall Metropolitan Area rely on newly expanded impervious areas

Option	Evaluation criteria	Estimated scenario
	Degradation of air quality	Highly prone in overall Metropolitan Area rely on sprawl development causing idling transportation system
	Degradation of water quality	Highly prone in overall Metropolitan Area rely on sprawl development causing idling transportation system
	Degradation of landscape	Highly prone in overall Metropolitan Area rely on disturbance of high extension of natural assets
	Public constraints on transportation	Highly prone in overall Metropolitan Area rely on sprawl development causing idling transportation system
	Positive and negative socio-economic effects	High loss on cost of opportunity in overall Metropolitan Area rely on sprawl development causing idling transportation system
Option 1B Trend development with arterial roads	Increase of temperature due to urban heat island effect	Highly prone in overall Metropolitan Area rely on high asphalt and building constructions
	Decrease of groundwater recharge capacity	Highly prone in overall Metropolitan Area rely on newly expanded impervious areas
	Degradation of air quality	Highly prone in overall Metropolitan Area rely on sprawl development causing idling transportation system
	Degradation of water quality	Highly prone in overall Metropolitan Area rely on sprawl development causing idling transportation system
	Degradation of landscape	Highly prone in overall Metropolitan Area rely on disturbance of high extension of natural assets
	Public constraints on transportation	Moderately prone in overall Metropolitan Area and partial benefits for population living in zones connected by newly constructed arterial roads
	Positive and negative socio-economic effects	Moderate loss on cost of opportunity in overall Metropolitan Area rely on sprawl development causing moderately idling transportation system; and also is prone to involuntary resettlement along newly constructed arterial roads
Option 2A Controlled urban development	Increase of temperature due to urban heat island effect	Moderately prone in overall Metropolitan Area rely on moderate asphalt and building constructions
	Decrease of groundwater recharge capacity	Moderately prone in overall Metropolitan Area rely on newly expanded impervious areas
	Degradation of air quality	Highly prone in overall Metropolitan Area rely on increased growth of small-size public vehicles
	Degradation of water quality	Highly prone in overall Metropolitan Area rely on increased growth of small-size public vehicles
	Degradation of landscape	Moderately prone in overall Metropolitan Area rely on disturbance of moderate extension of natural assets
	Public constraints on transportation	Moderately prone in overall Metropolitan Area and partial benefits for population living in zones connected by newly constructed arterial roads
	Positive and negative socio-economic effects	Moderate loss on cost of opportunity in overall Metropolitan Area rely on sprawl development causing moderately idling transportation system; and also is prone to involuntary resettlement along newly constructed arterial roads
Option 2B Controlled urban development with transit development	Increase of temperature due to urban heat island effect	Moderately prone in overall Metropolitan Area rely on moderate asphalt and building constructions
	Decrease of groundwater recharge capacity	Moderately prone in overall Metropolitan Area rely on newly expanded impervious areas
	Degradation of air quality	Moderately prone in overall Metropolitan Area rely on reduction of inefficient aspects of public transportation system
	Degradation of water quality	Moderately prone in overall Metropolitan Area rely on reduction of inefficient aspects of public transportation system
	Degradation of landscape	Moderately prone in overall Metropolitan Area rely on disturbance of moderate extension of natural assets

Option	Evaluation criteria	Estimated scenario
	Public constraints on transportation	Moderately prone in overall Metropolitan Area rely on reduction of inefficient aspects of public transportation system
	Positive and negative socio-economic effects	Moderate loss on cost of opportunity in overall Metropolitan Area rely on reduction of inefficient aspects of public transportation system
Option 3A Densification of the existing urbanized area	Increase of temperature due to urban heat island effect	Lowly prone in overall Metropolitan Area rely on low asphalt and building constructions based on vertical growth
	Decrease of groundwater recharge capacity	Lowly prone in overall Metropolitan Area rely on low expansion of impervious areas
	Degradation of air quality	Moderately prone in overall Metropolitan Area but highly biased prone in areas targeted for vertical growth
	Degradation of water quality	Moderately prone in overall Metropolitan Area but highly biased prone in areas targeted for vertical growth
	Degradation of landscape	Lowly prone in overall Metropolitan Area rely on disturbance of lowly extension of natural assets
	Public constraints on transportation	Lowly prone in overall Metropolitan Area rely on restricted development but highly idling transportation system at vertically grown areas
	Positive and negative socio-economic effects	Lowly loss on cost of opportunity in overall Metropolitan Area rely on restricted development but highly idling transportation system at vertically grown areas
Option 3B Densification of the existing urbanized area – transit-oriented development	Increase of temperature due to urban heat island effect	Lowly prone in overall Metropolitan Area rely on low asphalt and building constructions based on vertical growth
	Decrease of groundwater recharge capacity	Lowly prone in overall Metropolitan Area rely on low expansion of impervious areas
	Degradation of air quality	Moderately prone in overall Metropolitan Area but highly biased prone in areas targeted for vertical growth
	Degradation of water quality	Moderately prone in overall Metropolitan Area but highly biased prone in areas targeted for vertical growth
	Degradation of landscape	Lowly prone in overall Metropolitan Area rely on disturbance of lowly extension of natural assets
	Public constraints on transportation	Lowly prone in overall Metropolitan Area rely on restricted development but moderately idling transportation system at vertically grown areas
	Positive and negative socio-economic effects	Lowly loss on cost of opportunity in overall Metropolitan Area rely on restricted development but moderately idling transportation system at vertically grown areas
Option 4A Subcenter development – road oriented development	Increase of temperature due to urban heat island effect	Moderately prone in overall Metropolitan Area but highly prone in newly developed areas
	Decrease of groundwater recharge capacity	Moderately prone in overall Metropolitan Area but highly prone in newly developed areas
	Degradation of air quality	Moderately prone in overall Metropolitan Area but highly prone in newly developed areas
	Degradation of water quality	Moderately prone in overall Metropolitan Area but highly prone in newly developed areas
	Degradation of landscape	Moderately prone in overall Metropolitan Area but highly prone in newly developed areas
	Public constraints on transportation	Moderately prone in overall Metropolitan Area rely on biased development
	Positive and negative socio-economic effects	Moderate loss on cost of opportunity in overall Metropolitan Area rely on biased development; and also is prone to involuntary resettlement along newly constructed arterial roads
Option 4B Subcenter development – transit-oriented	Increase of temperature due to urban heat island effect	Moderately prone in overall Metropolitan Area but highly prone in newly developed areas
	Decrease of groundwater recharge capacity	Moderately prone in overall Metropolitan Area but highly prone in newly developed areas
	Degradation of air quality	Moderately prone in overall Metropolitan Area but

Option	Evaluation criteria	Estimated scenario
development		highly prone in newly developed areas
	Degradation of water quality	Moderately prone in overall Metropolitan Area but highly prone in newly developed areas
	Degradation of landscape	Moderately prone in overall Metropolitan Area but highly prone in newly developed areas
	Public constraints on transportation	Moderately prone in overall Metropolitan Area rely on biased development
	Positive and negative socio-economic effects	Moderate loss on cost of opportunity in overall Metropolitan Area rely on biased development

Source: JICA Study Team.

Regardless of the qualitative evaluation of the alternative scenarios, it is evident that environmentally and socially manageable options are desired for the future scenario of the Metropolitan Area. In that sense, except for the Option 2B "Controlled urban development with transit development", the alternatives are totally or partially highly prone to warned constraints, attaining the ecological and social resiliencies.

Once the development strategies are selected, a set of environmental monitoring indicators shall be identified to enhance the current policy responses to achieve reductions in pressures concomitantly upon the conduction of activities for the future plan.

The significant environmental effects of the implementation of development plan must be monitored to identify any unforeseen adverse effects and to enable appropriate remedial action to be taken. Monitoring allows the actual effects of the plan to be tested against those predicted in the SEA and helps to ensure that problems which arise during implementation, whether or not they were originally foreseen, can be identified and future predictions made more accurately. It can also be used to provide baseline information for future policies, plans or programs.

As a conclusion from the Second Stakeholder Meeting, a consensus was achieved with the Option 2B "Controlled urban development with transit development", as the foremost desirable strategy for the future development of the Santa Cruz Metropolitan Area.

Moreover, relevant linked indicators to monitor the constraint were shared as in following terms. The Tables list the context of each linked indicator and stakeholder responsibility, but not limited to this engagement, regarding monitoring tasks:

Table 4.5-3 Modified DPSIR linked indicators for monitoring

Indicator	Pressure	State	Benefit	Response
Increase of temperature due to urban heat island effect				
Context	Growth of urbanized zone and pavement of roads	Temperature (increase) of urban zone compared with to rural zone	Livable urban zone (degradation) with comfortable ambient temperature	Controlled growth of urbanization throughout sustainable spatial plan
Stakeholder responsibility	• Department of Santa Cruz: conduction of sustainable spatial plan; monitoring temperatures • Municipalities: conduction of sustainable spatial plan in coordination with Department of Santa Cruz; measurement of temperatures			
Decrease of groundwater recharge capacity				
Context	Extension of impervious areas due to civil construction and pavement of roads	Water table level (decay)	Accessibility (degradation) to potable water source with optimal cost performance on its abstraction	Controlled growth of urbanization throughout sustainable spatial plan
Stakeholder	• Department of Santa Cruz: conduction of sustainable spatial plan; supervision of water			

Indicator	Pressure	State	Benefit	Response
responsibility	rights procedures; monitoring water tables; sharing information on water tables with municipalities • Municipalities: conduction of sustainable spatial plan in coordination with Department of Santa Cruz; enforcement of water rights procedures; measurement of water tables; sharing information on water tables with water supply enterprises			
Degradation of air quality				
Context	Increase of vehicle gas emission	Air quality (degradation)	Livable urban zone (degradation) with comfortable air quality and healthiest atmosphere	Adaptation of measures for efficient vehicular mobility and vehicle emission control
Stakeholder responsibility	• Department of Santa Cruz: adaptation of measures for efficient vehicular mobility; supervision of vehicle emission control (application of Law of Transport No. 195); estimation of air pollutant loads including GHG; monitoring air quality in accordance with Regulation on Matter of Air Pollution (DS 24176); strengthening of Climate Change Program • Municipalities: implementation of vehicle emission control (application of Law of Transport No. 195); measurement of air quality parameters in accordance with Regulation on Matter of Air Pollution (DS 24176) • MONICA Network: provision of measured data and technical reports			
Degradation of water quality				
Context	Increase of wastewater and precipitation of vehicular contaminants	Water quality (degradation)	Livable urban zone with comfortable water quality free of related deceases	Controlled growth of urbanization and improvement of vehicular mobility
Stakeholder responsibility	• Department of Santa Cruz: monitoring of water quality in accordance with the Regulation on the Matter of Water Pollution (DS 24176); sharing information on water quality with municipalities • Municipalities: measurement of water quality in accordance with the Regulation on the Matter of Water Pollution (DS 24176); sharing information on water quality with water supply enterprises Santa Cruz Metropolitan Area Network for the monitoring of groundwater (*Red de Monitoreo de Calidad de Aguas Subterráneas*): provision of measured data and technical reports			
Degradation of landscape				
Context	Growth of urban zone affecting areas of conservation and protection	Conservation of ecosystem units (fragmentation) and sustainable use of soil and natural resources	Conservation of natural assets (degradation) comfortable for livelihood	Compliance with the norms related to activity allowance of areas for conservation and protection
Stakeholder responsibility	• Department of Santa Cruz: implementation of Departmental Strategy of Conservation of Protected Areas and Conservation Units of Santa Cruz to enforce the compliance with the norms related to activity allowance of areas for conservation and protection			
Public constraints on transportation				
Context	Inefficient transportation system	Accessibility to efficient (inefficient) transportation system	Facility for transportation	Controlled growth of urbanization and improvement of vehicular mobility
Stakeholder responsibility	• Department of Santa Cruz: conduction of sustainable spatial plan; adaptation of measures for efficient vehicular mobility			
Positive and negative socio-economic effects				
Context	Population growth and increase of time necessary for transportation	Population density and cost of opportunity loss due to time invested for transportation	Livable urban zone and facility for transportation	Controlled growth of urbanization and improvement of vehicular mobility
Stakeholder responsibility	• Department of Santa Cruz: conduction of sustainable spatial plan; adaptation of measures for efficient vehicular mobility			

Indicator	Pressure	State	Benefit	Response
	• Municipalities: conduction of sustainable spatial plan in coordination with Department of Santa Cruz; adaptation of measures for efficient vehicular mobility			

Source: JICA Study Team

4.5.3 Third Stakeholder Meeting

The third stakeholder meeting was conducted on May 5th, 2017 at Main Auditorium of CEA, with the following objectives:

- Definition of baseline conditions to be referenced for evaluation criteria;
- Establishment of a collaboration mechanism among the stakeholders for sharing data and information required for composing relevant indicators consequent with the evaluation criteria; and
- Definition of responsibilities of stakeholders to conduct the monitoring of selected indicators properly as part of the evaluation process.

As result of the meeting a consensus was achieved as listed in below Table:

Table 4.5-4 Consensus on baseline conditions

Evaluation criteria	Indicator	Source of data
Increase of temperature	Land surface temperature	NASA/NEO, Terra/Aqua satellites free downloadable data
Decrease of aquifer recharge capacity	Pressure indicator such as population density, instead of state indicator of water table logs	INE, ICE
Degradation of air quality	NO_2, ozone, PM10, CO, active fires	Red MONICA-Santa Cruz de la Sierra, NASA/NEO, Terra/Aura/Aqua satellites free downloadable data
Degradation of water quality	Pressure indicator such as population density, instead of state indicator of surficial and groundwater qualities	INE, ICE
Degradation of landscape	Vegetation indexes (NDVI, LAI)	NASA/NEO, Terra satellite free downloadable data
Mitigation of public constrain on transportation	Time spent for transportation	JICA Study Inquiry Survey
Positive and negative socio-economic effects	Loss on cost of opportunity due to inefficient transportation system	JICA Study Inquiry Survey

Source: JICA Study Team

Regarding the establishment of the collaboration mechanism, among the stakeholders for sharing data and information; and on the definition of responsibilities of stakeholders, to conduct the monitoring activities properly, JICA Study Team proposed to the stakeholders the issues listed in below Table.

Table 4.5-5 Stakeholders and responsibilities on monitoring mechanism

Evaluation criteria	Responsible entity	Required duty
Increase of temperature	Entity in charge of environmental issues of the Departmental and Municipal administrations	Monitoring of temperature, green areas
Decrease of aquifer recharge capacity	Entity in charge of environmental issues of the Departmental and Municipal administrations in collaboration with enterprises of waterworks (SAGUAPAC,	Monitoring of water table, urban expansion, green areas

Evaluation criteria	Responsible entity	Required duty
	etc.)	
Degradation of air quality	Entity in charge of environmental issues of the Departmental and Municipal administrations	Monitoring of air quality, state of slash-and-burn practice
Degradation of water quality	Entity in charge of environmental issues of the Departmental and Municipal administrations in collaboration with enterprises of waterworks (SAGUAPAC, etc.)	Monitoring of water quality
Degradation of landscape	Entity in charge of environmental issues of the Departmental and Municipal administrations	Monitoring of areas for conservation, green areas
Mitigation of public constrain on transportation	Entity in charge of transportation and traffic issues of the Departmental and Municipal administrations	Monitoring of grade of satisfaction by the users of transportation system
Positive and negative socio-economic effects	Entity in charge of planning issues of the Departmental and Municipal administrations in collaboration with statistic administration institutes (INE, ICE)	Monitoring of cost of opportunity associated with transportation system
Emission of GHGs	Entity in charge of environmental issues of the Departmental and Municipal administrations	Monitoring of GHGs

Source: JICA Study Team

To instruct the stakeholders in gathering and processing NASA-NEO satellites images, a Technical Workshop was held on May 12, 2017, at CEA. In this Technical Workshop was invited the staff of the Department Government and Municipal Administrations engaging environmental and planning duties. In addition, taking into account the suggestion from the Counterpart, professors and postgraduate students of principal universities of Santa Cruz, and relevant NGOs were invited.

The contents of the Technical Workshop consisted on:

- Availability of NASA-NEO satellite data and on the freely downloadable options of data formats to use for the composition of indicators (land surface temperature, nitrogen dioxide, ozone, aerosol, active fires, normalized difference vegetation index, leaf area index, etc.);
- Methodology for processing satellite image data pursuing conversion of collected NASA-NEO satellite raster images into numerical values using a shareware of GIS management (QGIS); and
- Methodology for numerical ordination throughout regression analysis using a shareware of multivariate statistical analysis tool (PAST).

4.6 Screening of Master Plan Components

4.6.1 Procedure of categorization

The EIA procedure in Bolivia starts with Screening. This step involves the allocation of a project to one of the categories that require different comprehensiveness of environmental assessment. After that, the impact assessment, the review process and the decision-making process regarding the issuance of an environmental license pursue. Finally, a set of compliance-monitoring is required.

VMABCCYDGDF and the local government are the authority responsible for the screening decision at the national and local level, respectively. The screening process involves the

categorization of projects to determine the level of assessment that is required. In fact, four categories are distinguished:

- Category 1: Integral analysis based environmental impact assessment study;
- Category 2: Specific analysis based environmental impact assessment study;
- Category 3: Projects and activities which require only a monitoring plan and an environmental plan with prevention and mitigation measures; and
- Category 4: Exemption of EIA.

The criteria for establishing the EIA category are as follows:

- Magnitude of the activity according to the affected surface and volume of production;
- Significant impact on the environment;
- Location near or in protected areas;
- Use of natural resources;
- Quality and quantity of effluents generated emissions and waste;
- Risk for health of the population;
- Permanent or temporary relocation, or other alterations of human settlements;
- Changes in social, cultural and economic conditions; and
- Impact on historical and cultural values.

Additional requirements are necessary for such projects that influence areas of natural, cultural and spiritual value such as sacred sites. Competencies for environmental approval for investment in protected areas and areas of national heritage are assigned to MMAyA. The National Service of Protected Areas (SERNAP) participates in the process of elaboration, review, and monitoring of the EIA of projects in protected areas.

The screening process of an established project, to categorize the required assessment level, is conducted with the revision of the respective Environmental and Project Information Sheet (*Ficha Ambiental:* FA).

The form of FA is comprised of the following sections:

(1) General information

This part should be filled with data related to submission of the document, such as date of submission, the name of the person who is submitting the project proposal, and the professional or institution who formulated the FA document.

(2) Data on activity unit

The legal and commercial registration regime concerning the activity under assessment should be certified in this section.

(3) Identification and location of the project

Name, physical location verifiable with cadastral records, with quotes on the land use classification, of the project should be certified in this part.

(4) Description of the project location

The size of the project infrastructure and facilities, topography, depth of water table, quality of water, predominant vegetation, natural drainage paths, and human environment of the surrounding should describe.

(5) Project description

The content of project description shall comprise by the following items:

- Type of activity: the sector and sub-sector specifying CIIU (*clasificación industrial internacional uniforme*) code, which is based on International Standard Industrial Classification (ISIC);
- Nature of the project: in case of a new or extension of an existing activity, specifying which stage (exploration, exploitation, operation, construction, maintenance, abandonment, etc.);
- Scope of the project: if the project is conducted in urban or rural area;
- General objective of the project;
- Specific objective of the project; and
- The identification of the project: if the project belongs to a plan, or a program, or is an isolated project; description of the plan or program if is the case that the project belongs to a plan or a program; and lifespan of the project.

(6) Alternatives and technology

A description and the justification of site selection and the technology including the machinery, equipment, and materials to be used to be applied and their processes shall be specified.

(7) Investment

Shall be specified if the project is in the stage of pre-feasibility, feasibility study, or final design; the total cost of investment and sources of financing.

(8) Activities

Each activity of the project shall be listed in order by naming the activity, its brief description, amount of activity and the duration.

(9) Human resources

Data on the number of skilled and unskilled personnel engaged permanently, and temporary in the project shall be listed.

(10) Natural resources of the influence area to be used

Data on volumes or amounts of natural resources shall be listed.

(11) Raw materials, consumables, and production of the project

Data on amounts of raw materials and consumables, energy, and annual production shall be listed, specifying their sources.

(12) Generation of wastes

Data of sources, amounts, and the way of final disposal or receptor of the waste generated (solid, liquid, and ga) by the project shall be listed, specifying by classification (non-hazardous, hazardous, etc.).

(13) Generation of noise

Data on noise range (minimum and maximum values in decibels) to be generated shall be listed specifying the source type.

(14) Description of storage method for consumables

Method and location of place for storing the consumables shall describe.

(15) Description of transportation for consumables

The process and handling of consumables shall describe.

(16) Description of contingencies

Unforeseen accidentals and contingencies shall describe.

(17) Environmental considerations

A synthetic list of environmental considerations shall be listed as follows:

- A resume of important environmental impacts for each stage (construction, operation, and maintenance, abandonment) specifying if they are negative or positive impact if they are cumulative, and their nature of short- or long-term temporality or permanently (irreversibility), and also if it affects directly or indirectly to the environment; and
- Proposal of mitigation measures for negative impacts specifying for each stage of the project (construction, operation, and maintenance, abandonment).

(18) Declaration

A declaration on the contents of FA signed by the project proposer and the authorized environmental consultant shall be committed.

Moreover, the FA document should be submitted as an attachment named Matrix of Impact Evaluation (*Matriz de Evaluación de Impacto*: M1) as listed in below Tables.

Table 4.6-1 Matrix of Impact Evaluation: Air and Water

Factor:	Air								Water											
Project activity	dispersion factor	suspended particles	sulfur oxides	nitrogen oxides	carbon monoxide	photochemical oxidants	hazardous & toxics	odor	aquifer recharge	flow-rate change	oil & fats	suspended solids	temperature	acidity & alkalinity	BOD_5	dissolved oxygen	dissolved solids	nutrients	toxic compounds	fecal coliforms

Source: JICA Study Team

Table 4.6-2 Matrix of Impact Evaluation: Soil, Ecology, and Water

Factor:	Soil						Ecology									Noise			
Project activity	salinity and alkalinity	compaction	nutrients	erosion	risks	soil use	terrestrial fauna	birds	aquatic fauna	terrestrial vegetation &	urban green areas	aquatic vegetation & flora	agriculture harvesting	vectors	Landscape	Physiologic effects	Communication	Labor performance	Social behavior

Source: JICA Study Team

Table 4.6-3 Matrix of Impact Evaluation: Socioeconomic

Factor:	Socioeconomic							
Project activity	Lifestyle	Physiologic system	Community needs	Employment	Public sector income	Per-capita consumption	Public property	Private property

Source: JICA Study Team

This Matrix (M1) shall be formulated for the construction phase and the induced future situation of the proposed project. The discrete scale of punctuation ranges "plus one" for low positive impact, "plus two" for moderate positive impact, and "plus three" for high positive impact. Similarly "minus one", "minus two", and "minus three" for negative impacts that are low, moderate, and high, respectively.

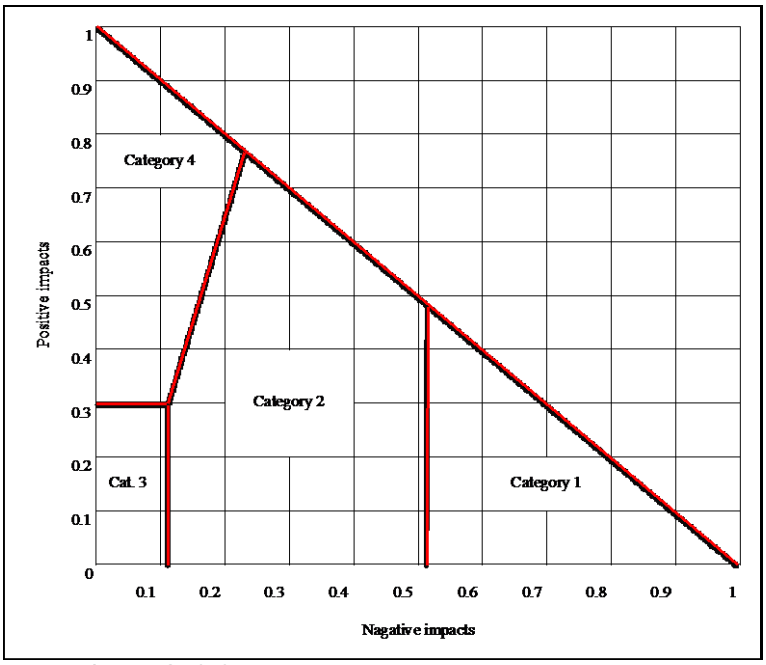
A quantitative evaluation was conducted with the total punctuation using the following formula, discriminating by negative and positive impacts:

$$\frac{\frac{\sum_{=1}^{=} \times 47}{\times 47}}{1 + \frac{\sum_{=1}^{=} \times 47}{\times 47}}$$

Where:

EAP: Environmental attribute punctuation (ranging discretely -3 to +3), classified by environmental factors air, water, soil, ecology, noise, and socioeconomic, totalizing 47 attributes.
m: Number of project activity
n: Number of the environmental attributes (1 to 47)

For the determination of category, it is defined by the position of the positive and negative scores, computed using the above formula, lays in the diagram shown in the Figure below.



Source: MMAyM. DS 28592.

Figure 4.6-1 Graph for determining the category of assessment level

4.6.2 Categorization precedents of transportation projects

Following Table lists the precedent process of categorization of transportation projects in the jurisdiction of Santa Cruz Metropolitan Area, applying the evaluation procedure.

Table 4.6-4 EIA categorization precedents in transportation sector

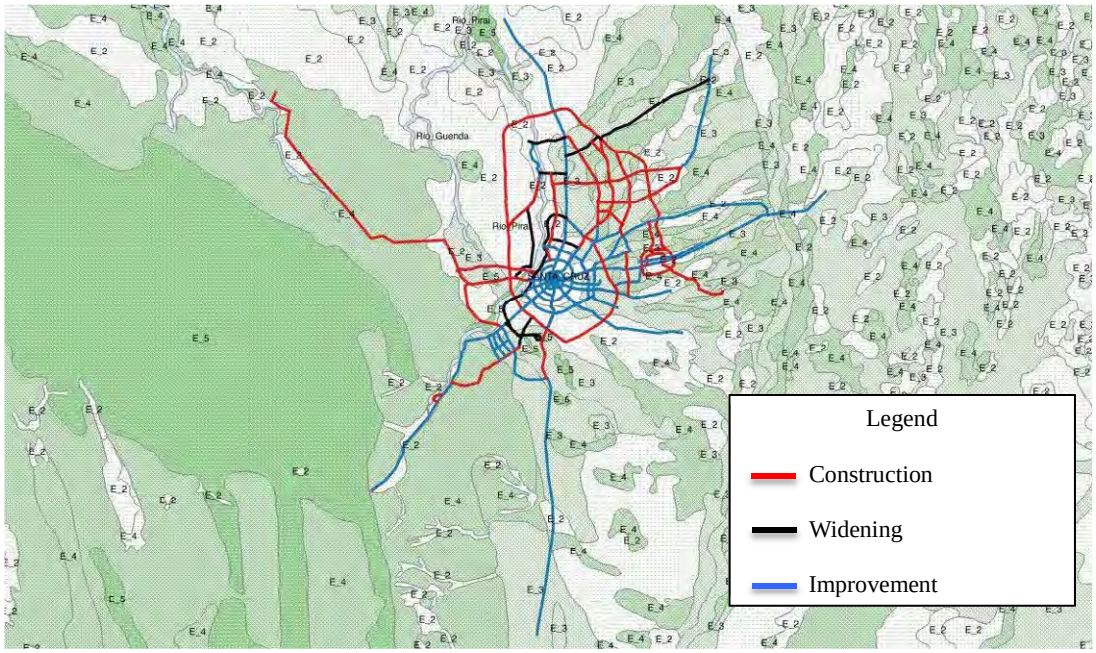
Project	Jurisdiction	FA/MA submission	Deliberation	Category
Construction of highway Santa Cruz-Las Cruces-Buena Vista	Provinces of Andres Ibañez and Ichilo	Dec. 11, 2009	Dec. 1, 2016	2
Construction of two-lane road Warnes-Montero and pavement of bypass Warnes West	Municipality of Warnes	Jan. 3, 2008	June 24, 2008	2
Construction of two-lane road Santa Cruz-Cotoca	Province of Andres Ibañez	June 29, 2007	Nov. 23, 2007	2
Construction of bridges, sidewalks (Program of Road Improvement)	Departments of Beni, Pando, and Santa Cruz	April 30, 2002	Aug. 2, 2002	3
Rehabilitation and improvement of highway La Guardia-Comarapa	Provinces of Andres Ibañez, Florida, and Manuel Maria Caballero	July 19, 2007	Feb. 29, 2008	3
Improvement of road Rio Pirai (Tacuarembo access)	Municipality of Porongo	Jan. 3, 2008	Mar. 3, 2011	3
Maintenance of bridges Limoncito-Santa Martha, and La Guardia; Maintenance of National Road (El Torno, La Guardia)	Province of Andres Ibañez	Dec. 10, 2010	Jan. 26, 2012	3
Maintenance of bridges Coca-Taruma and San Jose; Maintenance of National Road (Department of Santa Cruz)	Provinces of Andres Ibañez and Florida	Dec. 10, 2010	Jan. 26, 2012	3
Construction of vehicle-weight control station La Guardia	Municipality of La Guardia	Dec. 16, 2016	Dec. 28, 2016	4
Construction of vehicle-weight control station La Reforma	Municipality of Warnes	Dec. 16, 2016	Dec. 27, 2016	4
Reconstruction of bridge Carmen de Azuzaqui	Municipality of Warnes	Mar. 12, 2009	Mar. 26, 2009	4
Rehabilitation of bridge La Jungla-Los Ciervos	Municipality of Warnes	Mar. 12, 2009	Mar. 26, 2009	4

Project	Jurisdiction	FA/MA submission	Deliberation	Category
Rehabilitation of bridge San Juan de las Parcelas	Municipality of Warnes	Mar. 12, 2009	Mar. 26, 2009	4
Rehabilitation of bridge San Francisco (River Pedro Velez)	Municipality of Warnes	Mar. 12, 2009	Mar. 26, 2009	4
Rehabilitation of road Terebinto-El Hondo	Municipality of Porongo	Jan. 3, 2008	Mar. 26, 2009	4

Source: JICA Study Team

4.6.3 Initial attempt for categorizing Master Plan Projects

The Figure below shows the Master Plans components infrastructure and facilities classified by construction (red line), widening (black line), and improvement (blue line) overlapped to the map of ecological valuation (see for details in Section 4.2.2 Baseline Data (6) Ecological Valuation of Santa Cruz Metropolitan Area).



Source: Ecological valuation: Department of Santa Cruz Secretariat of Sustainable Development and Environment; Master Plan Projects: JICA Study Team.

Figure 4.6-2 Master Plan components (construction, widening, and improvement)

Based on the current regime of EIA and its precedent categorization for transportation sector concern of Santa Cruz Metropolitan Area, following categories are expected for the Master Plan components, taking into account roughly the features of the ecological value of the correspondent site, geography, socioeconomic aspects, and expected environmental performances.

For its simplicity, an outlook of each project is evaluated without detailed pondering on specific activities that comprise. The results are listed in following Tables.

Table 4.6-5 M1 (Environmental Factors Air and Water) of Master Plan components

Factor	Air								Water												Soil					
Project activity	dispersion factor	suspended particles	sulfur oxides	nitrogen oxides	carbon monoxide	photochemical oxidants	hazardous & toxics	odor	aquifer recharge	flow-rate change	oil & fats	suspended solids	temperature	acidity & alkalinity	BOD5	dissolved oxygen	dissolved solids	nutrients	toxic compounds	fecal coliforms	salinity and alkalinity	compaction	nutrients	erosion	risks	soil use
Road construction projects																										
Short-term																										
R100	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
R102	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
R103	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
Mid-term																										
R002	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
R009	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R014	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R015	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-3
R023	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R501	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R509	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R510	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R700	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	-1	-1	-1
Long-term																										
R006	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R013	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R101	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
R105	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
R300	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R400	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R401	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	-1	-1	-2
R403	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
R404	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
R500	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
R502	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
R503	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R504	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
R501	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R506	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R507	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R508	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1
R701	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
R800	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
R805	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-2
Road (bridge) widening projects																										
Mid-term																										
R003	0	-1	-1	-1	-1	-1	0	-1	0	0	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	-1	-1	-1
R021	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R022	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
R208	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
R209	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
R301	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
R303	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
Long-term																										
R020	0	-1	-1	-1	-1	-1	0	0	0	0	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	-1	-1	-1
R304	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
R402	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1

Factor	Air								Water												Soil					
Project activity	dispersion factor	suspended particles	sulfur oxides	nitrogen oxides	carbon monoxide	photochemical oxidants	hazardous & toxics	odor	aquifer recharge	flow-rate change	oil & fats	suspended solids	temperature	acidity & alkalinity	BOD5	dissolved oxygen	dissolved solids	nutrients	toxic compounds	fecal coliforms	salinity and alkalinity	compaction	nutrients	erosion	risks	soil use
Road improvement projects																										
Short-term																										
BRT	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium-term																										
R001	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R007	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R008	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R011	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R012	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R017	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R018	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R106	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R203	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R205	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R206	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BRT	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Long-term																										
R004	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R005	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R010	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R016	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R019	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R024	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R200	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R201	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R202	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R204	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R302	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R305	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R405	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R801	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R802	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R803	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R804	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R806	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R807	0	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Projects on construction and improvement of intersections																										
Short-term																										
Flyovers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mid-term																										
Intersection(a)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Intersection(b)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flyovers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Long-term																										
Intersection(a)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Intersection(b)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flyovers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Factor	Ecology									Noise				Socioeconomic								Results		
Project activity	terrestrial fauna	birds	aquatic fauna	terrestrial vegetation & flora	urban green areas	aquatic vegetation & flora	agriculture harvesting	vectors	Landscape	Physiologic effects	Communication	Labor performance	Social behavior	Lifestyle	Physiologic system	Community needs	Employment	Public sector income	Per-capita consumption	Public property	Private property	Total score of negative impacts	Total score of positive impacts	Assessment category
Road construction projects																								
Short-term																								
R100	0	0	0	-1	0	0	0	0	-1	-1	0	0	0	2	0	2	2	2	2	0	-1	0.469	0.175	2
R102	0	0	0	-1	0	0	0	0	-1	-1	0	0	0	2	0	2	2	2	2	0	-1	0.469	0.175	2
R103	0	0	0	-1	0	0	0	0	-2	-1	0	0	0	2	0	2	2	2	2	0	-1	0.516	0.175	1
Mid-term																								
R002	0	0	0	-2	0	0	0	0	-2	-1	0	0	0	2	0	2	2	2	2	0	-1	0.567	0.175	1
R009	0	0	0	0	0	0	0	0	0	-1	0	0	0	2	0	2	2	2	2	0	-1	0.343	0.175	2
R014	0	0	0	0	0	0	0	0	0	-1	0	0	0	2	0	2	2	2	2	0	-1	0.343	0.175	2
R015	-1	-1	0	-2	0	0	0	0	-3	-1	0	0	0	2	0	2	2	2	2	0	-1	0.808	0.175	1
R023	0	0	0	0	0	0	0	0	0	-1	0	0	0	2	0	2	2	2	2	0	-1	0.343	0.175	2
R501	0	0	0	0	0	0	0	0	0	-1	0	0	0	2	0	2	2	2	2	0	-1	0.424	0.175	2
R509	0	0	0	0	0	0	0	0	0	-1	0	0	0	2	0	2	2	2	2	0	-1	0.343	0.175	2
R510	0	0	0	0	0	0	0	0	0	-1	0	0	0	2	0	2	2	2	2	0	-1	0.343	0.175	2
R700	0	0	-1	0	0	0	0	0	-1	-1	0	0	0	2	0	2	2	2	2	0	0	0.469	0.175	2
Long-term																								
R006	0	0	0	0	0	0	0	0	0	-1	0	0	0	2	0	2	2	2	2	0	-1	0.343	0.175	2
R013	0	0	0	0	0	0	0	0	0	-1	0	0	0	2	0	2	2	2	2	0	-1	0.343	0.175	2
R101	0	0	0	-2	0	0	0	0	-2	-1	0	0	0	2	0	2	2	2	2	0	-1	0.567	0.175	1
R105	0	0	0	-2	0	0	0	0	-2	-1	0	0	0	2	0	2	2	2	2	0	-1	0.567	0.175	1
R300	0	0	0	0	0	0	0	0	0	-1	0	0	0	2	0	2	2	2	2	0	-1	0.343	0.175	2
R400	0	0	0	0	0	0	0	0	0	-1	0	0	0	2	0	2	2	2	2	0	-1	0.343	0.175	2
R401	0	-1	-1	-1	-1	-1	0	0	-1	-1	0	0	0	2	0	2	2	2	2	0	-1	0.808	0.175	1
R403	0	0	0	-1	0	0	0	0	-2	-1	0	0	0	2	0	2	2	2	2	0	-1	0.516	0.175	1
R404	0	0	0	-2	0	0	0	0	-2	-1	0	0	0	2	0	2	2	2	2	0	-1	0.567	0.175	1
R500	0	0	0	-2	0	0	0	0	-2	-1	0	0	0	2	0	2	2	2	2	0	-1	0.567	0.175	1
R502	0	0	0	-2	0	0	0	0	-2	-1	0	0	0	2	0	2	2	2	2	0	-1	0.567	0.175	1
R503	0	0	0	0	0	0	0	0	0	-1	0	0	0	2	0	2	2	2	2	0	-1	0.343	0.175	2
R504	0	0	0	-2	0	0	0	0	-2	-1	0	0	0	2	0	2	2	2	2	0	-1	0.567	0.175	1
R501	0	0	0	0	0	0	0	0	0	-1	0	0	0	2	0	2	2	2	2	0	-1	0.343	0.175	2
R506	0	0	0	-1	0	0	0	0	-1	-1	0	0	0	2	0	2	2	2	2	0	-1	0.424	0.175	2
R507	0	0	0	-2	0	0	0	0	-2	-1	0	0	0	2	0	2	2	2	2	0	-1	0.516	0.175	1
R508	0	0	0	-1	0	0	0	0	-1	-1	0	0	0	2	0	2	2	2	2	0	-1	0.424	0.175	2
R701	0	0	0	-2	0	0	0	0	-2	-1	0	0	0	2	0	2	2	2	2	0	-1	0.567	0.175	1
R800	0	0	0	-2	0	0	0	0	-2	-1	0	0	0	2	0	2	2	2	2	0	0	0.516	0.175	1
R805	0	0	0	-2	0	0	0	0	-2	-1	0	0	0	2	0	2	2	2	2	0	-1	0.567	0.175	1
Road (bridge) widening projects																								
Mid-term																								
R003	0	0	-1	-1	-1	-1	0	0	-1	0	0	0	0	2	0	2	2	2	2	0	0	0.567	0.175	1
R021	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R022	0	0	0	0	-1	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.237	0.096	2
R208	0	0	0	0	-1	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.237	0.096	2
R209	0	0	0	0	-1	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.237	0.096	2
R301	0	0	0	-1	0	0	0	0	-1	0	0	0	0	1	0	1	1	1	1	0	-1	0.27	0.096	2
R303	0	0	0	0	-1	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.237	0.096	2
Long-term																								
R020	1	0	-1	-1	-1	-1	0	0	-1	0	0	0	0	1	0	1	1	1	1	0	-1	0.567	0.113	1
R304	0	0	0	-1	-1	0	0	0	-1	0	0	0	0	1	0	1	1	1	1	0	-1	0.306	0.096	2
R402	0	0	0	0	-1	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.237	0.096	2

Factor	Ecology									Noise				Socioeconomic								Results		
Project activity	terrestrial fauna	birds	aquatic fauna	terrestrial vegetation & flora	urban green areas	aquatic vegetation & flora	agriculture harvesting	vectors	Landscape	Physiologic effects	Communication	Labor performance	Social behavior	Lifestyle	Physiologic system	Community needs	Employment	Public sector income	Per-capita consumption	Public property	Private property	Total score of negative impacts	Total score of positive impacts	Assessment category
Road improvement projects																								
Short-term																								
BRT	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
Medium-term																								
R001	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R007	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R008	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R011	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R012	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R017	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R018	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R106	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R203	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R205	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R206	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
BRT	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
Long-term																								
R004	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R005	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R010	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R016	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R019	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R024	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R200	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R201	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R202	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R204	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R302	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R305	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R405	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R801	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R802	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R803	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R804	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R806	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
R807	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	-1	0.175	0.096	2
Projects on construction and improvement of intersections																								
Short-term																								
Flyovers	0	0	0	0	-1	0	0	0	-1	0	0	0	0	1	0	2	2	1	2	0	-1	0.068	0.145	3
Mid-term																								
Intersection(a)	0	0	0	0	-1	0	0	0	0	0	0	0	0	1	0	2	1	1	2	0	-1	0.044	0.13	3
Intersection(b)	0	0	0	0	-1	0	0	0	0	0	0	0	0	1	0	2	1	1	2	0	-1	0.044	0.13	3
Flyovers	0	0	0	0	-1	0	0	0	-1	0	0	0	0	1	0	2	2	1	2	0	-1	0.068	0.145	3
Long-term																								
Intersection(a)	0	0	0	0	-1	0	0	0	0	0	0	0	0	1	0	2	1	1	2	0	-1	0.044	0.13	3
Intersection(b)	0	0	0	0	-1	0	0	0	0	0	0	0	0	1	0	2	1	1	2	0	-1	0.044	0.13	3
Flyovers	0	0	0	0	-1	0	0	0	-1	0	0	0	0	1	0	2	2	1	2	0	-1	0.068	0.145	3

Source: JICA Study Team

Chapter 5 Traffic Surveys

5.1 Survey Components

5.1.1 List of Traffic Surveys

Traffic surveys were conducted to obtain various data, such as person trip movements and vehicle movement patterns. The survey results were used to understand the current traffic situation, to develop models, and to collect detailed data required for future transport planning. Table 5-1 shows the summary of the transport surveys which were conducted in this Study.

