# Chapter 7 The Master Plan

## 7.1 Vision

The vision describes the future situation of the Metropolitan Area which will be achieved by the master plan. It is summarized in a simple statement shown below.

> The Metropolitan Area of Santa Cruz in 2035, the strategic center of the Department and the international corridor, will be an environmentally sustainable and integrated region with a multimodal transport system of high mobility and accessibility that provide all citizens with safe, convenient, comfortable, and reasonable transport choices.

More detail contents of the vision are described as follows.

**The Metropolitan Area**

The Metropolitan Area is integrated with proper transport network.

**Population**

The Metropolitan Area will have a population of 3 million in 2035, with continuous migration from other areas in the department and other departments in Bolivia.

**Economy**

The Metropolitan Area will be one of the strategic center of the department, country and international corridors in terms of agriculture, manufacture, commercial, trade, and culture. Agriculture is the most important industry in the Metropolitan Area, which provides many business opportunities. The manufacturing industry will also play an important role in the metropolitan economy, which provide job opportunities for the people in the Metropolitan Area. Export of agricultural and manufactural products will promote the trade industry. The Metropolitan Area will be the logistics center for domestic and international trade with logistics facilities and freight corridors.

**Mobility and Accessibility**

Public transport will be stable, reliable, safe, and reasonable for all the citizens. The municipalities in the Metropolitan Area will establish conditions of proper accessibility for all citizens, which will bind all public transport systems. The level of services of the public transport will be satisfactory with enough frequency and network. It is a very convenient transport mode, and people are willing to use the public transport system.

The Metropolitan Area is well integrated through the proper road network with paved roads and public transport systems of excellent services.

The pedestrian network will be given the first priority, which should be accessible safely, conveniently, and wealthy for the travel of all persons. The second priority will be given to the bicycle network, which should be developed in short-, medium-, and long-term target. The next priority will be public transport, and finally, it will be private cars.

**Opportunity**

People have equal opportunity to choose a proper transport mode to access all communities

in the Metropolitan Area, regardless their age, gender, income, physical and mental condition, and social status.

The results of traffic surveys show that there is a large gender gap regarding opportunities and availabilities of trips.
Women make fewer trips with a shorter distance than men. The trip rate of women is smaller than that of men as described in Chapter 5. The average distance to the workplace from home of women is 4.3km, which is slightly shorter than that of men at 5.0km.
The percentage of persons with driver's license of men is 39.4%, while that of women is as small as 7.6%. This means that women have less alternative for their trip than men. When the public transport is not available, women cannot make a long-distance trip while men can do by driving a car. Some percentages are calculated for persons who can have a driver's license (age is 18 and older) as follows. Public transport accounts for 68.2% of the major modes of women's trips, while that of men's trips is 55.4%. Taxi and mototaxi are important for women with the modal share of 6%, while that of men is 4%. The modal share of mototaxi is 2.3% for women and 1.4% for men. Traffic safety of mototaxi is important for women's trips. Walking trips of men and women account for 15.5% and 21.3%, respectively.

**Sustainable Development**

The urban growth is well controlled with proper environmental considerations. Water resources, agricultural lands, forests are well preserved. The Metropolitan Area will enjoy high air quality by controlling pollution caused by vehicles, with a concrete target of CO2 reduction. Public transport system contributes to the sustainable development. The urbanized area is adequately densified to support efficient transport services. The regional and urban development should consider the social, economic, and environmental components through an approach of sustainability with active participation and coordination of people, private enterprises, and institutions of different levels of the government such as municipalities, the department, and the central government.

**Non-motorized Transport**

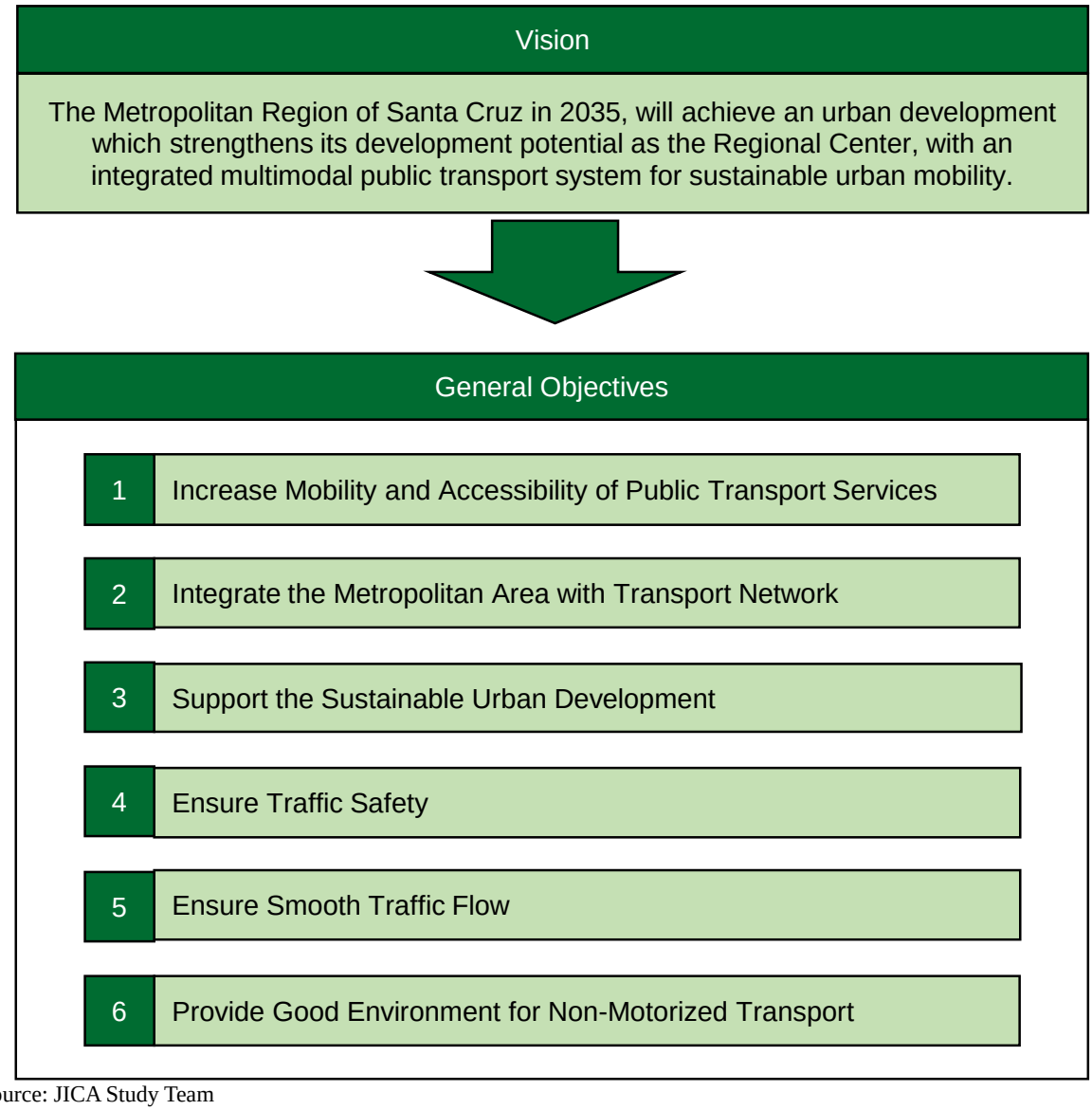
People will enjoy walking and cycling in a safe and comfortable environment, which will contribute healthy life. Streets are well designed for pedestrians including wheelchair users, elderlies, pregnant women, and children, providing good conditions without motorized transport methods. The bicycle will be one of the transport modes not only for pleasure but also commuting.

**Road**

Roads in the Metropolitan Area will be in good conditions. People will not be suffered from traffic congestion with proper traffic management and the good public transport system. The road system will be planned through the policies and conditions that promote walking, cycling, and public transport, considering inter-modality and discouragement of the use of cars.

## 7.2 General Objectives

The general objectives are a set of approaches of transport sector which is necessary to achieve the vision. There are seven general objectives as shown in the figure below.




Source: JICA Study Team

**Figure 7.2-1 Vision and General Objectives**

The following justifications have identified these general objectives.

### 7.2.1 Increase Mobility and Accessibility of Public Transport Services

The population increase and economic growth in the Metropolitan Area are increasing the number of private cars. If the current trend of the vehicle increase continues, the Metropolitan Area will follow the same path where many megacities in the World which are suffered by heavy congestion have experienced. Presently, the car ownership in the Metropolitan Area is estimated at 151 vehicles per 1000 inhabitants, which is still low compared to other countries of higher economic levels. If no action is taken, the car ownership is estimated to reach 327 vehicles per 1000 inhabitants in 2035. This means that the number of vehicles will increase three times the present level considering it is estimated that the population will be 1.5 times. This will prevent the achievement of the vision as following reasons.

1) It will cause more traffic congestion, which deteriorates the mobility for all people including private car users and public transport users.

2) It will increase the exhausted vehicle emission, which causes air pollution.

3) If public transport services remain under the same conditions as today, it will worsen the conditions of transportation and mobility of a large part of the population.

This will happen in the future if the level of public transport services remains in the present one. From this, it is necessary to improve the quality of public transport services to hinder the rapid increase in private cars.

### 7.2.2 Integrate the Metropolitan Area with Road Network

To achieve the vision as the Regional Center, every municipality needs to stimulate the industry based on their development potential such as agriculture, manufacture, tourism, trade, and so on. The transport infrastructure contributes such economic development by connecting places of demand and supply, and by increasing people's opportunities to visit each municipality, although the present transport system does not necessarily satisfy the interconnection among municipalities in the Metropolitan Area. The present road network forms polycentric urban structure, by connecting the center municipality of Santa Cruz de la Sierra to other municipalities, and the connection among other municipalities is very weak.

The rapid expansion of urbanized area as a sprawl development style caused a heavy concentration of traffic to radial roads from suburban areas to the center of Santa Cruz de la Sierra, without proper circular roads. Therefore, the Metropolitan Area should be integrated with a proper road network.

### 7.2.3 Support the Sustainable Urban Development

Presently, urban development through the real estate development of the private sector is very active, and the area of the approved urbanizations is already as large to accommodate the estimated population up to 2035. Nevertheless, due to the lack of urban control measures, it is expected more and more urbanizations would take place in the Metropolitan Area with the same tendency of the urban development, which results in the low-density of vast urbanized areas. The problems of the law density urban expansion have been pointed out. Public transport routes in low-density areas cannot collect enough passengers to make the business financially feasible, which results in deterioration of public transport services in terms of frequency, fare, reliability, and travel time. Due to this, the number of vehicles will increase because people rely on private cars in low-density areas where public transport services are not satisfactory. Since infrastructure investment is not cost-efficient, the low-density urban expansion will cause the deterioration of the level of public services such as water, drainage, and streets. The sustainable urban development aims to formulate the urbanized area with proper population density with sufficient public services, preserving the natural environment.

### 7.2.4 Ensure Traffic Safety

The number of traffic-related deaths per 100,000 inhabitants in Santa Cruz Department was 31.3 in 2012, which is higher than the national average of 15.5 (calculated from the database of INE). Increasing traffic accidents is a serious threat to the sustainable urban development. Death, injury, and damage to cars and other physical objects cause economic loss. The high traffic accident rate is a negative factor to promote investment in the Metropolitan Area. Even if high mobility is achieved by reducing travel time, it is not sustainable if traffic accidents increase by high-speed vehicles. Traffic safety is one of the major concerns of transport problem in the Metropolitan Area. Therefore, ensuring the traffic safety is one of the preconditions to achieve the vision.

### 7.2.5 Ensure Smooth Traffic Flow

In addition to the traffic accidents, traffic congestion, especially in the center of the Metropolitan Area, is one of the serious problems of the transport sector. Traffic congestion is also a negative factor to attract investment and a threat to the economic development in the Metropolitan Area as the Regional Center. Urban mobility is very poor if traffic congestion is very heavy. It also causes an environmental problem due to vehicle emission along congested roads. The traffic congestion in the historic center deteriorates its attractiveness. Although local congestions have been relieved by the recent improvement of intersections, increase in the travel demand in future will saturate major intersections if no countermeasures are taken place. A traffic congestion is the result of a complex mechanism involving various factors of demand and supply, and relieving traffic congestions is only possible by applying various countermeasures.

### 7.2.6 Provide Good Environment for Non-Motorized Transport

In the vision, pedestrians are given the top priority among transport modes. Bicycle use as a transport mode is also mentioned. However, the present situation in the urbanized area is far from the vision. First, the pedestrian network is not formulated well. Crossing arterial roads require a long detour, or people need to cross the roads where pedestrian crossing does not exist paying attention to the road traffic. Crossing minor streets also require careful attention for pedestrian even if pedestrian mark exist. This problem is strongly related to that of traffic safety, but this issue is considered as one of the General Objectives considering the importance of the good environment for pedestrians. Walkways are not designed well for wheelchair users, which need to be improved. Secondly, there is few infrastructure for bicycle users at present. Cyclists need to use the lanes for vehicles and use walkways. Because of the flat terrain and good weather condition, bicycle use can be promoted if proper infrastructure is provided and proper guidelines and rules are prepared.

## 7.3 Specific Objectives

### 7.3.1 Increase Mobility and Accessibility of Public Transport Services

- Provide the stable and reliable public transport services in all weather conditions.
- Provide sufficient public transport services in all urban areas.
- Provide safe, comfortable, high capacity, and high-speed public transport system
- Reduce air pollution from vehicle emission

**(1) Provide the stable and reliable public transport services in all weather conditions**

The Metropolitan Area has a rainy season, and sometimes heavy rain causes floods in streets where drainage system does not adequately work, and streets are not paved. In such case, the number bus services are reduced, and public transport users need to take a limited number of buses being patient with a long waiting time and the heavy congestion inside the buses, or they just give up their travel. This sometimes happens not only by heavy rain but also other various reasons. Due to the fluctuation of daily and hourly travel demand, the travel time of public transport is not predictable. Waiting time is not also predictable even on high demand routes. This is one of the reasons that small size vehicles such as minibus, trufi, and moto-taxi, including illegal services, offer alternatives for the traditional public transport systems. Providing stable and reliable public transport services is one of the important issues to improve the quality.

**(2) Provide sufficient public transport services in all urban areas**

Presently, bus routes cover most urbanized areas although some newly urbanized areas do not have enough routes for residents to access to public transport systems in walking distance. With the expansion of low density urbanized area, it will become more and more difficult to provide sufficient bus routes for residents. Financial feasibility of operating buses in a low-density area is one of the reasons. The present bus network connects origins and destinations directly based on the demand, which enables to provide sufficient bus routes in urbanized areas. However, this system will reach a limitation in future because it concentrates many bus routes in high demand area which will saturate the road capacity. If no action is taken, public transport services in the newly urbanized area will be insufficient. In addition to the density of bus routes, the frequency is also important to improve the quality of public transport services.

**(3) Provide safe, comfortable, high capacity, and high-speed public transport system**

Due to the rapid expansion of the urbanized area, it became difficult to construct arterial roads both for radial and circular directions. Large-scale urban developments are planned in Warnes and Cotoca, which will accommodate several hundred thousand residents. This will generate a large-scale traffic demand between the center of Santa Cruz de la Sierra and the new development areas. Buses of the present capacity will not be able to deal with the traffic demand, which results in low mobility, poor public transport services, and more usage of private cars. To promote the modal shift from private cars to public transport system, it is necessary to provide safe, comfortable, high capacity, and high-speed public transport system.

**(4) Reduce air pollution from vehicle emission**

Owing to its flat terrain and wind, the air pollution in the Metropolitan Area is not as severe as other cities. However, some old buses exhaust black and dark emissions that do not satisfy the environmental standard, even in the central area where vehicle emissions directly affect pedestrians.

### 7.3.2 Integrate the Metropolitan Area with Road Network

- Integrate both sides of the Pirai River.
- Keep the roads in good condition for vehicles.
- Connect every municipality directly with high mobility.
- Formulate the proper hierarchy of the road network

**(1) Integrate both sides of the Pirai River**

There is only a bridge between Porongo and Santa Cruz de la Sierra. Access to Porongo from La Guardia and El Torno requires a long detour to use the bridge; otherwise, it is necessary to cross the Pirai River where the depth is shallow enough to allow vehicles to go although such places are limited. Urban development in Porongo is very active, and many people live in Porongo and work in Santa Cruz. The commuter demand crossing the Pirai River is increasing, and the traffic on the bridge will reach its capacity in future. For the integration of the Metropolitan Area, the crossing of the Pirai River is very important.

**(2) Keep the roads in good condition for vehicles**

There remain a lot of unpaved roads in the Metropolitan Area. Presently, maintenance of

unpaved roads is not sufficient, especially in the urban sprawl areas. High accessibility within local communities is very important to connect origins and destinations in the Metropolitan Area. Heavy rain often deteriorates the conditions of unpaved roads, which affects the connectivity among communities. Mobility on paved roads also worsens after heavy rain due to the insufficient drainage system.

**(3) Connect every municipality directly with high mobility**

Santa Cruz de la Sierra is directly connected to the adjoining municipalities by radial roads, while travel among Cotoca, Warnes, Porongo, La Guardia, and El Torno needs to use the roads to Santa Cruz de la Sierra. In most cases, it is necessary to use the 4th Ring Road between Cotoca and Warnes, La Guardia and Cotoca, and Porongo and Cotoca. Providing the direction among these municipalities with high mobility is necessary to integrate the Metropolitan Area.

**(4) Formulate the proper hierarchy of the road network**

Roads of high hierarchy provide high mobility without interruption of intersections and roadside activities while those of low hierarchy provides access to the roadside areas. The hierarchy of the Departmental Roads is not apparent in the Metropolitan Area. There is no functional classification, and the roads just connect major points without consideration of the hierarchy. Santa Cruz de la Sierra has the road network of a proper hierarchy within the 4th Ring Road. However, other ring roads do not form the proper network due to missing links, dead ends, and lack of enough ROW. Formulation of the proper hierarchy is necessary for the integration of the Metropolitan Area.

### 7.3.3 Support the Sustainable Urban Development

- Formulate the urban structure with proper road network by controlling suburban developments.
- Support economic development in the Metropolitan Area
- Formulate the cost-effective road network in terms of construction and maintenance

**(1) Formulate the urban structure with proper road network by controlling suburban developments**

Large-scale urbanizations by private sector play an important role in the urban development in the Metropolitan Area. Due to the difficulty of shrinking the Urban Area which is already approved by the central government and disclosed to the public, there remains a possibility that the private sector proposes new urbanizations where the master plan considers as the future reserved area during the master plan period. Prohibiting such urbanizations is not possible under the present legal system, it is necessary to prepare the counterplan to control the developments.

**(2) Support economic development in the Metropolitan Area**

To support the economic development is one of the major roles of the development of transport infrastructure because creating the job opportunity is essential for the sustainable urban development. Efficient and sufficient freight movement is the key role of the road network for the economic development. On the other hand, traffic of trucks on roads in urbanized areas tends to cause various negative impacts such as congestion, noise, vibration, vehicle emissions, and damage to road infrastructure. Therefore, it is necessary to plan the proper freight corridor which does not cause negative impacts on the sustainable urban development.

**(3) Formulate the cost-effective road network in terms of construction and maintenance**

The necessity of new road construction and improvement of existing roads does not necessarily mean that the road network should be expanded with high density to cover the entire area of the Metropolitan Area. Expansion of the road network over the Metropolitan Area requires a large-scale investment and continuous road maintenance will be required. For the sustainable urban development, the road network should be cost-effective.