Table 5-1 Summary of the Transport Surveys

No	Survey Item	Volume	Method
1A	Household Interview Survey	7,500 households	Home interview (2 times visit to each household)
1B	Commuter Trip Survey	8,500 households	Home interview with simplified questionnaire
2	Cordon Line Survey	24 hours * 8 (6:00-18:00)	OD interview and traffic count at toll gates
3	Classified Vehicle Count Survey	24 hours * 8 locations 16 hours * 15 locations	Traffic count by vehicle type
4	Activity diary survey	900 households * 2person/ household	Detail activity data were collected from households which are selected from the Household Interview Survey.
5	Freight interview survey	Contacting 200 freight companies and get information from at least 50 companies	Interview survey to freight companies.
6	Truck movement survey	50 vehicles * 1 week	GPS tracking survey for trucks.
7	Opinion survey (SP survey)	2,000 samples	Additional interview for the stated preference for new transport modes.
8	Vehicle occupancy survey	16 hours (6:00-22:00) * 5 locations	Observation of number of passengers in car, bus, and taxi from roadside
9	Bus frequency survey	16 hours (6:00-22:00) * 10 locations	Observation of frequency of buses by route.
10	Travel speed survey	15 routes * 8-12 round trips * 2 cars	Probe vehicles equipped with the GPS logger travel along the survey routes and collect the location, time and speed.
11A	License plate recording survey	100m * 10 locations 12 hours every 15 minutes	Surveyors record number-plate of parking vehicles along the selected streets.
11B	On-street Parking Survey	Selected streets in the central area in the peak hour	The number of number vehicles by video recording.
11C	Off-street Parking Survey	Inside the 1st Ring Road	Surveyors visit parking places and record the number of cars.

Source: JICA Study Team

5.1.2 Outline of Surveys

(1) Household Interview Survey and Commuter Trip Survey

The objective of the Household Interview Survey (HIS) and Commuter Trip Survey (CS) is to obtain the detail information about travel behavior and socioeconomics of people living in the project area by conducting interview surveys to sampled households. The results of the survey are mainly used to develop the present Origin-Destination (OD) tables. This survey is the base of the transport demand model building.

(2) Cordon Line Survey (CLS)

The HIS and the CS collect trip information of the residents in the project area, while there are many non-resident trips within the project area. The objectives of the Cordon Line Survey (CLS) is to collect non-resident trip information regarding coming into and going out from the project area.

To collect the non-resident trip information, the vehicle counting survey and the interview survey was conducted at the toll gates nearby the boundaries of the project area. Those who were interviewed were passengers and drivers coming into and going out from the project area by private vehicles, buses, and freight vehicles.

(3) Classified Vehicle Counting Survey

The objective of this survey is to collect information of traffic flow such as traffic volume by vehicle type, peak and off-peak hours, hourly traffic fluctuation, etc. It is also used to verify the present OD tables which are estimated based on the results of the HIS, the CS, and the CLS.

(4) Activity diary survey

The Activity Survey is to obtain detail information on personal activities including not only trips but also activities at home and outside. The results of the survey are used to calibrate the trip generation rates estimated in the HIS.

(5) Freight interview survey

The objective of this survey is to collect information on the trip generation and attraction of trucks. The interview survey is conducted to freight companies to ask the number of trucks they have, the origin/destination and frequency of the trips. The results of the survey are used to estimate the trip generation rates of trucks.

(6) Truck movement survey

The objective of this survey is to collect origin and destination of trucks using GPS log data. The results of the survey are used to estimate truck ODs.

(7) Opinion survey (Stated Preference Survey)

The objective of this survey is to estimate the mode shares of new transport systems that do not currently exist. The Stated Preference (SP) for the new mode and the personal attributes of the respondents are obtained through the interview survey. The results of the survey are used to develop the mode choice model.

(8) Occupancy Survey

This survey is to collect the average occupancy data by vehicle type. The number of passengers in passenger vehicles and the loading level of micros, minibuses, and trufis is observed at roadsides. The results are used to convert the number of trips to the number of the vehicles in the transport demand forecast.

(9) Bus Frequency Survey

The objective of this survey is to grasp the service frequency of micros and minibuses. The number of micros and minibuses are counted by route number or route name at selected road sections.

(10) Travel Speed Survey

This survey is to collect actual travel time of the major radial and ring roads in the urban area. The travel time includes delay caused by traffic congestion. The results of the survey are used to understand the congestion level of each section of the arterial roads and to validate the results of the traffic demand forecast model. The data are collected by probe vehicles which are equipped with GPS logger. Probe vehicles travel along the survey routes collecting the location and time, which is used to calculate the average speed in morning, afternoon and evening.

(11) Parking Survey

The objective of this survey is to collect information about the demand and capacity of parking spaces inside 1st Ring Road. This survey consists of

1) On-street parking survey to get the number of vehicle parking on street

2) License plate survey on the selected streets to get the average parking duration

3) Off-street parking survey in the central area to get the capacity and demand of the parking outside of streets.

5.2 Household Interview Survey (HIS) / Commuter Trip Survey (CS)

5.2.1 Survey Coverage and Target Sample Size

The HIS and CS are conducted in the entire administrative area of Santa Cruz Metropolitan Area. The sample ratio of the HIS is set at approximately 1.8% of the population of the urban area of the Santa Cruz Metropolitan Area. The sampling ratio of the CS is set at approximately 2% of the population of the entire Santa Cruz Metropolitan Area.

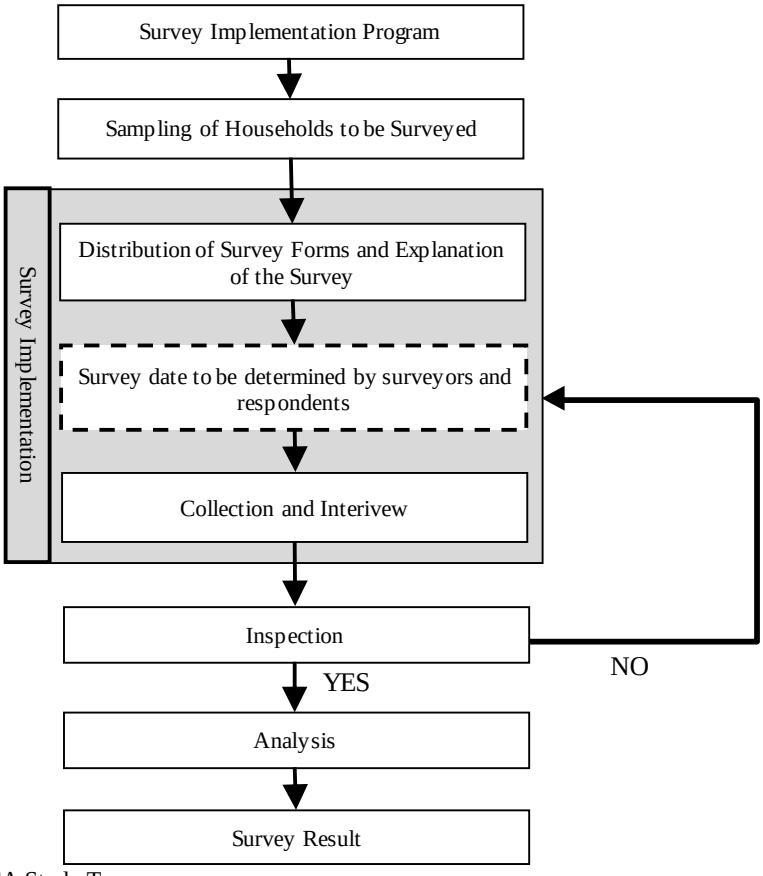
Table 5-2 Samples Size of the HIS and CS

Municipality	No. of HIS Samples (household)	No. of CS Samples (household)		
	Total	Urban	Rural	Total
Santa Cruz de la Sierra	6,500	7,056	59	7,115
Cotoca	110	107	94	201
Porongo	30	19	52	71
La Guardia	360	370	48	418
El Torno	140	154	86	240
Warnes	360	382	74	455
Total	7,500	8,087	413	8,500

Source: JICA Study Team

5.2.2 Flow of Survey

The flow of the survey is as shown in Figure 5-1.



Source: JICA Study Team

Figure 5-1 Flow of HIS and CS

(1) Interview Item/ Survey Form Design + Trip

The interview item consists of the following three forms.

- Form-1: Household information (One form for each household)
- Form-2: Household members' information
- Form-3: All the trip information of the members in one day

Form-3 trip information is collected only in the HIS, not in the CS. The target of the Form-2 and Form-3 is all the members aged 5 years old and above in the selected households.

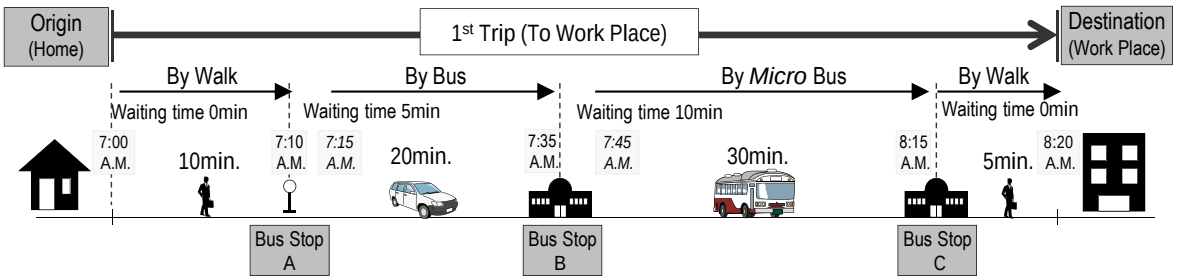
Table 5-3 Interview Items

Item	Detail
Form-1 Household information	- Address - Vehicle ownership - Number of household members - Household member list (name, gender, age) - Household income level - Opinion on road network - Opinion on public transport service
Form-2 Household members' information	- Relation with household head - Gender, age - Social status - Ownership of vehicle license - Educational attainment - Ordinary commuting trip information In case of employee - Industrial sector, occupation - Personal income level - Address and the type of working place In case of students/pupils - Location of school - Type of school (Public/private) - Grade of school
Form-3 All the trip information of the members in one day	- Location of Origin and Destination - Type of Origin and Destination place (Home/workplace/school place/others) - Transfer point - Trip purpose - Mode of transport - Travel fare - Departure and arrival time - Reason for the choice of the mode

Source: JICA Study Team

5.2.3 Concept of a Trip

This survey investigates the movement of a person, i.e., person trip. A trip is defined as "the movement of a person from an origin to a destination with a purpose". Figure 5-2 illustrates the concept of a trip.



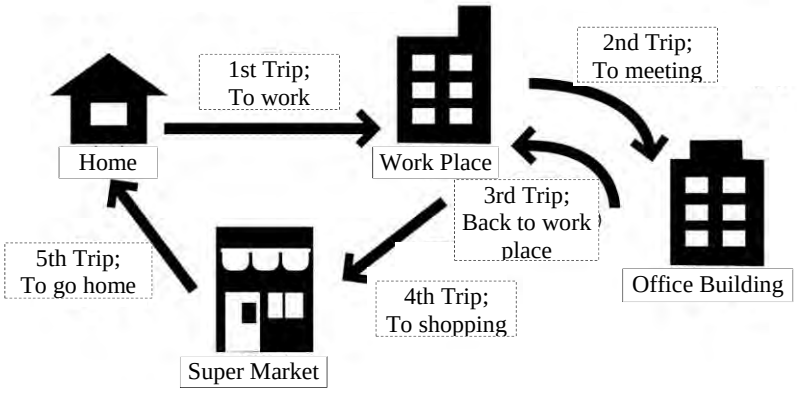
Source: JICA Study Team

Figure 5-2 Concept of a Trip

The following is an example of how to count the number of trips made within one day by a particular individual.

<Example of a one-day movement of Mr. A>

- 1st Trip; In the morning, Mr. A went to his office (his workplace) from his home.
- 2nd Trip; In the afternoon, he visited a company for a business meeting at the other office building.
- 3rd Trip; After the meeting, he went back to his office (his workplace).
- 4th Trip; In the early evening, he left his workplace for shopping at a supermarket.
- 5th Trip; After the shopping, he went home.



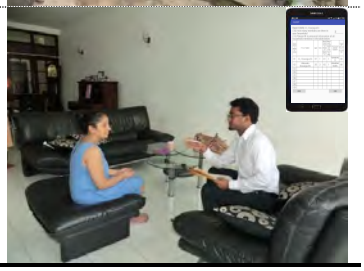
Source: JICA Study Team

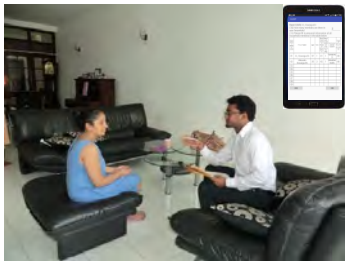
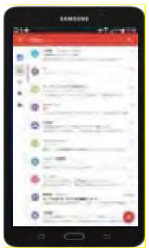
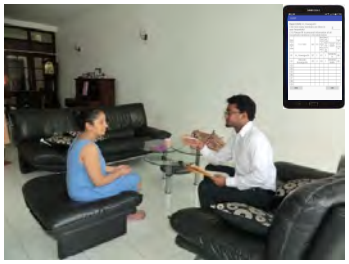
Figure 5-3 Example of Counting Trip

5.2.4 Methodology of the Field Survey

Table 5-4 shows the flow of the field survey. In this survey, two tablet applications are developed and utilized to improve the efficiency of the survey.

Table 5-4 Flow of the Field Survey

No.	Item	Task	Date / Place	
1. Preparation				
1	Training for surveyors	• Surveyors are instructed about contents, method, and requirements of the survey. • Full understanding of how to fill is required to surveyors.		
2	Reception of survey materials and sample list	• Receiving the required survey materials. • Surveyors receive sample list to be surveyed. • Preparing the schedule to visit the target households.	After the training	
2. Distribution Visit				
3	Visiting and confirming address	• Visiting the target households according to the address, coordinates, and contact person • Confirming address and coordinates of the predio		
4	Preparation before contact	• Inputting sample ID and name of contact person • Taking photo of the house	Before contacting the person in the house	
5	Greeting, cooperation request, and explanation	• Greeting and requesting cooperation for the survey. • Explaining what a trip means • Explaining the procedure of the survey	According to surveyor's schedule	
6	Initial interview	• Interview on the household information (Form-1) • Interview on the personal attribute information if respondents can answer (Form-2)	According to surveyor's schedule	

7	Distribution of trip memo	• Explaining how to fill the trip memo • Distributing sufficient sheets of the trip memo • Confirming the survey date and making appointment for the collection date • Leaving revisit card • Greeting appreciation for cooperation	According to surveyor's schedule	
3.Survey Data (Tuesday, Wednesday or Thursday)				
8	Filling trip memo by respondents	• Answering question if there is inquiry from the respondent	According to respondent's schedule	
4. Collection Visit				
9	Visiting and Preparation before Contact	• Revisiting the target households • Taking photo of the house	After the Survey Date According to surveyor's schedule	
10	Interview on remaining questions and trip information	• Greeting • Interview on the remaining questions on household information (Form-1) • Interview on the remaining questions on personal attribute information (Form-2) • Interview on the trip information according to the trip memo (Form-3) • Thanking respondents for the cooperation	After the Survey Date According to surveyor's schedule	
4. Verification				
11	Examination at Home	• Checking the interviewed results after Coming Home	According to surveyor's schedule	
12	Inspection Request	• Requesting inspection to the supervisor	According to surveyor's schedule	
13	Receiving Inspection Report	• Receiving inspection results by email • Understanding the results of inspection • Consulting the supervisor if necessary	After inspection by supervisor, editor	
14	Revision of Errors	• Revision of interview results by phone call or revisit according to the instruction of the supervisor [In case of Revisit] • Making appointment by phone • Revisiting the target household • Taking photo of the house • Revising of results by interview • Taking photo of household member	According to surveyor's schedule	

Source: JICA Study Team

5.2.5 Number of Samples Collected

The field survey started on June 10, 2016, and finished on March 31st, 2017. There were two breaks due to the winter and summer holiday seasons. The total number of collected samples is almost as same as the target of the original sample size as shown in Table 5-5.

Table 5-5 Progress of the Household Interview Survey

Unit: Households

Municipality	Original Sample Size			Actual Number of Samples		
	HIS	CS	Total	HIS	CS	Total
Santa Cruz de la Sierra	6,507	7,114	13,621	6,501	7,120	13,621
Warnes	365	456	821	358	457	815
Cotoca	110	201	311	110	198	308
La Guardia	357	418	775	360	418	778
El Torno	143	240	383	141	236	377
Porongo	18	71	89	30	71	101
	7,500	8,500	16,000	7,500	8,500	16,000

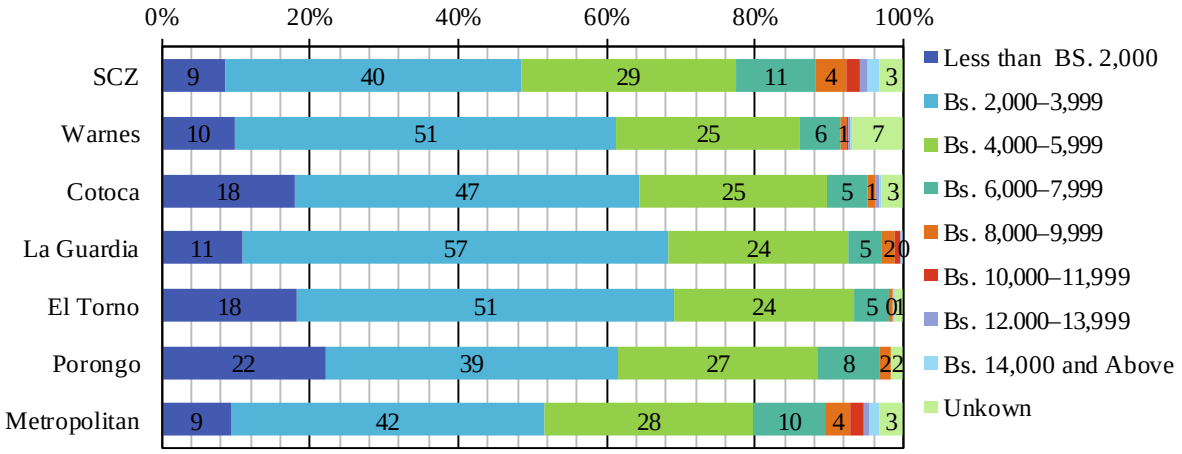
Source: JICA Study Team

5.2.6 Survey Results

(1) Household Characteristics

1) Household Income Distribution

In the Metropolitan Area, the share of households with monthly household income of Bs. 2,000 - 5,999 reaches 70% while fluctuation by municipality is observed. Sana Cruz de la Sierra has the largest share of high-income households such as over Bs. 6,000 per month.

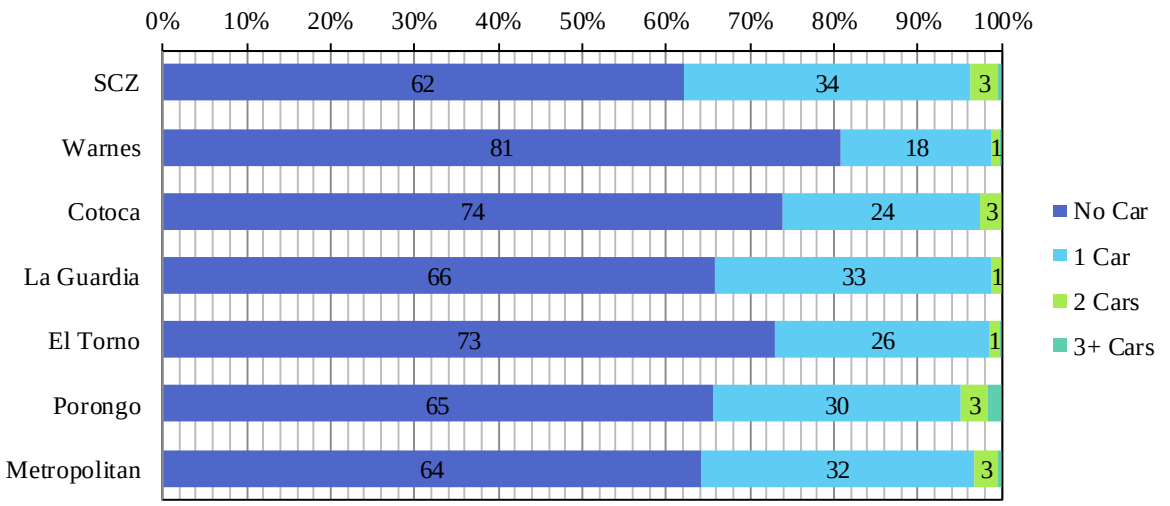


Note: "SCZ" stands for "Santa Cruz de la Sierra".
Source: JICA Study Team

Figure 5-4 Monthly household income by municipalities

2) Household Car Ownership

Generally, in the metropolitan area, approximately a half of households own a car. While most of them own only one car, there are roughly 10% of households own 2 or more cars in Porongo. Car ownership is higher in Santa Cruz de la Sierra and Porongo.

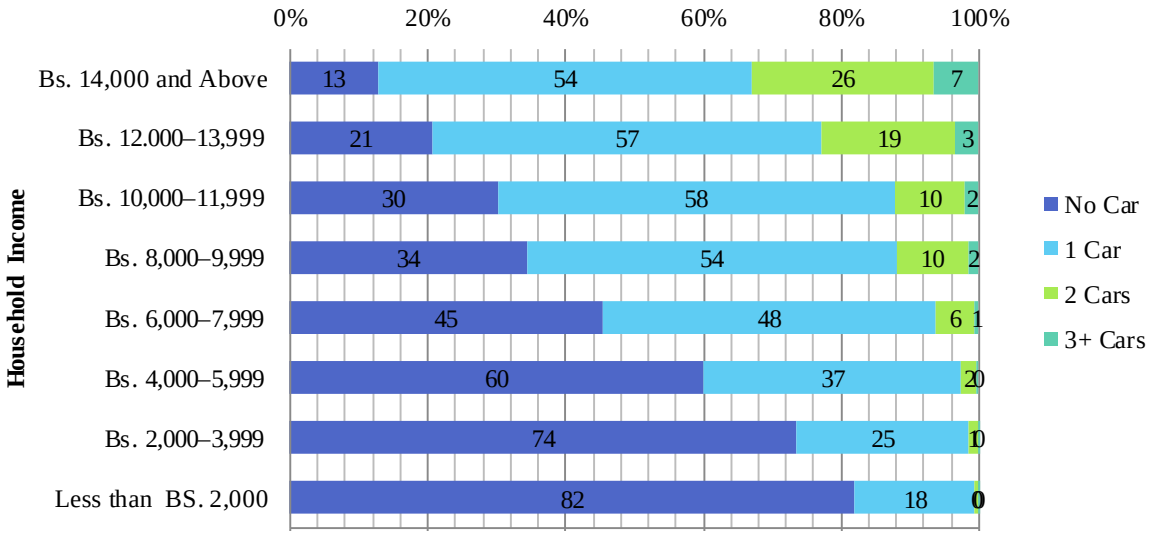


Note: "Car" includes the passenger car, jeep, sports utility vehicle (SUV), van, pickup, and truck; however, it does not include the motorcycle and trito.
Source: JICA Study Team

Figure 5-5 Household car ownership by municipality

3) Household Vehicle Ownership and Household Income Distribution

The graph on monthly household income and car ownership presented explicit relation between them. The higher a household earn income, the more they own a car. Especially for households with monthly household income over Bs. 12,000, more than one-third of them own 2 or more cars.



Note: "Car" includes the passenger car, jeep, sports utility vehicle (SUV), van, pickup, and truck; however, it does not include motorcycle and trito.
Source: JICA Study Team

Figure 5-6 Monthly household income and household car ownership

(2) Trip Rate and Trip Purpose

1) Trip Rate

Overall trip rate or the number of trips per day per person of the metropolitan area is 1.74. It is estimated that 3.5 million trips are made in a day in the metropolitan area. Regarding the

trip purpose, "to home (other than lunch)" purpose followed by "to work" and "to school" trips are dominant trip purposes.

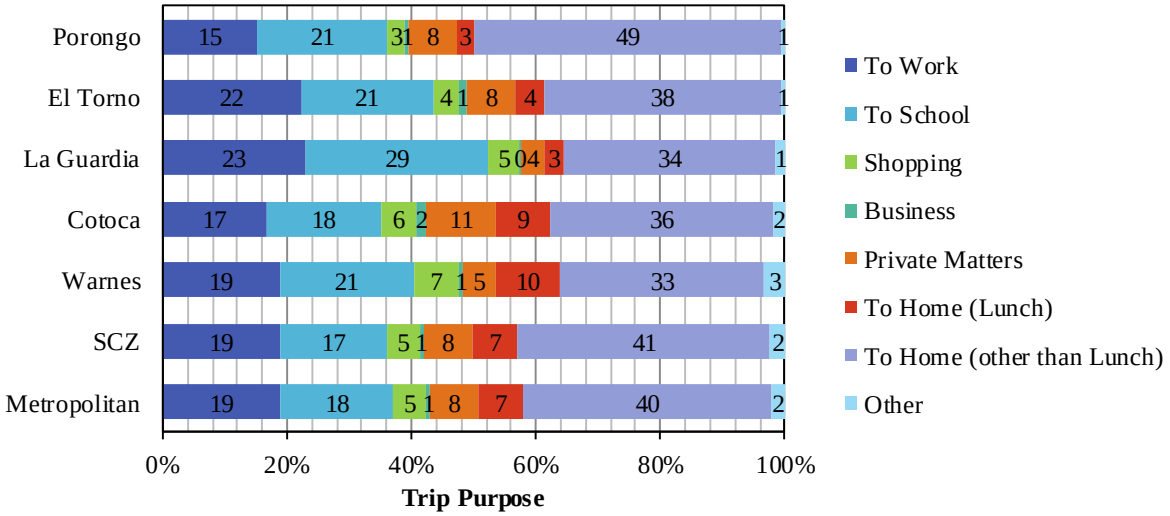
Table 5-6 Trip Rate by Trip Purpose of the Metropolitan Area

Trip Purpose	Trip ('000)	Population ('000)	Trip Rate
To Work	666	2,039	0.33
To School	625		0.31
Shopping	193		0.09
Business	49		0.02
Private Matters	303		0.15
To Home (Lunch)	265		0.13
To Home (other than Lunch)	1,370		0.67
Other	71		0.03
Total	3,541	2,039	1.74

Source: JICA Study Team

2) Composition of Trip Purpose

The composition of trip purpose is similar among six municipalities in the metropolitan area though minor fluctuation is observed.

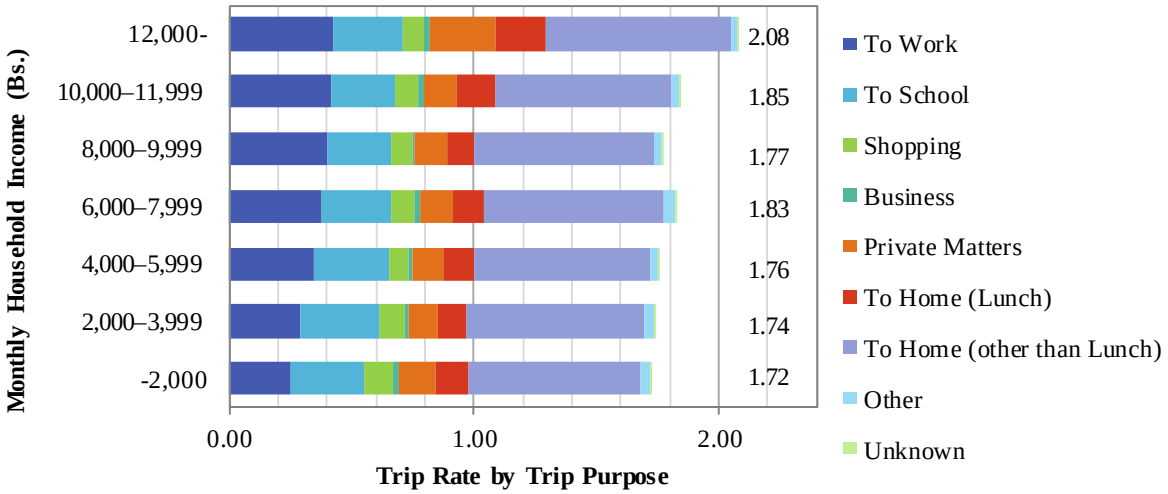


Note: Municipalities are identified by departure location.
Source: JICA Study Team

Figure 5-7 Composition of trip purpose by municipality

3) Trip Purpose and Trip Rate by Income

There is a positive linear trend between the household income and the trip rate. This implies that mobility of lower income group might be restricted by fare of public transport and less ownership of cars. It is assumed that other factors such as jobless people in the lower income group also affect it. The Exception to the linear trend of the highest income (14,000 Bolivianos and above) group might be affected by smaller sample size.

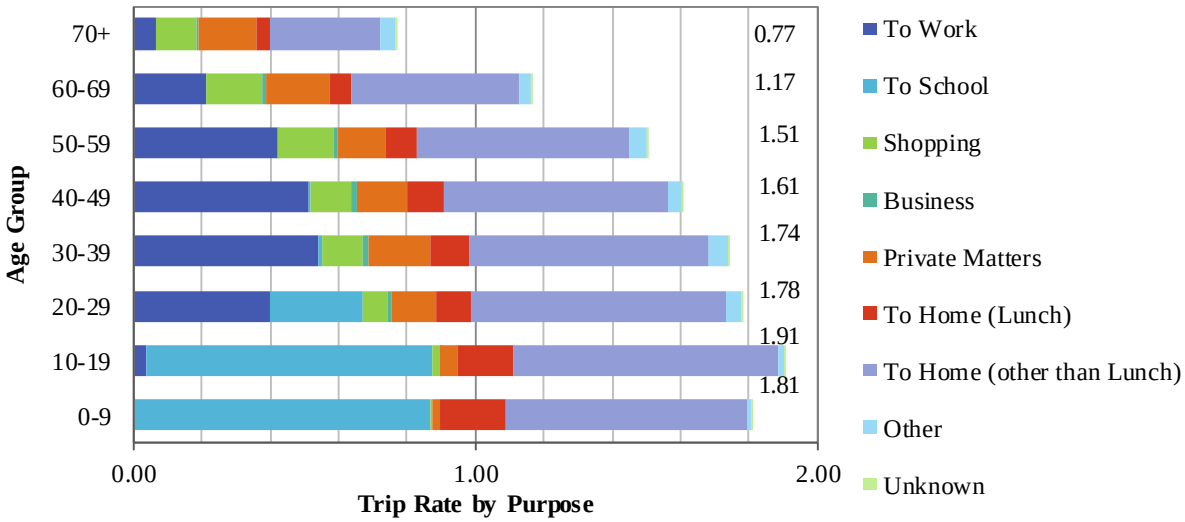


Source: JICA Study Team

Figure 5-8 Trip rate by monthly household income

4) Trip Purpose and Trip Rate by Age Group

The dominant trip purpose except for "to home" purpose is "to school" purpose for respondents under 20 years old. The share and trip rate of "to work" purpose increases after 20 years old. The trip rate as well as "to work" purpose trip gradually decreases after 40 years old.

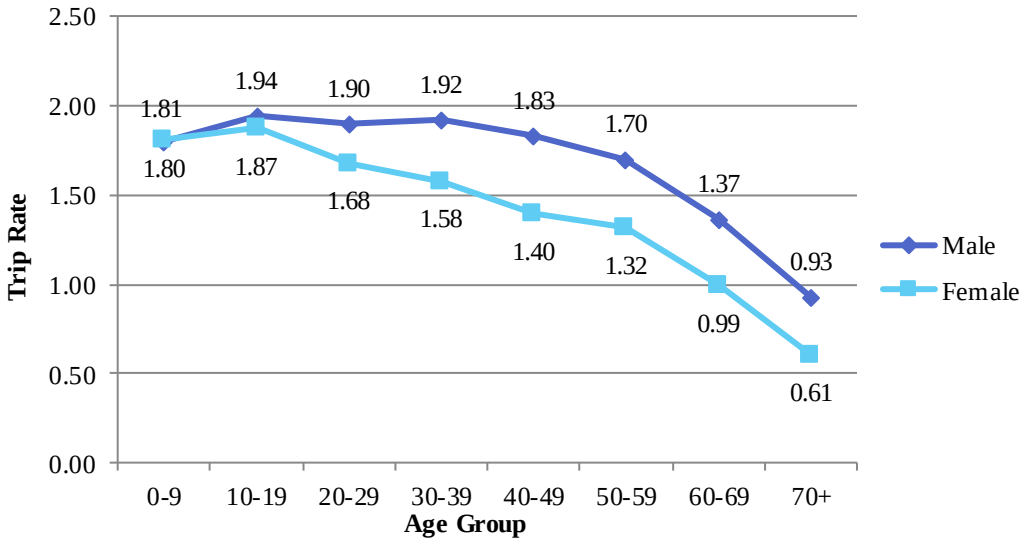


Source: JICA Study Team

Figure 5-9 Trip rate by purpose by age group

5) Trip Rate by Age Group and Sex

While trip rates of male and female of younger age group from 0-19 years old are almost similar level, the gap between male and female is evident especially after 30 years old. The trip rate of male is roughly 0.5 trips higher than female for the age group of 30 years old or older.

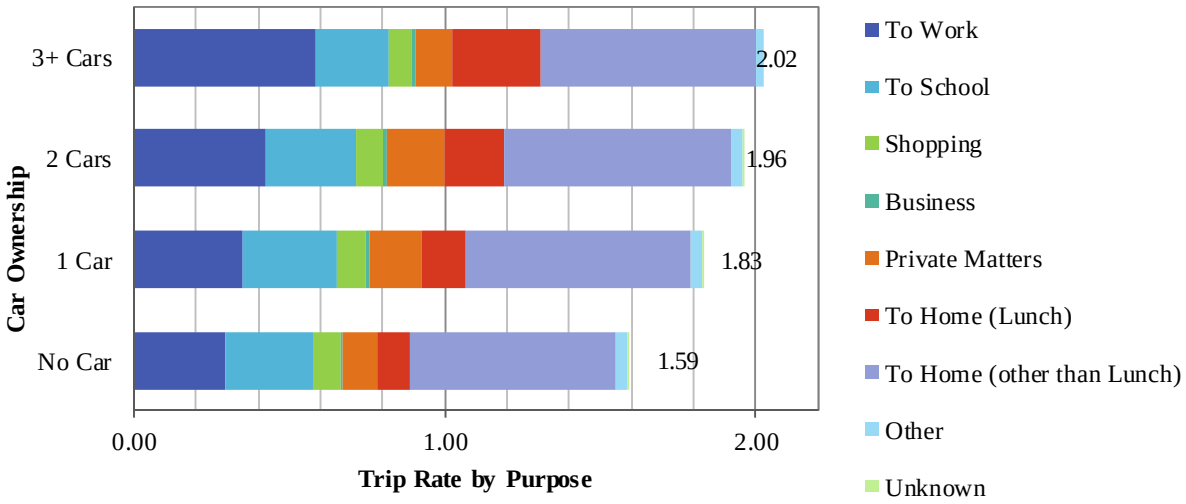


Source: JICA Study Team

Figure 5-10 Trip rate by age group and by sex

6) Trip Rate by Car Ownership

Car ownership is one of the key variables affecting the number of trips. The figure below shows the increase of trip rate as the number of cars in a household increase. While trip rates of "to school", shopping, and business purposes are almost the same range among all groups, "to work", private matters and "to home" purposes increase as the number of cars in a household increase.



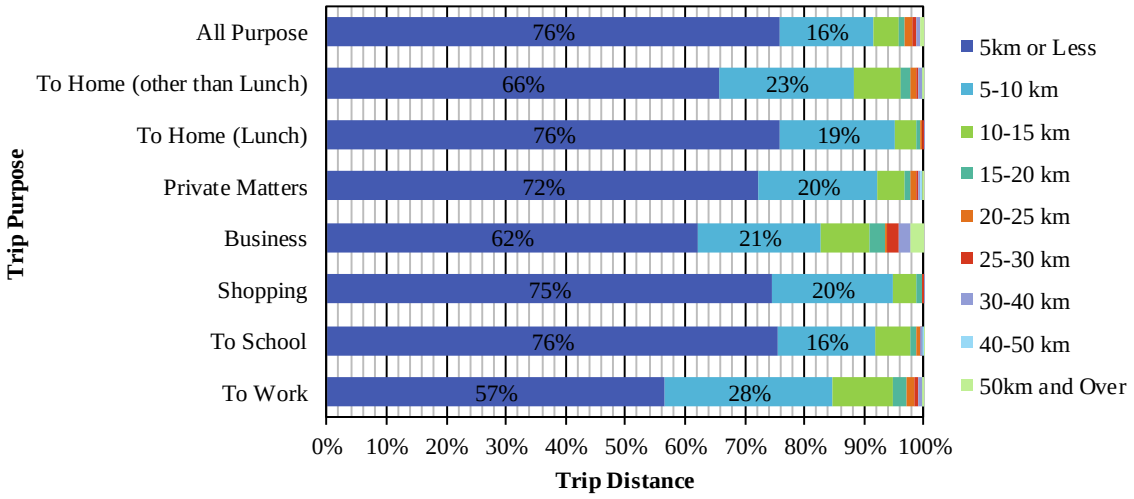
Source: JICA Study Team

Figure 5-11 Trip rate and car ownership

(3) Trip Distance and Time

1) Trip Purpose and Distance

Trip distance varies depending on the trip purpose. For business purpose, approximately half of the trip is more than 5km. The trip distance of commuting trips to the workplaces also longer than other trip purposes following the business trip.

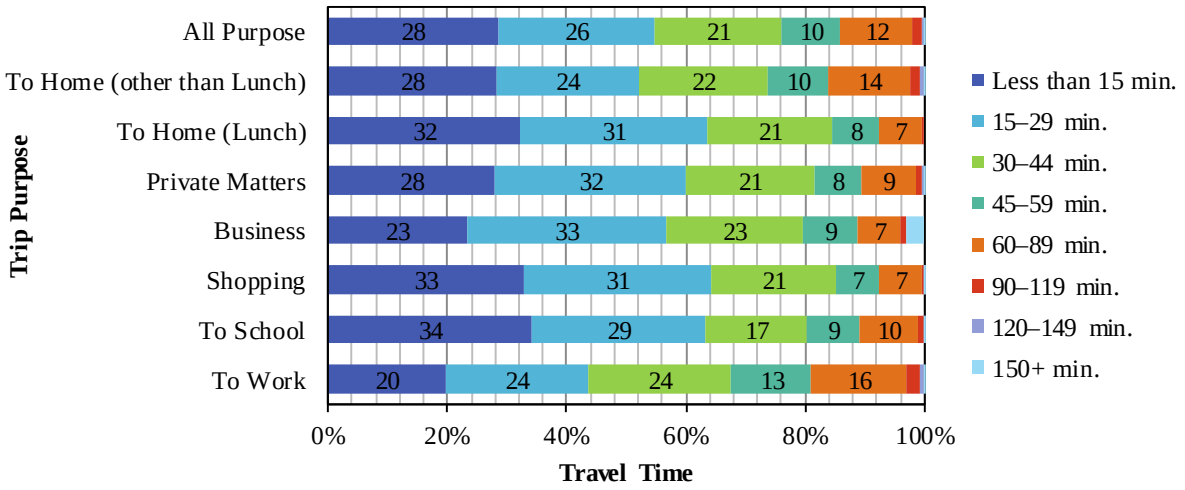


Source: JICA Study Team

Figure 5-12 Trip distance and trip purpose

2) Travel Time by Purpose

Apart from trip distance, the travel time of "to work" purpose is the highest among all purposes followed by business purpose. The majority of "to work" purpose trip is made during morning peak periods while business trips can be made throughout the daytime.



Source: JICA Study Team

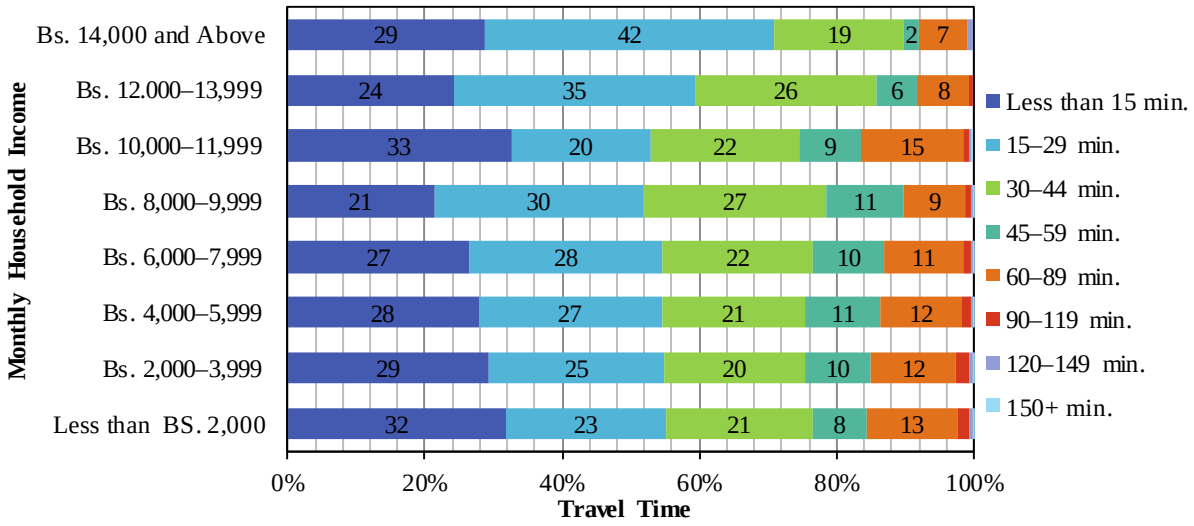
Figure 5-13 Travel time and trip purpose

3) Travel Time by Household Income Group

It is noteworthy that the share of long-duration (60 minutes or longer) trips decreases as the household income increases. On the other hand, the share of short-duration (less than 30 minutes) trips is lowest for medium income group of 8,000 to 9,999 Bolivianos per month per household.

The increase of long-duration trip might be due to dependence on public transport which usually takes longer time compared with private modes of transport. The increase of short-duration trip of the high-income group can be explained by their residential location as they can afford to reside in the area closer to the city center. The increase of short-duration trip of

the low-income group can be explained by their dependence on non-motorized transport.