### 7.3.4 Ensure Traffic Safety

- Eliminate fatal traffic accidents
- Reduce the number of traffic accidents
- Raise awareness of traffic safety and compliance with traffic rules
- Establish detail registration of traffic accidents with human damage

**(1) Eliminate fatal traffic accidents**

Traffic accidents sometimes kill persons or give serious injury. Eliminating the fatal traffic accidents is the top priority to ensure the traffic safety. The recent statistics show that the fatalities in Santa Cruz Department are increasing. Although it seems unrealistic to achieve zero fatality in the Metropolitan Area with 3 million population in 2035, this is very important objective to ensure traffic safety.

**(2) Reduce the number of traffic accidents**

Even if there is no death nor injury, traffic accident causes various problems. In addition to the damage to vehicles and facilities, it causes traffic congestion.

**(3) Raise awareness of traffic safety and compliance with traffic rules**

During the discussion of the problems in the transport sector, it has been pointed out that lack of awareness of traffic safety and violation of traffic rules are major problems relating to traffic safety. Countermeasures such as physical improvement of road design and pedestrian facilities are not enough to ensure traffic safety. It is very important to raise awareness of traffic safety and compliance with traffic rules.

**(4) Establish detail registration of traffic accidents with human damage**

It is necessary to have control and registration of all traffic accidents that result in personal damages, which should be used for the problem analysis and support for the decision making of policies and projects to achieve the objectives mentioned above.

### 7.3.5 Ensure Smooth Traffic Flow

- Relieve traffic congestion in the Historic Center
- Ensure mobility around markets, schools, and other facilities having high trip generation
- Eliminate bottlenecks in the road network
- Optimize the traffic flow using modern technology
- Encourage modal shift from private cars to public transport

**(1) Relieve traffic congestion in the Historic Center**

The central area within the 1st Ring Road, especially in the Historic Center, is the most congested area in the Metropolitan Area. Although the Historic Center is one of the most attractive areas in Santa Cruz, the traffic congestion in peak hours declines the economic activity, and the area is losing its commercial attractiveness. Relieving traffic congestion in the Historic Center is one of the major Specific Objectives of "Ensure Smooth Traffic Flow".

**(2) Ensure mobility around markets, schools, and other facilities having high trip generation**

Traffic congestions on arterial roads are observed around major markets, especially Abast Market and Mutualista Market along the 3rd Ring Road. Traffic congestion around markets reduces the mobility of the arterial roads. Traffic congestion also occurs around schools where students use cars or parents send and pick up their children. Since buildings that generate high trip demand are located along important roads in most cases, it is necessary to ensure the mobility around such places.

**(3) Eliminate Bottleneck in the Road Network**

Recently, traffic congestions at major intersections have been relived owing to the improvements of intersections such as the construction of flyovers and prohibiting left turn. However, there remain intersections which are the bottleneck of the traffic flow. To improve the mobility, it is necessary to eliminate the bottlenecks in the road network.

**(4) Optimize the traffic flow using modern technology**

Information technology can contribute to relieving traffic congestion. For example, providing information about traffic flow to drivers enables them to choose the optimum route to avoid the congestion. Optimizing signaling phase based on the real-time situation of traffic flow is introduced in many cities in the World. Using smart cards at toll gates can relieve the congestion around the toll gates. In addition to the supply side improvements such as investment on the road network, controlling the demand side is also important to control traffic flow. Choice of the proper transport mode at the proper time based on the traffic information enables people to avoid the congestion.

**(5) Encourage modal shift from private cars to public transport**

Reducing the number of vehicles is the most efficient method to reduce the traffic congestion. The passenger occupancy survey shows that only 1-2 persons ride in a private car, while a public transport can carry more passengers. The capacity of a micro is approximately 30 passengers, while it uses the road space approximately 3 times private cars. To reduce the traffic flow, modal shift from private cars to public transport should be encouraged.

### 7.3.6 Provide Good Environment for Bicycle Use and Pedestrian

- Develop a safe, comfortable and functional bicycle network
- Improve the pedestrian network
- Encourage urban development within walking distance (TOD)

**(1) Develop a safe, comfortable and functional bicycle network**

Presently, there are few bicycle lanes in the Metropolitan Area. It is dangerous for bicycle users if they use carriageway of a road, and is dangerous for pedestrians if they use walkway (According to Law 3988, bicycles must use carriageway which is close to walkway). To

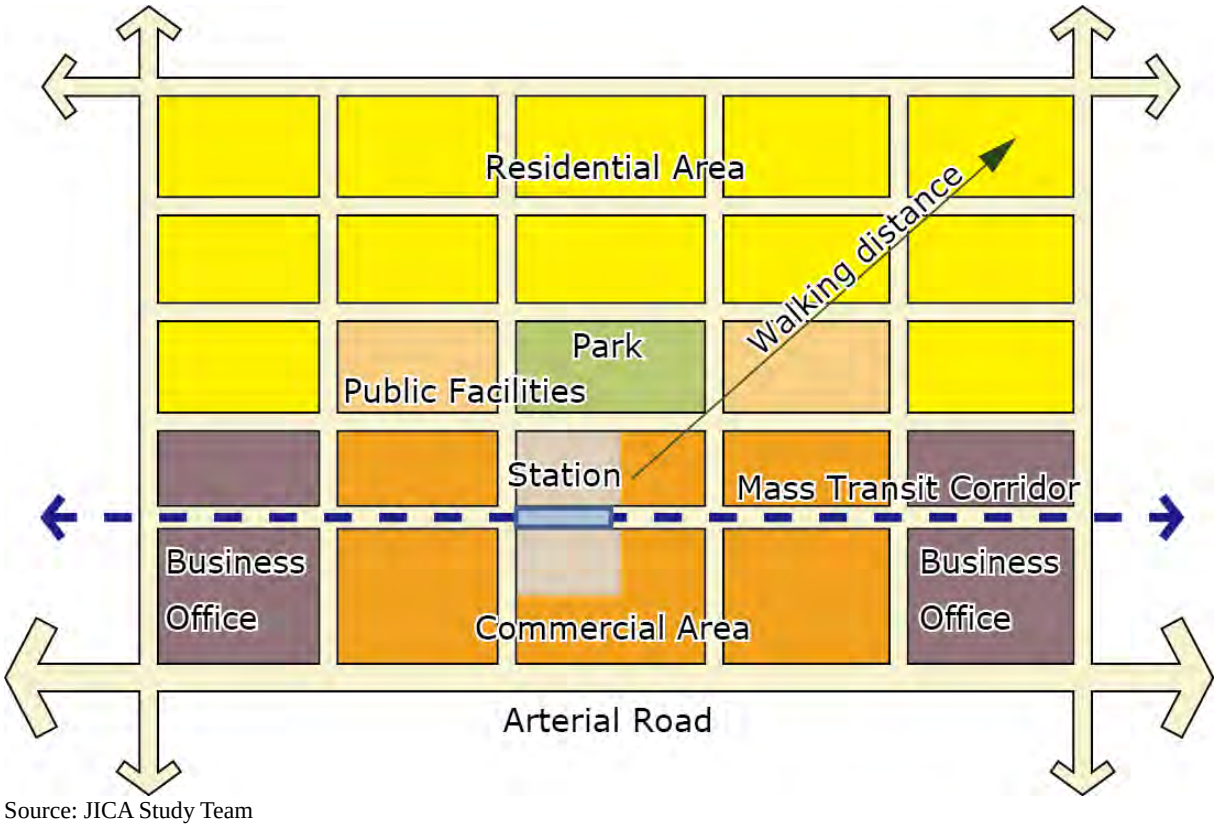
promote the use of bicycle, it is necessary to develop a safe, comfortable and functional bicycle network.

**(2) Improve the pedestrian network**

People in the metropolitan prefer taking public transport or private car instead of walking even if the distance is within walking distance. This is because it is easy to get public transport even if bus stop does not exist. On the other hand, lack of proper pedestrian facilities is also one of the reason. Crossing roads is inconvenient due to lack of crossing path along major roads. Walking on streets in the night time is not safe in some areas where street lighting is insufficient. To avoid traffic accident during the night time, ensuring the visibility for drivers to recognize pedestrians is very important. It is necessary to improve the pedestrian network to provide the better environment.

**(3) Encourage urban development within walking distance (TOD)**

A Transit-Oriented Development (TOD) aims to develop an urban area giving the top priority to pedestrians by allocating urban activities within walking distance around a station of public transport system. Many urbanizations still in planning stage, and the introduction of TOD to these urbanizations will improve the environment for pedestrians and bicycle users.




Source: JICA Study Team

**Figure 7.3-1 Concept of Transit-Oriented Development**

## 7.4 Targets

Targets of the objectives are proposed as follows. Some targets can be evaluated by using information from relevant authorities, while some targets should be measured by some surveys or additional analyses. The targets are selected considering easiness to get the indicators.

**Table 7.4-1 Targets of General Objective-1**

| **General Objective** | Increase Mobility and Accessibility of Public Transport Services |
|---|---|
| **Specific Objectives** | **Target** |
| • Provide the stable and reliable public transport services in all weather conditions. | • The number of buses that stop the operation in a rainy day is zero. |
| • Provide sufficient public transport services in all urban areas. | • The frequency of bus services during off-peak hours is 4 or more per hour in all urban areas.<br>• At least one bus stop exists within 500m distance in the urban area.<br>• At least one bus stop exists within 1,000m distance in rural communities. |
| • Provide safe, comfortable, high capacity, and high-speed public transport system | • There are at least 10 public transport routes that are faster than private cars in peak hours. |
| • Reduce air pollution from vehicle emission | • All buses satisfy the regulations on exhaust gas emission. |

Source: JICA Study Team

The frequency represents one of the levels of public transport services. For the accessibility, the distance to bus stops is a good indicator that can be evaluated using GIS data.

**Table 7.4-2 Targets of General Objective-2**

| **General Objective** | Integrate the Metropolitan Area with Road Network |
|---|---|
| **Specific Objectives** | **Target** |
| • Integrate both sides of the Pirai River. | • The urban area in Porongo is connected to the center of the rest of the metropolitan area in 60 minutes in maximum. |
| • Keep the roads in good condition for vehicles. | • Maximum speed in free-flow traffic condition is the enforced maximum speed of roads. |
| • Connect every municipality directly with high mobility. | • Travel time between the centers of municipalities is: Cotoca-Warnes (40 min), Wares-Porongo (60 min), Porongo-La Guardia (15min), La Guardia -El Torno (20 min). |
| • Formulate the proper hierarchy of the road network | • All arterial roads have crossing points with other arterial roads for all the sections. |

Source: JICA Study Team

Travel time by road would be the best indicator to evaluate how communities are integrated into the Metropolitan Area. Since the estimation of the average travel time in the Metropolitan Area using travel demand forecast requires traffic analysis based on the same demand model in the base year, it is proposed to use more simple indicators such as travel time between selected pairs.

**Table 7.4-3 Targets of General Objective-3**

| **General Objective** | Support the Sustainable Urban Development |
|---|---|
| **Specific Objectives** | **Target** |
| • Formulate the urban structure with proper road network by controlling suburban developments. | • No urban development is approved if it does not conform to the Master Plan. |
| • Support economic development in the Metropolitan Area | • Trucks can move between Warnes and La Guardia within 1 hour without pass through the area inside the 4th Ring Road<br>• Trucks can move between Porongo and Cotoca within 1 hour without pass through the area inside the 4th Ring Road |
| • Formulate the cost-effective road network in terms of construction and maintenance | • The total length of roads in the Metropolitan Area is less than 10,000 km. |

Source: JICA Study Team

The transport sector can contribute to the sustainable urban development by improving and controlling the freight movements, so the travel time of truck is selected as the indicator. For the sustainable development, the maintenance cost of the road network should be within the budget of the infrastructure sector.

**Table 7.4-4 Targets of General Objective-4**

| **General Objective** | Ensure Traffic Safety |
|---|---|
| **Specific Objectives** | **Target** |
| • Eliminate fatal traffic accidents | • Traffic-related death is zero.<br>• Traffic casualty rate in the metropolitan area is the lowest in the country. |
| • Reduce the number of traffic accidents | • Traffic accident rate in the metropolitan area is the lowest in the country. |
| • Raise awareness of traffic safety and compliance with traffic rules | • No. of violations of traffic rule recorded by the traffic police is 50% of the present statistics. |

Source: JICA Study Team

There are various indicators to evaluate the traffic safety as far as the statistics of traffic accidents is available. Presently, the available data of the traffic accidents in the Metropolitan area is limited, which makes it difficult to establish the base year benchmark for the indicators.

**Table 7.4-5 Targets of General Objective-5**

| **General Objective** | Ensure Smooth Traffic Flow |
|---|---|
| **Specific Objectives** | **Target** |
| • Relieve traffic congestion in the Historic Center | • Travel speed by car inside the Historic Center is more than 20km/h. |
| • Ensure mobility around markets, schools, and other facilities having high trip generation | • Travel speed of 3rd and 4th Ring Road is more than 25km/h in all sections. |
| • Eliminate bottlenecks in the road network | • The average delay per vehicle at major intersections is less than the level of the base year. |
| • Optimize the traffic flow using modern technology | • Dynamic traffic flow information is collected through probe data.<br>• A high-level car navigation system is provided. |
| • Encourage modal shift from private cars to public transport | • Modal share of public transport is 50% in 2025 and 60% in 2035. |

Source: JICA Study Team

As indicators for the smooth traffic flow, travel speed is one of the simplest evaluation factors which can be obtained by a simple survey. It is necessary to conduct a person trip survey or a similar survey to estimate the modal share in future.

**Table 7.4-6 Targets of General Objective-6**

| **General Objective** | Provide Better Environment for Bicycle Use and Pedestrian |
|---|---|
| **Specific Objectives** | **Target** |
| • Develop a safe and comfortable bicycle network | • Modal share of bicycles in terms of the major transport mode will be 3% in 2035. |
| • Improve the pedestrian network | • The crossing of roads for pedestrians is possible within 500m distance. |
| • Encourage urban development within walking distance (TOD) | • At least 3 urban areas should be developed as TOD. |

Source: JICA Study Team

The number of bicycle users or its share in transport mode would be the best indicators which can reflect the quality of the environment of bicycle use.

# 7.5 Urban Development and Land Use

## 7.5.1 Policies

To support the sustainable urban development objective, following policies shall be applied;

### (1) Urban Expansion Control

Following policies shall be applied to avoid unplanned scattered urban expansion.

**Table 7.5-1 Policies on Urban Expansion Control**

| Issue | Policy |
|---|---|
| • Unplanned scattered urban expansion without appropriate road network | • Establishment of the metropolitan level master plan together with coordination mechanism among local government. |
| • Low population density | • Appropriate high-density area allocation with public transportation network. |
| • Lack of appropriate development control mechanism | • Establishment of development control system with sharing information. |
| • Municipality boundary problem and land use management | • Solving the boundary problem as soon as possible to get approval for revised land use plan to manage urban development. |

### (2) Appropriate Land Reform

The land reform policy has been affecting *urbanization* proliferation in Santa Cruz metropolitan area. The appropriate policy is required between land reform and *urbanization* development.

**Table 7.5-2 Policies on Appropriate Land Reform**

| Issue | Policy |
|---|---|
| • Ambiguous difference between land redistribution and *urbanization* | • Establish a clear definition of land redistribution policy and *urbanization* development policy. |
| • Lack of unified cadastral database causing conflicts on land ownership | • Develop an integrated cadastral database to monitor land transaction. |
| • Weakness on law enforcement | • Establish new regal institute to minimize land conflict over land. |

### (3) Clear Demarcation and Support for Decentralization

Some demarcation rules cause rapid expansion of *urbanization*. Metropolitan-level planning and decision-making power are necessary. Moreover, also strengthening municipality level capability is key to promote decentralization policy.

**Table 7.5-3 Policies on Local Government Management**

| Issue | Policy |
|---|---|
| • Overlapping demarcation among governmental agencies | • Determine clear demarcation for governmental agencies especially departmental government. |
| • Lack of reeducation opportunity for local government staff | • Provide re-education and training opportunity from university and inter-municipal technical working group. |

**(4) Strengthen Local Level Revenue System**

Strengthening local level revenue system is key to the decentralized governing system.

**Table 7.5-4 Policies on Local Level Revenue System**

| Issue | Policy |
|---|---|
| • Population-based actuating revenue allocation from central government | • Improvement of local level revenue system |
| • Difficulty on updating cadastral database for real estate property tax collection | • Funding support for upgrading the cadastral database. |
| • Difficulty of unpaid measures of tax | • Awareness for citizens to know the importance of tax payment. |

**(5) Appropriate Development Control**

*Urbanizacion* development activities should be under control of each municipality. Following policies are necessary to avoid unexpected development.

**Table 7.5-5 Policies on Local Level Revenue System**

| Issue | Policy |
|---|---|
| • Lack of inspection and penalty system | • Improvement of development permission procedure and timing to control *urbanization* development. |
| • Lack of ethics of law compliance | • Establishment of regular learning and coordination opportunity of development codes for private developers. |
| • Lack of independence of local government | • Transfer of all development related permission procedures from the central level to local level. |
| • Long procedure and lack of data linkage among cadastral databases | • Establishment of coordination mechanism on land transaction. |

## 7.5.2 Proposed Project

Potential projects related to urban development based on the policies are proposed as follows;

**(1) Establishment of Metropolitan Planning and Regulation Coordination Mechanism**

Historically, there have been several conflicts happening among Department and Municipalities.

**1) Coordination Committee**

Metropolitan-level coordination committee must be established based on TWG (Technical Working Group) activities of this Master Plan Study which consist architects and engineers from related Municipalities and Department Government. Periodical meetings should be secured to discuss and solve common issues and to build up mutual relationship among Municipalities. Each government staff can join the committee on an equal footing to discuss for mutual interests.

**2) Public Participation**

Public participation mechanism should be secured to discuss specific issues to share the consideration for the urban development. Especially, related professionals from academics and private business shall be involved to collect ideas and comments on the issue.

The public consultation also provides important opportunities for the people to familiarize the issue and collect their concern to be reflected in the plan or projects.

**(2) Development Control Management Program**

To support sustainable urban development, development control management improvement is essential.

**1) Cadastral Database Integration**

The cadastral database is developed in each governmental agency without any coordination and information sharing. The integrated cadastral database at the metropolitan level is important to manage and control land transaction and urban development activity. Furthermore, this database is necessary for property tax collection for municipalities.

**2) Land Transaction Monitoring Mechanism**

Based on the integrated cadastral database system, land transaction activities should be monitored to avoid wide spreading of unplanned and scattered *urbanization* in rural areas. It is necessary to share this information among INRA, IGM, *Derecho Reales* and local governments.

**3) Unified EIA Approval Procedure**

EIA approval process shall be handled by the departmental government to avoid uncontrolled approval for development activity by the central government.

**4) Revision for Detailed Land Use Plan**

Based on this Transportation master plan, detailed land use plan shall be revised in each municipality. This revision work shall be coordinated under metropolitan planning coordination mechanism which established based on TWG on Planning.

**(3) Revenue System Improvement Program**

Revenue collection system at municipality is still weak. Improvement of revenue system is an urgent issue to make local governance healthy.

**1) Revenue Allocation System Improvement**

Stable and adequate budget allocation to local government needed for sustainable urban development management. Revenue allocation is the matter of the central government. However, technical support for revenue allocation system alteration is necessary to improve local government management.

**2) Routine Tax Rate Revision**

Routine tax rate revision is the key to collect revenue based on economic growth. Small municipalities need financial support to revise tax rate for property taxation. This system is related to the above mentioned cadastral database system.

**3) Awareness Program for Tax Payment**

Awareness of people for the importance of tax payment is necessary to receive public service from local government.