Source: JICA Study Team

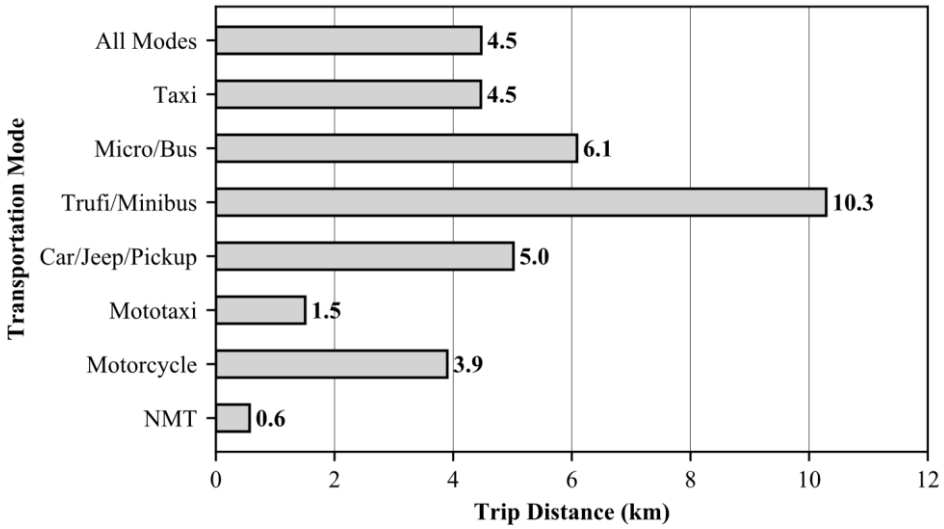
Figure 5-14 Monthly household income and travel time

4) Trip Distance and Time by Mode

Trip distance and travel time by transportation mode are shown in the figures below respectively. Average trip distance by trufi and minibus are the highest among all transportation modes. This might be due to a lot of medium distance routes from 5 suburban municipalities to Santa Cruz de la Sierra.

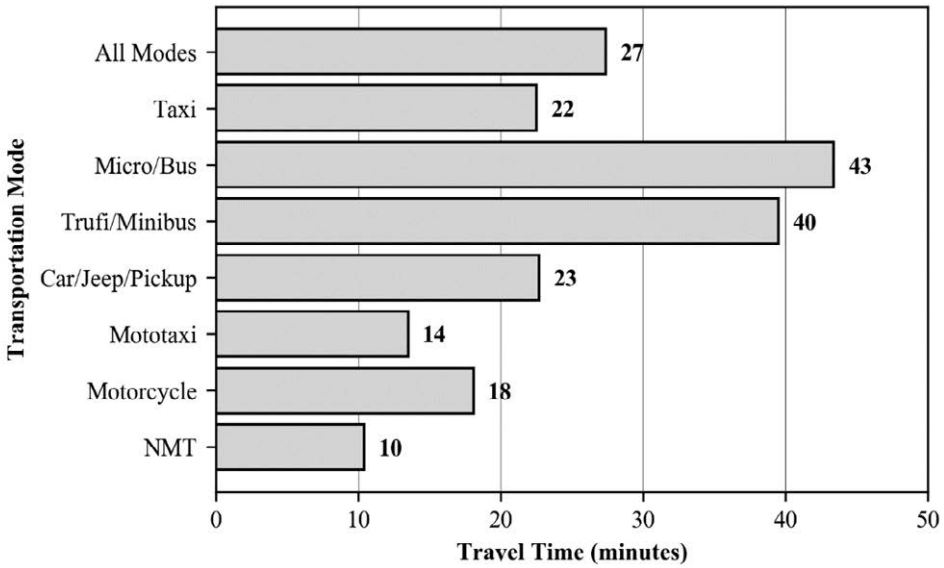
In contrast, the travel time of microbuses and large buses are the highest among all transportation modes.

Two-wheel vehicles such as motorcycle and mototaxi serve for short distance and short time trip compared with four or more wheeled vehicles.



Source: JICA Study Team

Figure 5-15 Average trip distance by travel mode

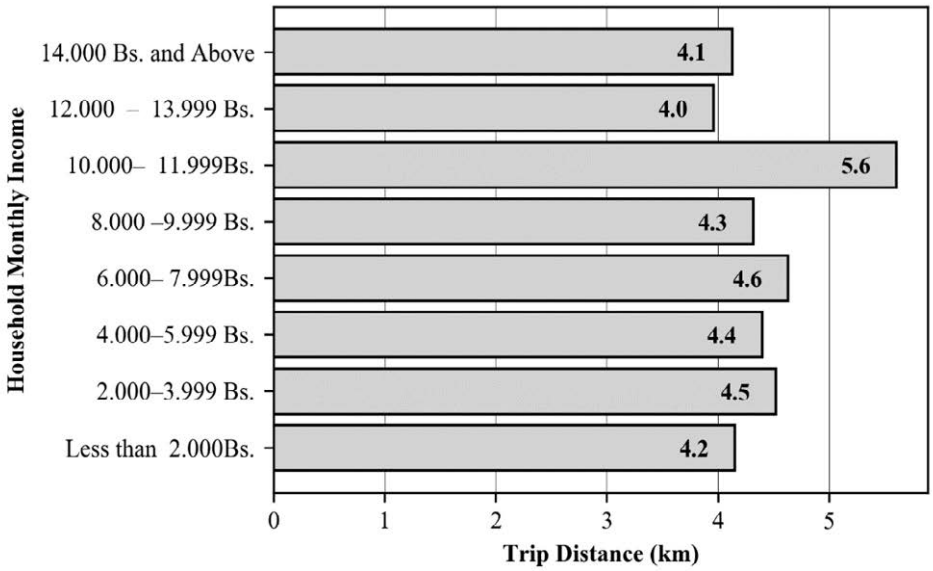


Source: JICA Study Team

Figure 5-16 Average travel time by transportation mode

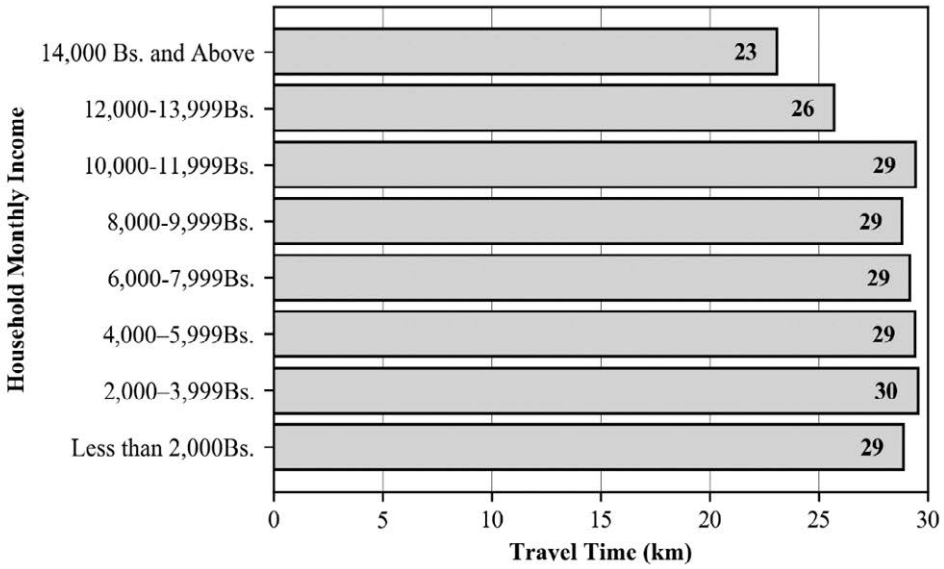
5) Trip Distance and Time by Household Income Group

According to the following two graphs on trip distance and travel time by household income, both time and cost increase as household income decrease. It is assumed that this might be caused by their residential location. However, travel time and cost of household income below 8,000 Bolivianos are in the same range.



Source: JICA Study Team

Figure 5-17 Average trip distance by monthly household income

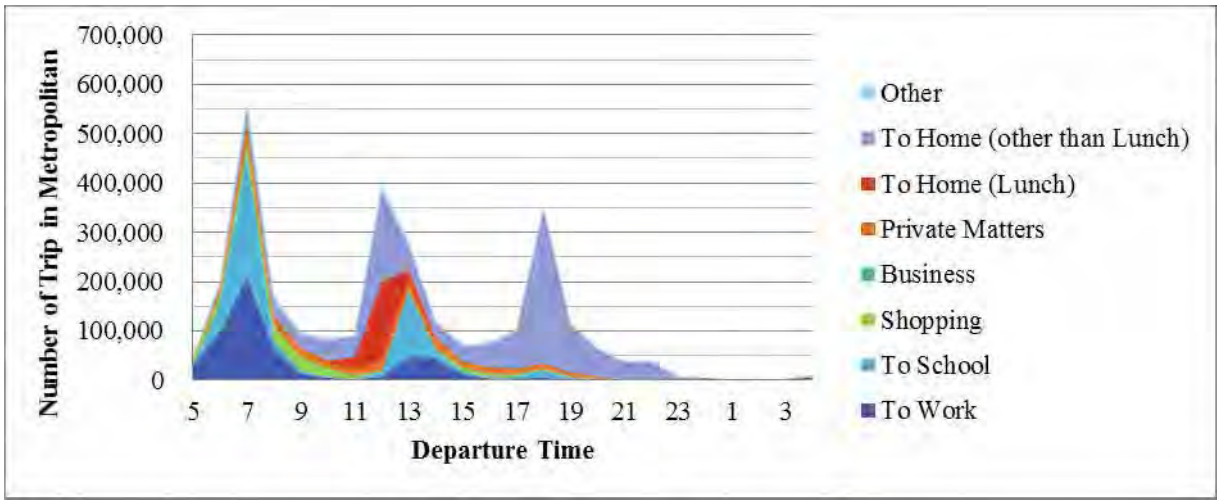


Source: JICA Study Team

Figure 5-18 Average travel time by monthly household income

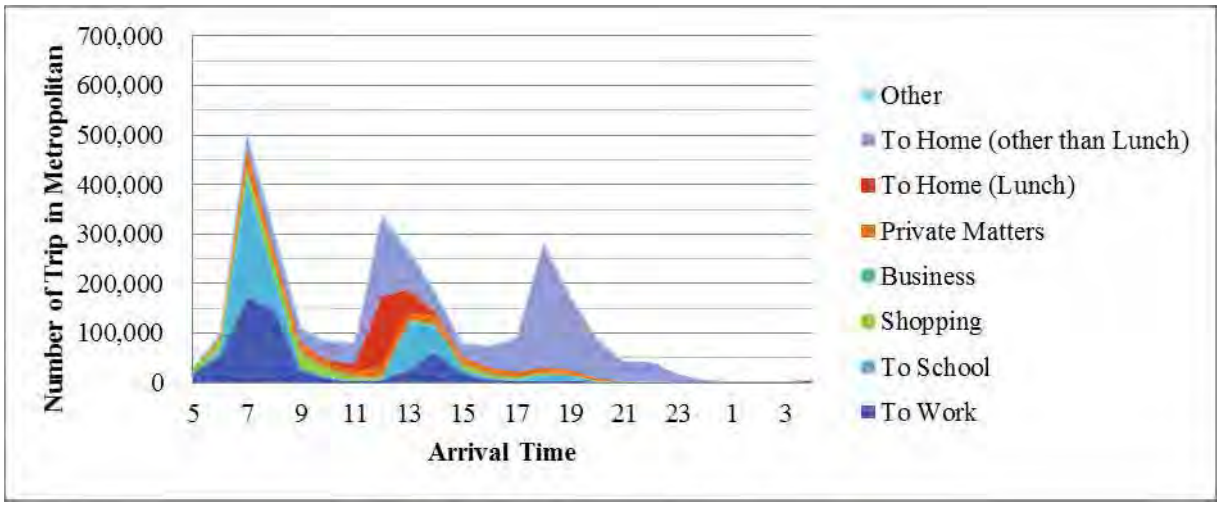
6) Departure and Arrival Time

There are three peaks of departure time and arrival time at 7:00, noon and 18:00 respectively. The morning peak between 7:00 and 8:00 is the highest because of many commuter trips to workplaces and schools depart and arrive during this period. Apart from other countries without a long lunch break, lunchtime peak between noon and 13:00 is the second highest. Evening peak is somewhat dispersed compared with morning and lunchtime peak.



Source: JICA Study Team

Figure 5-19 Departure time by trip purpose



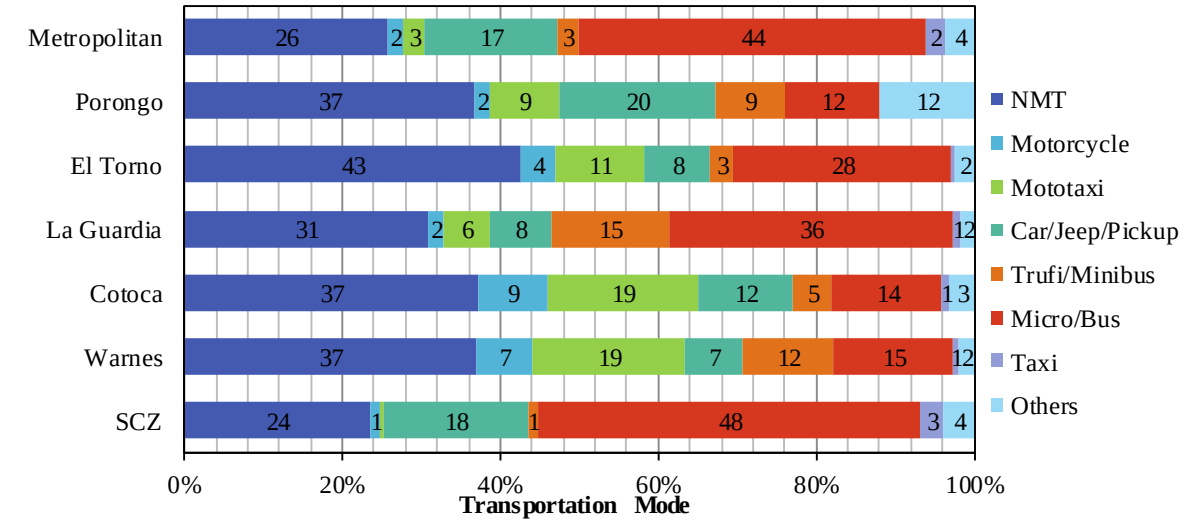
Source: JICA Study Team

Figure 5-20 Arrival time by trip purpose

(4) Transportation Mode and Mode-Related Characteristics

1) Transportation Mode by Municipality

The modal share by municipalities is shown in the figure below. In the entire metropolitan area, microbuses and buses are the dominant motorized mode of transport with 42 percent share followed by non-motorized transport (NMT) of 25 percent and a car, a jeep and a pickup of 21 percent. While the share of other transportation modes such as the motorcycle, mototaxi, trufi, minibus, and taxi is less than 4%. The mototaxi, trufi and minibus are playing the key role in the suburban municipalities. It is also noteworthy that modal share of non-motorized transport is higher in suburban municipalities.

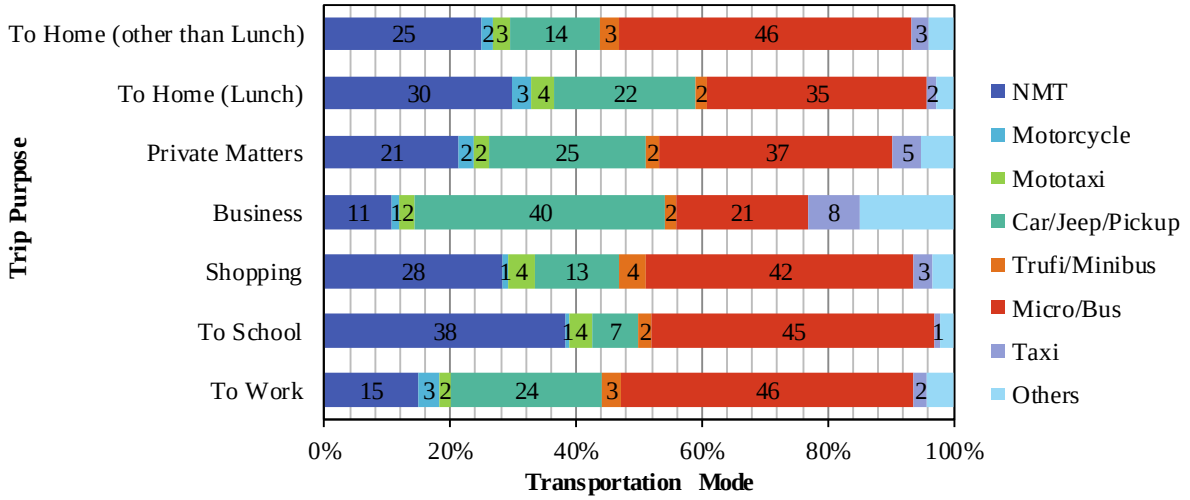


Note: Municipalities are identified by departure location. NMT stands for non-motorized transport. SCZ stands for Santa Cruz de la Sierra.
Source: JICA Study Team

Figure 5-21 Transportation modal share by municipality

2) Transportation Mode by Purpose

Purpose-wise transportation modal share is shown in the following figure. A higher share of a car, a jeep and a pickup is observed for business, private matters and to work trips. For to school and shopping trips, non-motorized transport has a higher share.

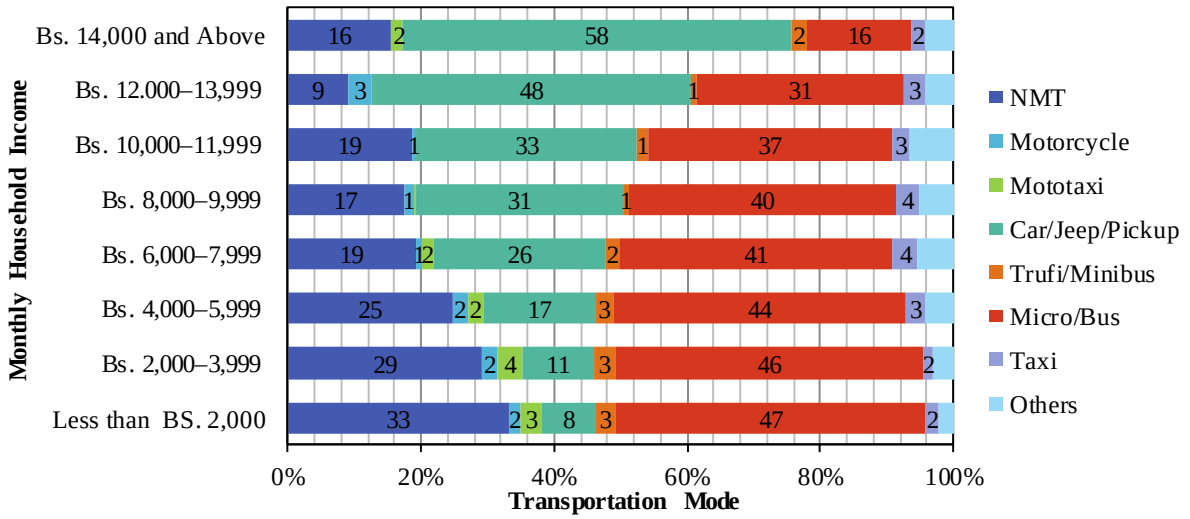


Note: NMT stands for non-motorized transport.
Source: JICA Study Team

Figure 5-22 Transportation modal share by trip purpose

3) Transportation Mode by Household Income Group

The high-income groups depend mainly on private cars while low-income groups use public transport and non-motorized transport.

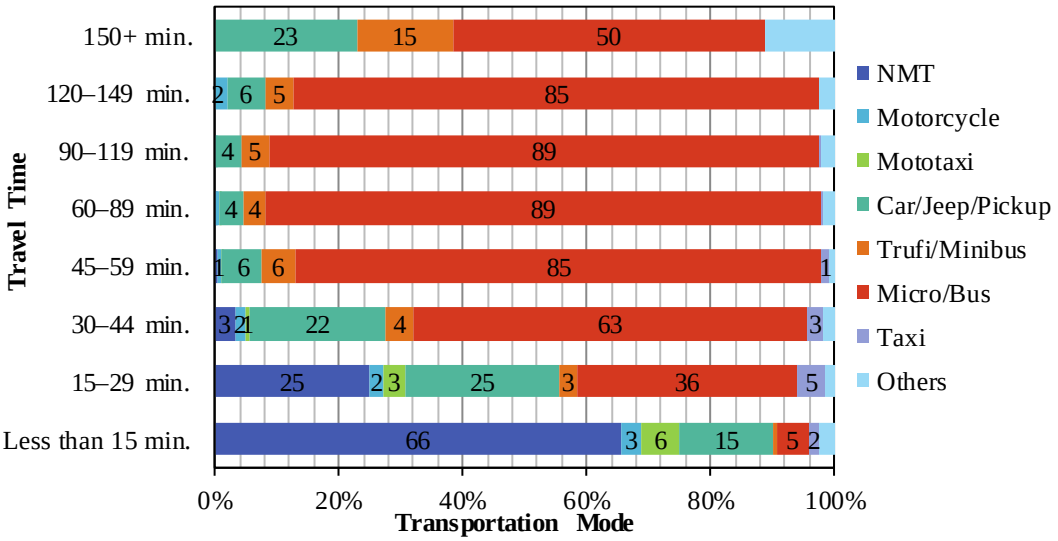


Note: NMT stands for non-motorized transport.
Source: JICA Study Team

Figure 5-23 Transportation modal share by monthly household income

4) Transportation Mode by Travel Time

For trips of long travel time, microbuses and buses are the dominant modes of transportation except for the trips over 150 minutes. In contrast, roughly 70% of trips are made by non-motorized transport (NMT) for trips less than 15 minutes.

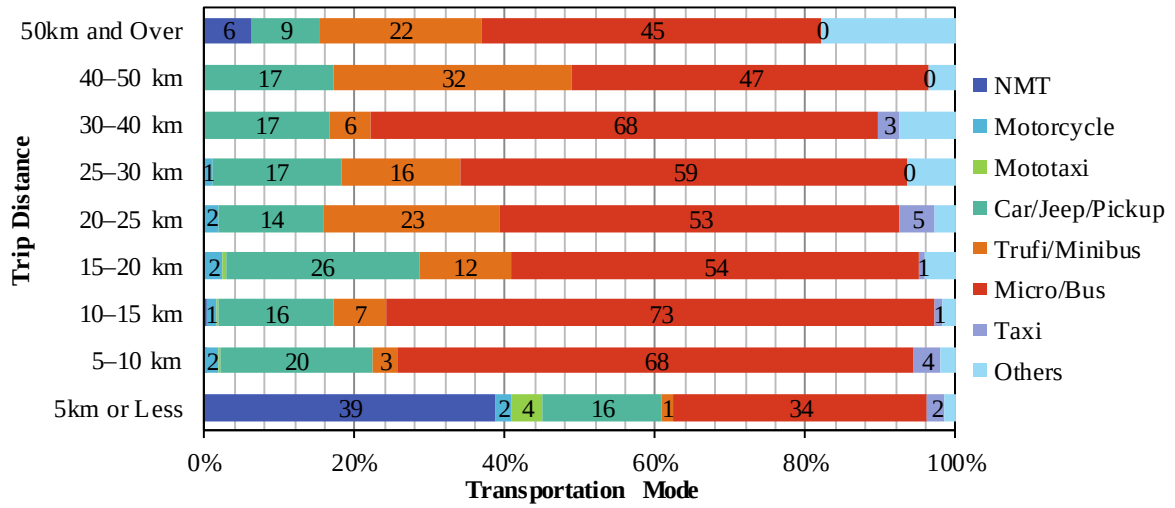


Note: NMT stands for non-motorized transport.
Source: JICA Study Team

Figure 5-24 Transportation modal share by travel time

5) Transportation Mode by Trip Distance

Similar to the modal share by travel time, microbuses and other buses are the major modes of transportation for long-distance trips followed by the private car (Car/Jeep/Pickup), trufi and minibus.

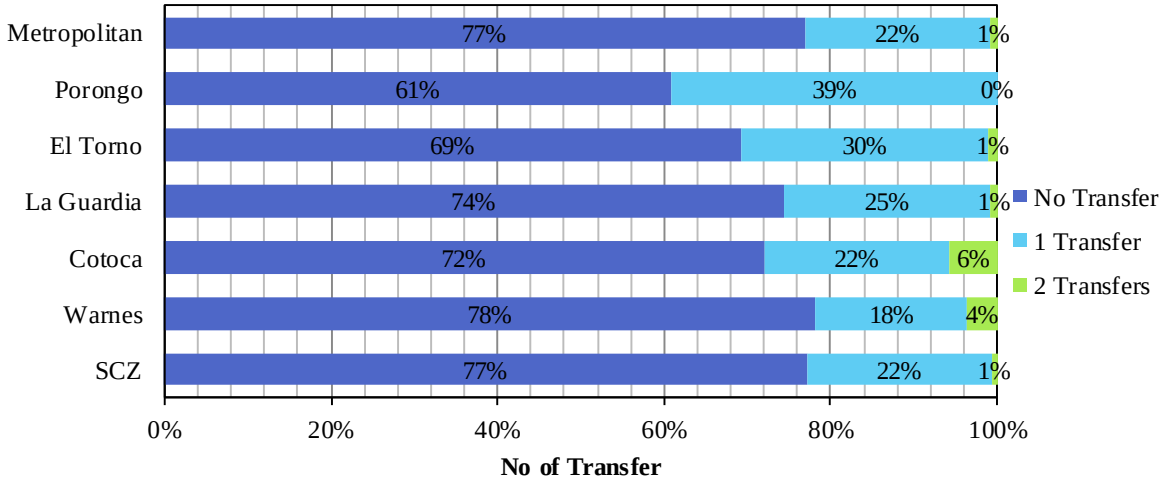


Note: NMT stands for non-motorized transport.
Source: JICA Study Team

Figure 5-25 Transportation modal share by trip distance

6) Number of Transfer of Public Transportation Passengers

In the metropolitan area, a quarter of trips made by public transportation mode requires one or more transfers. In suburban municipalities, the number of transfer is higher compared to Santa Cruz de la Sierra. This might be affected by bus route density. For instance, roughly a half of trips from Cotoca need transfer at least once.

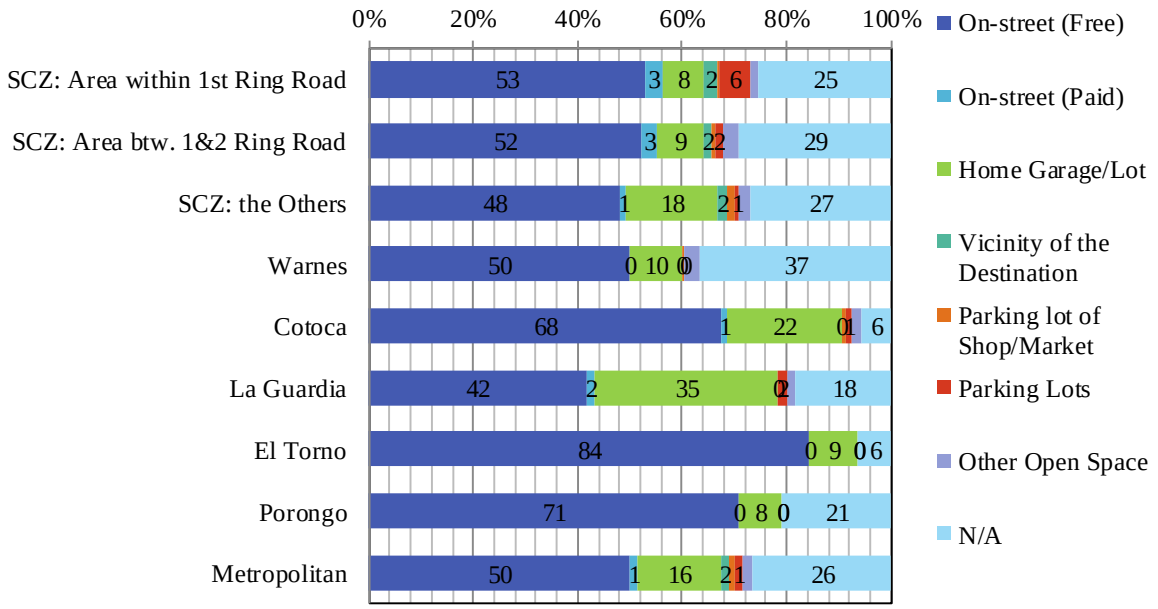


Note: Municipalities are identified by departure location.
Source: JICA Study Team

Figure 5-26 Number of Transfer of Trips by Public Transportation

7) Parking Location

For the entire metropolitan area, roughly half of private mode user park their car on the street free of charge although the parking locations of roughly 30% of respondents are unknown. Paid parking including on-street parking and parking lots are less than 10% even in the area surrounded by the 1st ring road.



Source: JICA Study Team

Figure 5-27 Parking location of private mode users

(5) Trip Distribution

1) Composition of Trip Distribution by Municipality – All Trips

The figure below shows the compositions of the trip distribution of all trip purposes by the municipality. While most trips are made within each municipality, more than a quarter of trips of La Guardia and Porongo is between the municipality and Santa Cruz de la Sierra. In case of Santa Cruz de la Sierra, more than 95% of trips are made within the municipality.

2) Composition of Trip Distribution by Municipality – To Workplace

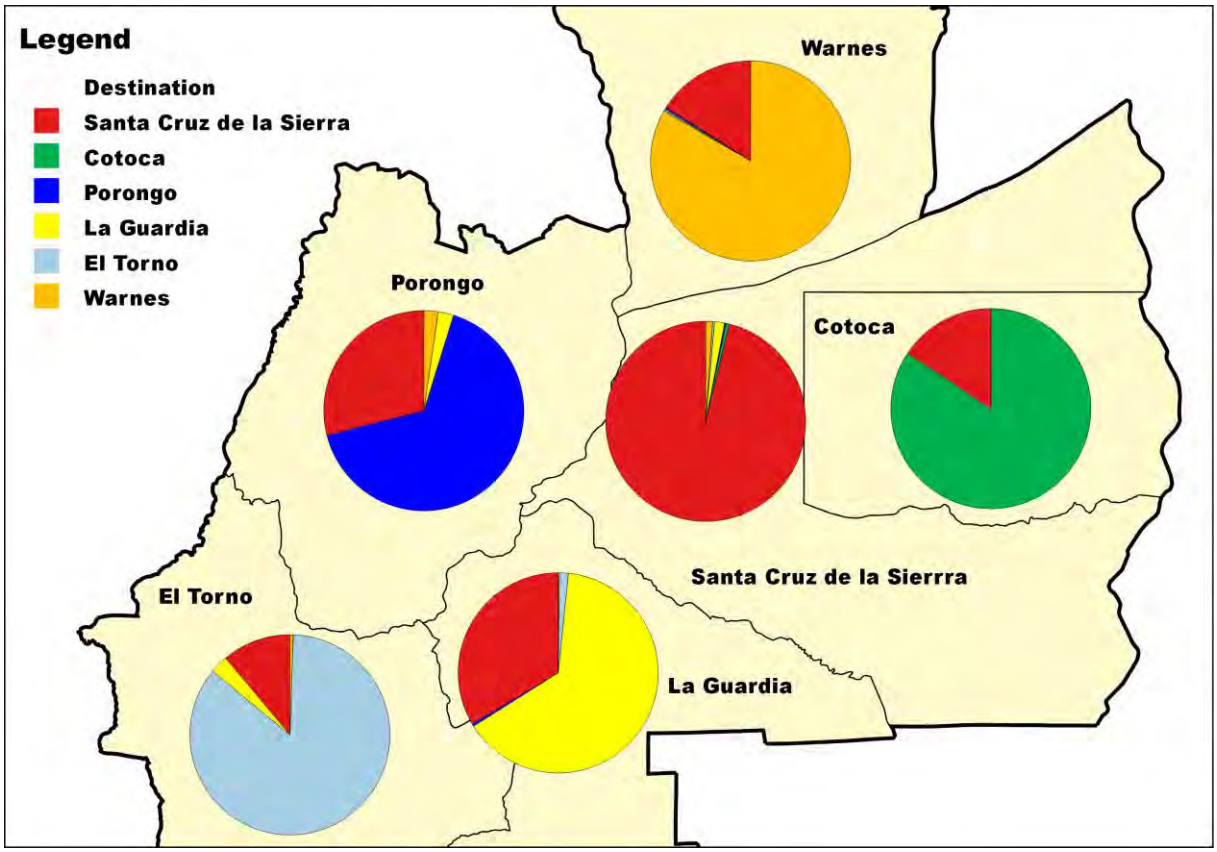
The composition of the trip distribution of the commuting trip to the workplace is similar to that of all purposes. The share of "to workplace" trips within each municipality is lower than that of all purposes. Roughly 40% of workers in La Guardia commute to Santa Cruz de la Sierra, and, a third of workers in Warnes commute to Santa Cruz de la Sierra.

3) Composition of Trip Distribution by Municipality – To School

Most students in the metropolitan area go to schools in their municipality. However, more than a quarter of students in Porongo and La Guardia go to school in Santa Cruz de la Sierra.

4) Desire Line of All Trips

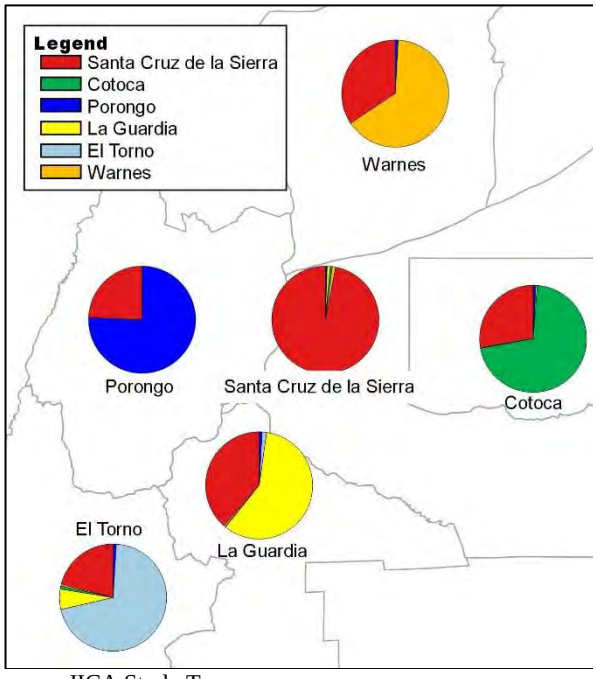
Figure 5-30 illustrates trips between each municipality in the metropolitan area. Trips within each municipality are not shown. Most of the inter-municipal trips are between Santa Cruz de la Sierra and surrounding five municipalities. The largest number of trips is observed between Santa Cruz de la Sierra and La Guardia followed by Warnes, Cotoca, El Torno and Porongo. There are also not a negligible number of trips between La Guardia and El Torno as these two municipalities are connected by a national road.



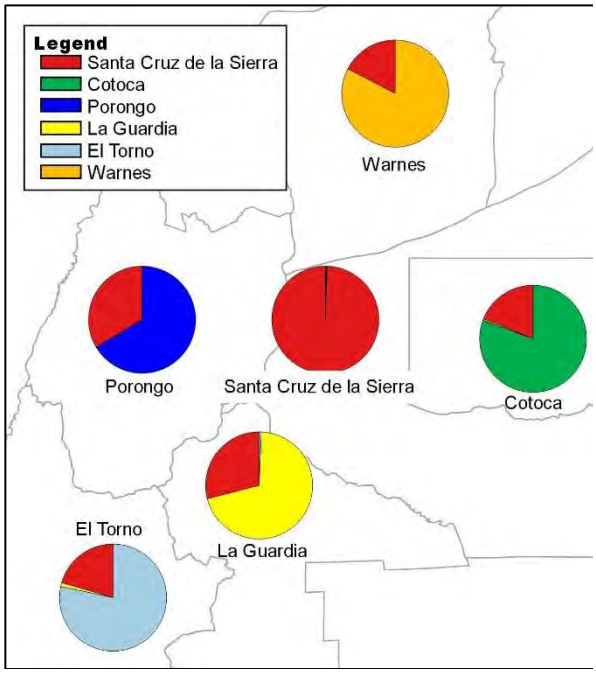
Source: JICA Study Team

Figure 5-28 Composition of trip distribution by municipality – all trips

To Work

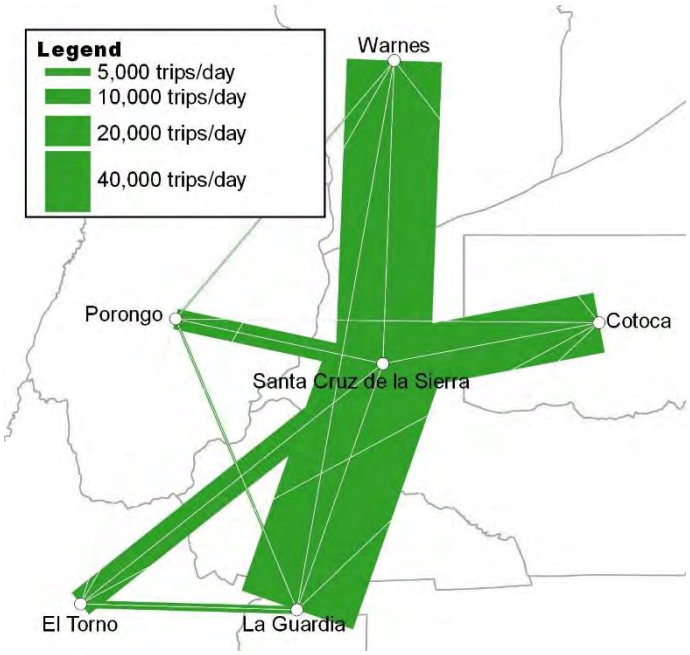


To School



Source: JICA Study Team

Figure 5-29 Composition of trip distribution by municipality



Source: JICA Study Team

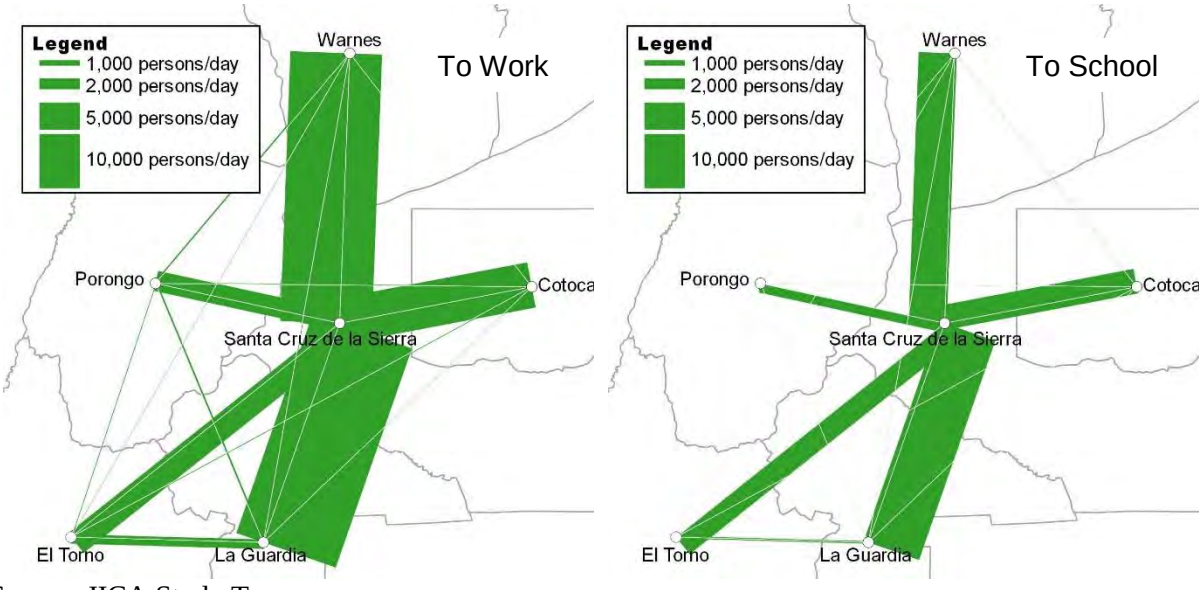
Figure 5-30 Desire line of all trips

5) Desire Line of Commuting Trip to Workplace

The number of workers from the adjoining municipalities to Santa Cruz de la Sierra outweighs that of from Santa Cruz de la Sierra to the municipalities except for Porongo. The number of workers to Porongo might be affected by construction sites in it. The largest number is from La Guardia followed by Warnes, Cotoca, El Torno and Porongo.

6) Desire Line of Commuting Trip to School

The number of inter-municipal students is smaller than that of workers. The number of students from Santa Cruz de la Sierra to the adjoining municipalities is much smaller than that from the adjoining municipalities to Santa Cruz de la Sierra.



Source: JICA Study Team

Figure 5-31 Desire line of commuting trip to workplace

(6) Commuting Characteristics

1) Distance to Workplace by Municipality

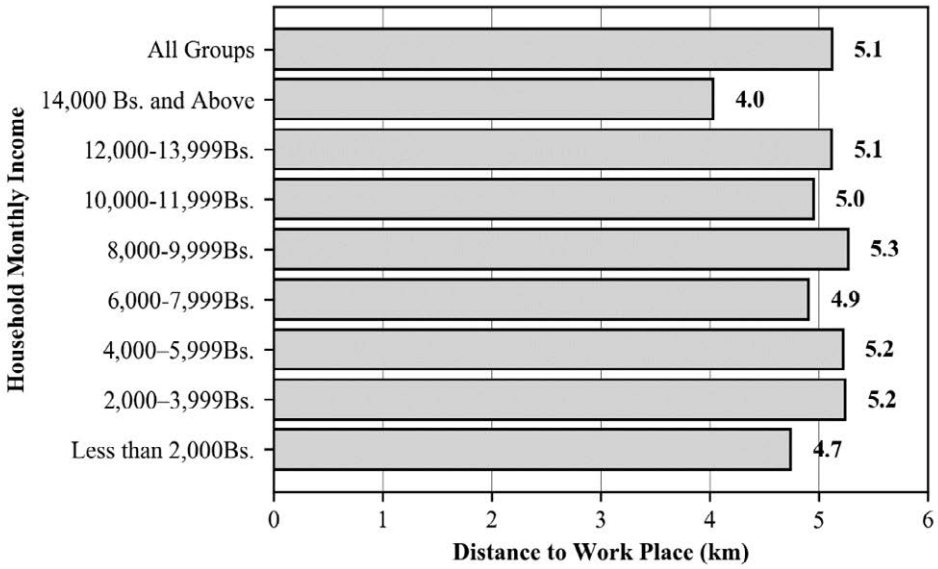
The average distance from residential locations to workplaces in the metropolitan area is 5.0 km. However, the commuting distance significantly varies depending on municipalities. The distance of El Torno is the longest with 10.2 km

Source: JICA Study Team

Figure 5-32 Average distance to workplace by municipality

2) Distance to Work Place by Monthly Household Income

In general, the higher the household income is, the shorter their commuting distance to their workplace is. This trend is obvious for the household with the monthly income of more than 14,000 Bolivianos.