# 7.6 Road Infrastructure Plan

## 7.6.1 Policies

Policies of the road infrastructure were established so that they can contribute to achieving the objectives as shown in Table 7.6-1. The pavement of unpaved roads is one of the major policies of the road infrastructure plan.

**Table 7.6-1 Policies of Road Infrastructure with Related Objectives**

| General Objectives | Specific Objectives | Policy |
|---|---|---|
| Increase Mobility and Accessibility of Public Transport Services | • Provide the stable and reliable public transport services in all weather conditions. | • All roads for public transport should be paved in the early stage.<br>• The drainage system should be developed to flow rainwater without flooding. |
| Integrate the Metropolitan Area with Transport Network | • Integrate both sides of the Pirai River. | • Bridges should be constructed along the Pirai River. |
| | • Keep the roads in good condition for vehicles. | • Rehabilitation and maintenance works of the road network should be carried out. |
| | • Connect every municipality directly with high mobility. | • Construct a bypass route of the center of the Metropolitan Area. |
| | • Formulate the proper hierarchy of the road network | • "Missing links" of arterial roads should be developed to formulate the proper network. |
| Support the Sustainable Urban Development | • Formulate the urban structure with proper road network by controlling suburban developments. | • The proposed ROW should be properly protected in future. |
| | • Support economic development in the Metropolitan Area | • Construct a bypass route of the center of the Metropolitan Area. |
| | • Formulate the cost-effective road network in terms of construction and maintenance | • Priority is given to the effective use of the existing road network instead of new construction.<br>• The road network size should be under the size at which maintenance work can be done within the budget. |
| Ensure Traffic Safety | • Eliminate fatal traffic accidents | • Monitor the road conditions. |
| | • Reduce the number of traffic accidents | • Humps should be installed on local streets. |
| Ensure Smooth Traffic Flow | • Eliminate bottlenecks in the road network | • Flyover should be constructed at saturated intersections where any traffic management cannot resolve the saturation. |
| Provide Good Environment for Non-Motorized Transport | • Encourage urban development within walking distance (TOD) | • Road network should be developed to support TOD. |

Source: JICA Study Team

## 7.6.2 Road Network

### (1) Corridors

The Santa Cruz Metropolitan Area is located on important corridors such as the Fundamental Road 4 (F4) going to Brazil in the east and Peru in the west. F4 also plays an important role in the Metropolitan Area as the corridor connecting Santa Cruz de la Sierra and Warnes. F7, which is the alternative route of F4, connects the metropolitan area with to Cochabamba and La Paz from the 4th Ring Road through La Guardia and El Torno in the south. F9, which branches from F7 in La Guardia, connects the metropolitan area with Argentina.

As a part of the Bioceanic Corridor, which connects the Pacific Ocean and the Atlantic Ocean through Bolivia, a new road is planned to be constructed between La Guardia and Buena Vista through Porongo.

Presently, these corridors connect to the Ring Roads in Santa Cruz de la Sierra, and there is no bypass route other than the 4th Ring Road to avoid passing through the center of the metropolitan area. To reduce the traffic congestion, bypass routes are necessary for the long-distance trips which pass through the center of the metropolitan area.

The bypass routes are also necessary for the connection among municipalities. Since Av. Virgen de Cotoca is one of the most congested roads, a bypass route that connects Cotoca and La Guardia is necessary. Warnes is expected to become an important freight hub with the industrial park and the international airport. Therefore, Cotoca and Warnes should be directly connected without entering the urbanized area of Santa Cruz de la Sierra.

Large-scale urban development projects in the east of the international airport need new roads connecting the area with the center of the Metropolitan Area. The new road that is under construction along the railway line is expected to become the corridor for the new urban developments.

Figure 7.6-1 illustrates the important corridors in Santa Cruz Metropolitan Area in future.

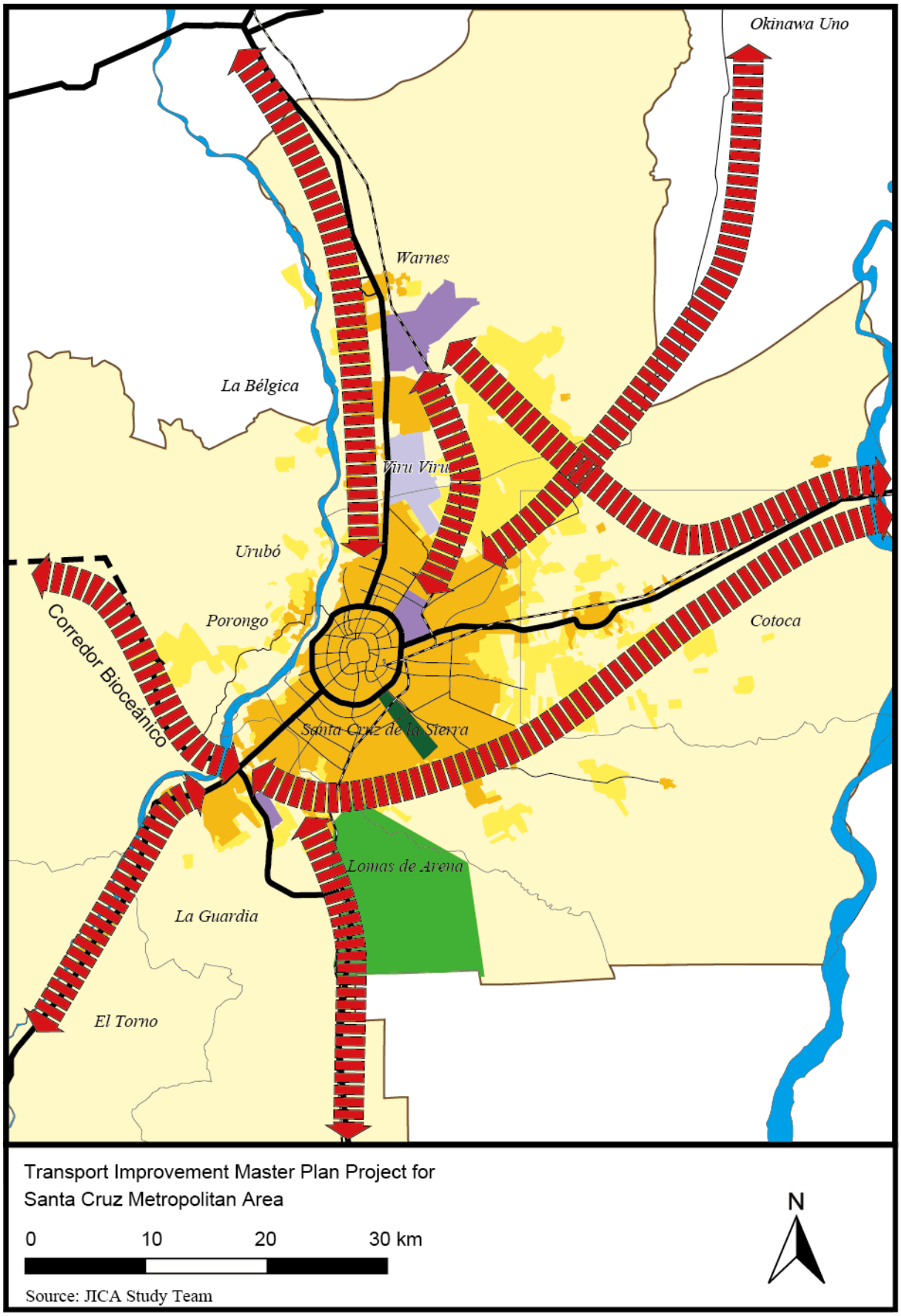



**Figure 7.6-1 Future Corridors in the Metropolitan Area**

**(2) Road Network Plan**

Figure 7.6-2 illustrates the future road network in the Master Plan. Presently, many urbanizations have been approved but have not been developed. The road plans in such urbanizations are considered for the future road network, and the road plans of the approved urbanizations are not changed in the proposed road network.

The Costanera Road along the Pirai River, which connects La Guardia and Warnes without passing through the center of Santa Cruz de la Sierra, is included in the Master Plan as the bypass route of the "Doble Via", because the traffic volume between La Guardia and Santa Cruz de la Sierra through "Doble Via" would exceed the road capacity even if the BRT, which is proposed public transport system in the Master Plan, is introduced.

In PLOT 2005, the Metropolitan Expressway, an express road along the boundary of the urbanized area as a ring road, was proposed, although the Metropolitan Expressway has not been implemented yet. Due to the rapid urban growth, a part of the Right-of-Way of the Metropolitan Expressway was occupied by houses, and the housing development along the Metropolitan Expressway continues. The Metropolitan Expressway was expected to play an important role to provide a detour of the urbanized area of Santa Cruz de la Sierra, connecting La Guardia, Cotoca, and Warnes with high speed. However, it is difficult to construct the road because it requires a large-scale resettlement. The route was reviewed, and the new alignment was proposed as shown in the figure. The proposed road still requires resettlement, and it is necessary to analyze the feasibility of the road before the implementation stage.

The new road in Porongo, running north and south on the west side of the Pirai River, connects La Guardia, Urubo in Porongo, and Warnes. This road uses an existing road, but there is a section where new construction is necessary. Since a large-scale urbanization is planned in La Belgica, which is located to the north of Porongo, the Master Plan considers the connection between La Belgica and the Santa Cruz Metropolitan Area.

The road along the railway line from the Industrial Park in Santa Cruz de la Sierra to that of Warnes plays an important role to connect the new urbanized area to the east of Viru Viru International Airport. The road network to the east of Viru Viru Airport is in principle as same as the plan of the private developer of this area because the municipality of Warnes has already approved the urbanizations.

Missing links of ring roads proposed in PLOT 2005 are included in the Master Plan, except for some sections which are not possible to be constructed due to the housing development.

**(3) Highway Illumination**

Street lights should be installed along the Fundamental Highway to ensure traffic safety and reduce the traffic accidents. It is important that drivers can recognize pedestrian along the roads to avoid accidents involving pedestrians. Recently, sodium lamps are being replaced by LED lamps in many cities in the world because it can save energy and the cost became reasonable. One of the advantages of LED lamps is that it improves visibility in night time which can reduce traffic accidents. It is recommended to consider the introduction of LED lamps for the street lights.

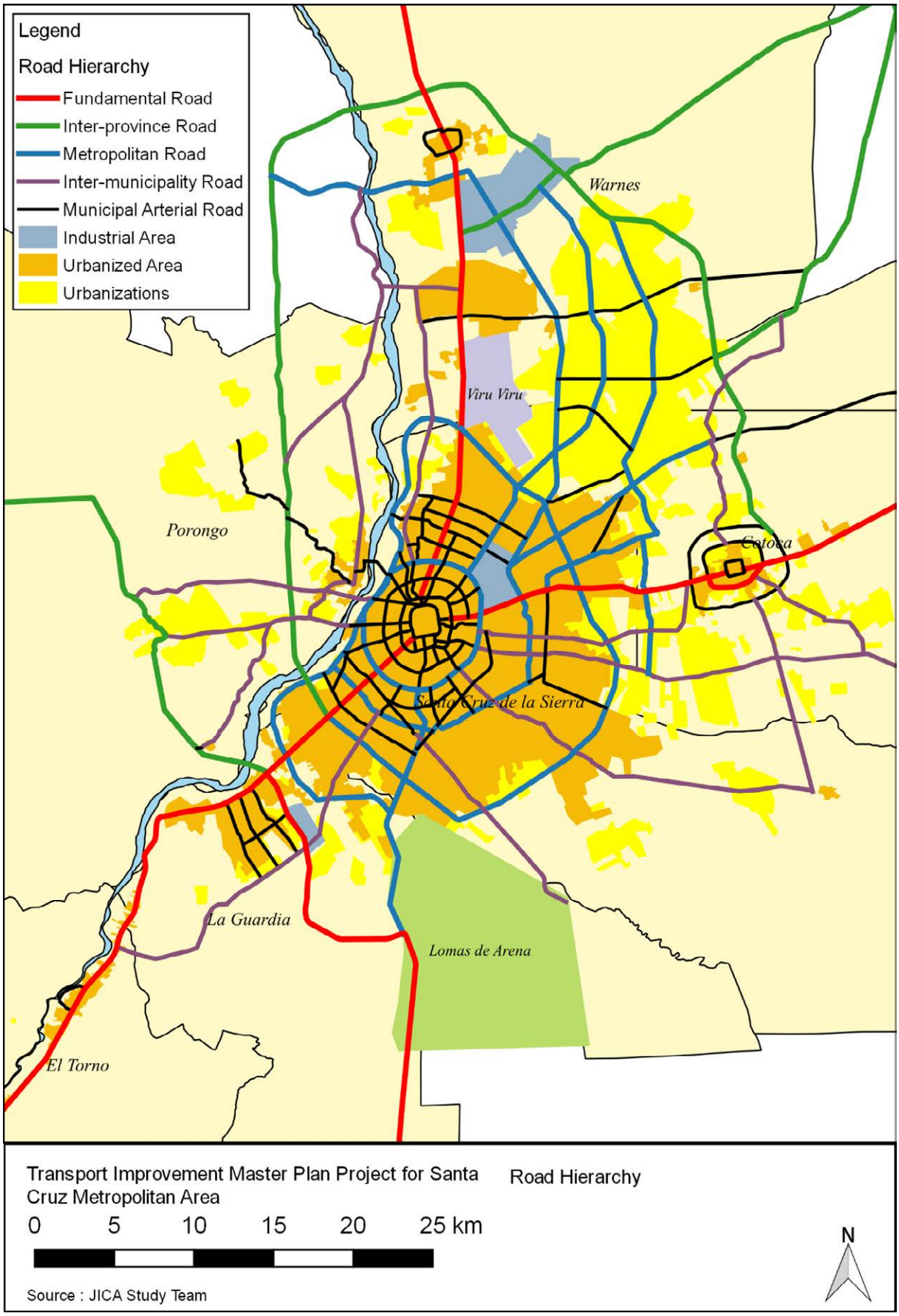



**Figure 7.6-2 Future Road Network**

Figure 7.6-2 illustrates the future road network consisting of arterial roads at the metropolitan level. The roads are classified as:

- **Fundamental Road Network** is as same as the Fundamental Road Network defined in Law 165.
- **Inter-province Roads** connect the Santa Cruz Metropolitan Area to other provinces.
- **Metropolitan Roads** form the urban structure at the metropolitan level. The roads run through urbanized areas in principal.
- **Inter-municipality Roads** connect two municipalities or the center of each municipality and communities in rural areas. The roads run through both urbanized areas and rural areas.
- **Municipal Arterial Roads** form the arterial road network at the municipal level.

## 7.6.3 Projects

### (1) Project Category

The road projects are categorized into (1) construction of new roads (including the construction of new bridges), (2) road widening, (3) road improvement, (4) pavement of local streets, and (5) improvement of intersections. The road improvement includes the pavement of arterial roads, rehabilitation, and realignment of arterial roads. The project list is shown in Chapter 9.

### (2) Project Cost

The project cost in the cost estimation of the road projects consists of the pre-investment, the engineering studies, and the construction. The construction cost was estimated by applying the unit cost per kilometer which was estimated based on the information of road projects in the Metropolitan Area. Table 7.6-2 shows the unit costs of the road projects.

**Table 7.6-2 Unit Costs of Road Projects**

Unit: US$/m

| Type of work | No. of lanes | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Improvement (pavement) | 108 | 216 | 324 | 432 |
| Improvement | 160 | 320 | 470 | 630 |
| New construction | 270 | 540 | 800 | 1,070 |

Source: JICA Study Team

The unit cost of a new bridge construction was assumed at US$ 605/m$^2$. The cost of pre-investment and the engineering studies was assumed at 1.5% and 3% of the construction cost, respectively. The maintenance and rehabilitation costs after the construction were assumed to arise every year at 1% of the construction cost.

These projects should be implemented in the short-, medium- and long-term. For this purpose, a schedule considering the investment amount for each case has been calculated based on estimated costs, which were presented in Table 7.6-3 to Table 7.6-5. The location of the road projects by the development phase is shown in Figure 7.6-3.

Figure 7.6-4 illustrates the location of the road projects by road administrator, while Figure 7.6-5 illustrates that by the number of lanes.

**Table 7.6-3 Estimated Costs of Road Infrastructure Projects - Short Term (2020)**

Unit: Million US$

| Type | No. | Length | Pre-investment | Engineering studies | Construction and Supervision of field works | Total |
|---|---|---|---|---|---|---|
| Road Construction | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Road Improvement | 3 | 27.8 | 0.2 | 0.5 | 16.2 | 16.8 |
| Road Widening | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Intersections and Interchanges | 2 | | 0.2 | 0.4 | 12.7 | 13.3 |
| Total | 5 | 27.8 | 0.4 | 0.8 | 28.9 | 30.1 |

Source: JICA Study Team

**Table 7.6-4 Estimated Costs of Road Infrastructure Projects - Medium term (2025)**

Unit: Million US$

| Type | No. | Length | Pre-investment | Engineering studies | Construction and Supervision of field works | Total |
|---|---|---|---|---|---|---|
| Road Construction | 9 | 47.6 | 0.9 | 1.8 | 64.4 | 67.1 |
| Road Improvement | 11 | 117.7 | 1.3 | 2.5 | 89.3 | 93.0 |
| Road Widening | 8 | 80.0 | 1.8 | 3.5 | 125.2 | 130.5 |
| Intersections and Interchanges | 29 | | 1.4 | 2.8 | 98.1 | 102.2 |
| Total | 57 | 245.3 | 5.3 | 10.7 | 376.9 | 392.9 |

Source: JICA Study Team

**Table 7.6-5 Estimated Costs of Road Infrastructure Projects - Long term (2035)**

Unit: Million US$

| Type | No. | Length | Pre-investment | Engineering studies | Construction and Supervision of field works | Total |
|---|---|---|---|---|---|---|
| Road Construction | 25 | 351.9 | 5.5 | 11.0 | 389.9 | 406.4 |
| Road Improvement | 25 | 364.7 | 3.5 | 6.9 | 244.5 | 254.9 |
| Road Widening | 6 | 50.0 | 0.6 | 1.3 | 45.0 | 46.9 |
| Intersections and Interchanges | 96 | | 4.3 | 8.7 | 305.9 | 318.9 |
| Total | 152 | 766.6 | 13.9 | 27.9 | 985.2 | 1027.1 |