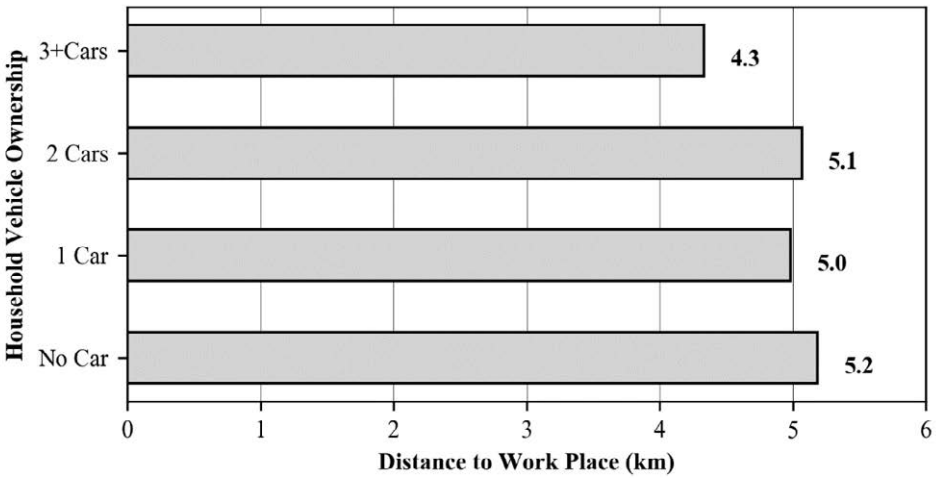
Source: JICA Study Team

Figure 5-33 Average distance to workplace by monthly household income

3) Distance to Workplace by Household Car Ownership

The distance to the workplace of households with 3 or more cars is the shortest at 4.3km, while

that of other households is around 5km. It is inferred that accessibility of household with 3 or more cars is significantly higher than other groups due to their car availability and the shorter distance to their working place.

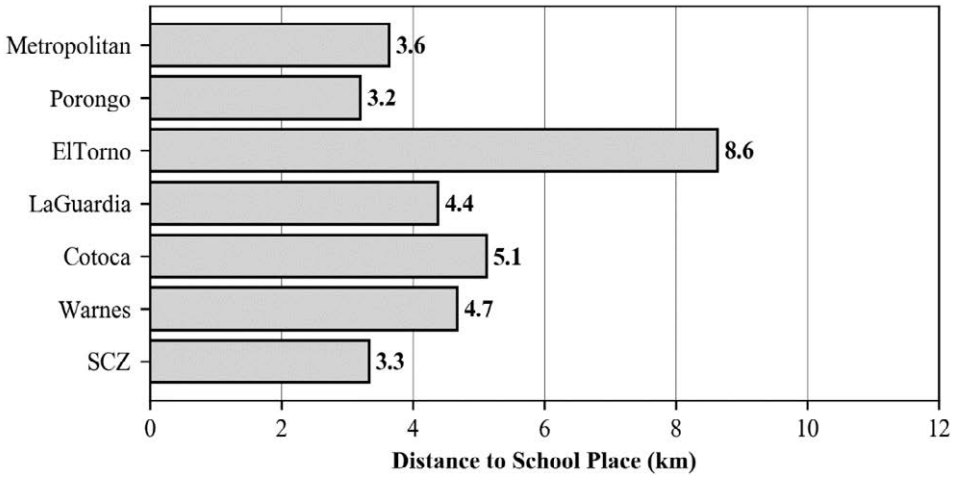


Source: JICA Study Team

Figure 5-34 Average distance to workplace by household car ownership

4) Distance to School by Municipality

The trip distance of going to school is roughly 80% shorter than that to the workplace. The average trip distance of going to school is 3.8km.

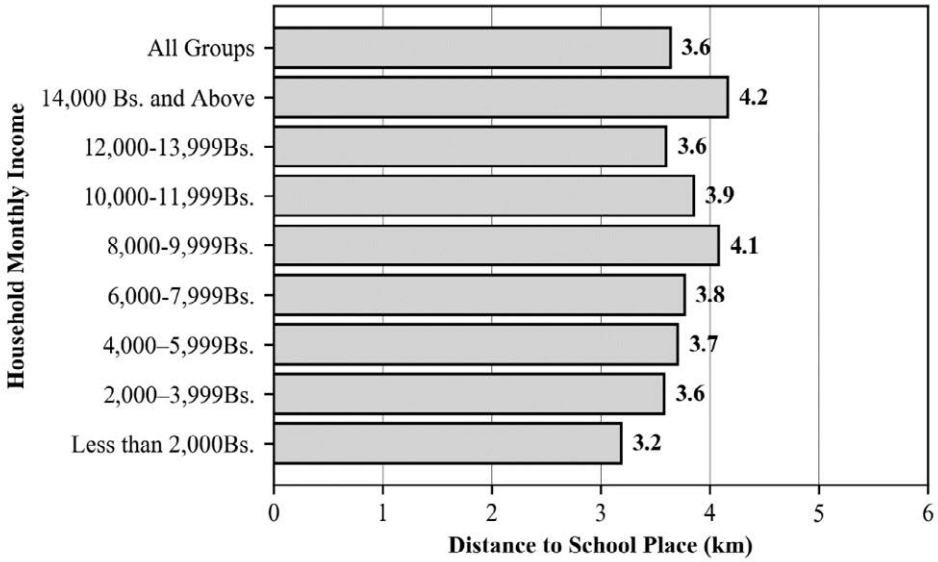


Source: JICA Study Team

Figure 5-35 Average distance to school by municipality

5) Distance to School by Monthly Household Income

It is noteworthy that trend of distance to school by monthly household income is almost opposite to distance to the workplace. Distance to the school of higher income group is longer than those of lower income group. This can be explained by selection of school by high-income groups.

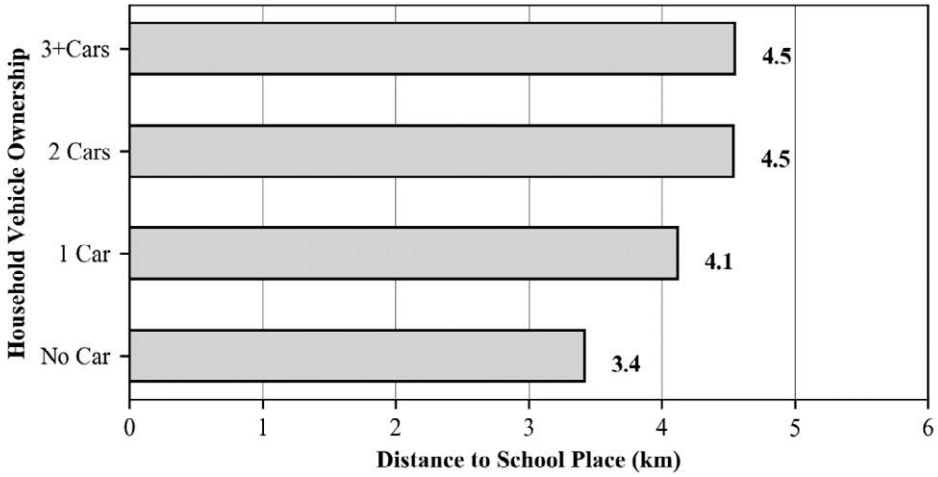


Source: JICA Study Team

Figure 5-36 Average distance to school by monthly household income

6) Distance to School by Vehicle Ownership

Students of households with one or more cars travel longer to their school. In case a student's household owns 3 or more cars, their average travel distance reaches 4.7 km. This shows that a household with plural cars can choose schools far from their house by dropping off/ picking up their student by a car by parents.



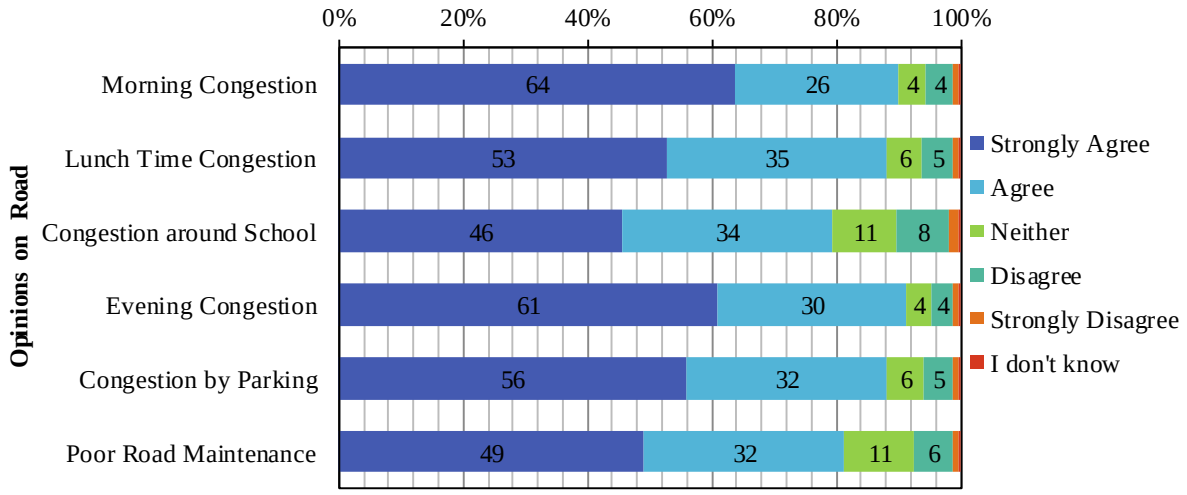
Source: JICA Study Team

Figure 5-37 Average distance to school by vehicle ownership

(7) Opinions on Transportation Issues

1) Opinions on Road

Opinions on transportation issues in the metropolitan area were surveyed to the head of households. Regarding questions related to roads, over 90% of respondents agreed / strongly agreed that traffic congestion during evening peak hour is an issue. Other issues acknowledged by many respondents are congestion during lunch time and congestion caused by a parking car on the street.

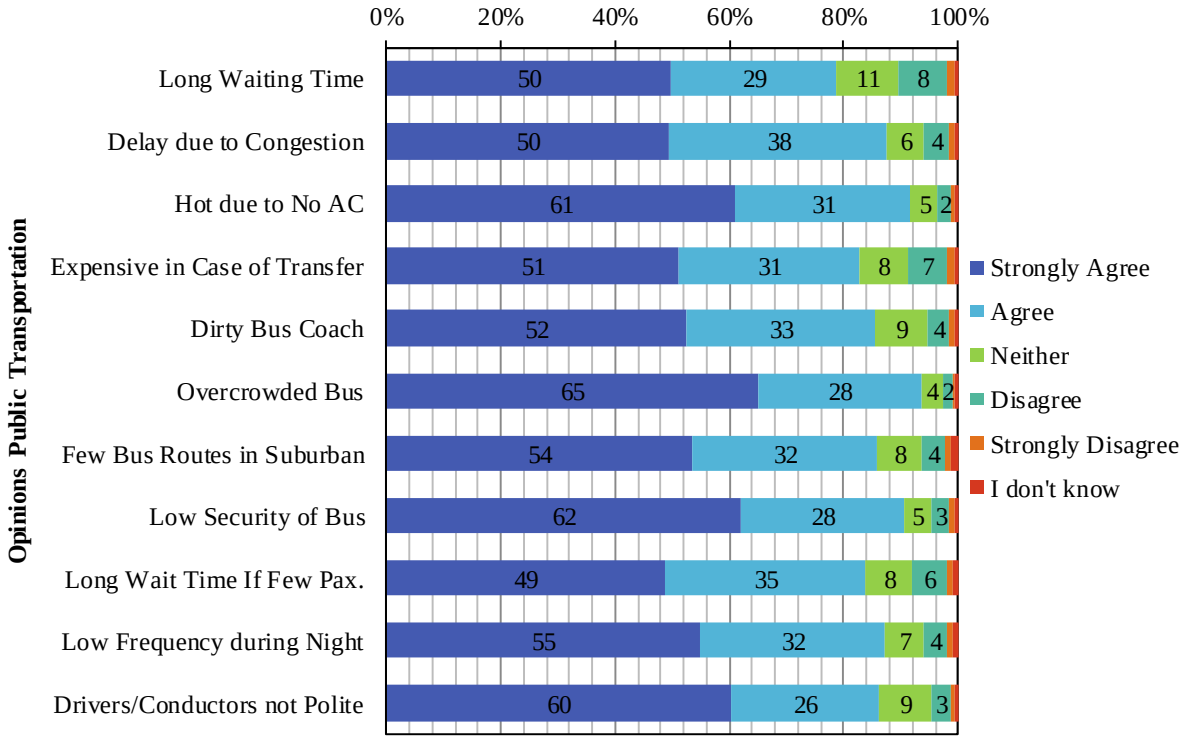


Source: JICA Study Team

Figure 5-38 Opinions on road-related issues in the metropolitan area

2) Opinions on Public Transportation

More than 90% of households agreed that overcrowded, non-air-conditioned and low-security buses are the problems. Also, approximately 80% of households agreed that long waiting time and expensive fare are the problems.



Source: JICA Study Team

Figure 5-39 Opinions on public transport issues in the metropolitan area

5.3 Cordon Line Survey (CLS)

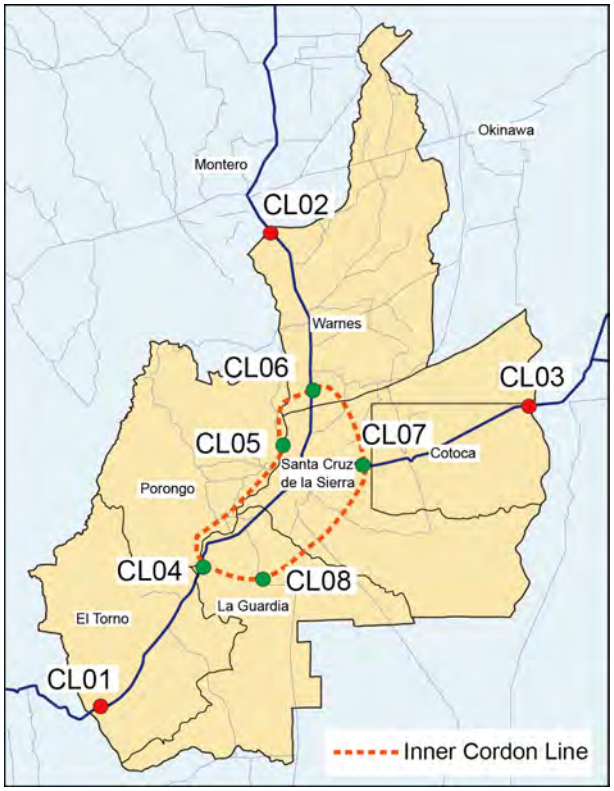
5.3.1 Composition

There are two subcomponents of the CLS.

1) Interview Survey: this survey is to interview vehicle drivers and bus passengers at roadsides to collect information about Origin and Destination of their trip.
2) Traffic Count Survey: the number of vehicles is counted by vehicle type and by direction at the same locations as the interview survey.

5.3.2 Survey Location

The CLS was carried out at 8 locations (both direction) as shown in Figure 5-40. All the survey locations except CL-05 are located at toll gates because it is easier to stop vehicles. Locations from CL-01 to CL-03 are the outer cordon line to collect trip information of vehicles come-into/go-out-from the project area. On the other hand, points from CL-04 to CL-08 are the inner cordon line to collect the information of vehicles come-into/go-out-from the Santa Cruz de la Sierra.




CL-01 Angostura


CL-03 Pailas


CL-08 Pedro Lorenzo

Source: JICA Study Team

Figure 5-40 Survey Locations for Cordon Line Survey

5.3.3 Survey Period

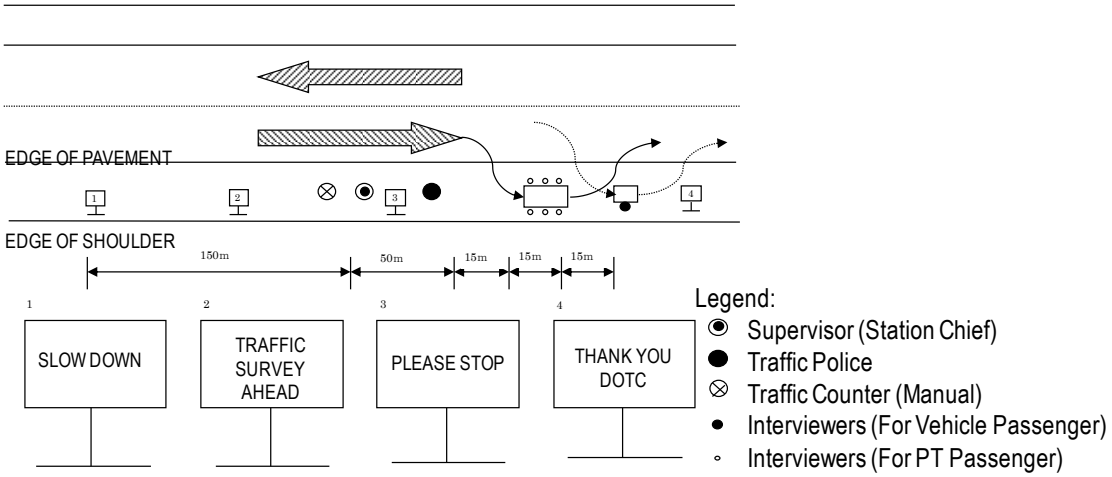
The survey at each location was conducted on one day from either Tuesday, Wednesday or Thursday between 26th of July and 31st of August 2016. The interview survey and the traffic count survey at the same location were conducted on the same day. The duration of the survey was 24 hours (6:00 to 6:00).

5.3.4 Methodology

(1) Roadside Interview Survey

Surveyors flag down vehicles with police assistance before or after the toll gates, and guide the vehicles to stop at roadside spaces. Surveyors make several questions to the drivers and the bus passengers based on the questionnaire. In case of the bus, 2-3 surveyors get onto the bus and each surveyor interviews to 2-3 passengers for each bus. The survey items include the followings.

- Survey date, Location code, Direction (from, to), Time of survey
- Resident/non-resident in the project area
- Detail location of Origin/Destination
- Vehicle type
- Purpose of the trip
- Frequency of the trip
- No. of passengers
- Route name/no. (micro/minibus /bus)
- Name of goods (freight vehicles)



Source: JICA Study Team

Figure 5-41 Typical Setup at Cordon Line Survey

(2) Traffic Count Survey

The classified vehicle count survey was conducted in both directions for all the vehicles passing through the survey locations. Surveyors continuously count and record the number of vehicles by vehicle type and by direction every 15 minutes.

5.3.5 Sampling Rate

The target sampling rate of the interview survey was set as more than 10% for each vehicle type, for each location, and for each direction. The sample rate was monitored during the survey to prevent the deviation of sample rate by vehicle type, by comparing the traffic volume in the traffic count survey that was conducted simultaneously at the same locations.

5.3.6 Vehicle Classification

Vehicles are classified into the following 12 categories: 1) Motorcycle, 2) Three Wheeler (Torito), 3) Car/Jeep/Van, 4) Pickup, 5) Trufi, 6) Minibus, 7) Microbus, 8) Bus, 9) Medium truck (2 axels), 10) large truck (3 axels and more), 11) Container trailer, and 12) Others.

5.3.7 Survey Results

The results of interview survey are

(1) Daily Traffic Volume

The daily traffic volume by vehicle type at each survey location is summarized in Table 5-7. The greatest traffic volume, 31,327 vehicles/day, was observed at the CL-06 in "to metropolitan area" direction. CL-02, CL-05 and CL-07 had traffic volume more than 10,000 vehicles/day/direction.

The reason why the traffic volume of inflow and outflow at CL-06 was different is that there is an alternative way in the outgoing direction. The actual number of vehicles outgoing through CL-06 is considered as a close number of that of incoming direction. This must be taken into consideration in the following analysis to make OD matrix.

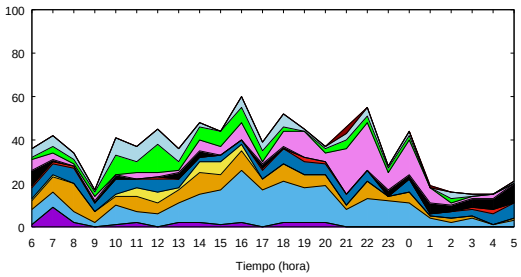
Table 5-7 Daily Traffic Volume at Each Cordon Line Survey Site (Unit: Vehicles/day)

Location	Direction	1	2	3	4	5	6	7	8	9	10	11	12	Total
		Motorcycle /Motorbike	Three-Wheeler Torito)	Car/ Jeep/Van/taxi	Pick Up	Trufi	Mini Bus	Micro Bus	Bus	Medium Truck (2axels)	Large Truck (3axels and more)	Container Trailer	Others	
CL-01	A	28	0	230	123	27	106	11	51	136	81	75	4	872
CL-01	B	12	0	182	77	9	107	14	38	228	121	45	0	833
CL-02	A	322	41	6,041	2,105	2,729	1,597	54	165	713	265	801	4	**14,837**
CL-02	B	282	4	3,012	1,874	2,423	1,173	56	110	888	440	942	4	**11,208**
CL-03	A	328	2	842	603	258	762	14	115	277	153	401	2	3,757
CL-03	B	292	2	843	706	342	809	20	106	427	290	424	3	4,264
CL-04	A	644	14	2,584	630	1,709	226	334	60	535	455	224	9	7,424
CL-04	B	553	13	2,701	502	1,104	299	310	43	432	375	203	8	6,543
CL-05	A	444	4	9,118	1,451	817	232	44	3	290	75	30	32	12,540
CL-05	B	563	8	4,750	2,351	904	294	127	1	269	141	100	20	9,528
CL-06	A	1,078	30	9,949	4,443	5,878	6,184	597	147	1,331	591	1,099	0	**31,327**
CL-06	B	421	17	3,965	1,519	1,937	2,314	621	265	1,529	932	1,447	1	**14,968**
CL-07	A	752	8	4,023	1,629	2,518	972	317	116	972	401	643	6	**12,357**
CL-07	B	577	4	4,118	1,803	1,581	1,012	366	130	1,242	352	486	14	**11,685**
CL-08	A	156	0	499	372	66	256	12	73	272	82	293	4	2,085
CL-08	B	104	0	517	404	80	317	14	76	303	139	285	0	2,239

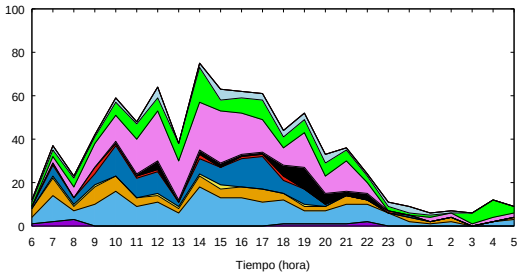
Source: JICA Study Team
Direction A: To metropolitan area, B:From metropolitan area

(2) Hourly Traffic Volume

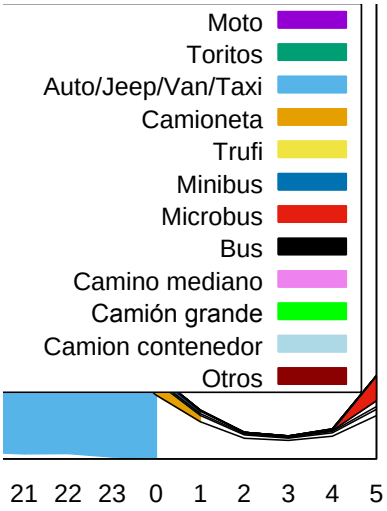
The hourly traffic volume at each location by direction is shown in Figure 5-42.

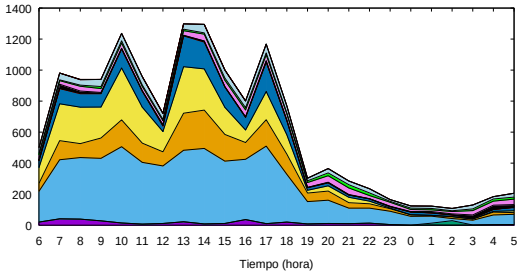


CL01 (A)

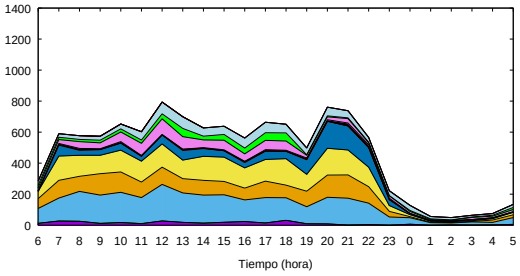


CL01 (B)

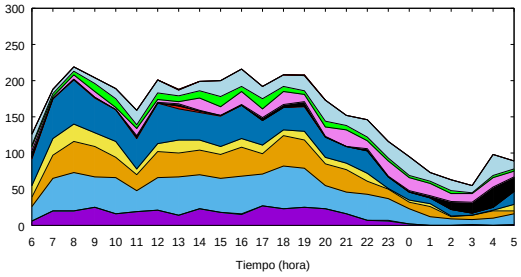




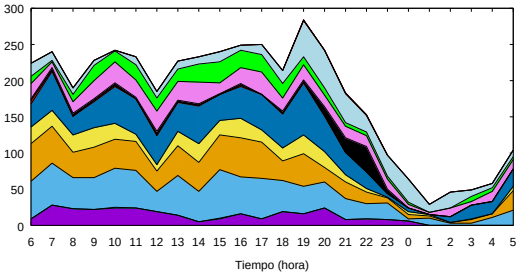
CL02 (A)



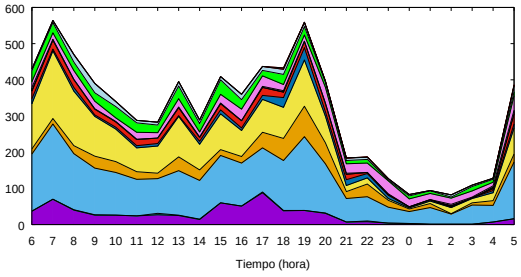
CL02 (B)



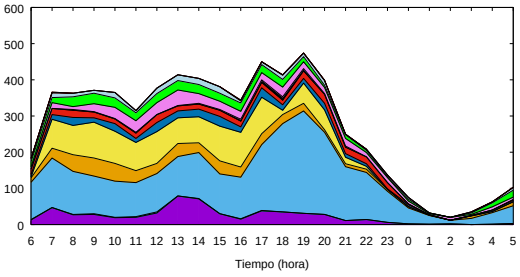
CL03 (A)



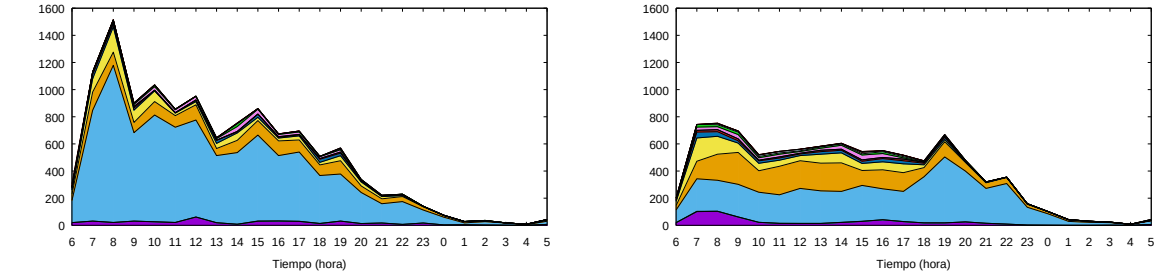
CL03 (B)



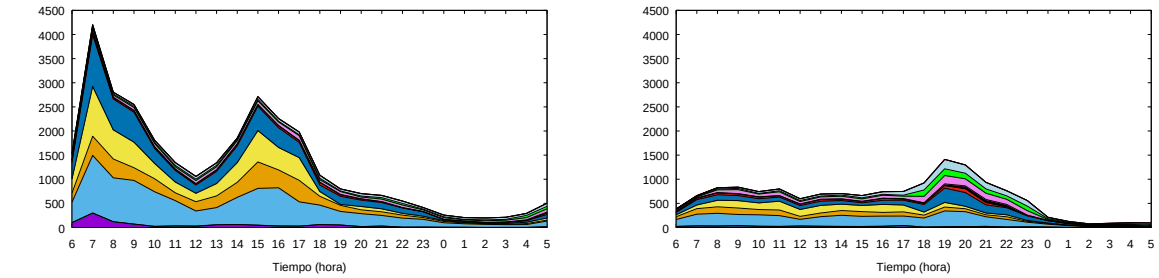
CL04 (A)



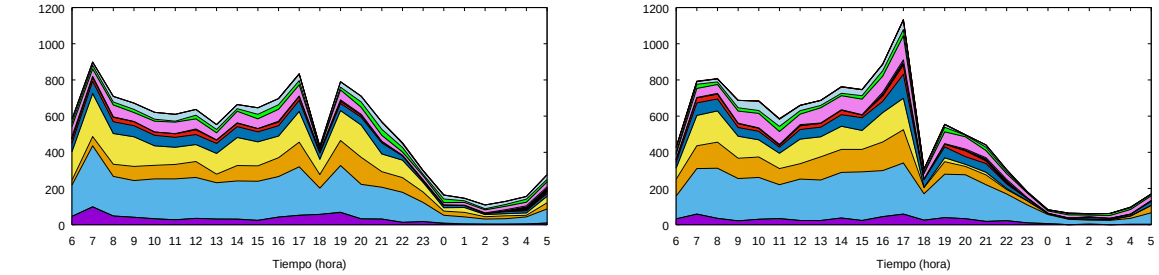
CL04 (B)



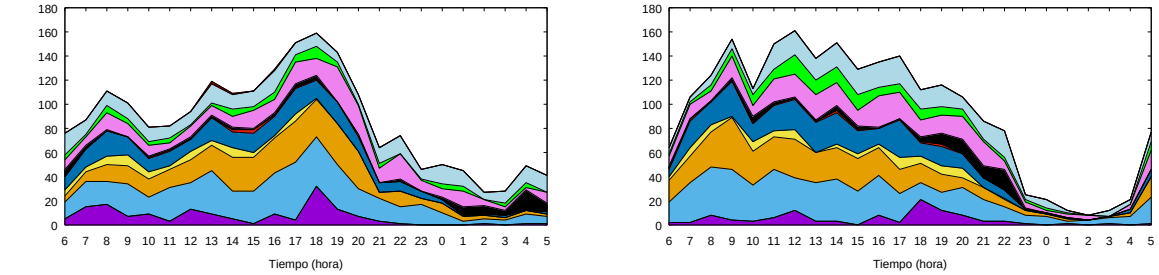
CL05 (A) CL05 (B)



CL06 (A) CL06 (B)



CL07 (A) CL07 (B)



CL08 (A) CL08 (B)

Source: JICA Study Team

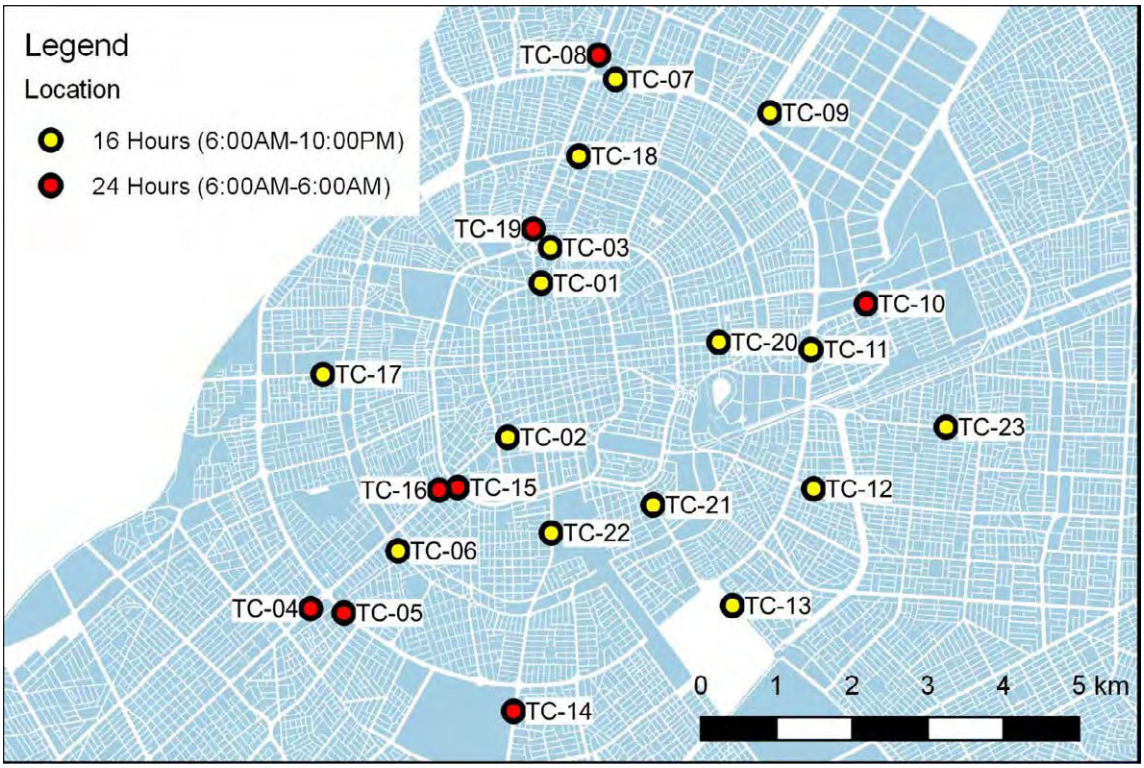
Figure 5-42 Number of Vehicles per hour

5.4 Classified Vehicle Counting Survey

5.4.1 Survey Location and Period

The Traffic Count Survey was carried out at 23 locations in the urban area of the project area as shown in Figure 5-43. The survey was conducted on one day from either Tuesday, Wednesday or Thursday from the end of June to end of August 2016.

- 8 locations (24 hours: 6:00 to 6:00) with a video camera
- 15 locations (16 hours: 6:00 to 22:00) with a video camera



Source: JICA Study Team

Figure 5-43 Classified Vehicle Count Survey Location

5.4.2 Methodology

To ensure the efficiency and accuracy, video cameras are used for vehicle counting. This survey consists of two phases, 1) Video shooting at the survey locations and 2) Classified vehicle counting.

(1) Video shooting at the survey locations

To capture the image of traffic at the survey locations, trial video shooting should be held to check the point, height, and angle of the camera. It is recommended to place the camera on lampposts in the center median, on pedestrian bridges or from buildings near the survey location. The video of traffic flow is continuously recorded during all the survey period. So, the arrangement of batteries and recording media must be properly prepared.

(2) Classified vehicle counting

Surveyors manually count the number of vehicles by monitoring the recorded video in another day, by filling out the printed survey form. After the manual counting, the results are inputted to excel sheet. The classification of the vehicle type is 12vehicle types, the same as in the Cordon Line Survey.

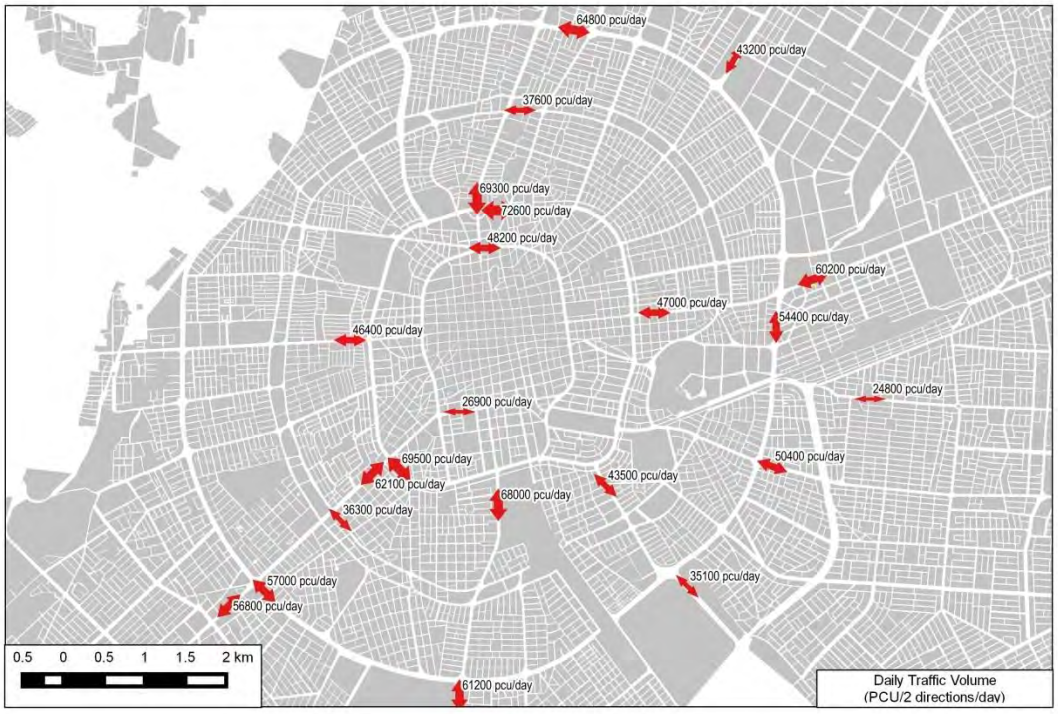
Source: JICA Study Team

Figure 5-44 Example of Equipment for Video Shooting in this survey

5.4.3 Survey Results

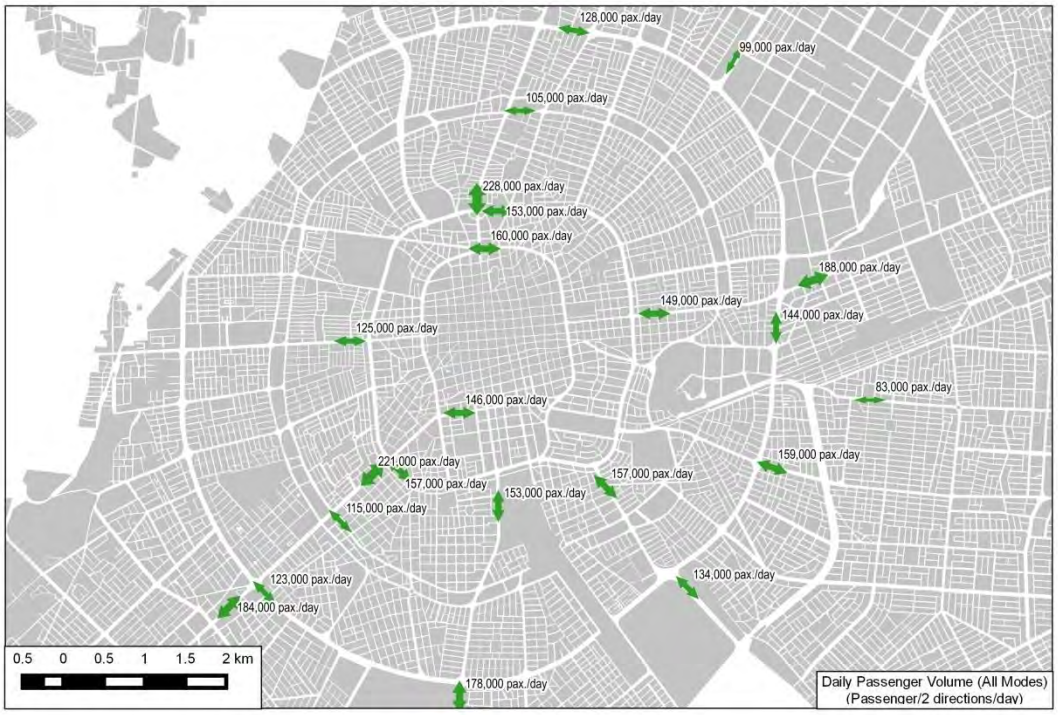
(1) Daily and Peak Traffic Volume

Figure 5-45 and Figure 5-46 shows the daily volume of vehicles (PCU) and passengers. These figures show that both the circular road and the radial road are heavily used at the intersections of 2nd Ring Road and Av Cristo Redentor, and 2nd Ring Road and Avenida Grigota.



Source: JICA Study Team

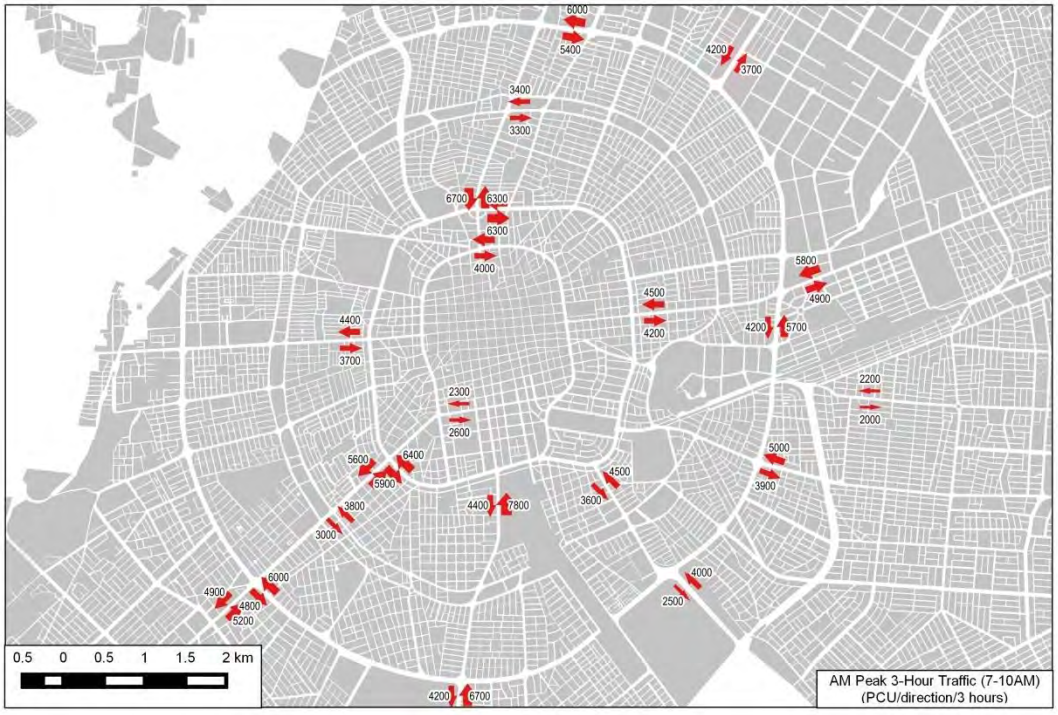
Figure 5-45 Counting Survey Result of Daily PCU (Passenger Car Unit)



Source: JICA Study Team

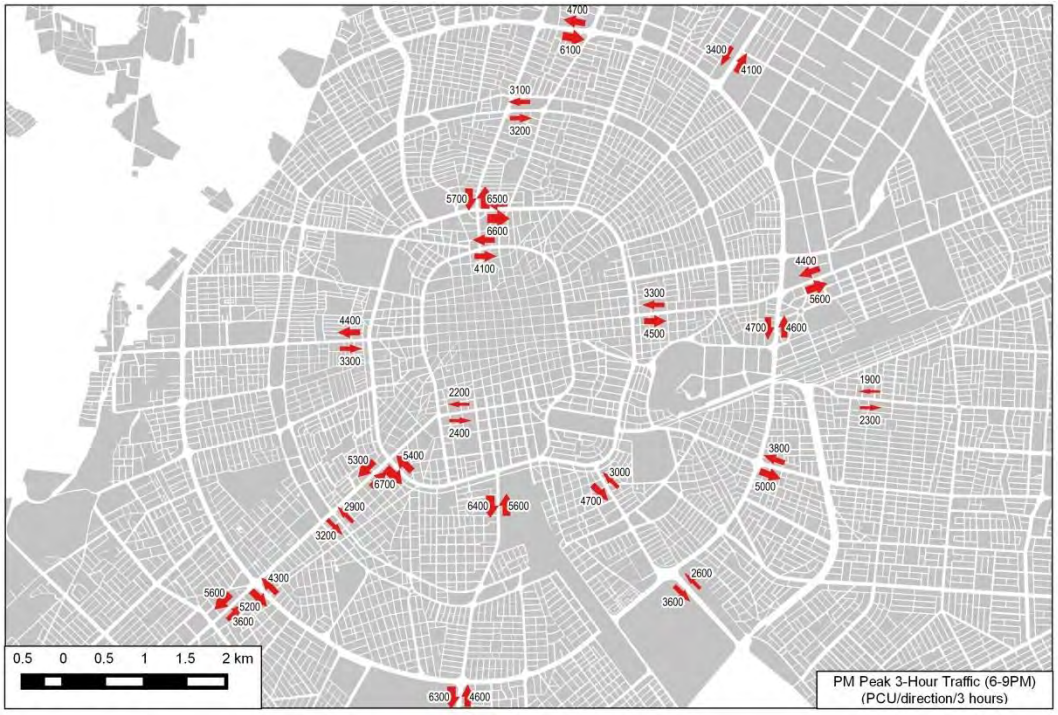
Figure 5-46 Counting Survey Result of Daily Passenger

Figure 5-47 and Figure 5-48 show the morning and evening traffic volume in PCU. The hourly traffic volume exceeds 2,000 PCU/direction at some severe points.



Source: JICA Study Team

Figure 5-47 Counting Survey Result of PCU during Morning Peak (7AM-10AM)



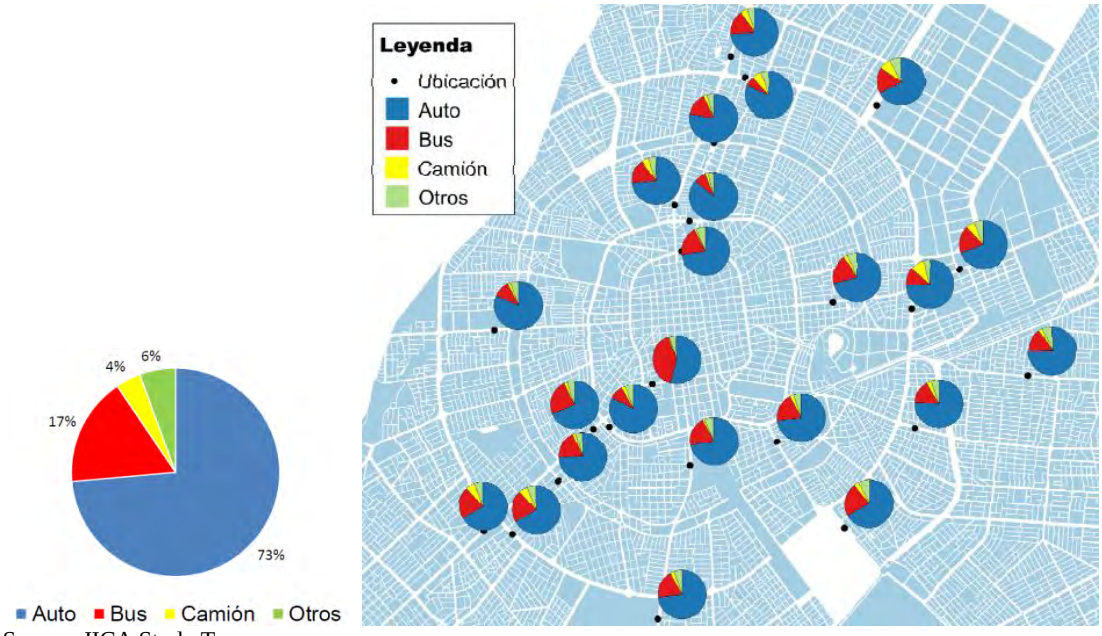
Source: JICA Study Team

Figure 5-48 Counting Survey Result of PCU during Evening Peak (6PM-9PM)

(2) Percentage of each vehicle type

Figure 5-49 shows the percentage of each vehicle type. Private vehicle accounts for 73% of the total traffic, followed by buses (17%), trucks (4%) and others (6%).

Regarding the spatial difference, the ratio of trucks is much higher on the arterial roads outside the 4th Ring Road.



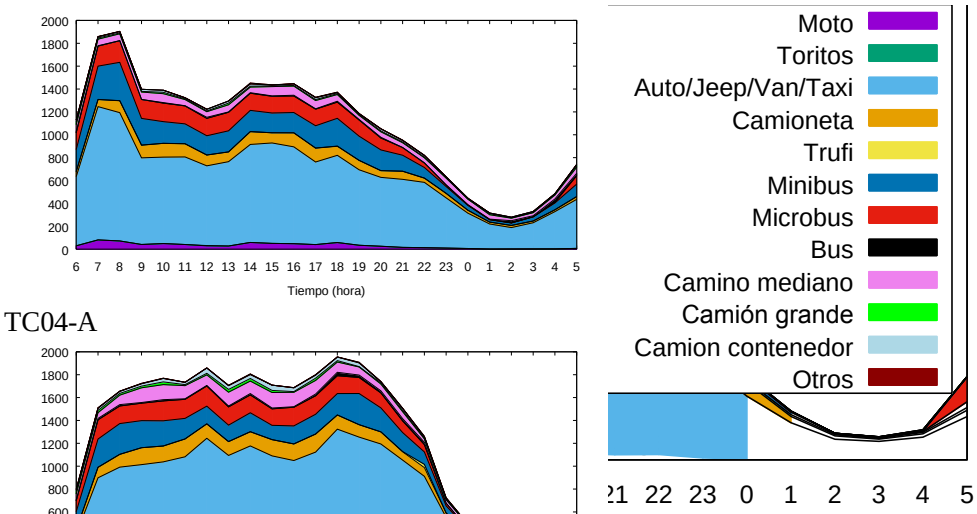
Source: JICA Study Team

Figure 5-49 Percentage of each vehicle type (Left: Summary of all locations, Right: Each Location)

(3) Time-Series Traffic Volume

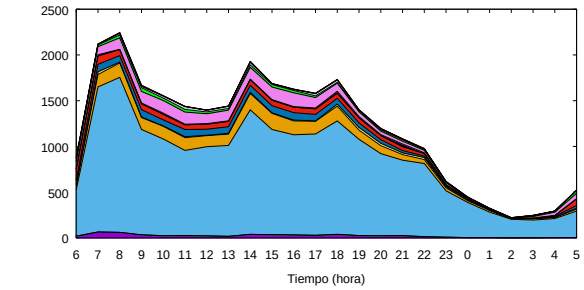
The hourly traffic volume by vehicle type is shown in Figure 5-50. These locations had comparatively high traffic among the survey locations. The traffic peak is appeared in the lunchtime (12:00-14:00) in addition to the morning and evening peak, at some location (TC-05, 08, 10, 14, and 15). Increase in private passenger vehicles contributes to these traffic peaks.

The maximum hourly traffic is observed at TC-08, and it reached 3,968 PCU/hour in the incoming direction in the morning time. The hourly traffic exceeded 2,500 PCU/hour at TC-14 and TC-15.

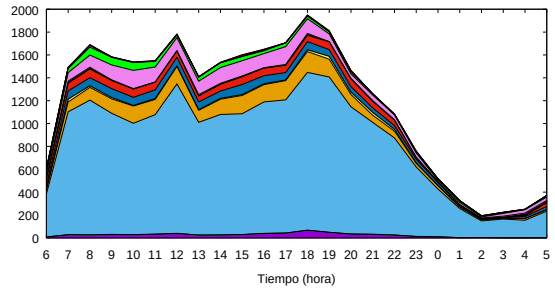


TC04-A

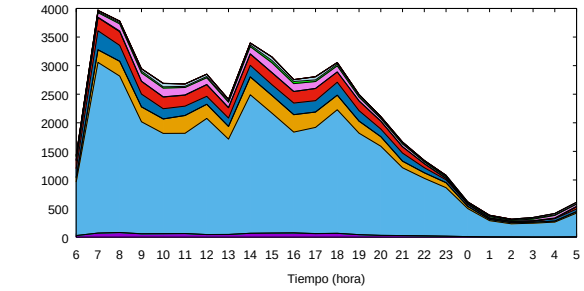
TC04-B



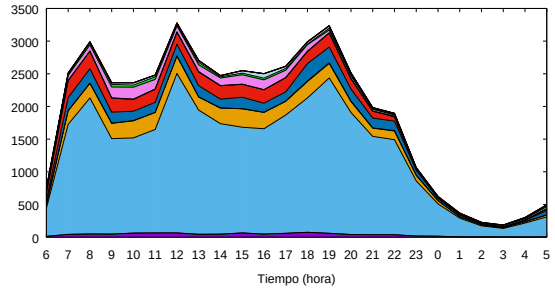
TC05-A



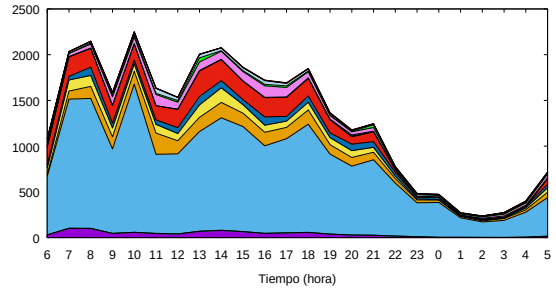
TC05-B



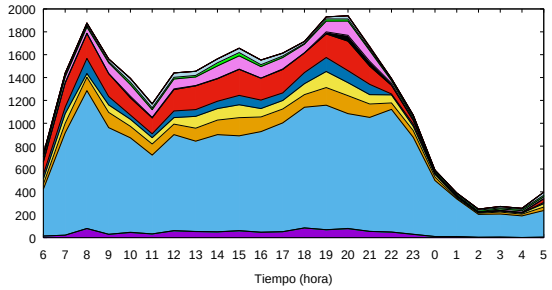
TC08-A



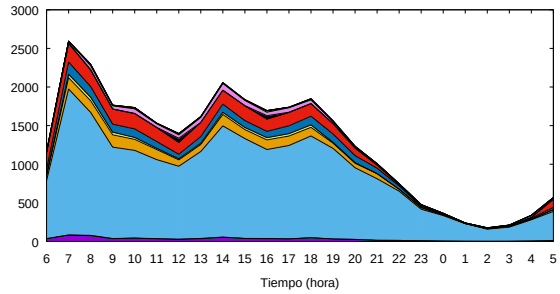
TC08-B



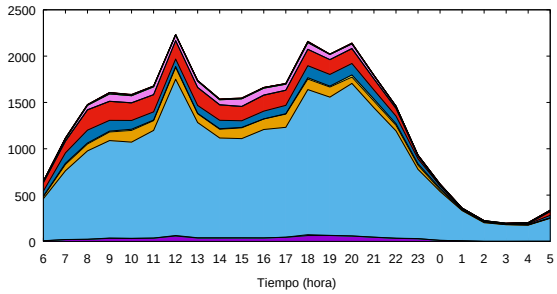
TC10-A



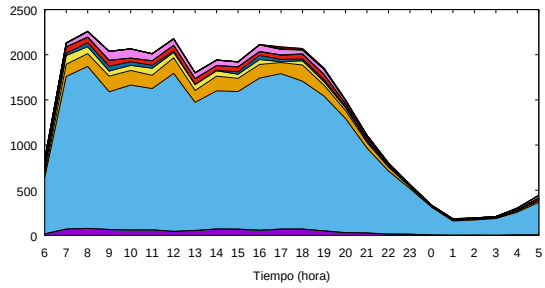
TC10-B



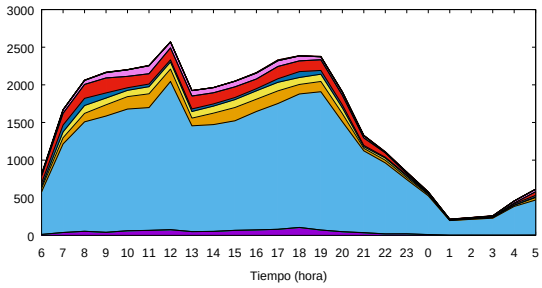
TC14-A



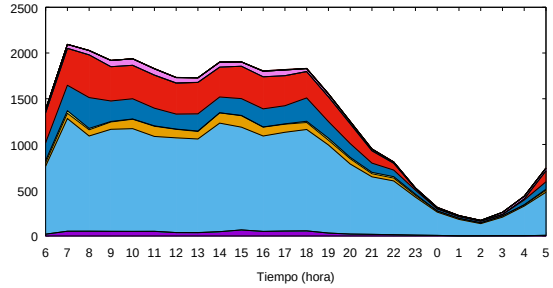
TC14-B



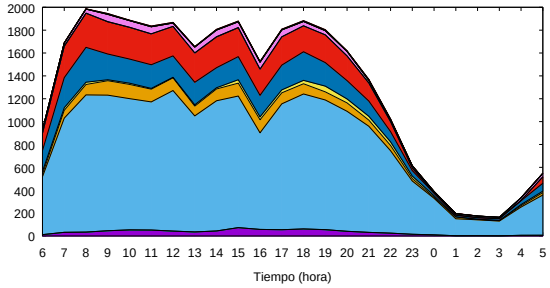
TC15-A



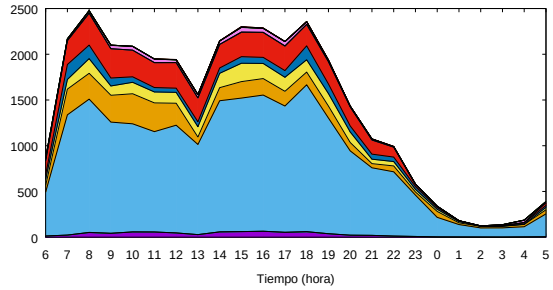
TC15-B



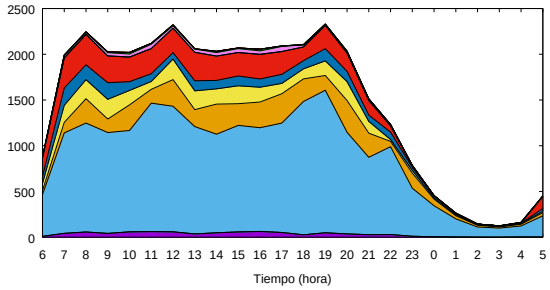
TC16-A



TC16-B



TC19-A



TC19-B

Source: JICA Study Team

Figure 5-50 Counting Survey Result of Time-Series PCU

5.5 Activity Diary Survey

5.5.1 Methodology

Surveyors visited the selected two persons of the selected households and interview with them. All the activities and movement in one day from either Tuesday, Wednesday or Thursday were recorded in time sequence with 15 minutes' interval.

The number of surveyed persons was 1,800 in total. 900 households were sub-sampled from the HIS/CS. Two persons were randomly selected from one household.

5.5.2 Survey Results

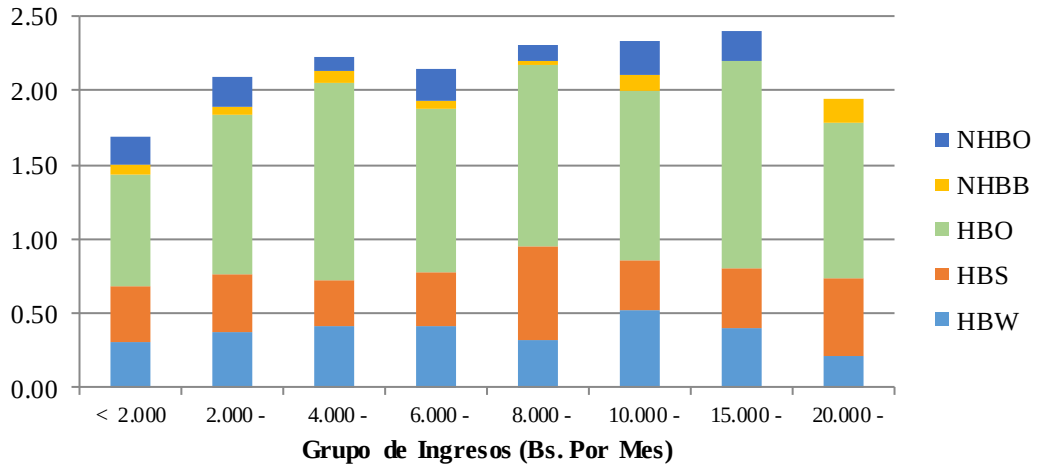
The data of activities of the respondents were recorded, and the trip data are extracted from the activity data. Furthermore, the trip purposes are combined into the following five purposes listed in Table 5-8.

Table 5-8 Combined Trip Purpose and Examples

Trip Purpose	Examples of Trips
1) Home Based Work (HBW)	Home to Work (Place), Work (Place) to Home
2) Home Based Education (HBE)	Home to School (Education), School to Home
3) Home Based Other (HBO)	Home to a shop, a restaurant, a hospital, a house of relatives or friends
4) Non-home Based Business (NHBB)	Work (place) to attend meetings, Places other than home (business) back to Workplace
5) Non-home Based Others (NHBO)	Work Place/School to a shop, a restaurant, a hospital, a house of relatives and friends

Source: JICA Study Team

Trip production rates are calculated by trip purpose and by household income as illustrated in Figure 5-51.



Source: Activity Diary Survey, 2016

Figure 5-51 Trip Rates by Trip Purpose by Income Group based on Activity Diary Survey

Trip rates by trip purpose were calculated based on the activity data obtained from the Activity Diary Survey. Compared with the trip rates obtained from the Home Interview Survey, adjustment factors are estimated for two trip purposes, Non-home Based Business and Non-

home Based Others as listed in Table 5-9.

Table 5-9 Comparison of Trip Rates and Adjustment Factors

Trip Purpose	Income Group	Trip Rates		Adjustment Factors
		Home Interview Survey	Activity Diary Survey	
Non-Home Based Business	Low	0.008	0.067	8.114
	Middle	0.011	0.045	4.168
	High	0.005	0.098	18.239
Non-Home Based Others	Low	0.070	0.150	2.135
	Middle	0.083	0.181	2.166
	High	0.121	0.148	1.224

Note: Low-income group consists of the households with monthly income less than Bs 6,000. The monthly income of the middle-income group is between Bs. 6,000 and Bs. 10,000. The monthly income of the high-income group is Bs. 10,000 and more.
Source: Home Interview Survey 2016 and Activity Diary Survey 2016

5.6 Freight interview survey

5.6.1 Methodology

Information of the selected company was collected by interviews with the person in charge of the companies. Information on truck movements was collected by mailing and visiting methods. The following information was collected.

(1) Company Information

- Location of the factory or warehouse
- Business activity
- No of workers in the factory warehouse
- Site area/Floor Area

(2) Vehicle Trips Related to Goods

- Origin/Destination of trips by vehicle type
- Frequency of trips by vehicle type
- Monthly fluctuation of number of trips

5.6.2 Samples

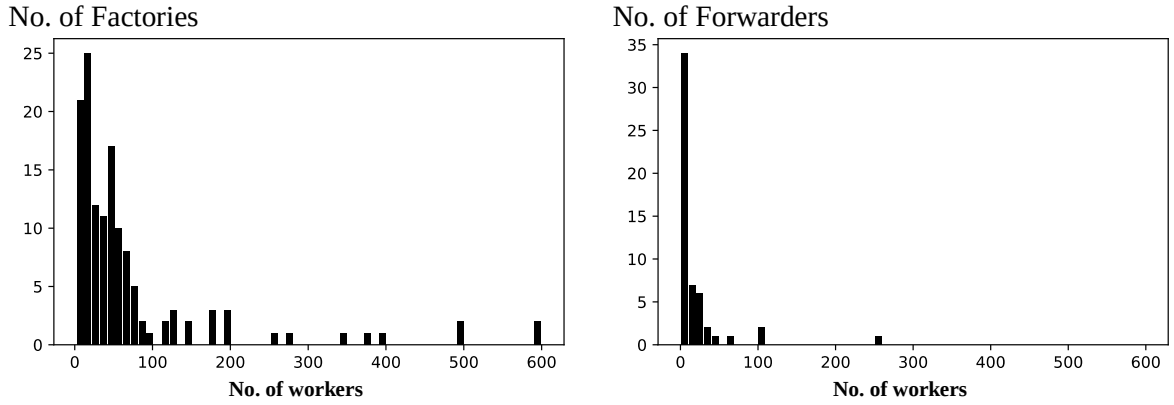
200 companies including (1) manufacturing factories, (2) trucking companies/forwarders, and other enterprises in the project area were contacted. Figure 5-52 shows the distribution of the collected samples by the size of the company in terms of the number of workers.

5.6.3 Results

Table 5-10 shows the percentages of vehicles that generate from the facilities of the interviewed companies. Due to the nature of its activity, truck movements are the major trip generation and attraction of the factories, although the trips of small trucks (pick-up/vans) account for 32.8%.

The difference in the trip characteristics among factories and truck companies are significant. The correlation between the number of vehicle trips and the number of employees and that between the number of vehicle trips and the area of the office were not found.

The average trip rates are calculated as shown in Table 5-12.



Source: Freight Interview Survey, 2016

Figure 5-52 Sample Distribution of the Freight Interview Survey

Table 5-10 Composition of Vehicle Type of Trip Generation

(Unit: %)

	Car	Pickup/Van	2-Axle truck	Large truck	Other truck
Factories	9.6	32.8	28.5	11.5	17.6
Forwarders	2.9	15.9	15.4	55.8	10.0
Total	8.2	29.3	25.8	20.7	16.0

Source: Freight Interview Survey, 2016

Table 5-11 All trips divided by the sum of the number of workers or area

Vehicle type	Unit	Factories	Forwarders	Total
Car	Per worker	0.088	0.121	0.091
	Per area (ha)	3.22	21.7	3.53
Truck	Per worker	0.130	0.522	0.166
	Per area (ha)	4.81	92.0	6.37
Total	Per worker	0.218	0.643	0.257
	Per area (ha)	8.03	114	9.90

Source: Freight Interview Survey, 2016

Table 5-12 Average Trip Rate

Vehicle type	Unit	Factories	Forwarders	Total
Car	Per worker	0.252	0.165	0.227
	Per area (ha)	54.6	111	66.0
Truck	Per worker	0.289	1.14	0.534
	Per area (ha)	46.9	1399	394
Total	Per worker	0.541	1.31	0.761
	Per area (ha)	101	1510	460

Source: Freight Interview Survey, 2016

5.7 Truck movement survey

5.7.1 Methodology

There are two subcomponents of this survey, 1) Collecting GPS logger record of truck movements and 2) Extract required trip information from the GPS log.

(1) Collecting GPS logger record of truck movements

GPS loggers were installed in the selected trucks of the companies which cooperated with this survey. The movements of trucks were recorded with a GPS Logger for one week.

(2) Extract required trip information from the GPS log

The following information was extracted from the collected data by trucks.

- Latitude and longitude of Origin and Destination of each trip
- Time of departure and arrival of each trip

5.7.2 Cooperative companies

After contacting to 21 companies including manufacturing and freight companies, nine companies were selected as shown in Table 5-13. The criteria for the selection were as follows. 50 trucks from the selected nine companies were surveyed.

- Their trucks mainly move inside the project area.
- Type of goods covers a wide variety.
- The movement of the truck is random or different every day in a week.

Table 5-13 List of Companies

Company	Type	GPS Tracking Company	No. of Trucks	Type of Destination
1	Food	A	15	Markets, supermarkets.
2	Drinks	C	30	Markets, supermarkets, shops, and provinces.
3	Drinks	A	170	Markets, supermarkets, and provinces.
4	Construction	B	50	Construction companies
5	Drinks	B	6	Markets, supermarkets, agencies.
6	Transport	D	10	Within the urban area and provinces.
7	Daily products	A	50	Markets, supermarkets, and provinces.
8	Plastics	A	2	Markets, supermarkets.
9	Distributor	A	15	Markets, supermarkets, and provinces.

Source: JICA Study Team

5.7.3 Survey Results

(1) Characteristics of Truck Movements

1,218 truck trips were collected from the GPS loggers. The survey data were collected between July and September 2016.

Table 5-14 shows the summary of the surveyed truck movements. The average number of

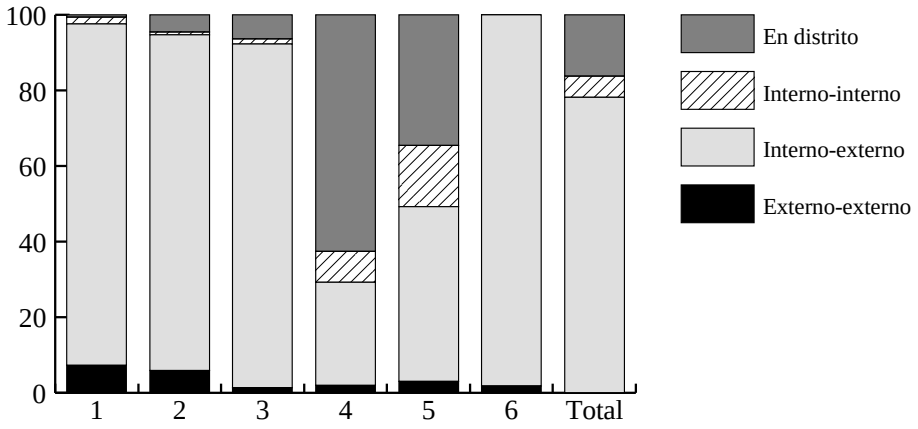
trips was 4.8 per day per truck while the average trip length was 25.5 km with the average travel time of 86 minutes.

Figure 5-53 shows the composition of the origin and destination of trips. Trips within the Project Area account for approximately 80%. Trips made by the company 4 and 5 have comparatively long distance than others.

Table 5-14 Summary information of surveyed truck movements

Company	Type	# of Trucks for survey	# of Truck*day	# of Trips	Avg. # of Trips/day/truck	Avg. Trip Length (km)	Avg. Trip Time (Min)	Avg. Travel Speed (k/h)
1	Construction	10	67	327	4.9	9.5	67	8.5
2	Food	7	42	304	7.2	10.6	58	11.1
3	Dairy products	4	22	143	6.5	18.3	58	18.9
4	Freight Transport	5	25	99	4.0	60.2	107	33.8
5	Drinks	10	91	292	3.2	53.9	148	21.8
6	Drinks	6	6	53	8.8	8.3	52	9.6
Total		42	253	1,218	4.8	25.5	86	17.9

Source: JICA Study Team

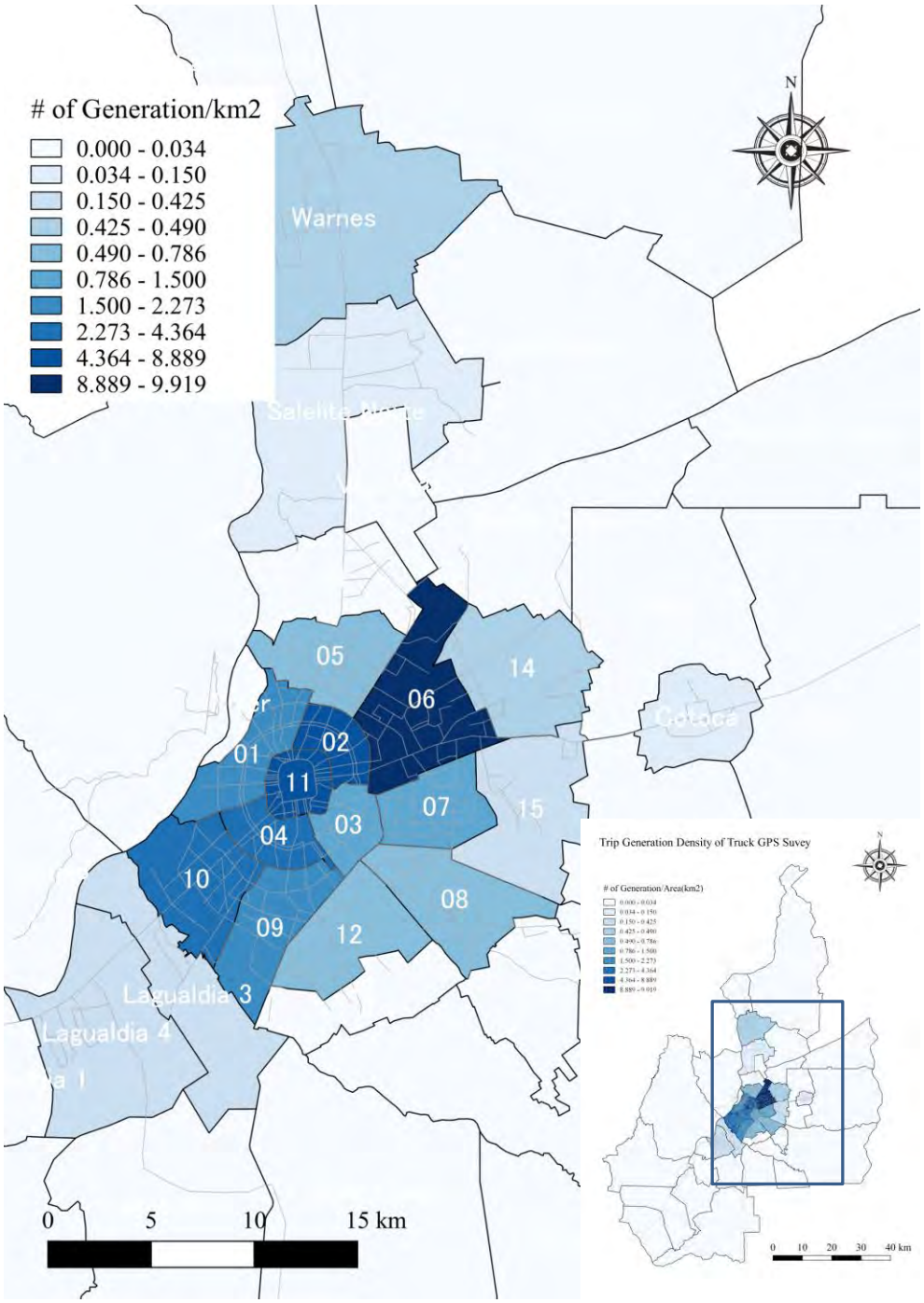


Source: Truck Movement Survey 2016

Figure 5-53 Origin and Destination Pattern of Surveyed Trucks

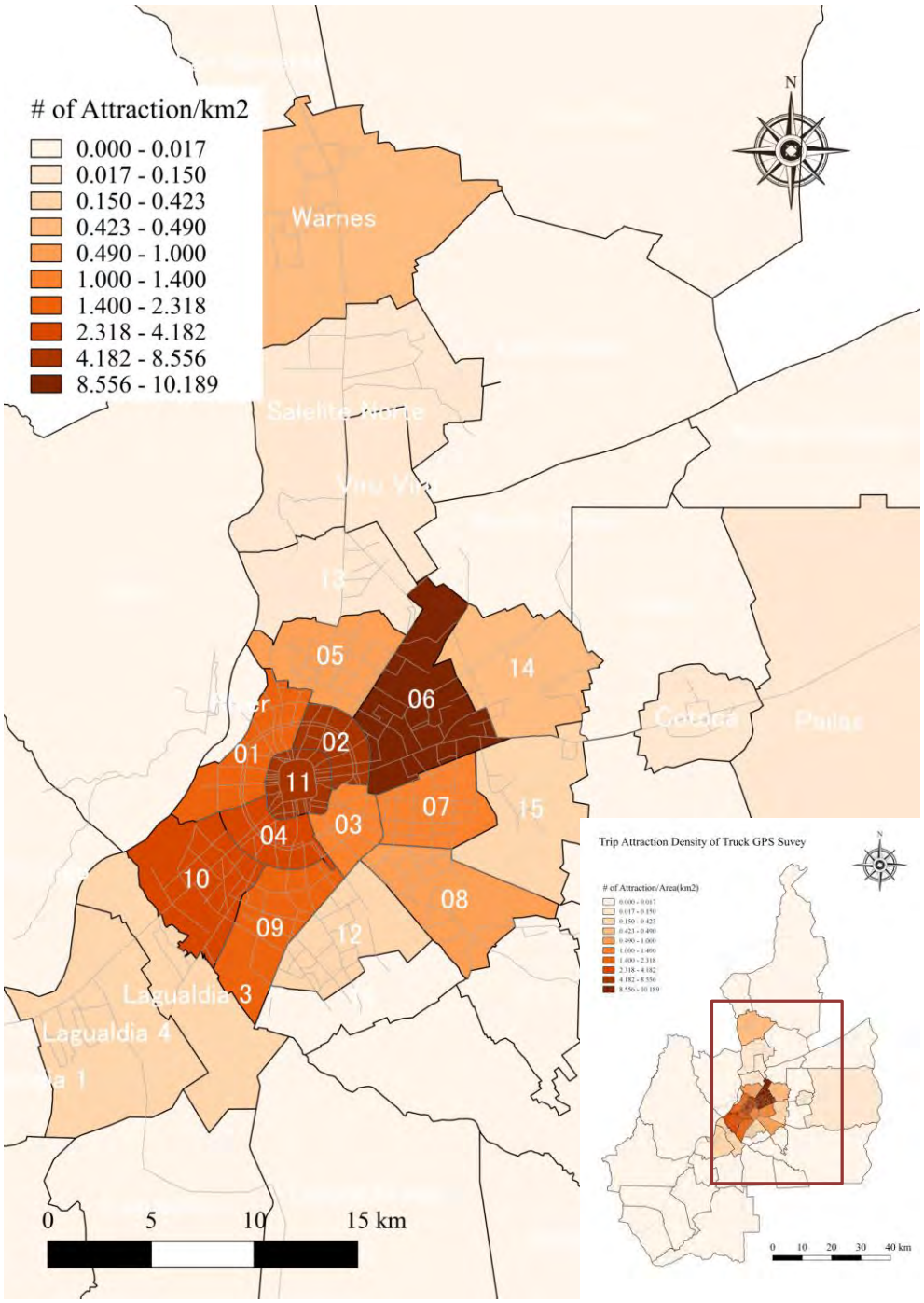
(2) Generation/Attraction Density of the collected truck GPS

Figure 5-54 and Figure 5-55 show the density of the trip generation and the trip attraction, respectively. Both maps show a similar trend. The industrial zone (District 6) and District 10 have higher trip generation and attraction because there are some distribution centers of companies. Other than that, the generation and attraction are concentrated in the area inside 4th Ring Road, such as Distrito 1, 2, 4 and 11.



Source: Truck movement survey 2016

Figure 5-54 Trip Generation Density of Truck Movements

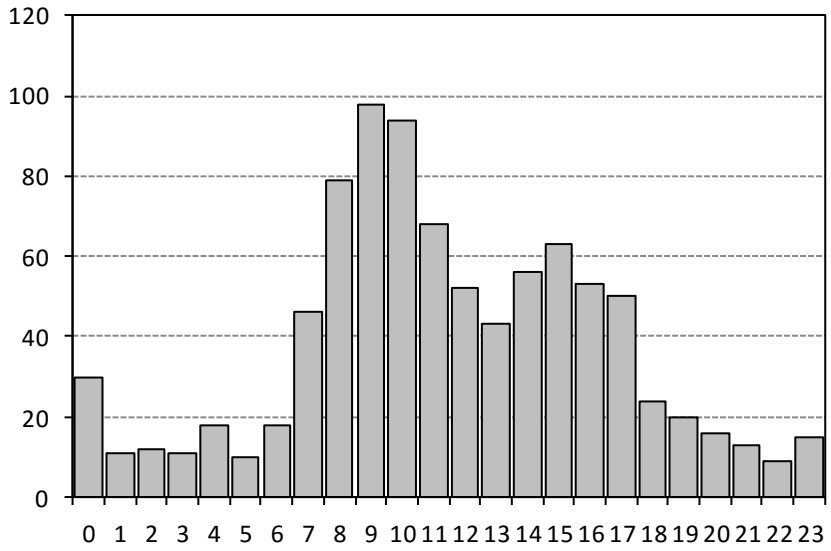


Source: Truck Movement Survey 2016

Figure 5-55 Trip Attraction Density of Truck Movements

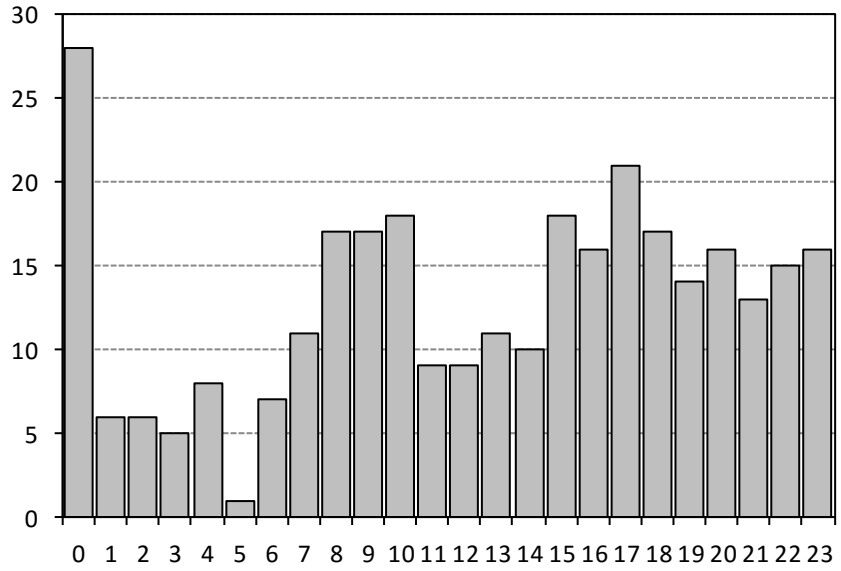
(3) Departure Time of the surveyed trucks

Figure 5-56 shows the departure time distribution of trips within the Project Area, whereas Figure 5-57 shows that of trip crossing or outside of the Project Area. There is a sharp peak between 8:00 and 12:00 and a less sharp peak between 14:00 and 18:00 for the trips within the Project Area. On the other hand, even though a peak is observed from 0:00 to 1:00, there is a less significant peak for long distance trips.



Source: Truck Movement Survey 2016

Figure 5-56 Departure Time Distribution of trip within the Project Area

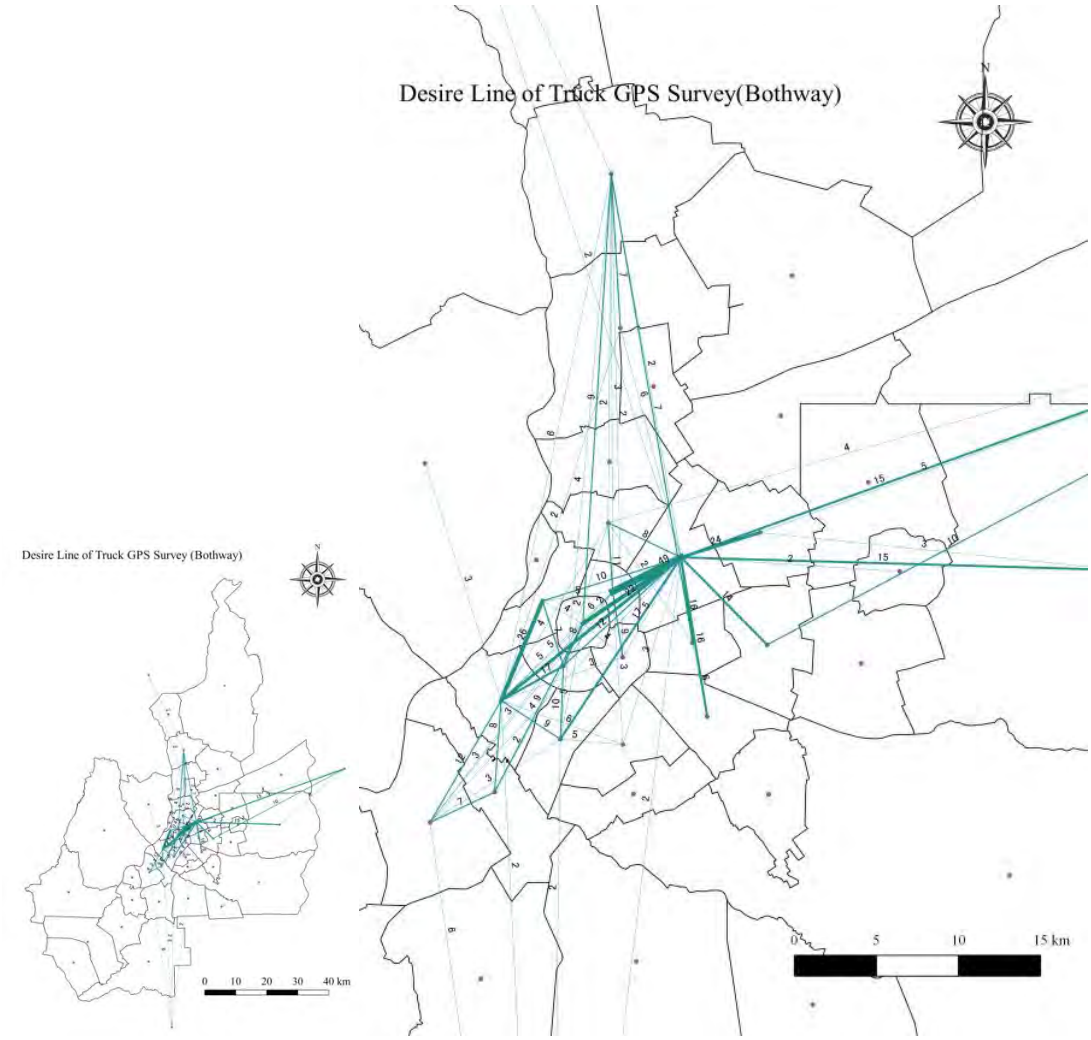


Source: Truck Movement Survey 2016

Figure 5-57 Departure Time Distribution of trip crossing or outside the Project Area

(4) Trip Distribution of surveyed truck movements

Figure 5-58 shows the desired line of the truck movement survey. It shows that District 6 and 10 are two major hubs in the project area. Many trucks have the trip between south-west and north-east directions.