Source: JICA Study Team

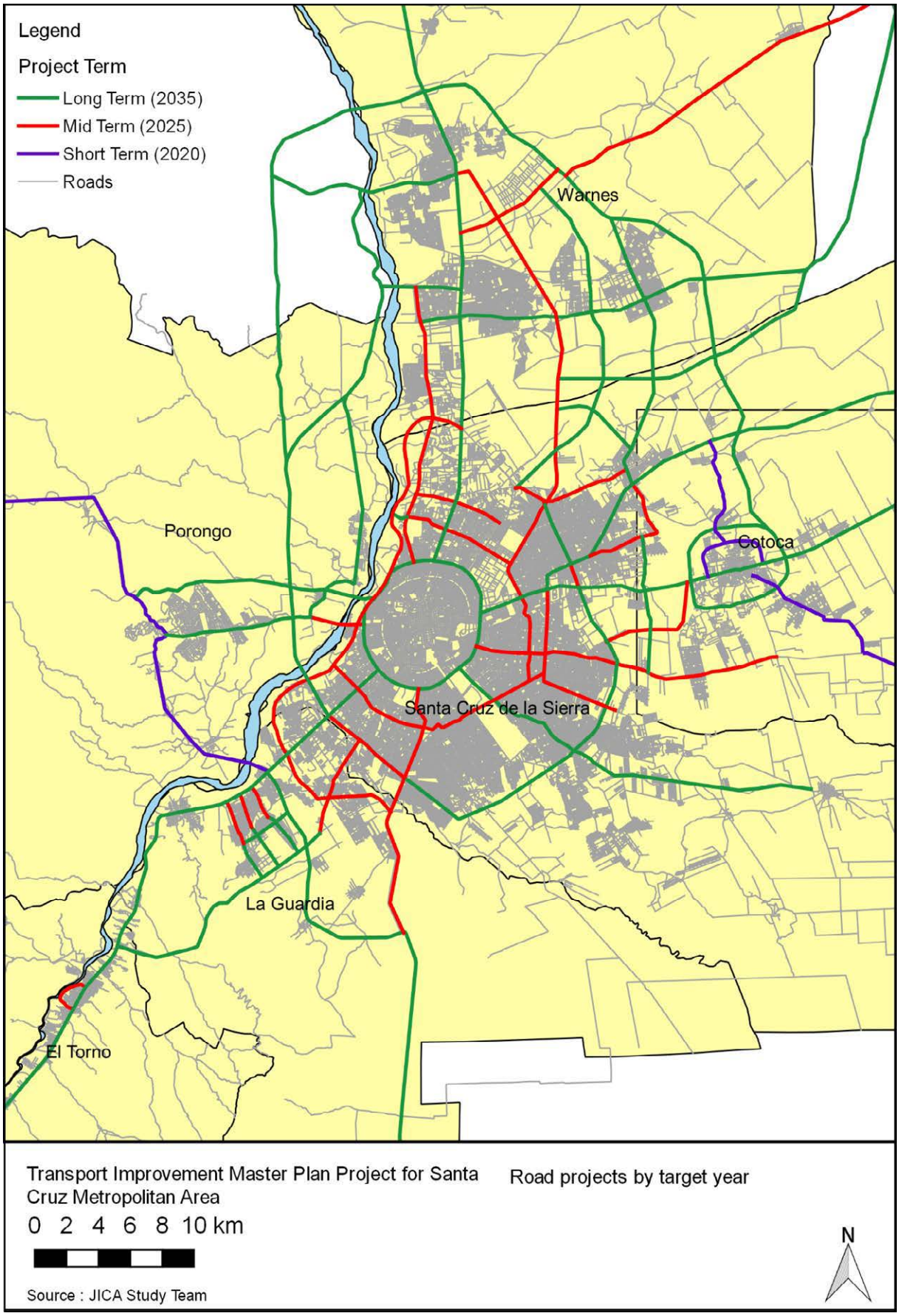



**Figure 7.6-3 Road Projects by Development Phase**

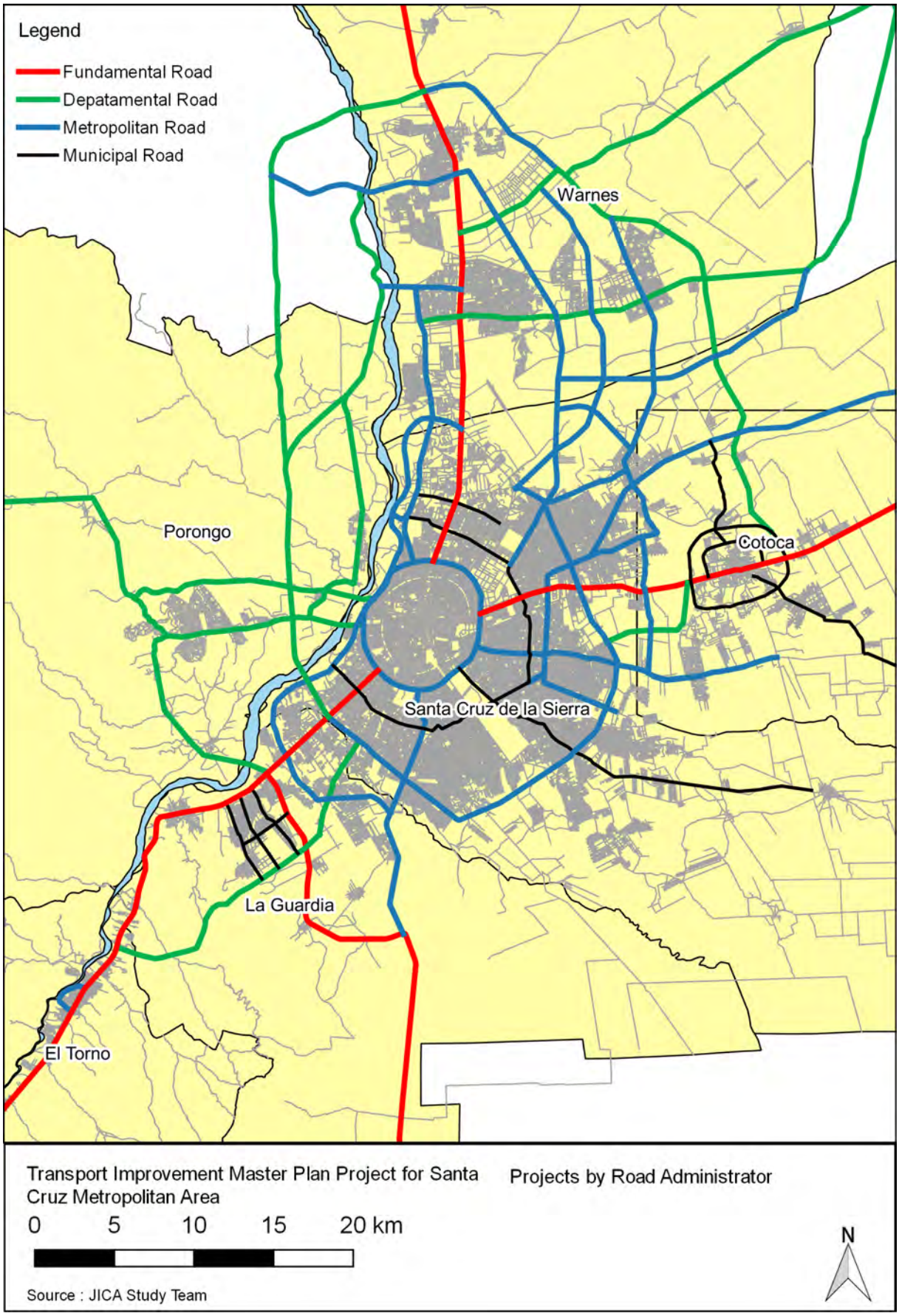



**Figure 7.6-4 Road Projects by Road Administrator**

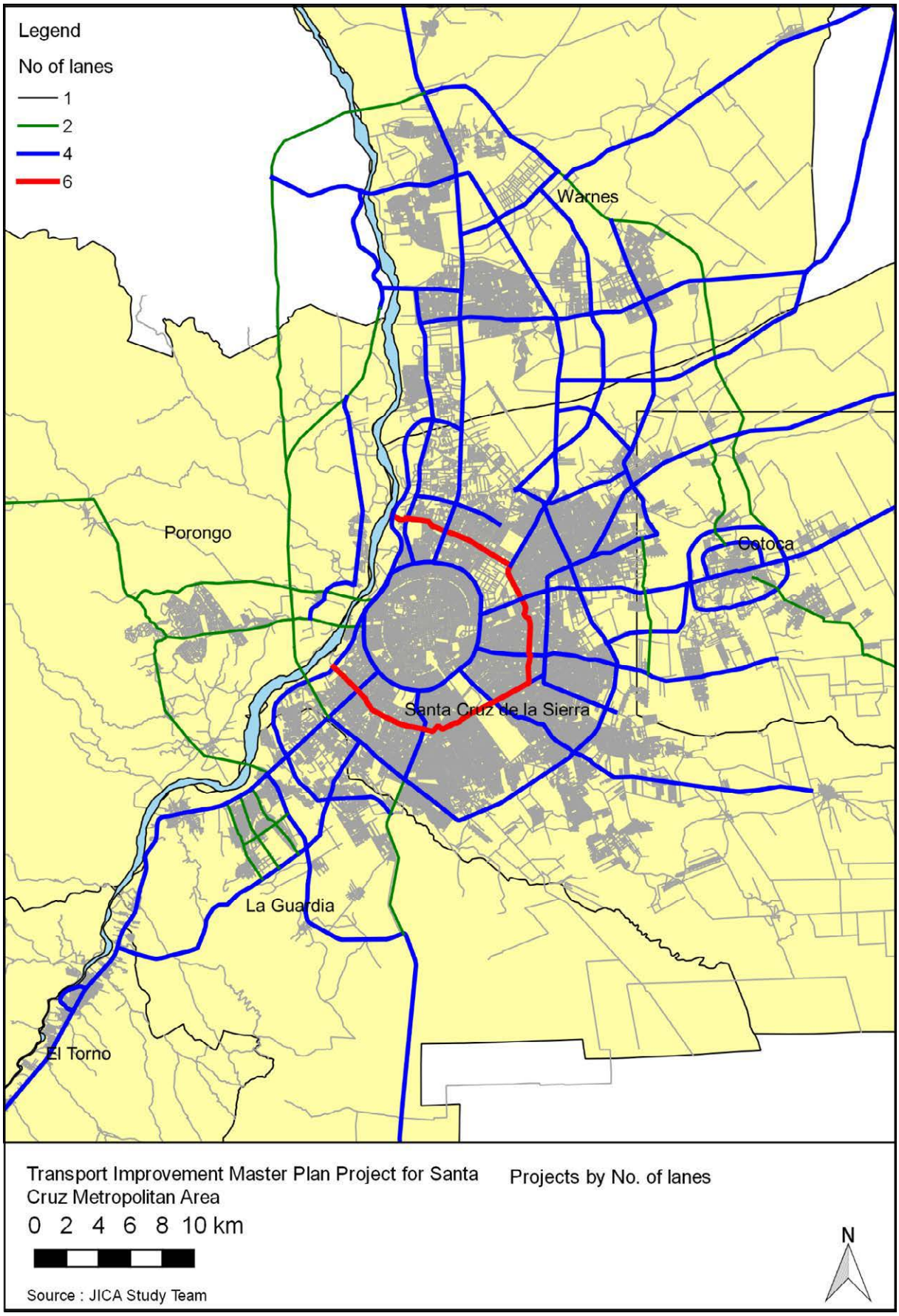



**Figure 7.6-5 Road Projects by Number of Lanes**

# 7.7 Public Transport System Development Plan

## 7.7.1 Policies

Policies of the public transport system development were established so that they can contribute to achieving the objectives as shown in Table 7.7-1.