Source: JICA Study Team
Note: Desire line for 1 trip and trip within the district is hidden on the map for simplicity.

Figure 5-58 Desire Line of Truck GPS Survey (Both directions)

(5) Trip Distribution of collected truck GPS

Figure 5-59 shows the trajectory of the GPS tracking record. The bright lines indicate that the road section is heavily used by the freight traffic. The three radial roads outside 4th Ring Road and the road around the industrial road are the most used road for freight traffic.

The numbers on the map indicate the number of truck trips observed at each section. Some points are selected from the traffic count survey point, which is displayed as green points on the map.

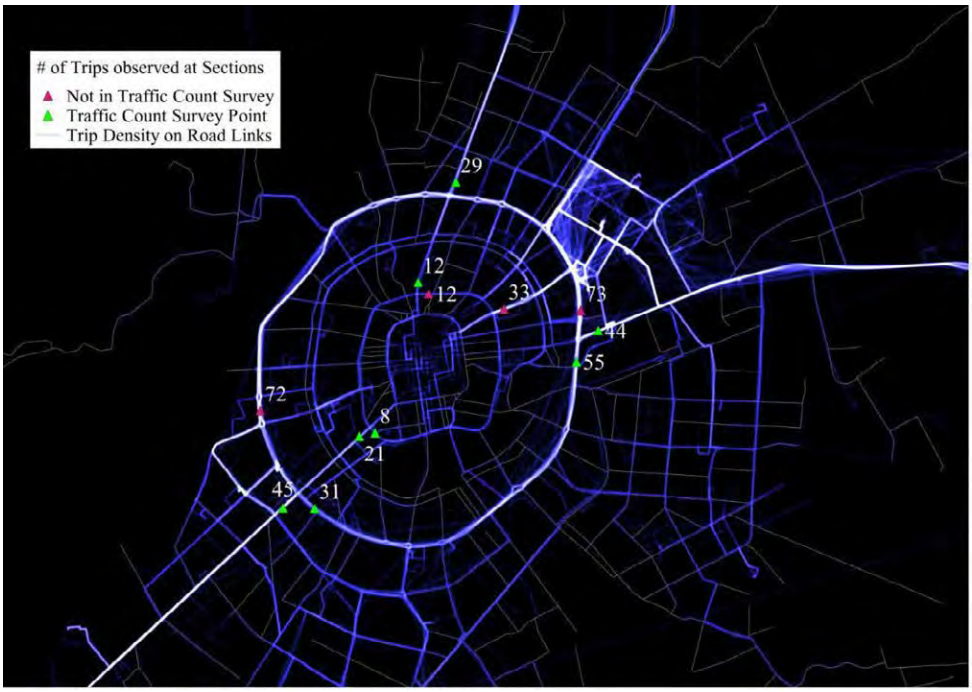


Figure 5-59 Trajectory of freight vehicles in central area

5.8 Opinion Survey (Stated Preference Survey)

5.8.1 Methodology

The opinion survey was conducted to understand preference on new modes of public transportation such as a bus rapid transit (BRT) and a light rail transit (LRT) system. The survey was face-to-face paper-based interview survey by an interviewer. Contents of the interview are described below.

(1) Personal Attributes

Since the respondents of the survey were sub-sampling of the HIS/CS, minimum information to identify a household and a member were collected.

(2) Explanation on the New Transit System

The interviewer explained the new transit system to the interviewee in detail including the punctuality, safety condition, air-condition, operation headway (frequency), congestion in the vehicle and access/egress to the station. Images of train and bus coaches used for the interview are shown below.

Source: JICA Study Team, http://indiatoday.intoday (right)

Figure 5-60 Image of LRT BRT utilized for the opinion survey

Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan

Figure 5-61 Image of congestion level in a coach utilized for the opinion survey

(3) Question on Preference of New Public Transportation Modes

Interviewees answered their willingness to change the transportation mode for 24 questions, which consist of eight cases and three purposes. Each case had different assumptions on travel time, fare, number of transfer, and a new public transportation mode (BRT or LRT). The three purposes are the trip from home to work/school place, private, and business.

(4) Sampling

The number of samples is 2,000 persons in total. 1,000 households of the HIS/CS respondents were sub-sampled considering the income distribution. Two persons were surveyed from one household. The opinion interview survey was conducted from January to April 2017.

5.8.2 Results

(1) Number of Samples by Current Transport Mode

Table 5-15 shows the number of respondents by purpose and by current transport mode[1]. Because not all respondents answered questions for three trip purposes, the number of respondents is different by purpose. The number of answers for business purpose question was very small, so it is not shown in the table and not analyzed in the following section. Mode category is summarized as shown in Table 5-16 following the "Combined Mode of Transport" in Table 5-15. In addition to the number of respondents, the percentage of the answer="2 New Transportation" is calculated. Because the percentage of "2 New Transportation" is very small for Non-Motorized transport mode users, it is concluded that they would not shift to the new mode.

Considering the number of samples and the percentage of "2 New Transportation", the modal shift models were developed for only Motorcycle, Car and Public Transport in the following sub-section.

[1] When the respondents used several modes for their trip, main mode was defined with the following rule, Micro > Trufi > Torito > Moto Taxi. Only this combination was observed in the survey.

Table 5-15 Number of Respondents by Purpose by Current Transport Mode

	Current Transport Mode	Combined Mode of Transport	Work/School	Private Maters
1	Walking	Non-Motorized Trip	51	75
2	Bicycle	Non-Motorized Trip	0	2
3	Motorcycle driven by the respondent	Motorcycle	14	8
4	Motorcycle driven by the other person	Motorcycle	4	4
5	Sedan/Jeep/Minivan driven by the respondent	Car	85	74
6	Sedan/Jeep/Mini Van driven by the other person	Car	22	23
7	Private van handled by the respondent	Others	0	0
8	Private truck driven by another person	Others	1	0
9	Employee Transportation	Public Transport	2	0
10	School transportation	Public Transport	9	0
11	Moto Taxi	Public Transport	3	4
12	Torito	Public Transport	2	1
13	Cab	Public Transport	6	16
14	Trufi	Public Transport	23	28
15	Mini Bus	Public Transport	3	1
16	Micro	Public Transport	703	480
17	Fleet (for long distance)	Others	0	0
18	Medium truck	Others	0	0
19	Big truck or trailer	Others	0	0
20	Others	Others	0	0
99	Unknown		91	303
	Total		1019	1019

Source: JICA Study Team

Table 5-16 Number of Respondents by Purpose by Current Transport Mode (Summarized)

Current Mode	**Work/School**	**Private**	**% of Answer="2 New Transport" Work/School and Private**
Non-Motorized Trip	51	77	1%
Motorcycle	**18**	**12**	**13%**
Car	**107**	**97**	**8%**
Public Transport	**751**	**530**	**19%**
Others	1	0	50%
N/A	91	303	
Total	1019	1019	

Source: JICA Study Team

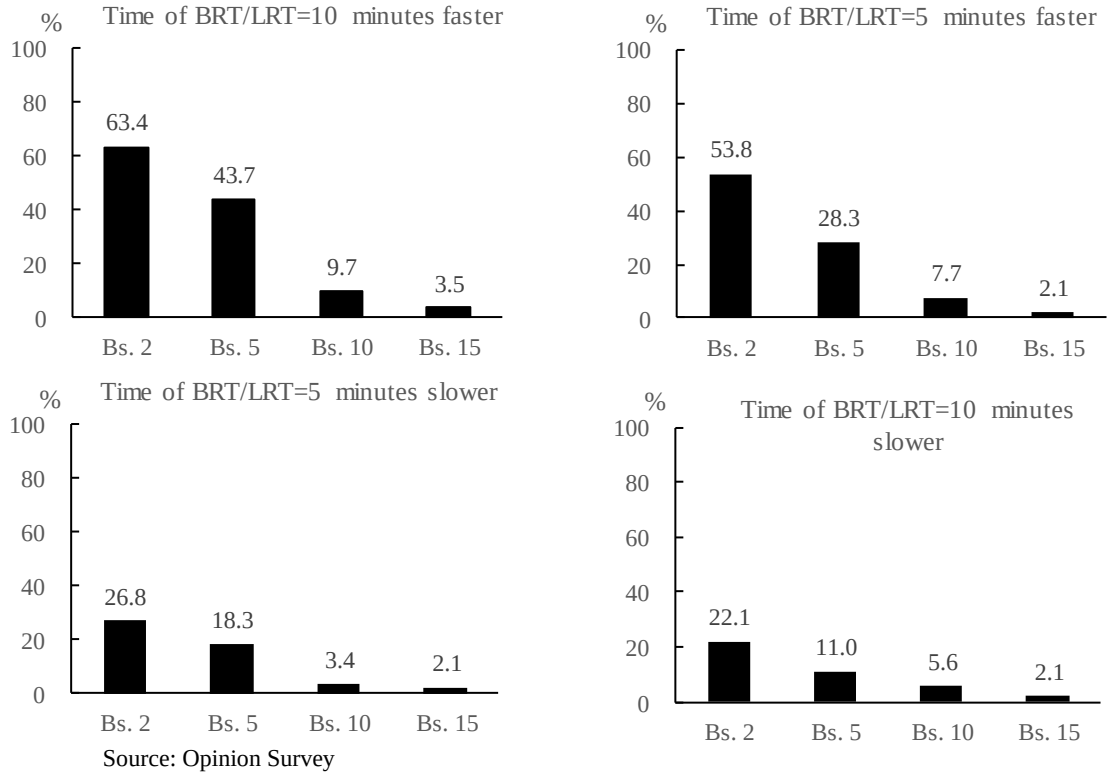
(2) Willingness to Shift to BRT or LRT

Figure 5-62 shows the willingness to shift from the car to BRT or LRT by the travel time reduction. The charts in the figure show that if BRT or LRT is faster than the car with the fare of Bs.2, 63.4% of car users is expected to shift to the new public transport system. Even if it is 10 minutes slower than the car, 22.1% of car users is expected to choose the new public transport system.

Figure 5-63 shows the willingness to shift from the car to BRT or LRT by the fare of the new system. The charts in the figure show that car user would not shift to the new public transport system if the fare is Bs.10 and more.

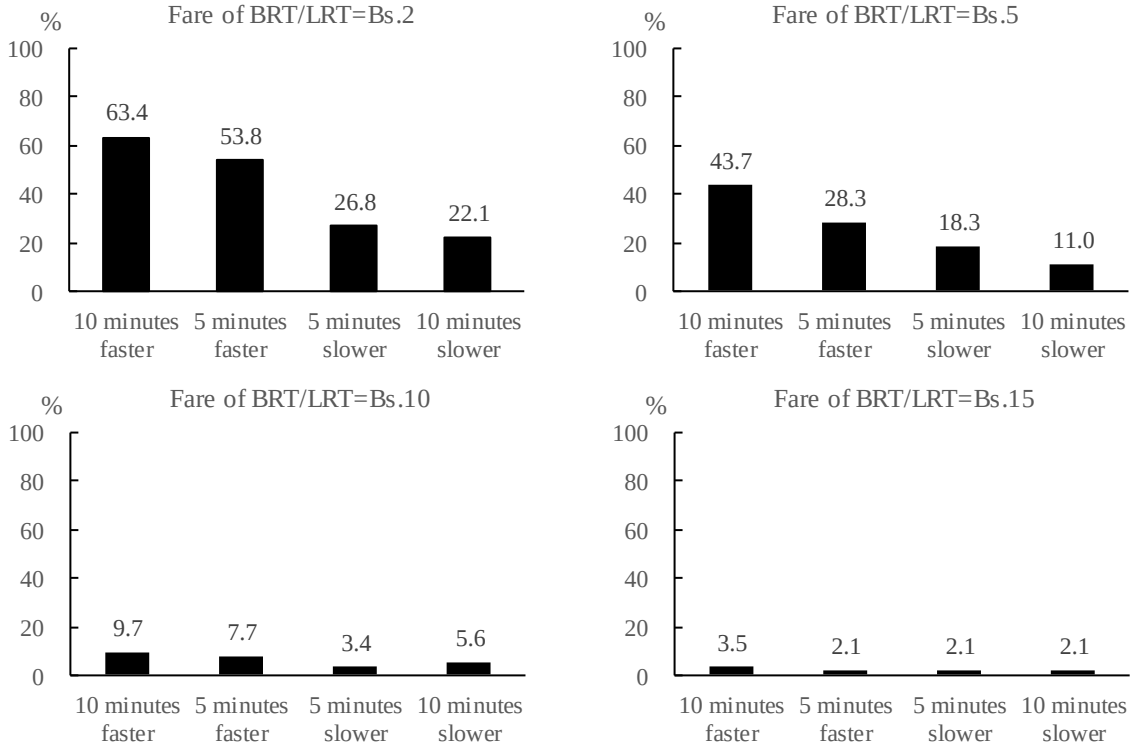
Figure 5-64 shows the willingness to shift from the microbus to BRT or LRT by the travel time reduction. Even if the new transport system is slower than the microbus, approximately 40% of the passengers are expected to shift to BRT or LRT.

Figure 5-65 shows that microbus passengers would not shift to the new public transport system if the fare is Bs.10 and more even if it is faster than the microbus.



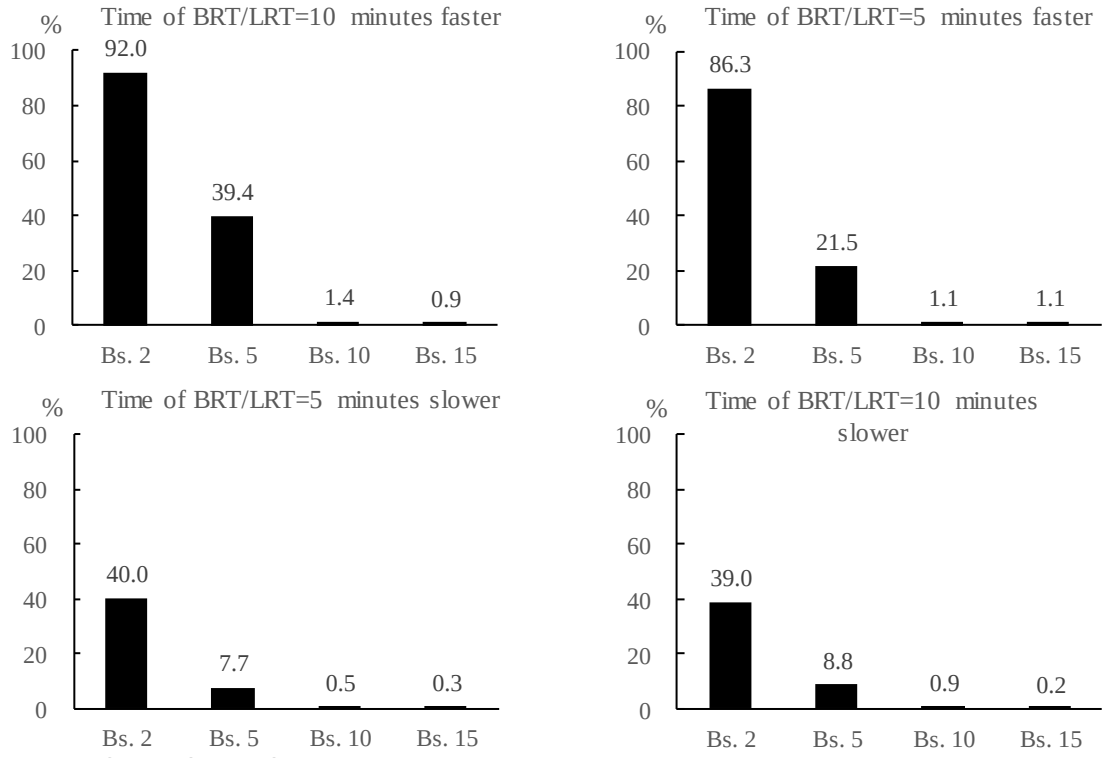
Source: Opinion Survey

Figure 5-62 % of Willing to Shift from Car to BRT/LRT by Fare



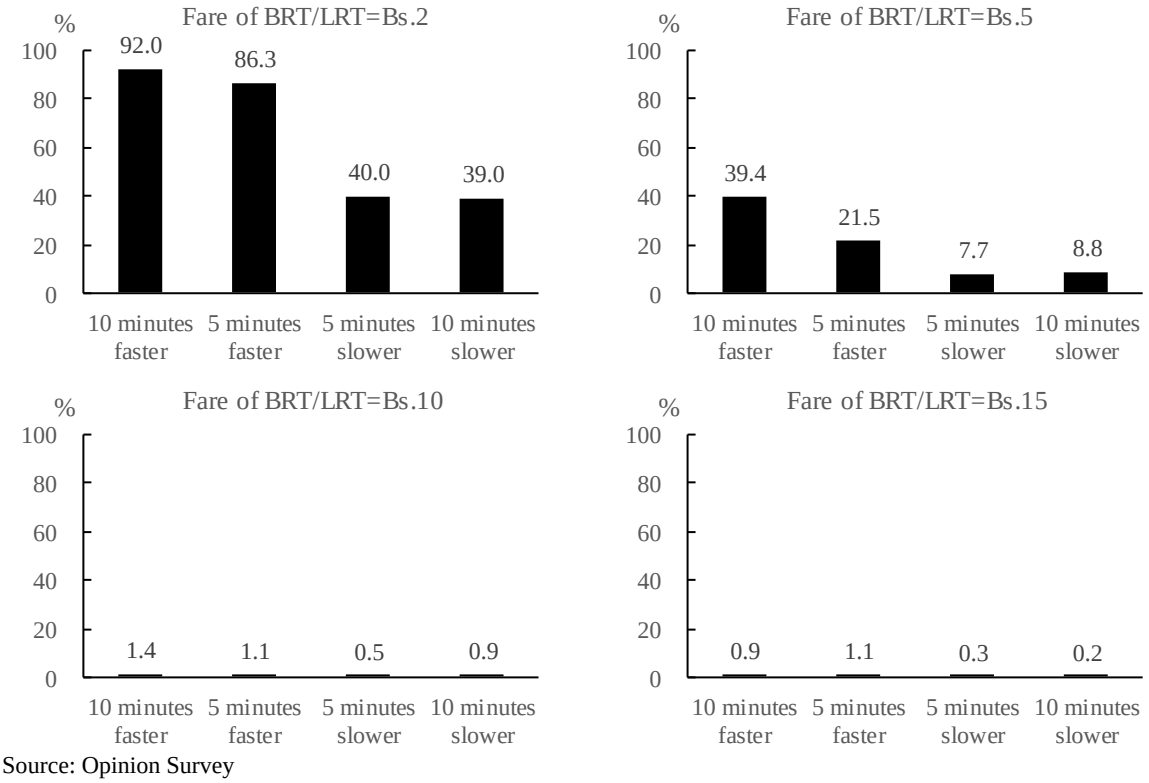
Source: Opinion Survey

Figure 5-63 % of Willing to Shift from Car to BRT/LRT by Travel Time Reduction



Source: Opinion Survey

Figure 5-64 % of Willing to Shift from Microbus to BRT/LRT by Fare



Source: Opinion Survey

Figure 5-65 % of Willing to Shift from Car to BRT/LRT by Travel Time Reduction

5.9 Occupancy Survey

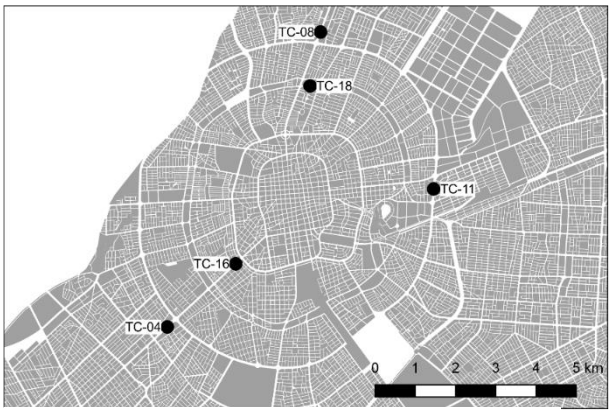
5.9.1 Survey Condition

(1) Location and Period

Five locations are selected for occupancy survey from the traffic count survey locations as shown in Figure 5-66. The survey was conducted from 6:00 to 22:00 on 29th of June 2016.

(2) Methodology

One or two surveyors observed the number of passengers from the roadside and recorded it to the survey form. Since it is not possible to observe for all vehicles passing through, surveyors randomly selected and counted the passengers in the vehicle. In case of minibus and micro, surveyors observed congestion rate, which is 100% when all seats were occupied, and the standing space was also fully occupied.



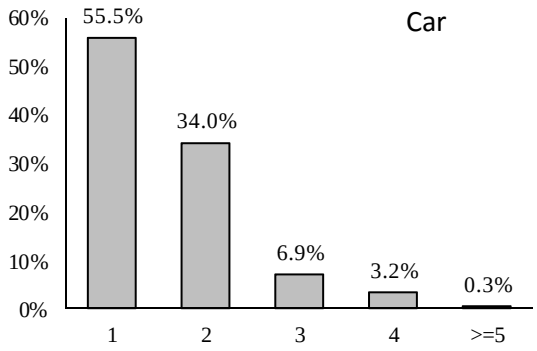
Source: JICA Study Team

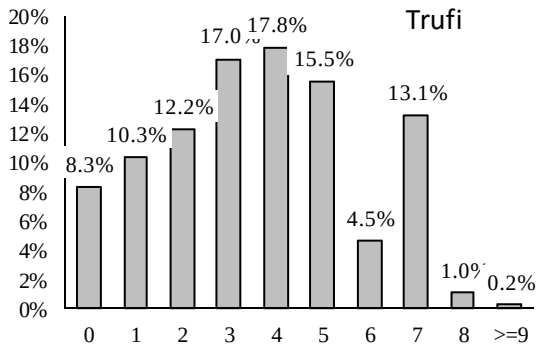
Figure 5-66 Occupancy Survey Location

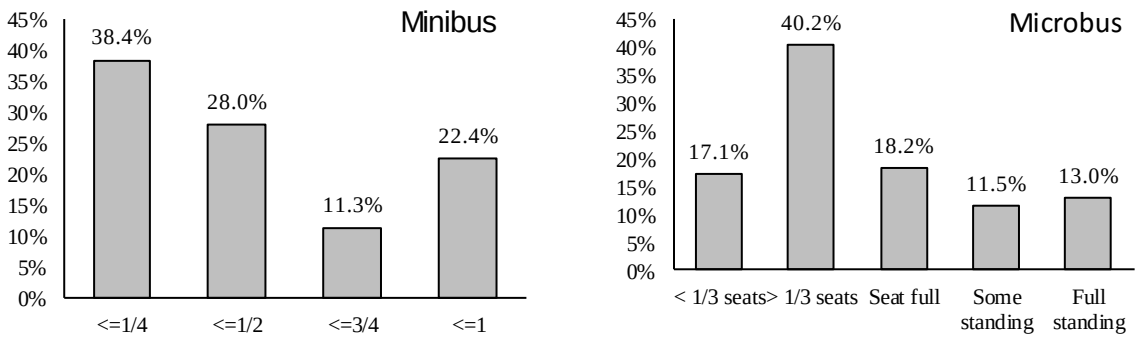
5.9.2 Survey Results

The distribution of occupancy is calculated by vehicle type as shown in Figure 5-67. The result shows that nearly 90% of auto carries only 1 or 2 passengers, including the driver. On the other hand, about 70% of trufis carries more than or equal to 3 passengers.

Regarding minibus, 22% of the minibus is fully occupied, but 2/3 of minibus has no more than half of its capacity. On the other hand, more than 80% of microbuses have passengers more than 1/3 of its capacity, and about 40% of them are fully seated.







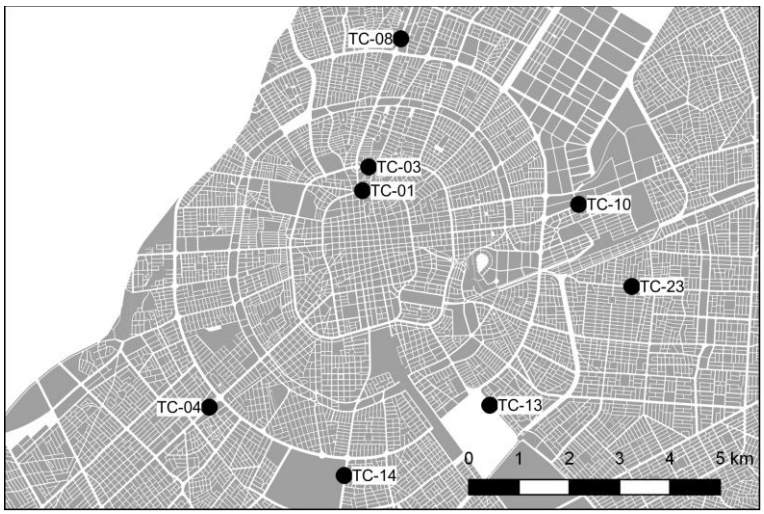
Source: JICA Study Team

Figure 5-67 Distribution of Vehicle Occupancy

5.10 Bus Frequency Survey

5.10.1 Survey Condition

10 locations were selected for the bus frequency survey from the traffic count survey locations as shown in Figure 5-68. The survey was conducted from 6:00 to 22:00 on 19th and 21st of July 2016.



Source: JICA Study Team

Figure 5-68 Microbuses and Minibuses Frequency Survey Location

5.10.2 Methodology

Surveyors recorded the route number and the time of all microbuses and minibuses that passed through the survey location by observation from the roadside.

5.10.3 Survey Results

The survey result is shown in Table 5-17.

Table 5-17 Number of Micro Bus Trips per Day by Bus Route

Bus Route	Number of Bus Trips		Bus Route	Number of Bus Trips		Bus Route	Number of Bus Trips		Bus Route	Number of Bus Trips	
No.	Daily	8:00 -9:00	No.	Daily	8:00-9:00	No.	Daily	8:00-9:00	No.	Daily	8:00-9:00
1	90	8	41	*	*	81	99	9	121	*	*
2	126	12	42	*	*	82	*	*	122	56	9
3	173	13	43	197	17	83	*	*	123	*	*
4	110	10	44	210	32	84	*	*	124	*	*
5	141	13	45	176	15	85	139	11	125	*	*
6	*	*	46	126	9	86	108	10	126	103	9
7	196	19	47	198	18	87	93	7	127	111	10
8	149	16	48	76	9	88	210	15	128	*	*
9	284	29	49	94	12	89	132	11	129	*	*
10	238	20	50	101	20	90	84	9	130	*	*
11	143	14	51	162	13	91	*	*	131	208	19
12	*	*	52	135	12	92	112	9	132	*	*
13	*	*	53	226	14	93	*	*	133	*	*
14	277	25	54	143	12	94	117	10			
15	268	25	55	222	23	95	*	*			
16	228	22	56	*	*	96	*	*			
17	456	43	57	*	*	97	82	7			
18	448	37	58	*	*	98	187	15			
19	*	*	59	135	9	99	141	13			
20	162	17	60	184	16	100	158	12			
21	161	12	61	63	4	101	*	*			
22	143	12	62	139	13	102	*	*			
23	122	9	63	95	7	103	172	14			
24	75	7	64	98	10	104	159	12			
25	119	12	65	49	3	105	90	8			
26	73	5	66	125	10	106	61	4			
27	*	*	67	163	15	107	*	*			
28	*	*	68	177	16	108	172	14			
29	*	*	69	139	9	109	75	7			
30	64	6	70	111	13	110	*	*			
31	123	8	71	72	6	111	35	3			
32	274	26	72	239	38	112	76	7			
33	155	17	73	232	21	113	81	8			
34	*	*	74	448	33	114	*	*			
35	*	*	75	*	*	115	86	8			
36	220	18	76	138	13	116	*	*			
37	241	21	77	177	14	117	*	*			
38	*	*	78	61	7	118	*	*			
39	122	13	79	*	*	119	222	21			
40	*	*	80	125	9	120	*	*			

Source: Bus Frequency Survey 2016

*: Not surveyed in Bus Frequency Survey

5.11 Travel Speed Survey

5.11.1 Survey Condition

(1) Survey Location

The survey was conducted along the arterial roads in the Santa Cruz de la Sierra. Both radial and ring roads are included in the survey routes. To capture the travel time during peak hour, one route was set to be no longer than 15 km so that probe vehicles can travel through one route within 60 minutes.

(2) Survey Period

The survey was conducted for the following three time periods on weekdays in July and August 2016.

- Morning Period (6:00-10:00)
- Lunch break Period (11:00-15:00)
- Evening Period (16:00-20:00)

(3) Methodology

Probe vehicles equipped with the GPS logger traveled along the survey routes, and collect the location, time and speed. The probe vehicle ran as many times as possible (maximum four rounds) in each period to collect travel speed data. Based on the collected data, the travel time of each route and section were calculated.

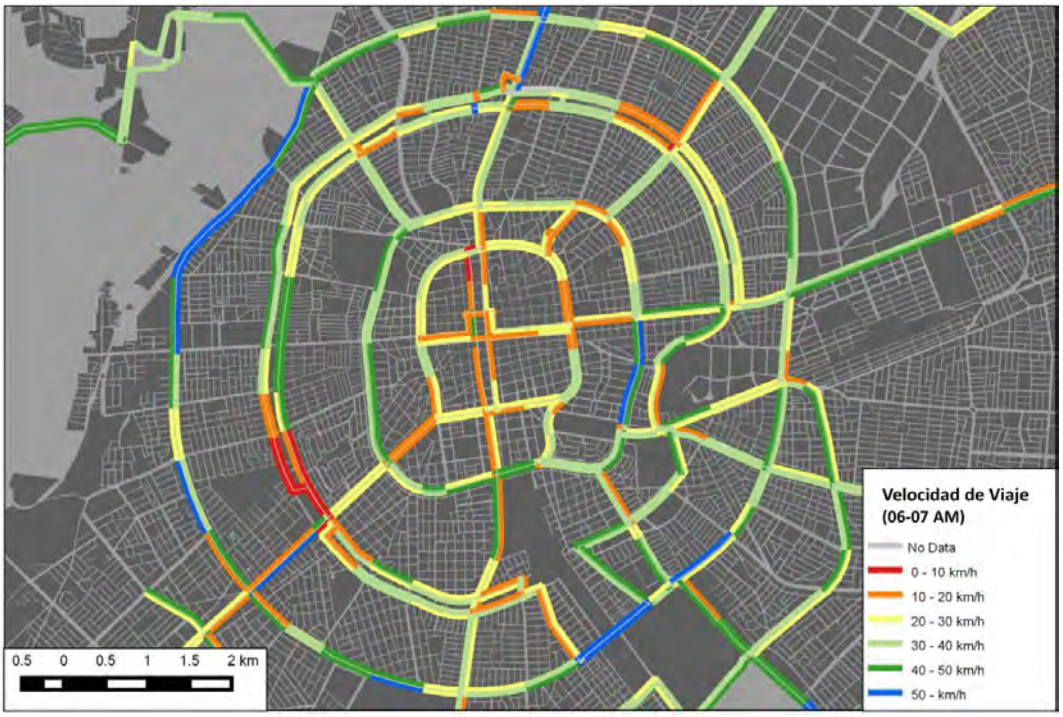
5.11.2 Survey Results

(1) Average Travel Speed on Arterial Road Sections

Figure 5-69 and Figure 5-70 show the average travel speed in the morning peak. The speed degradation started before 8:00 on the south-west part of 3rd Ring Road, and that congestion was not dissolved until the end of the survey. Between 8:00 to 10:00, the sections with average velocity less than 10 km/h spread in many sections.

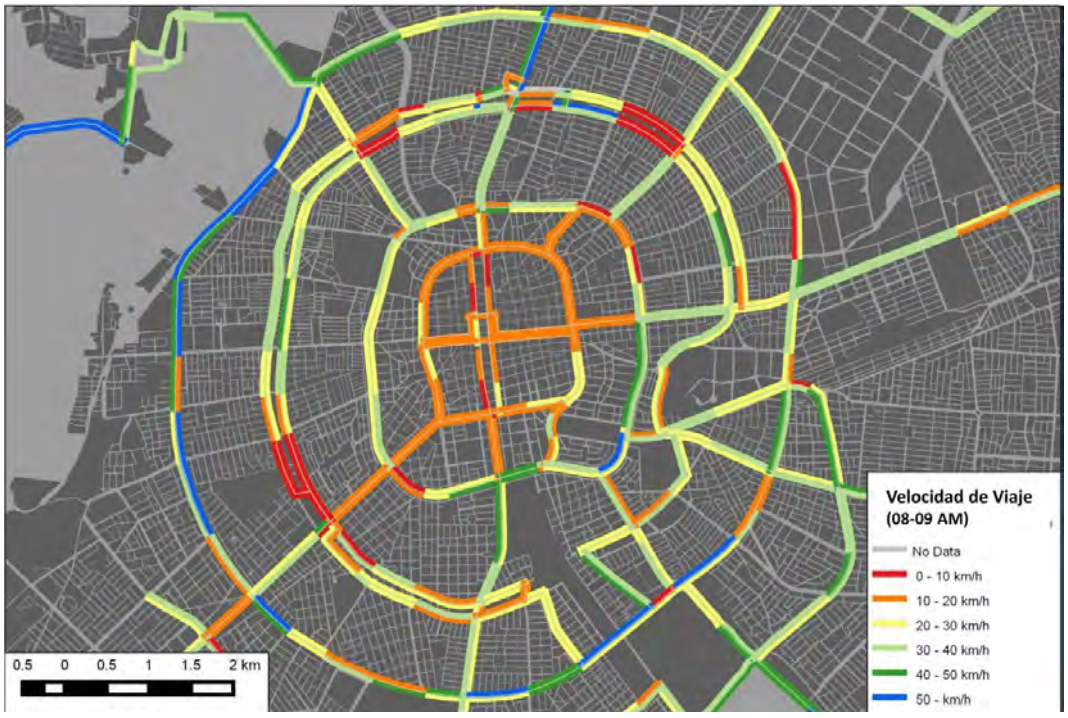
Figure 5-71 and Figure 5-72 show the average travel speed during the lunch break time. Between 11:00 and 13:00, the significant speed degradation is observed on 1st Ring Road and road sections in Centro.

Figure 5-73 and Figure 5-74 show the average travel speed in the evening peak time. The sections with the travel speed less than 10 km/h were continuously observed inside 2nd Ring Road.



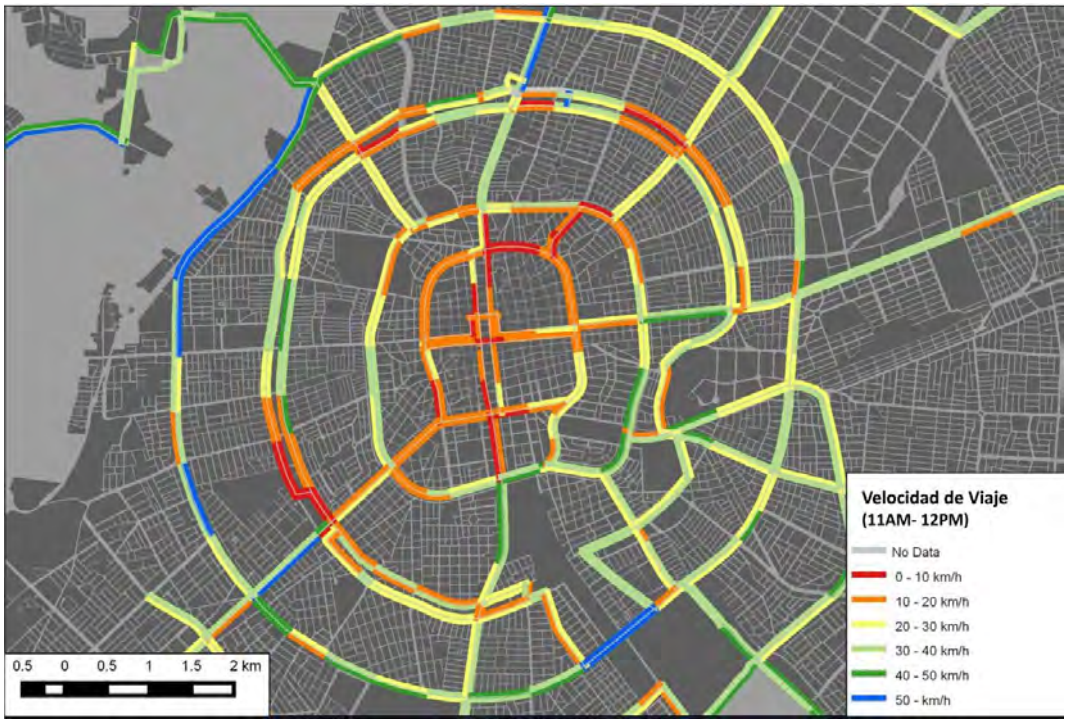
Source: JICA Study Team

Figure 5-69 Distribution of Vehicle Travel Speed (6:00-8:00)



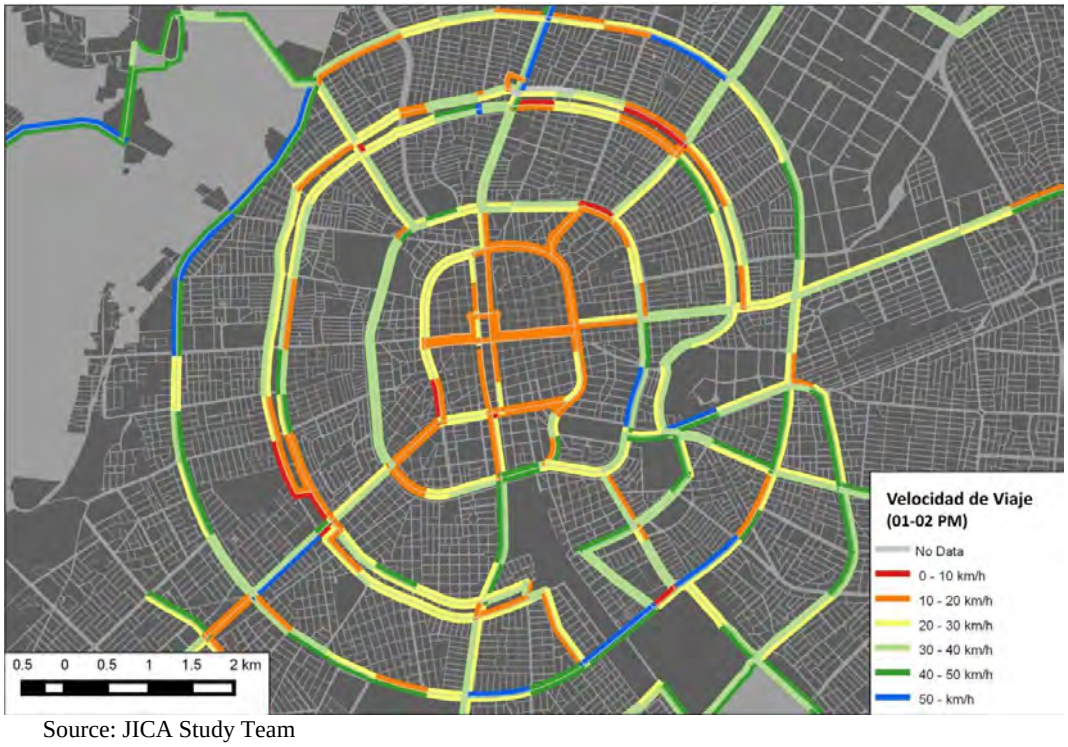
Source: JICA Study Team

Figure 5-70 Distribution of Vehicle Travel Speed (8:00-10:00)



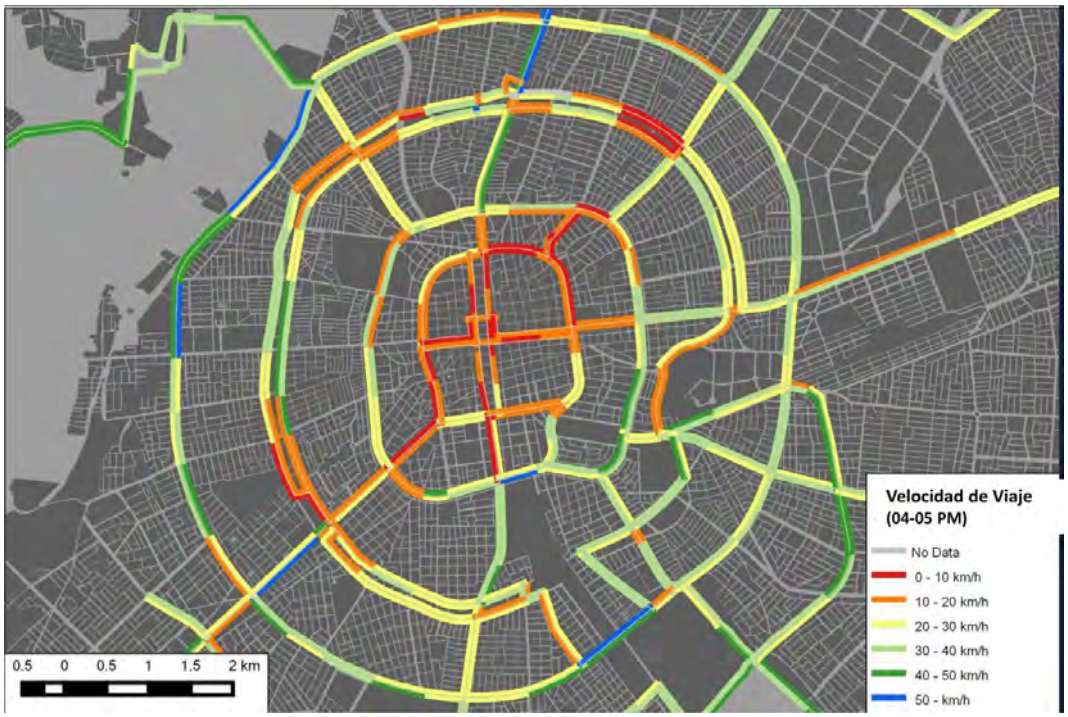
Source: JICA Study Team

Figure 5-71 Distribution of Vehicle Travel Speed (11:00-13:00)



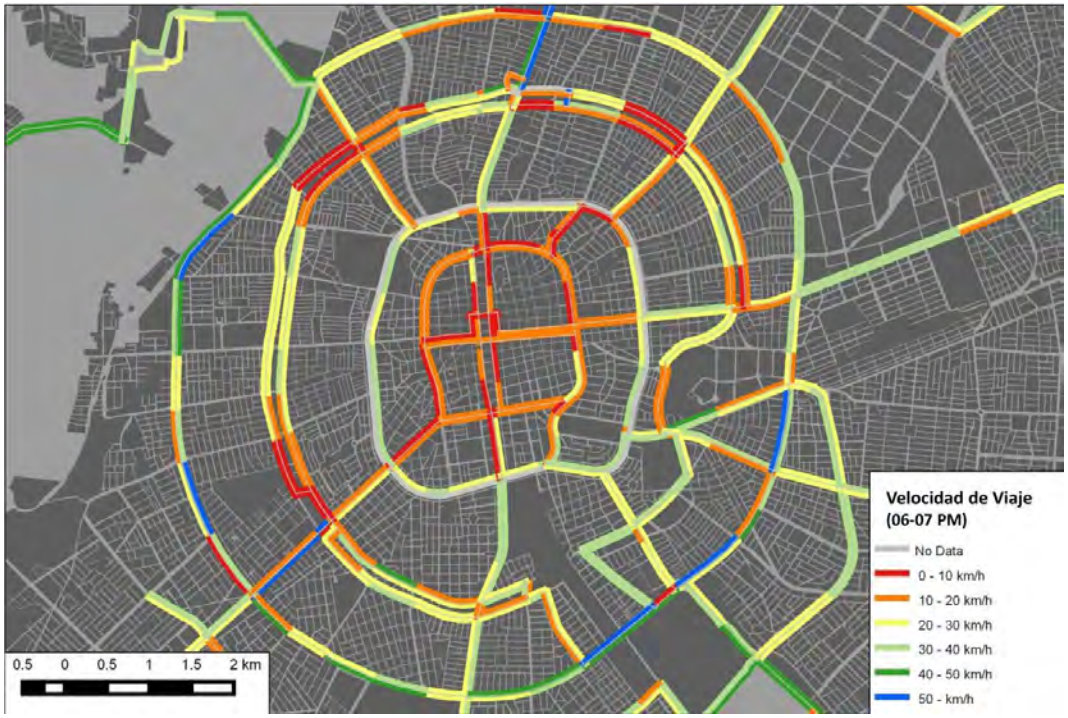
Source: JICA Study Team

Figure 5-72 Distribution of Vehicle Travel Speed (13:00-15:00)



Source: JICA Study Team

Figure 5-73 Distribution of Vehicle Travel Speed (16:00-18:00)

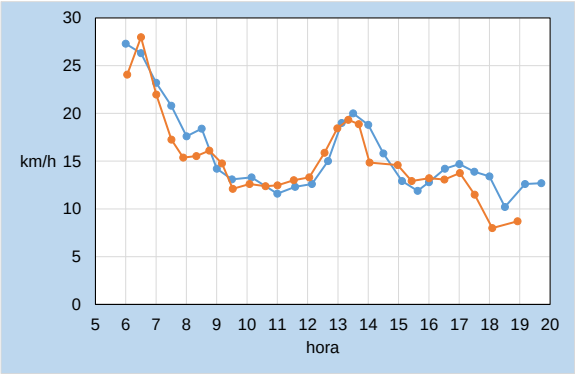


Source: JICA Study Team

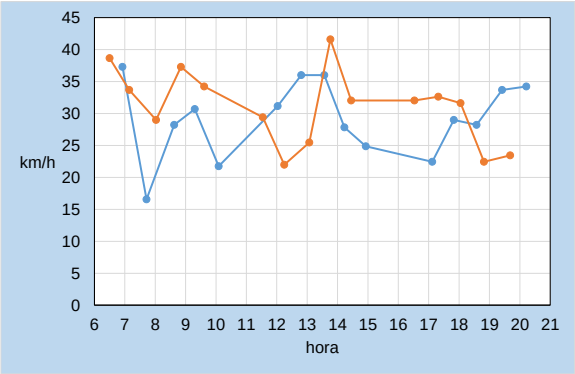
Figure 5-74 Distribution of Vehicle Travel Speed (18:00-20:00)

(2) Time-Series Variation of Average Travel Speed (Arterial Road)

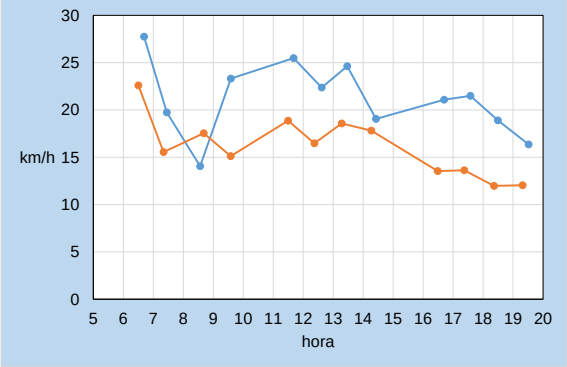
The average travel time in each hour in a day is shown in Figure 5-75.



1st Ring Road



Av. Cristo Redentor



Av. Grigota

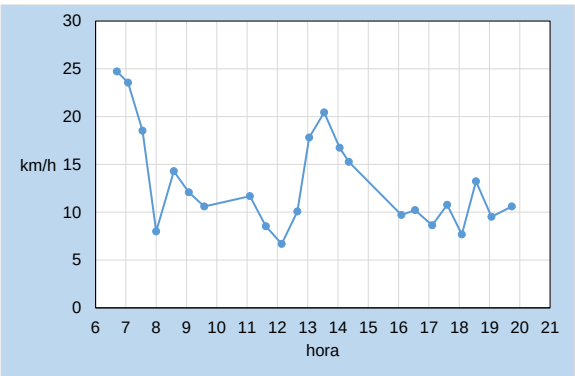
Source: JICA Study Team

Figure 5-75 Average Travel Speed

(3) Time-Series Variation of Average Travel Speed (Centro)

The average travel time of the road section inside 1st Ring Road is shown in Figure 5-76. The target road section is as shown in Figure 5-77.

There are similar characteristics among the four road sections. The average travel time reduced to 10 km/h or less than that of the lunchtime peak and evening peak hour. There are some differences between the north-south section and east-west section. For example, the severe speed degradation was observed in morning peak hour in the north-south section, but not observed in the east-west section.



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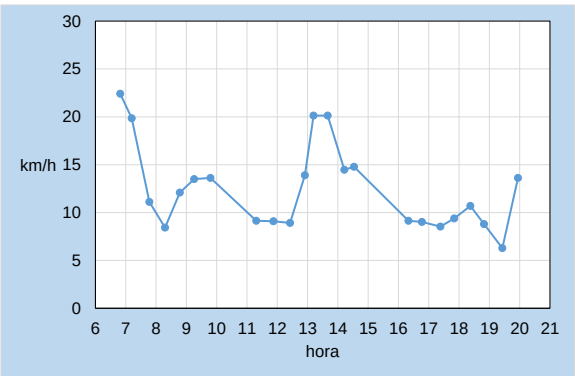
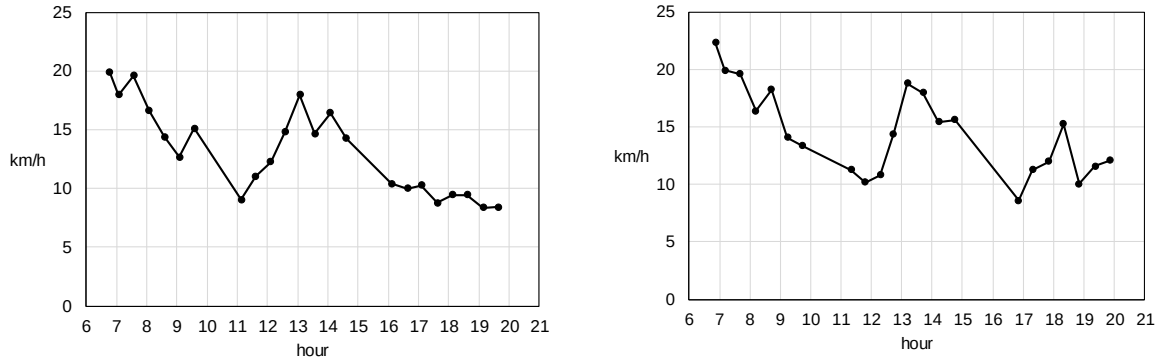


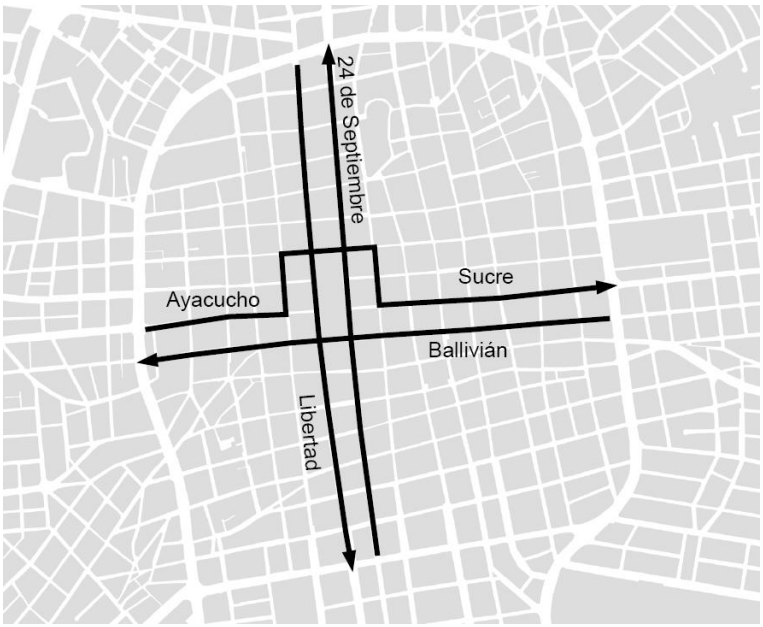
24 de Septiembre



Ayacucho-Sucre Balivián

Source: JICA Study Team

Figure 5-76 Average travel speed in the central area



Source: JICA Study Team

Figure 5-77 Target Roads inside the 1st Ring Road

5.12 Parking Survey

5.12.1 Survey Composition

The survey consists of three sub-components:

- License plate recording survey on the selected streets
- On-street parking survey in the central area
- Off-street parking survey in the central area

5.12.2 Methodology

(1) License plate recording survey on the selected streets

In the license plate recording survey, surveyors walked through the selected street and record the plate number of the vehicle in a 15-minute interval from 7:00 to 19:00. The surveyors take geotagged photographs of license plates. The survey was conducted on weekdays in

December 2016.

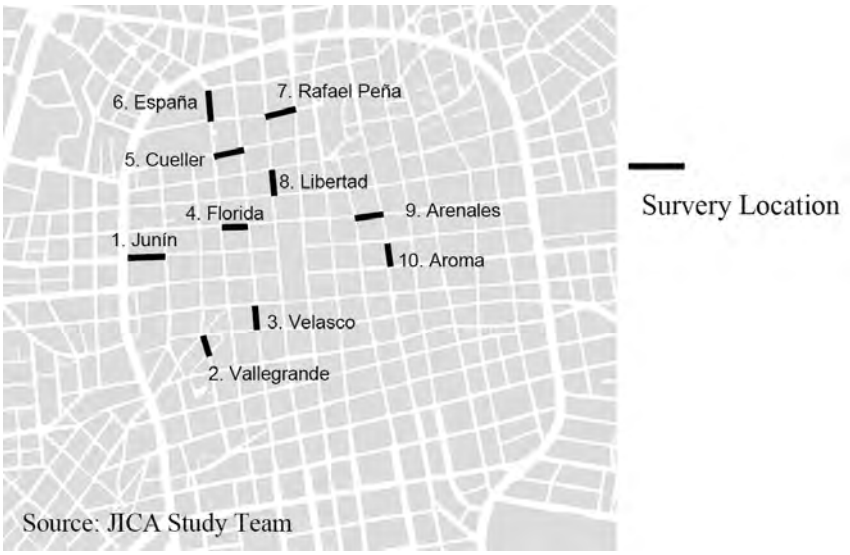


Figure 5-78 Location of license plate recording

(2) On-street parking survey in the central area

The survey was carried out from 15:00 to 17:00 on 29th of June 2016.

The number of parked cars on the streets in the central area was counted through observation from survey cars, which passed through the survey area. The surveyors also conducted video-shooting from survey cars to confirm the location of on-street parking. Surveyors added up numbers of parked cars for each section and recorded the following survey items based on the video-shooting and GPS logger data after the survey.

- Number of parked cars on the streets
- Number of cars violating parking rule on the streets
- Vehicle type of parked vehicles (car, bus, van, truck, others)

To survey all streets in the central area within two hours, two survey cars were used.

(3) Off-street parking survey in the central area

The number of parked cars in each parking lot inside the 1st Ring Road was counted through observation of the survey area. Surveyors recorded the following items using documents relating to the parking lot survey.

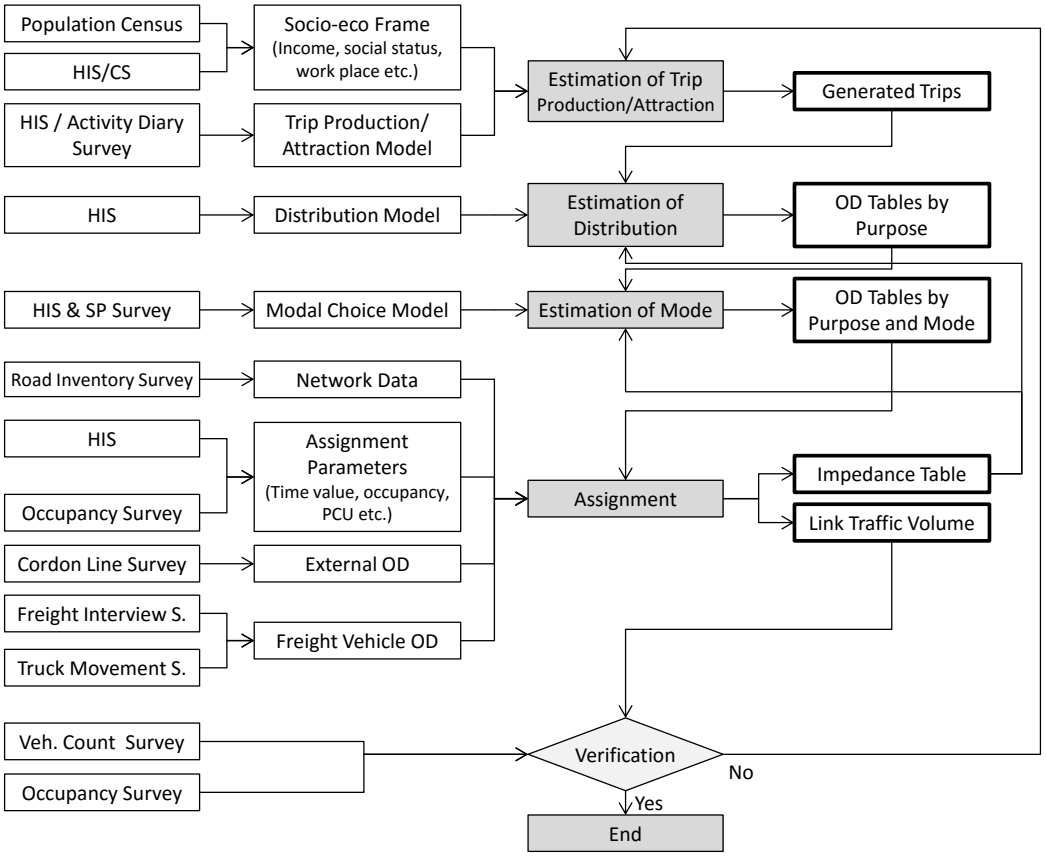
- Parking fee
- Structure of parking space (multi-story parking lot, ground-level parking lot, underground parking lot)
- Number of parked cars when surveyors visit
- Parking capacity

The off-street parking survey was carried out for two-hour peak period from 15:00 to 17:00 on 28th of June 2016.

Chapter 6 Travel Demand Forecast

6.1 Methodology

The four-step demand forecast model, which is one of the most popular demand forecast models, is applied, although there are some modifications to consider the particular conditions of the Project Area. The four-step demand forecast model consists of the following steps: 1) Trip Generation, 2) Trip Distribution, 3) Mode Choice, and 4) Trip Assignment. The demand forecast is done from 1) to 4), although there are some feedbacks from the result to the upper steps to consider the complex relationships. The overall flow of travel demand forecast, as well as relations with the traffic surveys conducted in the Project, is described in Figure 6-1.



Source: Elaborated by JICA Study Team

Figure 6-1 Estimation Flow of Travel Demand Forecast

The trip Generation model requires socioeconomic variables that explain the activity of each traffic zone such as the number of workers in their working places.

Based on the generated trips, travel impedance (ex. distance, travel time and travel cost) between each pair of origin and destination and Origin-Destination (OD) tables by trip purpose are estimated.

The OD tables by trip purpose by transport mode are estimated from the OD tables which are estimated in the trip distribution step and Modal Choice model.

Traffic and public transport assignment are conducted using the OD tables by trip purpose by transport mode, road and transit network data, and parameters for the assignment such as

vehicle occupancy, passenger car unit (PCU) and value of time.

A part of estimation steps from distribution to assignment requires an iterative calculation because the travel impedance table is estimated after the assignment. The estimated data has been verified with the results of the traffic count survey.

6.2 Zoning

A zone is a geographical representation of the specific area in the Project Area for transport-related surveys and analyses. In the Project, two types of zones are defined depending on the purpose. For transport survey, the detailed zone called "Survey Zone" was defined for recording transport survey results. On the other hand, traffic analysis zone (TAZ) is defined for the travel demand forecast.

6.2.1 Survey Zone

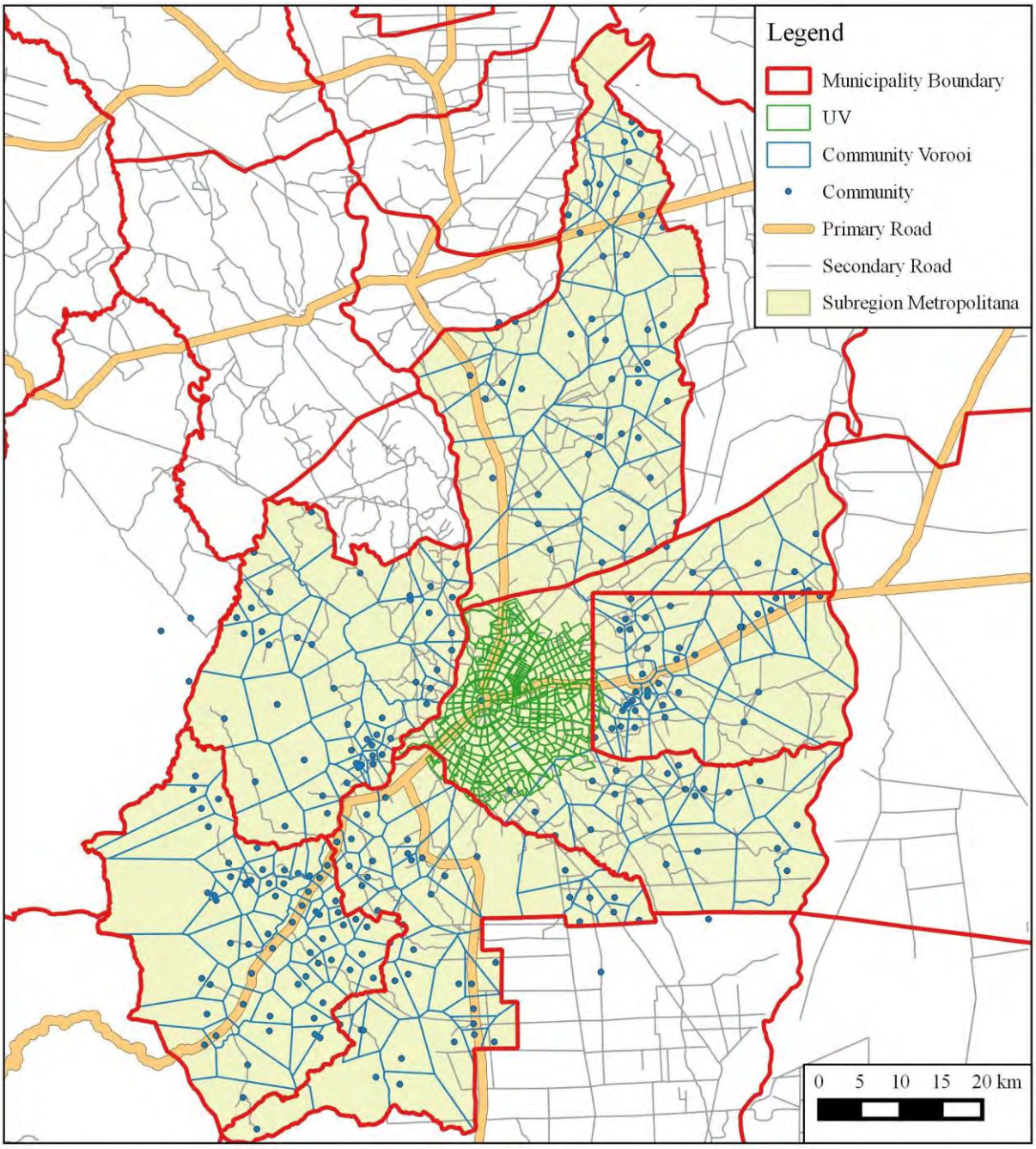
The survey zones are prepared for both urban area and rural area while the methods are different. The methods are described in the following subsections.

(1) Urban Area of Santa Cruz de la Sierra

For the urban areas of Santa Cruz de la Sierra, the detailed Survey Zone was defined considering dense population and urban activities. The zone is generally in line with *Unidad Vecinals*, *UVs* which are larger than *Manzanas* and smaller than *Distritos* (Districts). The boundaries of *UVs* were identified based on the GIS data provided by the Department of Santa Cruz. In addition, some *UV*s in the central area were divided taking population size and urban activity level into consideration. The boundary of UV is shown in Figure 6-2.

(2) Other Areas

The Survey Zone of the other areas including rural areas and urban areas of Warnes, Cotoca, La Guardia, El Torno and Porongo was defined based on the locations of *Comunidades* (Community), which were provided by the Department of Santa Cruz. As the original data contains only coordinates of one specific point in *Comunidades*, a Voronoi diagram, which defines regions based on the distance to each point, is created from the point data. Since the Voronoi diagram does not necessarily represent geographical features such as river, road, and mountain, the borders were adjusted with these features. In addition, some zones based on Voronoi of *Comunidades* were divided considering the volume of urban activities, settlement conditions as well as future development plans. The image of Voronoi-based survey zone is shown in Figure 6-2.

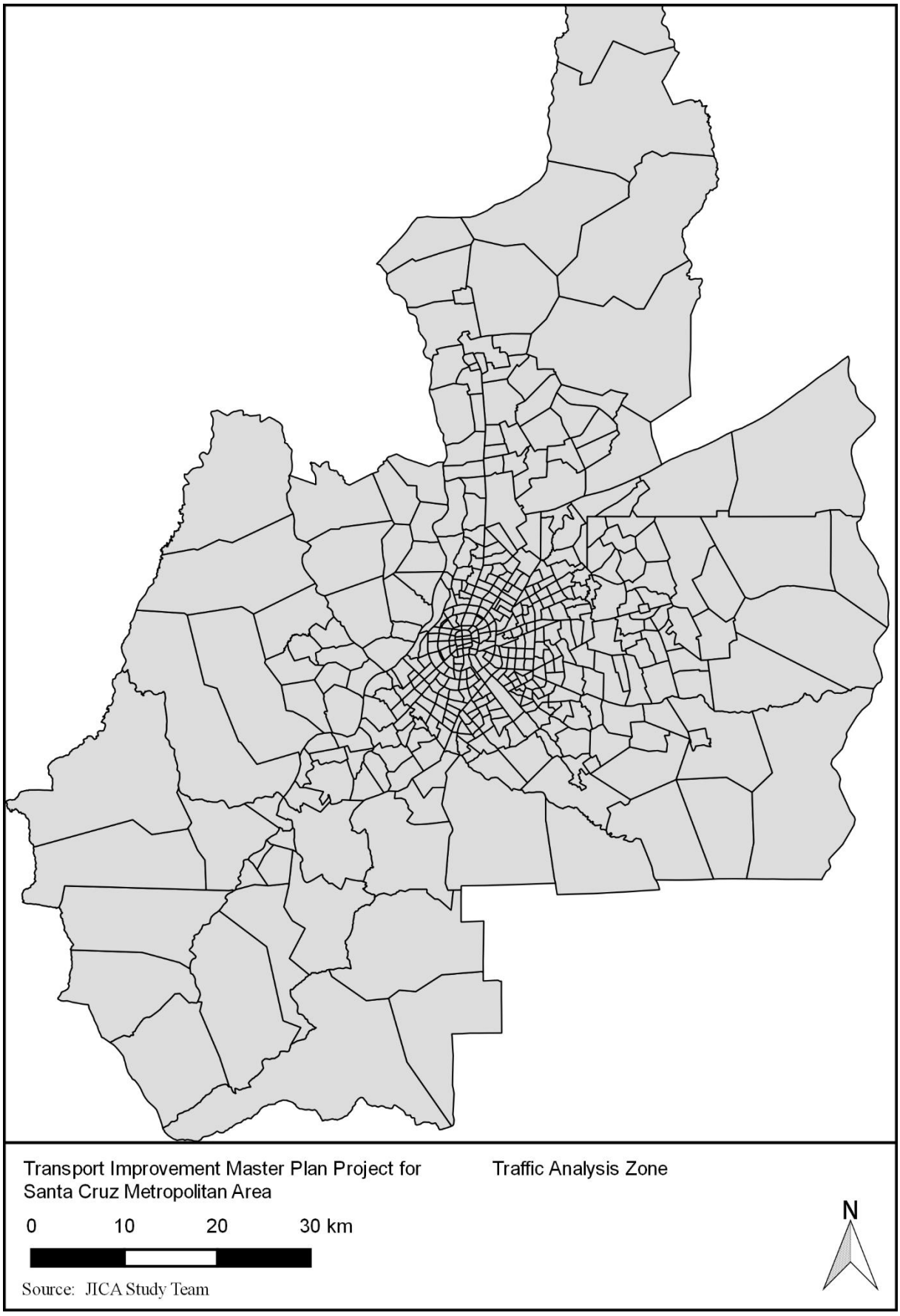


Source: Elaborated by JICA Study Team

Figure 6-2 UVs in Santa Cruz de la Sierra and Community Voronoi

6.2.2 Traffic Analysis Zone (TAZ)

The Traffic Analysis Zone (TAZ) were prepared by merging several Survey Zones considering the simulation time and consistency with the road network. The TAZ and road network should be consistent in terms of density of road network and zone size because the results of the traffic assignment will be inaccurate if the TAZ is too large or too small compared to the road network. Figure 6-3 shows the TAZ.



Source: Elaborated by JICA Study Team

Figure 6-3 Traffic Analysis Zone

6.2.3 Socio-economic Framework

(1) Modeling of Market Relocation

To consider the market relocation project, the projected number of employees at the workplace was adjusted as shown in Table 6-1.

Table 6-1 Adjustment of Zone Attributes for Market Relocation

TAZ	Market Name	Changing in the number of employees at workplace
170	Loz Pozos (existing)	-2,700
176	La Ramada (existing)	-4,000
38	Abasto (existing)	-1,200
66	Los Pozos (new)	+2,700
158	La Ramada (new)	+4,000
166	Abasto (new)	+1,200

Source: JICA Study Team

(2) International Industrial Park in Warnes

The number of workers at the International Industrial Park in Warnes was estimated by assuming the average density of the number of workers would be 26 workers per hectare, which was as same as that of the industrial park of Santa Cruz de la Sierra.

Table 6-2 No. of Workers in the International Industrial Park in Warnes

TAZ	Area (ha)	Workers (2035)
431	750	19,500
432	1,000	26,000
Total	1,750	45,500

Source: JICA Study Team

(3) Variables

The following variables are used for the demand forecast model.

Variable Name	Description
Workers (O)	No. of workers at resident place
Workers (D)	No. of workers at workplace
School Children (O)	No. of school children at resident place
School Children (D)	No. of school children at school place
Students (O)	No. of students at resident place
Students (D)	No. of students at school place
Service	No. of workers of the service sector at workplace
Population	Population
Car-own	Car ownership rate

Source: JICA Study Team

6.3 Demand Forecast Model

(1) Trip Purpose

The trip purposes are categorized into the following group.

- HBW: Home-based Go to Work
- HBS1: Home-based Go to Primary and Secondary School

- HBS2: Home-based Go to Other Schools
- HBO: Home-based Other Trips
- NHB: Non Home-based Business Trips
- NHO: Non Home-based Other Trips
- HOME: Go to home

(2) Trip Generation

The trip generation was estimated by the trip purpose as shown in Table 6-3.

Table 6-3 Trip Generation Model

Production/ Attraction	Purpose	Model
Production	HBW	0.6849 * Workers (O)
	HBS1	0.8129 * School children (O)
	HBS2	0.7848 * Students (O)
	HBO	0.3453 * Population
	NHB	0.1542 * Workers (D)
	NHO	0.5981 * Workers (D) + 0.2453 * Students (D)
Attraction	HBW	0.8207 * Workers (D)
	HBS1	0.9119 * School children (D)
	HBS2	0.8764 * Students (D)
	HBO	3.384 * Service
	NHB	0.1542 * Workers (D)
	NHO	MAX(0.7483 * Workers (D) + 0.1935 * Students – 245, 0)

Source: JICA Study Team

Note that the market demand was added based on Table 6-1.

(3) Trip Distribution

Walk trips were excluded from the trip production and attraction before the trip distribution using the rates of motorized trips shown in Table 6-4.

Table 6-4 Motorized Trip Rates and Gravity Model Parameter

Purpose	Car own household	Non car own household	Parameter *a*
HBW	0.922	0.817	0.180
HBS1	0.600	0.466	0.608
HBS2	0.966	0.941	0.101
HBO	0.806	0.704	0.420
NHB	0.922	0.850	0.162
NHO	0.833	0.613	0.265

Source: JICA Study Team

The OD matrix by trip purpose was estimated by a gravity model using the following impedance function.

Impedance function: R(*distance*) = exp(*a* * *distance*)

Where, *a* is a parameter by trip purpose and distance is the distance between origin and destination zone in the network model. The parameters are shown in Table 6-4. The Home Trips were estimated by inverting the matrices of home-based trips.

(4) Mode Split Model

The trip by mototaxi was estimated for TAZs (288, 290, 292, 424, 429, 353, 364) using the following formula. The parameters of *a* and *b* are shown in Table 6-5.

The trip rate of mototaxi to motorized trips = $a + b$ * trip distance (< 5 km)

Table 6-5 Parameters of the Mototaxi Model

Purpose	Parameter *a*	Parameter *b*
HBW	0.225	-0.0296
HBS1	0.326	-0.0390
HBS2	0.250	0
HBO	0.250	0
NHB	0.150	0
NHO	0.225	-0.0332

Source: JICA Study Team

The modal share of car trips was calculated from the motorized trips excluding the mototaxi trips using the following formula:

Car trip rate (i) = Ci/{1+exp(U)}
U = *k1**(Tp-Tc)+*k2**F+*k3*

Where, Tp and Tc are travel time by public transport and car, respectively. F is the fare of public transport. C_0 is the parameter for car own households while C_1 is the parameter of non-car own households.

Table 6-6 Parameters of Mode Split Model

Purpose	C_0	C_1	*k1*	*k2*	*k3*
HBW	0.786	0.162	-0.1154	-0.02992	3.029
HBS1	0.509	0.102	-0.1154	-0.02992	3.029
HBS2	0.219	0.018	-0.1154	-0.02992	3.029
HBO	0.696	0.168	-0.1196	-0.1017	4.188
NHB	0.762	0.762	-0.1154	-0.02992	3.029
NHO	0.581	0.581	-0.1154	-0.02992	3.029

Source: JICA Study Team

(5) Peak Hour Trips

The OD matrices of the peak hour and off-peak hour were estimated by applying the peak rates shown in Table 6-7.

Table 6-7 Peak Rates

Purpose	Peak Rate (7:00–8:00)	Off-peak Rate (9:00–10:00)
HBW	0.375	0.0247
HBS1	0.552	0.0012
HBS2	0.254	0.0341
HBO	0.185	0.1238
NHB	0.166	0.0322
NHO	0.057	0.0578
HOME	0.030	0.0309

Source: JICA Study Team

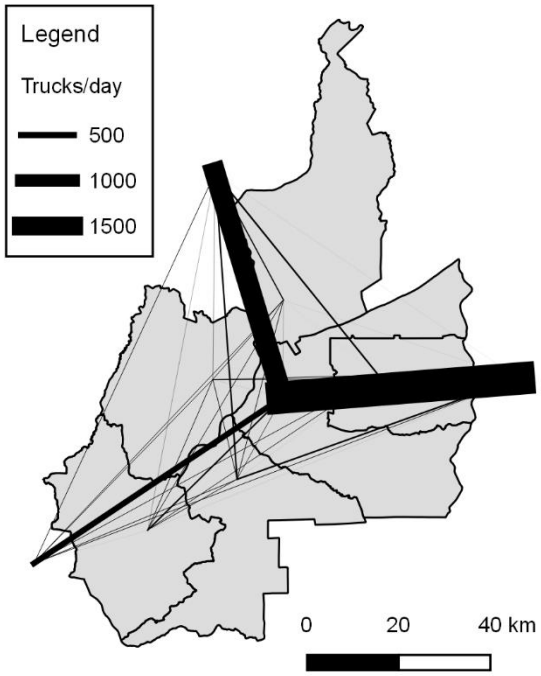
(6) Vehicle OD

The person OD matrix for cars was converted to the vehicle OD by applying a factor of 1.2 (1.2 persons per car).

The external OD estimated bases on the Cordon Line Survey was added to the OD matrices. Figure 6-4 illustrates the external truck OD.

For the freight trips, the production and attraction of truck trips were estimated by applying a trip rate of 0.1875 to Workers (D). The same distribution model (parameter is -0.162) was used to make the truck OD. A factor of 0.0979 was used to convert the daily matrix to both

peak and off-peak matrices.



Source: Cordon Line Survey

Figure 6-4 Desired Line of Trucks (External–External and External–Internal)

(7) Traffic Assignment

The car and truck OD were assigned to the road network by applying the user equilibrium assignment. A PCU factor of 2.0 was used for trucks. The following link cost function was used.

$$t(V) = T_0 \left\{ 1 + \alpha \left(\frac{V}{C} \right)^{\beta} \right\}$$

Where t(V) is the travel time of the link and T0 is that of free speed condition. V is the traffic volume in PCU, and C is the capacity of the link (Table 6-8). Parameters of *a* and *b* are 6 and 3, respectively. The tariff at the toll gates on the Fundamental Roads was not considered because the tariff is small.

The OD matrix for the public transport was assigned to the transit network applying the algorithm in Cube Voyager. Multiple routes were evaluated by the probability that was calculated based on the generalized costs. The value of time of Bs. 12 per hour was used. The formula of the probability in Cube Voyager is like a logit model as:

$$\frac{\exp(-\lambda GC_i)}{\sum_k \exp(-\lambda GC_k)}$$

Where CGi is the generalized cost of the route *i*, and λ is the parameter. The default value (0.2) in Cube Voyager was used for the parameter. The present fare was used for the public transport systems except for the BRT. Network Model

6.3.2 Road Network

A network data in a demand forecast model is a simplified model of the transport system of the real world, consisting of links, nodes, and public transport routes. The network data of the Project consists of arterial roads and other important roads such as radial and ring roads. It does not necessarily include all roads and streets because the resolution or level of detail should be consistent with the zone system. The network data was developed in the format of the ESRI Shapefile based on the Road Inventory Survey, and it was converted to the Cube Voyager format.

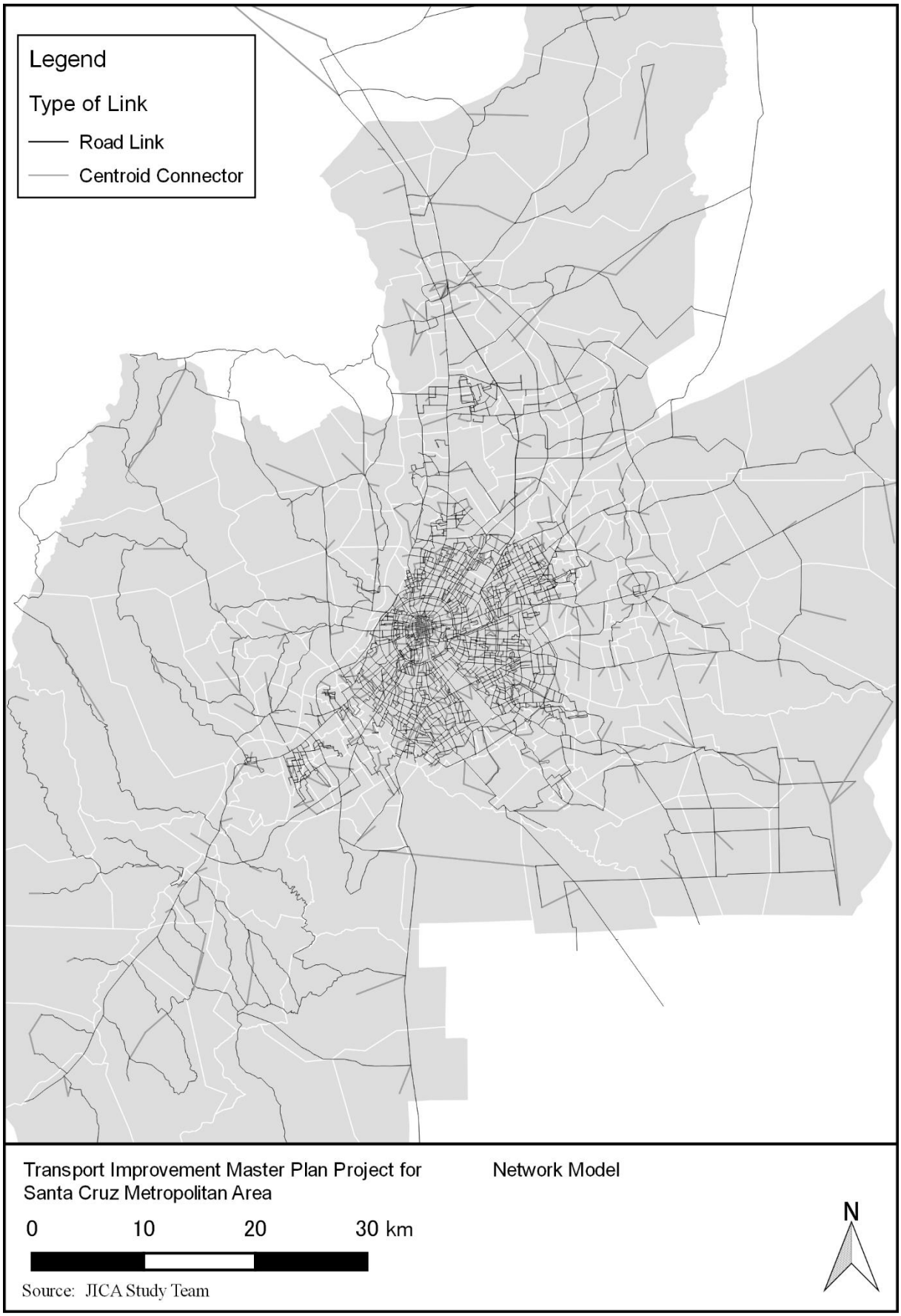
Table 6-8 shows the attributes of the links.

Table 6-8 Link Attributes

Road Type	Code	No. of lanes	Speed (km/h)	Capacity (PCU/hour)
Urban roads in the central area	11	1	20	900
	12	2	20	1800
	13	3	20	2700
	14	4	20	3600
	15	1	20	900
	16	2	20	1800
	17	3	20	2700
	18	4	30	3600
	19	5	30	4500
Urban roads in suburban areas	21	1	40	1200
	22	2	50	2400
	23	3	60	3600
	24	4	60	4800
	25	1	50	1350
	26	2	60	2700
	27	3	60	4050
	28	4	60	5400
	29	5	60	6750
Urban multi-lane highways	31	2	80	2850
	32	3	80	4275
	33	4	80	5700
Rural multi-lane highways	41	2	80	2850
	42	3	80	4275
Two-lane highways	51	1	40	1125
Unpaved roads	61	1	20	600
	62	2	30	1200
	63	3	30	1800
	64	4	10	2400
Local streets	71	2	15	500
	999	-	15	1000

Source: JICA Study Team

The developed road network for network assignment is shown in Figure 6-5.



Source: Elaborated by JICA Study Team

Figure 6-5 Road Network for Assignment

6.3.3 Transit Network

(1) Travel Speed

The travel speed of microbuses and buses except for the BRT was calculated as:

Table 6-9 Bus and Microbus Speed in Transit Assignment

Link speed after the traffic assignment (CSPD)	Bus and microbus speed (km/h)
CSPD <= 20 km/h	CSDP
20 < CSPD <= 40	20+0.6*(CSPD-20)
40 < CSPD	32

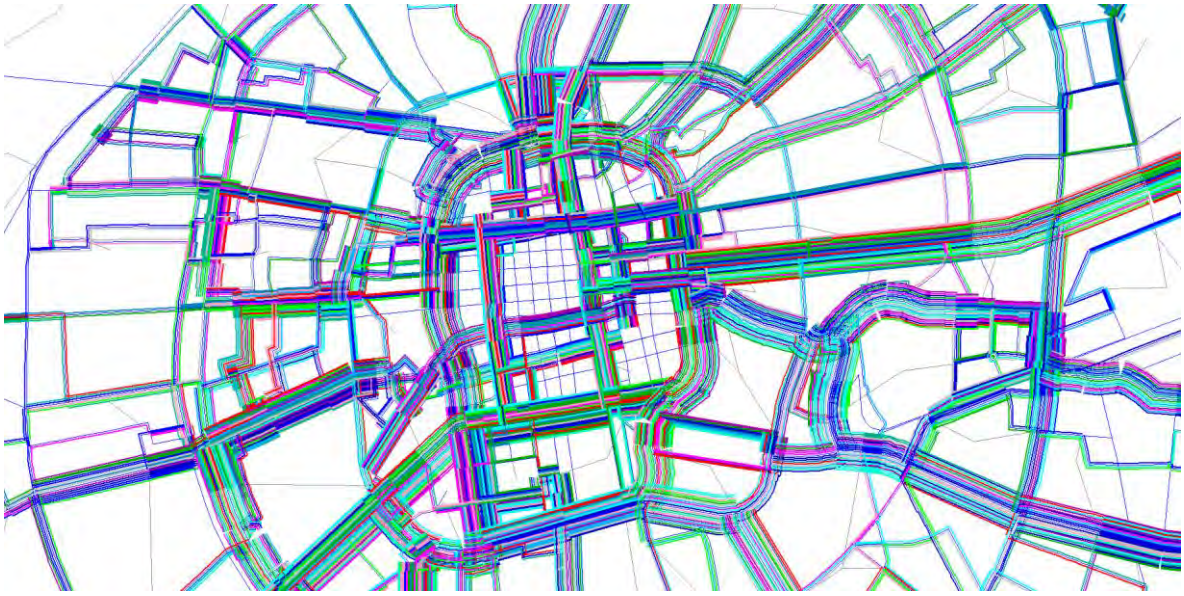
Source: JICA Study Team

(2) Present public transport network

The public transport modes to be modeled are the microbus, minibus, railway, and trufi. The network data of public transport system includes routes, frequency, fare, and capacity based on the occupancy survey on buses.

All microbus routes registered in the municipality of Santa Cruz de la Sierra were inputted into the transit assignment model, although some duplicated or similar routes were removed from the model.

In case of zones where no public transport service is provided, dummy routes were added to the transit network model so that the public transport passengers from or to such zones can be appropriately assigned to the network.



Source: public transport network shown in Cube Voyager

Figure 6-6 Public Transport Network for Assignment (Central Area)

(3) Public transport network for the Master Plan

As described in Chapter 7, the Master Plan proposes the radial and circular network for the public transport services. The future transit network was prepared to satisfy the policy of the public transport in Chapter 7 as much as possible. However, it is not possible to apply the principal of radial-circular network and trunk-feeder system to all roads in the Metropolitan

Area, and it was necessary to put direct service routes and isolated routes to cover the area.

6.4 Results of the Demand Forecast

6.4.1 Present and Future Demand without Projects

The traffic assignment for the AM peak hour in 2016 is shown in Figure 6-7. The assigned traffic was compared with the results of the traffic count surveys, and the parameters were calibrated.

Figure 6-8 shows the assigned passenger volumes in the peak hour for the present (2016) situation and the future (2035) situation of without projects. In the demand forecast model, the passenger demand is assigned only along the routes of public transport. Although there are many public transport routes in the Metropolitan Area, passengers are concentrated on some corridors

To see the impact of the increase in private cars, an extreme case was analyzed in which all public transport passengers are assumed to use private cars. Figure 6-9 shows the results of the assignment. The result clearly shows that it is not possible that all people use private cars for their trips in the present road network.

6.4.2 Future Demand

Figure 6-10 shows the desired lines of the demand forecast in 2035, estimated based on the socio-economic framework of Option 2B. The desired line represents the demand between two zones, which shows an OD matrix visually.

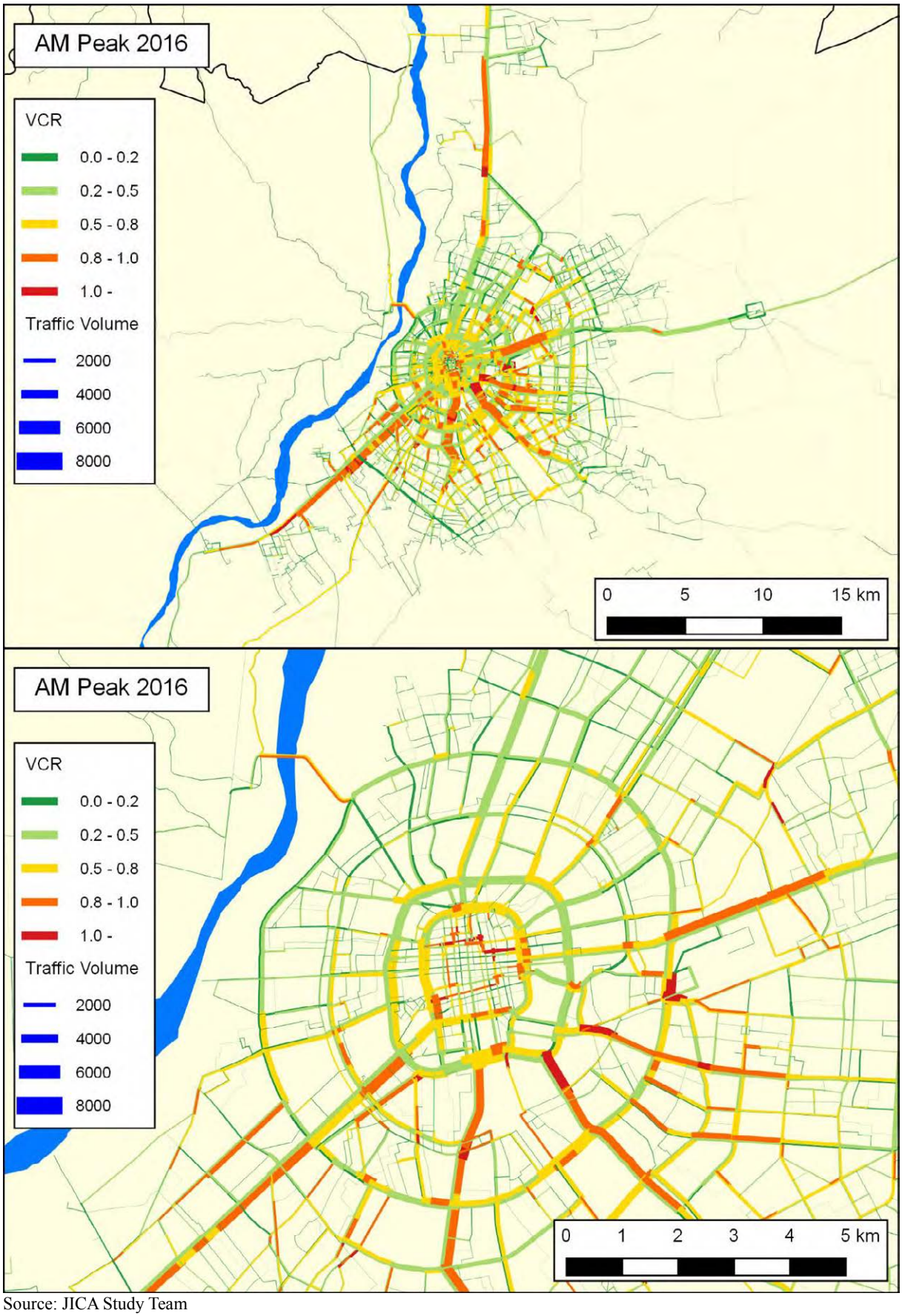
The result of the traffic assignment in 2025 is shown in Figure 6-11, which shows that the congestion remains in the peak hour. As analyzed in Chapter 7, improvement of the traffic situation by the Master Plan is significant compared with the without project case.

The traffic assignment for the Master Plan in 2035 is shown in Figure 3-30 of Chapter 3, as the result of the "Option 2B". The peak hour situation in 2035 is similar to that of present condition in spite of the population increase. The Master Plan will contribute to reducing the traffic congestion in 2035. This is further analyzed in Chapter 7. Figure 6-12 shows the result of the traffic assignment in 2035 focusing on the central area. The demand forecast model can produce the passenger volume information by public transport route. Figure 6-13 shows the result of the demand forecast of the BRT systems in 2020.

Figure 3-29 of Chapter 3 shows the case of "Option 1A", in which the future urbanized area is expanded, but no road development is taken place.

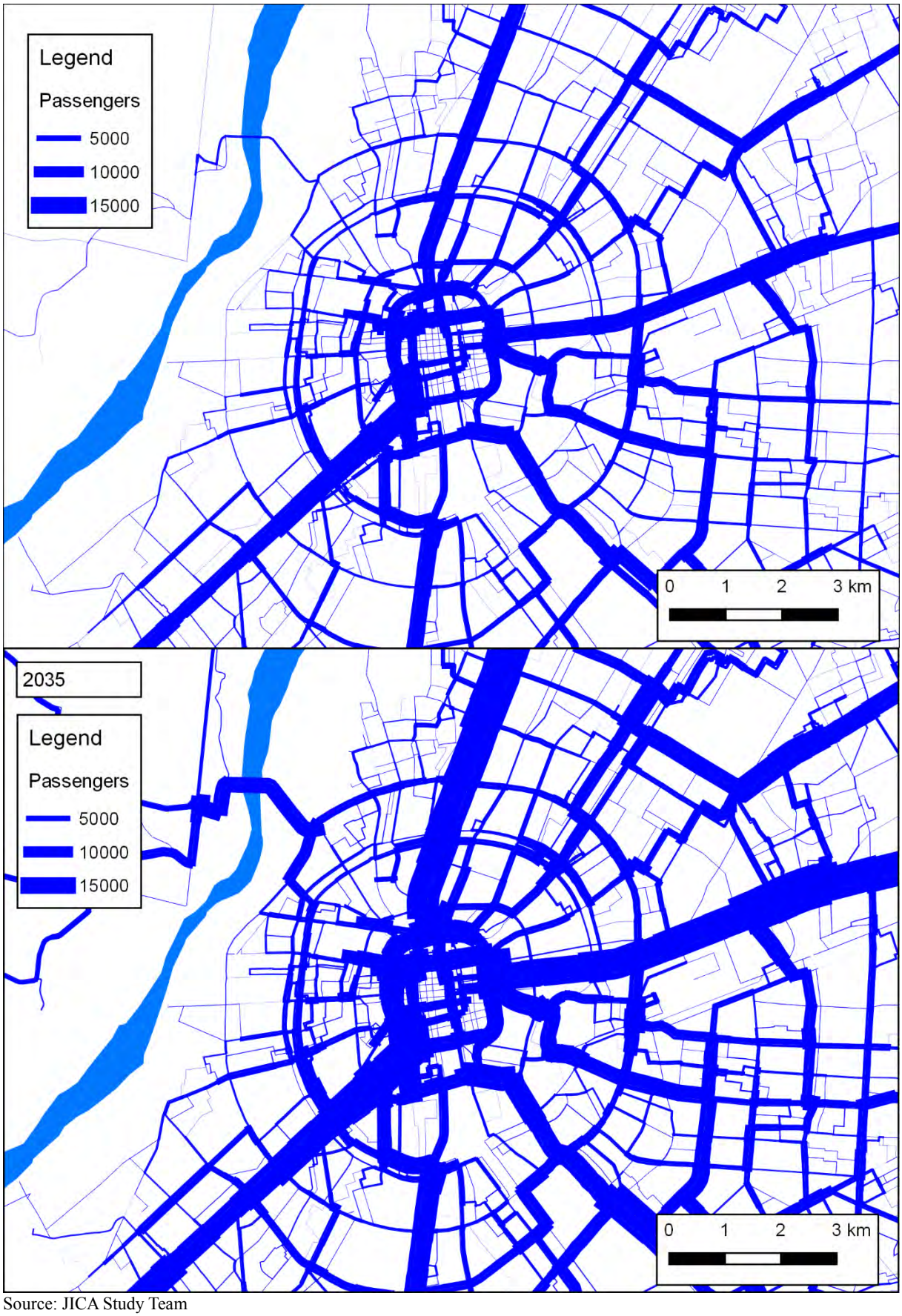
The demand forecast for 2020 was conducted although its figure is not presented in the report. The results of with and without cases are used in Chapter 7.

The traffic assignment was also carried out for an off-peak hour to estimate the daily traffic volume, which was used in the economic evaluation in Chapter 7.



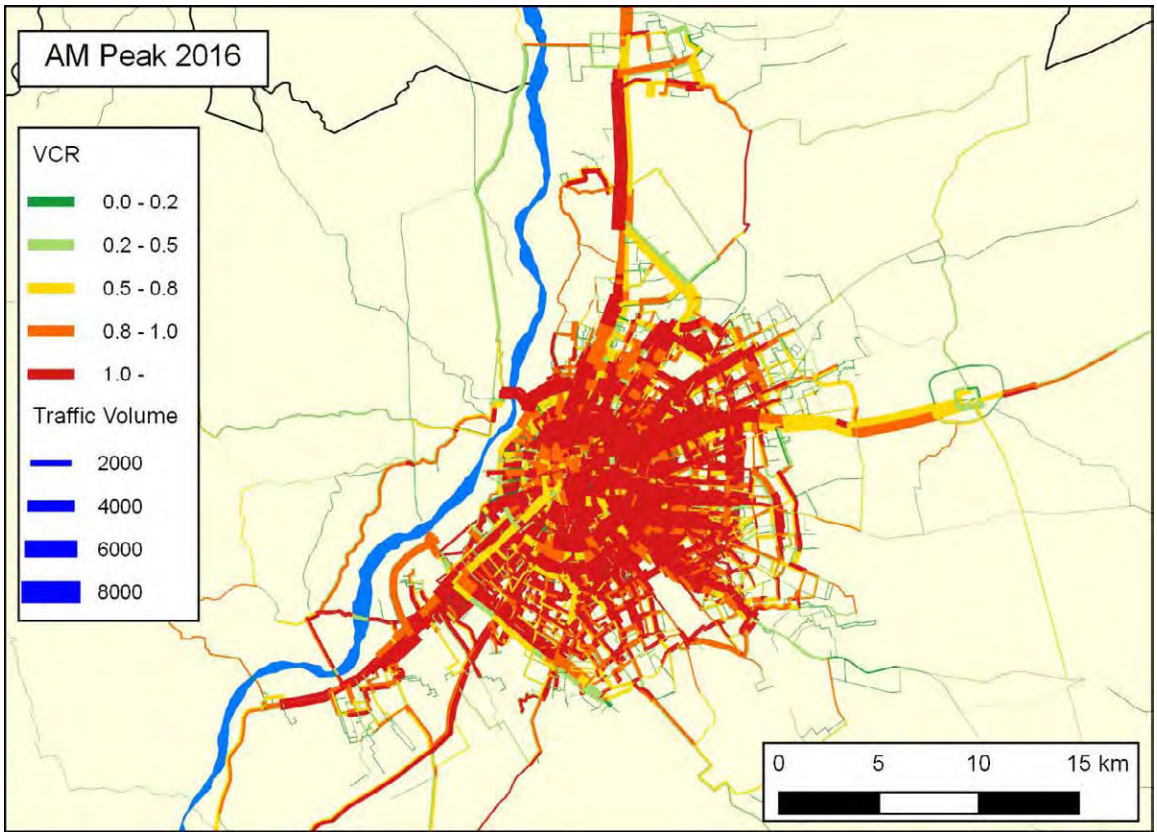
Source: JICA Study Team

Figure 6-7 Traffic Assignment (Present)



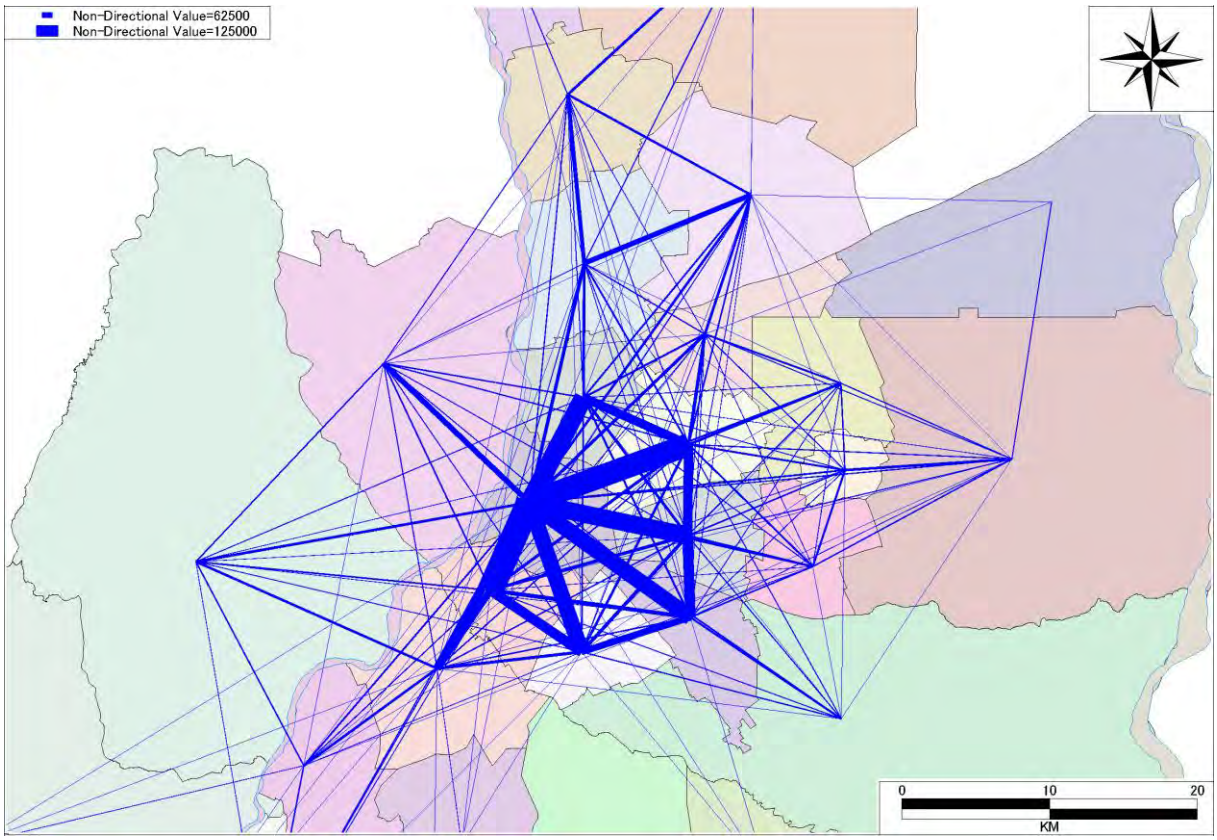
Source: JICA Study Team

Figure 6-8 Passenger volume in 2016 and 2035 (Without projects)



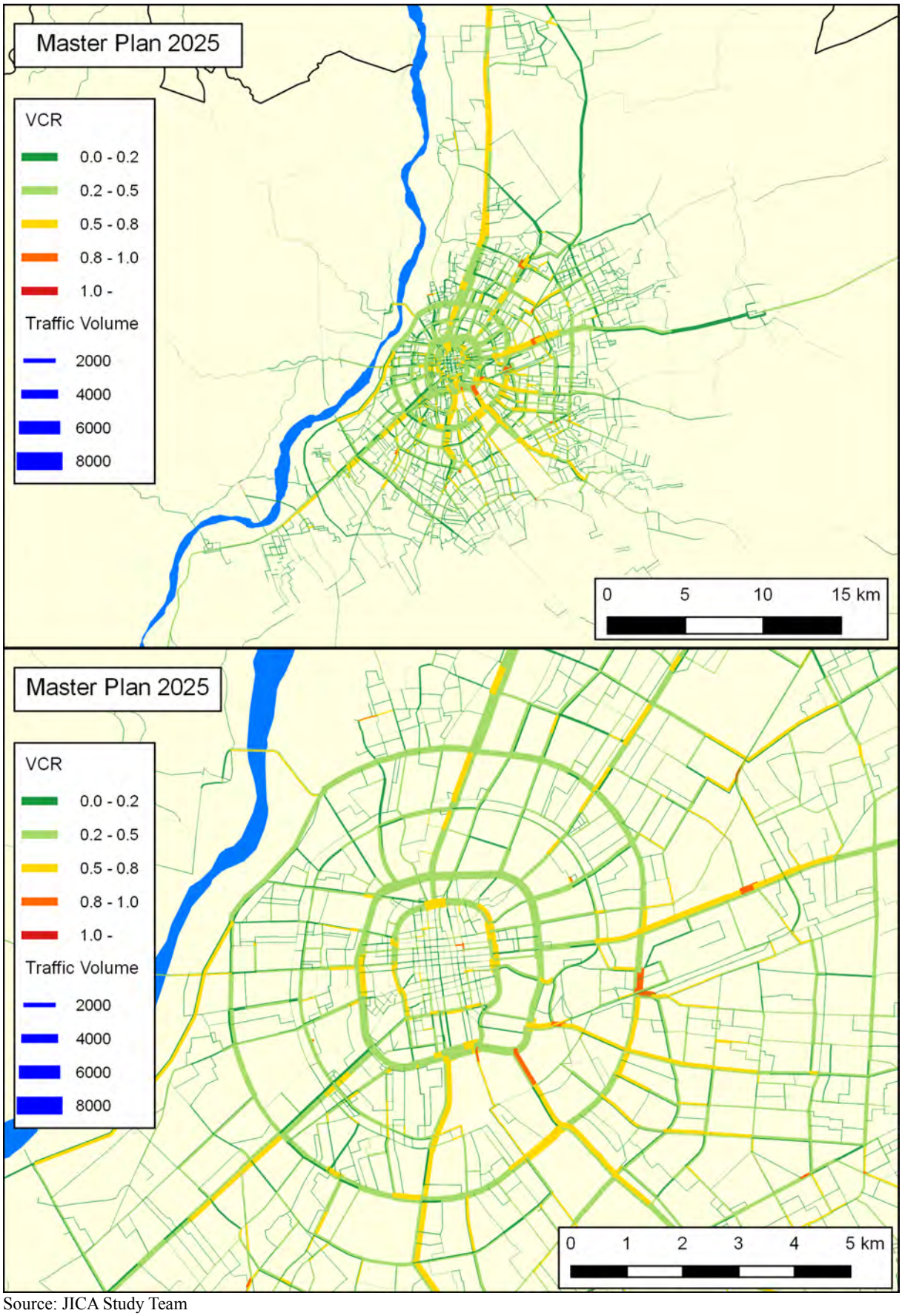
Source: JICA Study Team

Figure 6-9 Traffic Assignment in case of 100% car use



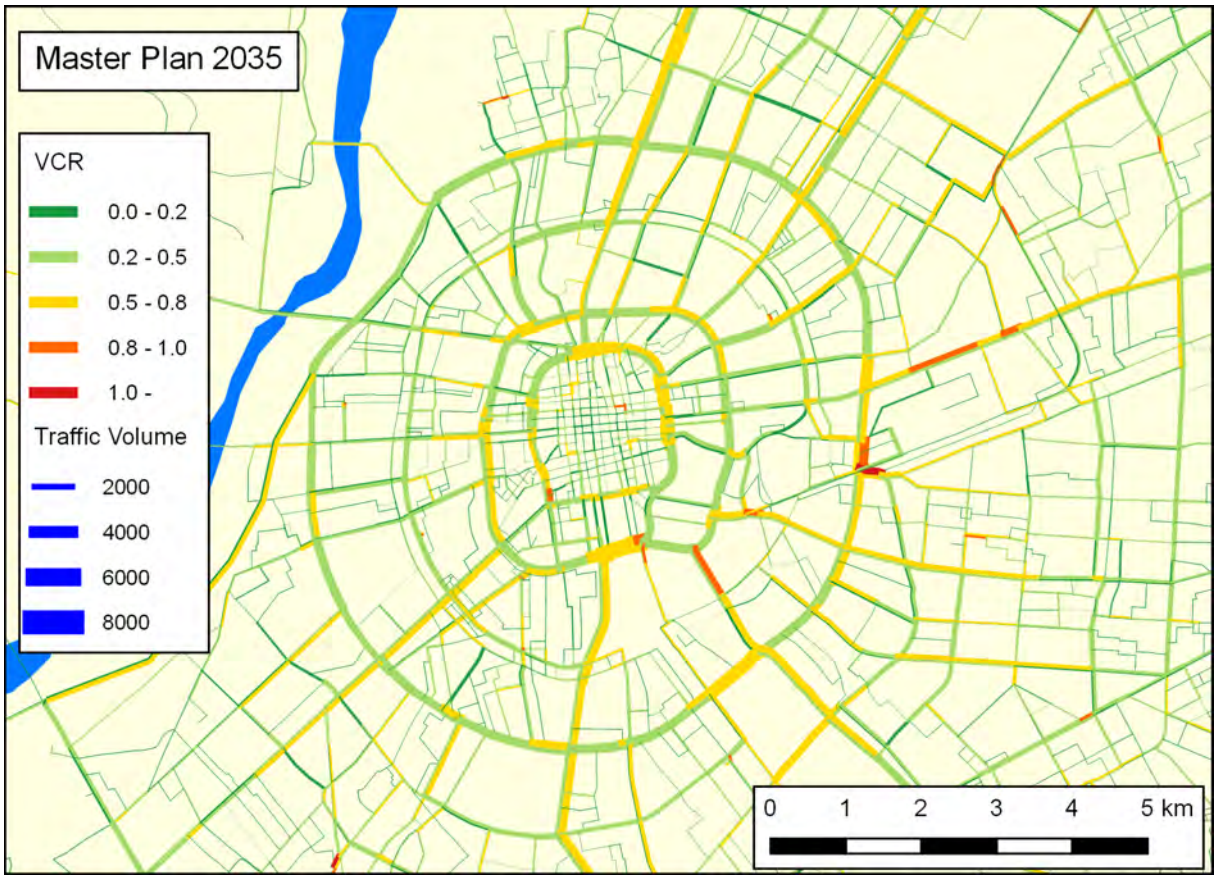
Source: JICA Study Team

Figure 6-10 Desired Line in 2035



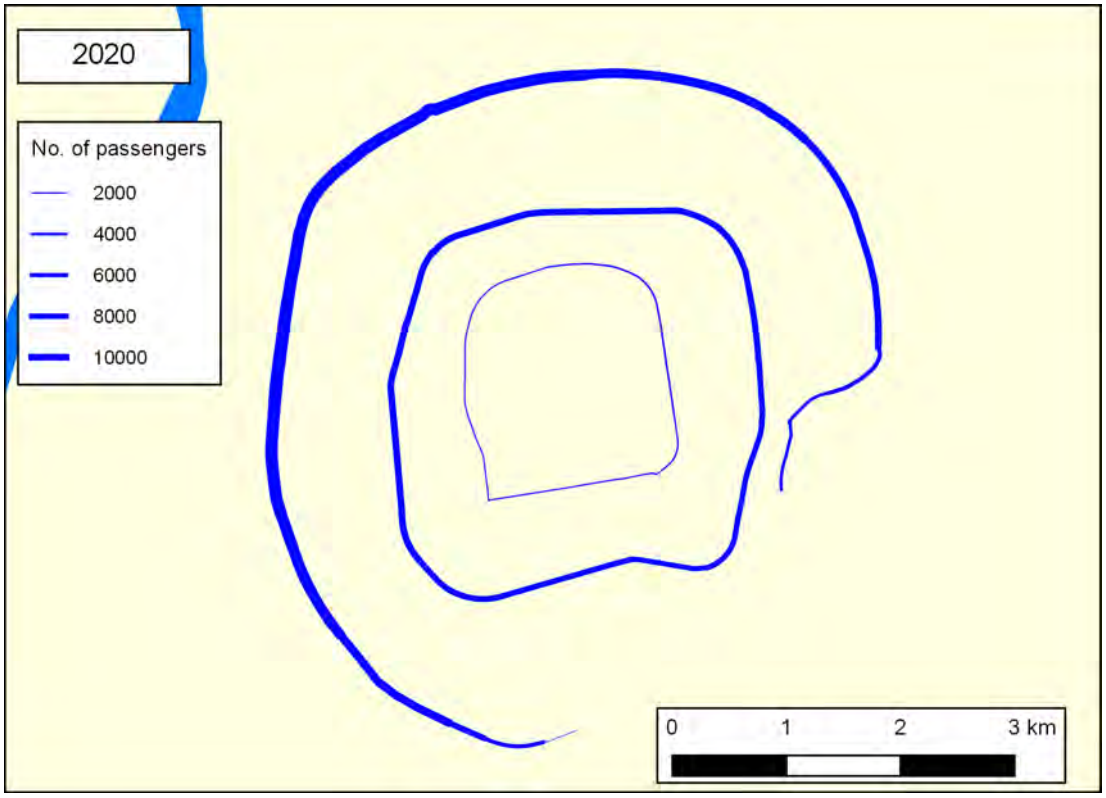
Source: JICA Study Team

Figure 6-11 Traffic Assignment in 2025



Source: JICA Study Team

Figure 6-12 Traffic Assignment in 2035 (Center)



Source: JICA Study Team

Figure 6-13 Passenger Demand of BRT (2020)

6.4.3 Passenger Demand of the BRT

(1) Fare System

A flat fare of Bs. 3 was employed for the fare system of the BRT network. Passengers pay Bs. 3 at the time of boarding and the transfer among the BRT lines is free.

(2) Speed

The speed of the BRT system in the demand forecast model is 35 km/h. Although the BRT network in the Master Plan includes sections without exclusive lanes, it was assumed that the traffic control gives priority to the BRT operation.

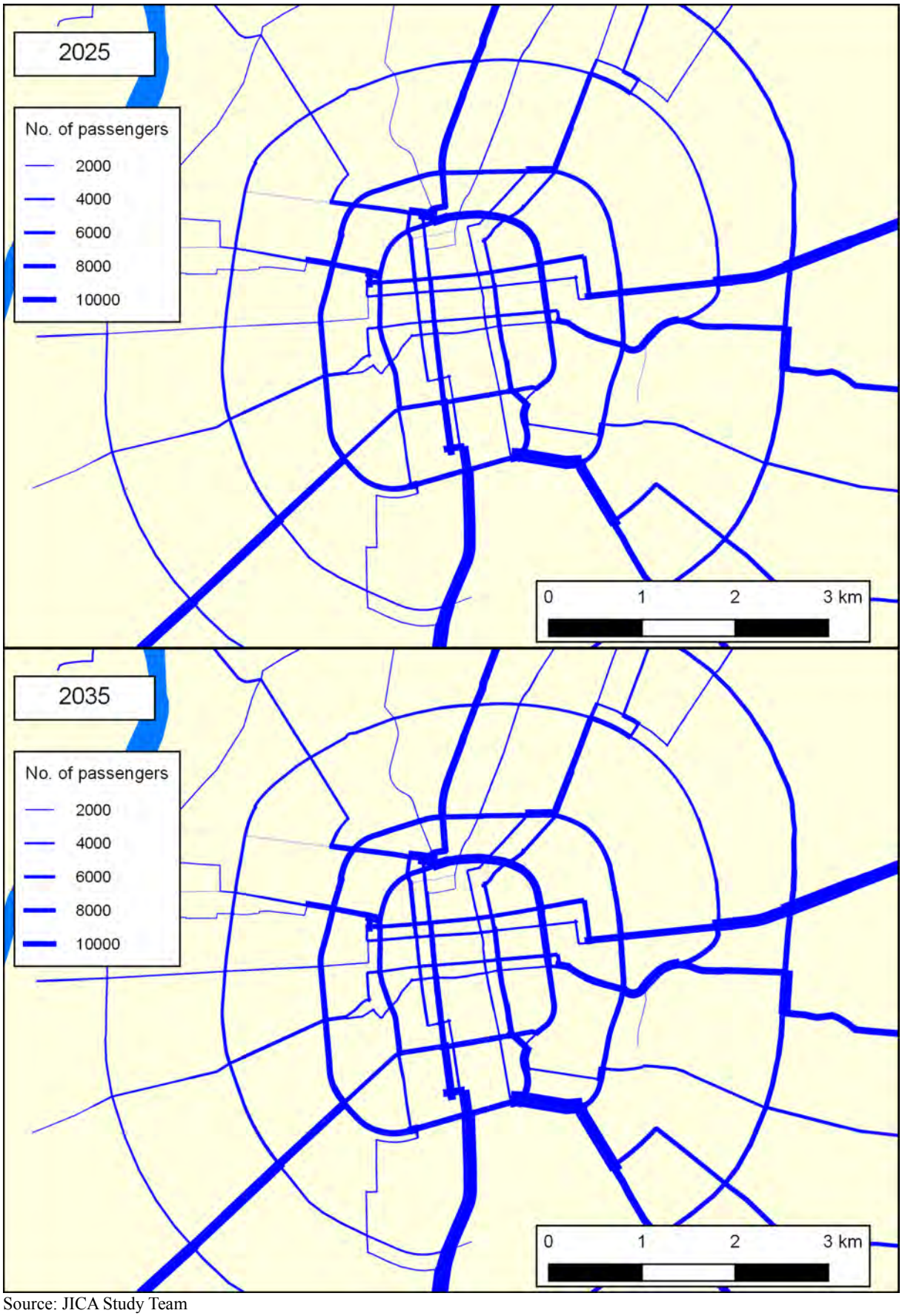
(3) Results

Figure 6-13 shows the peak-hour passenger volume of the BRT system in 2020. It was assumed that existing lines remain in 2020 and the operation of the BRT system is in the pilot project stage. The maximum passenger volume of 1st, 2nd, and 3rd Ring Road in the peak hour is 350, 2,070, and 4,870 passengers per hour per direction (PPHPD), respectively. Since the radial network is not integrated with the BRT system and competitive lines remain in this case, the passenger volume of the 1st Ring Road is very small.

Figure 6-14 shows the peak-hour passenger volume of the BRT system in 2025 and 2035. The network includes branch lines other than the BRT lines proposed in Chapter 7.

In 2025, the maximum passenger demand inside the 1st Ring Road is as high as 9,730 pphpd on Ave. Velasco, which requires a high-frequency operation. The maximum passenger demand among all lines is 19,400 pphpd of the line on Ave. Santos Dumont between the 3rd and 4th Ring Road. Since the demand is high for a BRT system, an overtaking lane would be necessary for the line. The passenger demand also exceeds 10,000 pphpd on Ave. Grigota, Ave. Virgen de Cotoca, and Ave. San Aurelio. The passenger demand for the 3rd Ring Road is 4,130 pphpd, which is smaller than that in 2020. On the other hand, the BRT line on the 1st Ring Road needs to carry 9,600 pphpd at the peak section.

In 2035, the maximum passenger demand of the BRT network is as high as 22,400 pphpd. The modern type BRT system can deal with the demand, but the operation of high frequency and the high-capacity buses are necessary.



Source: JICA Study Team

Figure 6-14 Passenger Demand of BRT (Top: 2025, Bottom: 2035)

6.4.4 Passenger Demand of the Inter-city Train

(1) Stations

The locations of the stations of the inter-city train in the analysis are: 1) Bimodal, 2) 6th Ring Road, 3) New Santa Cruz City, 4) Satelite Norte, and 5) Warnes.

It is recommended to include a station at the industrial park in Warnes, because it is necessary to transfer to feeder modes from Satelite Norte or Warnes to the industrial park if the station does not exist.

(2) Fare system

The passenger demand of the inter-city train depends on the assumption of the fare system because the demand forecast model includes the fare of each transit line. The fare of the inter-city train can be higher than that of existing public transport modes because passengers are willing to pay for its attractive services, although the increase in the fare of inter-city train will reduce the passenger demand. To simplify the analysis, it was assumed that the fare of the inter-city train would be similar to those of the current public transport modes. The table below shows the assumed fare system of the inter-city train.

Table 6-10 Fare Setting of Inter-city Train for the Demand Analysis

Station (A)	Station (B)	Fare (Bs.)
Bimodal	6th Ring Road	2
	New Santa Cruz City	3
	Satelite Norte	4
	Warnes	6
6th Ring Road	New Santa Cruz City	3
	Satelite Norte	4
	Warnes	6
New Santa Cruz City	Satelite Norte	2
	Warnes	3
Satelite Norte	Warnes	2

Source: JICA Study Team

(3) Speed

It is assumed that the maximum operation speed is 100km/h, while average speeds between station nodes in the demand forecast model were assumed as 60km/h between Bimodal and 6th Ring Road, 100km/h between 6th Ring Road and New Santa Cruz City, and 90km/h for other sections.

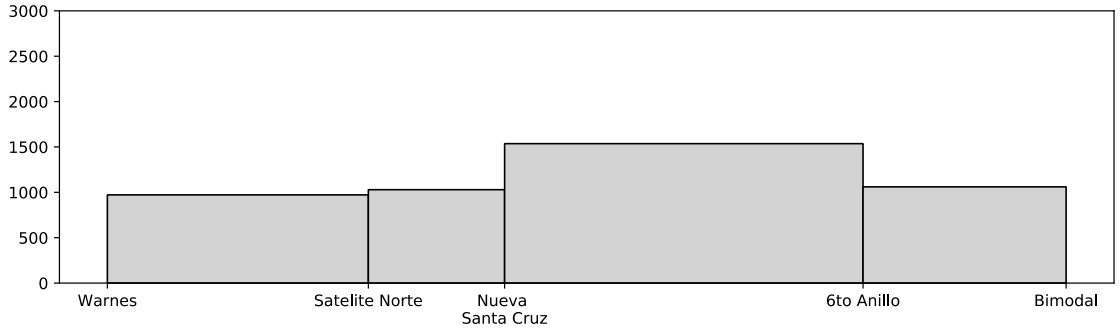
The frequency is assumed to be 4 trains per hour (15 minutes headway).

(4) Socio-economic scenario

The result of the analysis shows that the inter-city train can be replaced with a BRT system because the passenger volume would be within the capacity of BRT systems. The socio-economic scenario for the analysis is as same as that of the Master Plan case, in which the population in new urbanizations were estimated by applying low population density. If the population in the New Santa Cruz City reaches 400,000 as proposed by the developer, the passenger demand of the inter-city train will be high enough to justify the railway system.

(5) Results

The figure below shows the result of the demand forecast in the peak hour to the peak direction (from Warnes to Santa Cruz de la Sierra) in case that the inter-city train exists at present. Although there is no public transport service at New Santa Cruz City at present, it is assumed that feeder services are available between existing communities and the station; otherwise, no passenger will use the train. The maximum passenger volume, which appears between the New Santa Cruz City and the 6th Ring Road, is estimated at 1,500. This is large enough for the operation of a high-speed train as far as the financial feasibility is ignored. Without the feeder lines, the passenger demand will be very small.

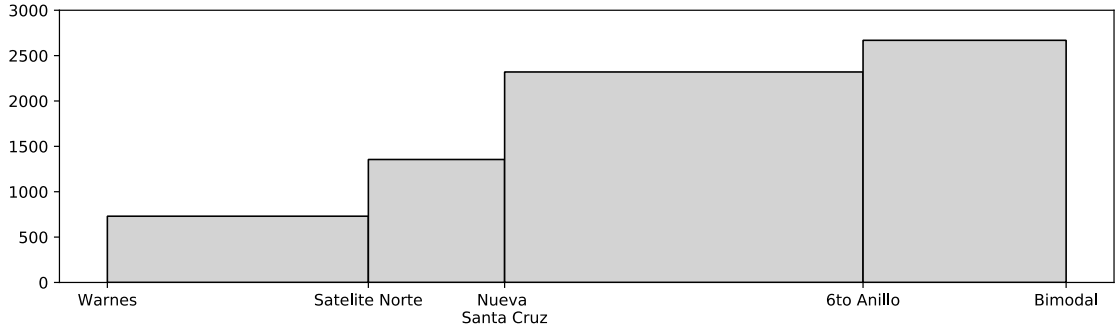


Source: JICA Study Team

Figure 6-15 Passenger Demand of the Inter-City Train (2016)

The passenger demand in 2035 is estimated as shown in the figure below. The maximum passenger volume per hour is 2,700. If the high-speed train has 270 seats, the frequency should be ten trains per hour (every 6 minutes).

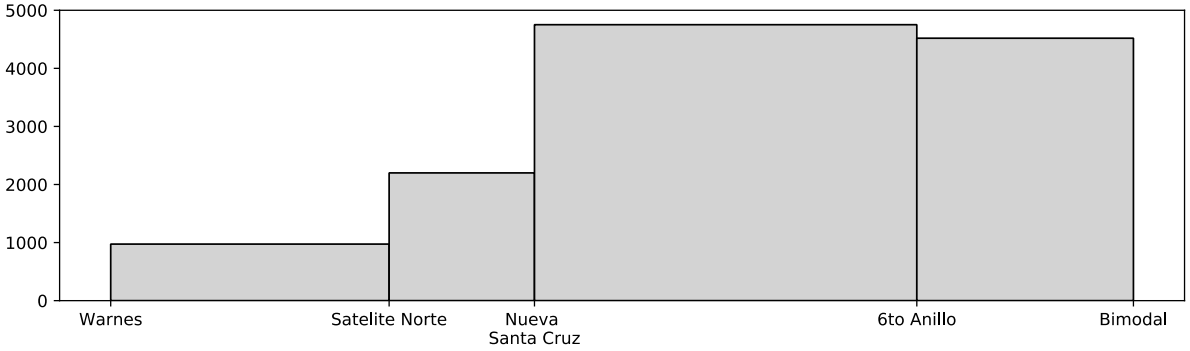
The forecast assumes that transport infrastructure will be developed based on the Master Plan, which means that the bus network including the BRT system is the competitor of the inter-city train. The decrease in the passenger volume from Warnes to Satelite Norte compared to the projection in 2016 is due to the improvement of traffic congestion by the Master Plan.



Source: JICA Study Team

Figure 6-16 Passenger Demand of the Inter-City Train (2035)

The figure below shows the demand forecast in case of the New Santa Cruz has a population of 400,000 in 2035. The maximum passenger volume reaches 4800 passengers per hour per peak direction. Many high-speed trains have the capacity of around 500, and it is possible to carry the demand.



Source: JICA Study Team

Figure 6-17 Passenger Demand of the Inter-City Train (New Santa Cruz Development Case)

(6) Evaluation

The forecast shows that the passenger demand is high enough for the proper operation of the inter-city train as a high-speed system. On the other hand, large buses can carry the estimated number of passengers. For example, a BRT system having the vehicle capacity of 50 passengers can carry 3,000 passengers in case of a 1-minute interval. There are articulated buses having a capacity of 80-100, which can carry 4,800 passengers per hour. The capacity can be increased if dual lanes are used. Buses can be operated at the maximum speed of 100km/h if the geometry of the road design allows. Note that the present bus system in Santa Cruz de la Sierra, a mixture of microbuses and trufis, carries 10,000 passengers in the busy streets, although the speed is very small.

In addition, the assumed tariff of the inter-city train is too small, considering the world examples of high-speed trains. The introduction of the inter-city train is not financially feasible considering the tariff level in Bolivia.

In the Master Plan, a BRT system is proposed for the inter-city route, although a more detail study is needed to select the best system to the corridor. There is a possibility that the future population in urbanizations in Warnes is larger than the assumption in the Master Plan due to the promotion of the developers. In that case, the proposed system should be reviewed.