The policies focus on existing public transport system, including the introduction of trunk and feeder system and the integrated fare system.

The public transport sector should contribute to the Transit Oriented Development (TOD), which can be applied to the urban development to the east of the international airport.

Modal shift from private cars to public modes is one of the important policies of the public transport sector. Due to the difficulty to construct new radial roads connecting new urbanized areas and the center of Santa Cruz de la Sierra, an introduction of a public transport system is necessary in the future. The system should be attractive enough to encourage private car users to change their transport mode.

**Table 7.7-1 Policies of Public Transport with Related Objectives**

| General Objectives | Specific Objectives | Policy |
|---|---|---|
| Increase Mobility and Accessibility of Public Transport Services | • Provide the stable and reliable public transport services in all weather conditions. | • All public transport should satisfy the pre-defined conditions by the authority.<br>• Install bus stops with roof |
| | • Provide sufficient public transport services in all urban areas. | • Public bus services should be provided to cover all urban areas<br>• Restructure the bus network by trunk bus and feeder bus system<br>• Public transport corridor should be developed to encourage the Transit Oriented Development |
| | • Provide safe, comfortable, high capacity, and high-speed public transport system | • Introduce a mass transit system<br>• Bus fleets should be inspected by vehicle inspection system<br>• Introduce an integrated public transport fare system |
| | • Reduce air pollution from vehicle emission | • Vehicle inspection should be enhanced and conducted more strictly<br>• Old bus fleet should be replaced with modern buses |
| Ensure Smooth Traffic Flow | • Relieve traffic congestion | • Introduce BRT system<br>• Introduce high-capacity buses<br>• Introduce transit mall in the historical center area where possible |
| | • Optimize the traffic flow using modern technology | • Introduce the bus location system |
| | • Encourage modal shift from private cars to public transport | • Promote modal shift by providing attractive public transportation system |
| Provide Good Environment for Non-Motorized Transport | • Develop a safe and comfortable bicycle network | • Integration of bicycle road network with BRT network |
| | • Improve the pedestrian network | • Provide good pedestrian path to bus shelters/stops |
| | • Encourage urban development within walking distance (TOD) | • Mass transit corridors should be introduced to support TOD |

Source: JICA Study Team

## 7.7.2 Proposed Public Transport System

### (1) Hierarchy of Bus Routes

Comprehensive bus route restructuring is desired to make bus transport system efficient and convenient for passengers. The following hierarchy of bus routes is established for bus route restructuring.

a) Trunk Bus Route

Trunk bus routes carry massive passengers at high speed. Bus Rapid Transit is proposed to operate on the trunk bus routes.

b) Sub-Trunk Bus Route

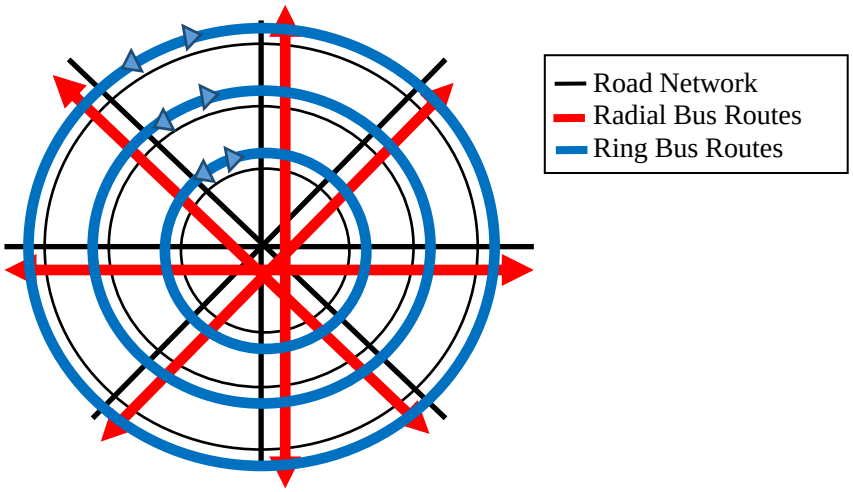
Sub-trunk bus routes supplement the trunk bus routes by connecting them or by branching from them.

c) Feeder Bus Route

Feeder bus routes collect bus passengers from residential areas where population density is low and carry to the trunk bus routes or the sub-trunk bus routes.

### (2) Basic Concept of Bus Route Structure

Road network in Municipality of Santa Cruz de la Sierra consists of radial roads and ring roads. If the bus route structure is formulated in accordance with the structure of the road network, the bus route structure could be a simple structure with radial routes and ring routes as illustrated in Figure 7.7-1. The benefit of such structure is convenient for bus passengers because they can reach the destination if they transfer once from a bus route to another route.



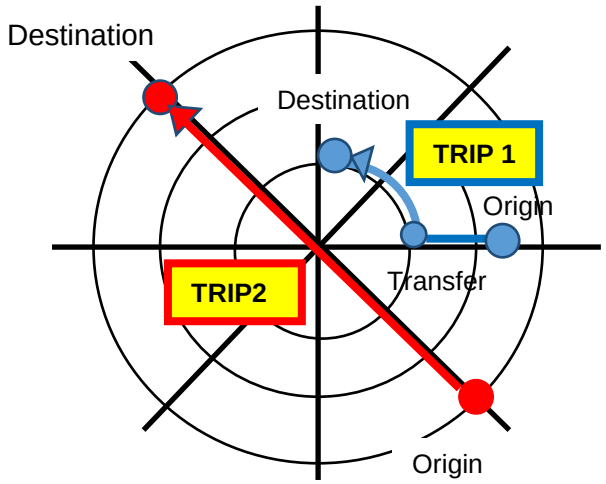

Source: JICA Study Team

**Figure 7.7-1 Desirable Trunk Bus Route Structure**

An integrated bus fare system encourages transfer from one bus route to another. The fare system supports to make it easier to develop simple bus route structure since bus passenger can travel on multiple bus routes without considering doubling bus fare caused by transfer.

The present bus fare system in Municipality of Santa Cruz de la Sierra is flat tariff system. A bus passenger pays Bs. 2 for one ride. If they transfer from a bus route to another, they

should pay the bus fare twice. Figure 7.7-2 illustrates an inequitable problem among bus passengers.




Source: JICA Study Team

**Figure 7.7-2 Example of Transfer Trip and Direct Trip**

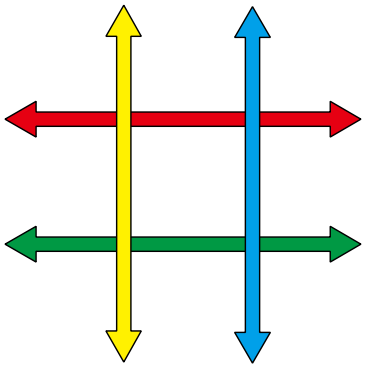
The distance of TRIP 1 is shorter than that of TRIP 2, however, a traveler of TRIP 1 should pay twice in the present fare system. It is more reasonable to determine a tariff by distance traveled. The distance proportional bus fare is reasonable and could be accepted by bus passengers.

The bus route structure consisting of radial and ring routes would provide higher frequency and high speed, which shorten the travel time. It would, however, cause an increase in total bus fare for a trip since the radial and ring bus route structure requires transfers. In order not to discourage the use of bus transport, additional payment by transfer should be avoided or minimized.

### (3) Bus Routes inside the 1st Ring Road

Presently, there are two north-south bus routes and two east-west bus routes inside the 1st Ring Road as shown in Figure 7.7-3. Since each route uses one road per direction due to its one-way street system in the central area, there are eight routes in total. This concept is inherited in the Master Plan, while some routes are proposed to use a different street.

There are some duplications in the present network. For example, microbus lines from west to east and those of north to south use the same section of Aroma Street between Caballero and Arenales. The future bus network is planned to avoid using the same street by different corridors inside the 1st Ring Road.

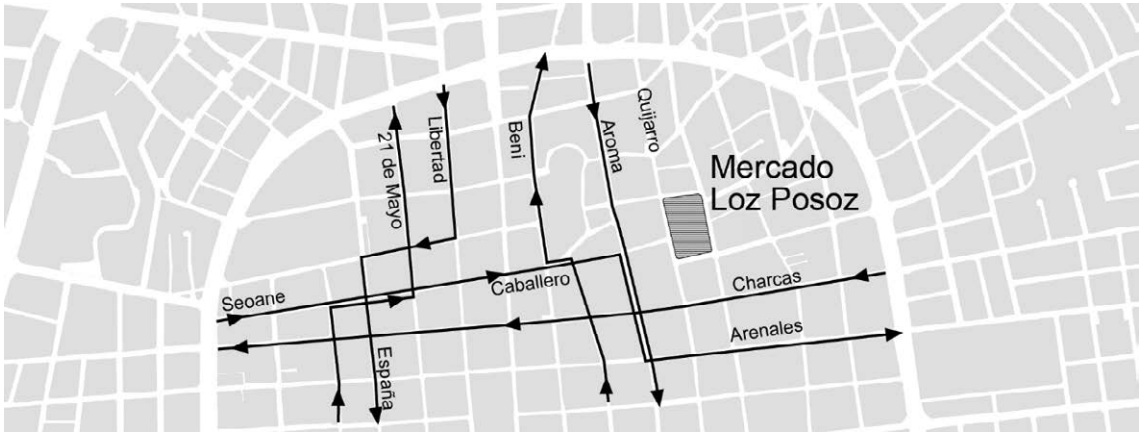


Source: JICA Study Team

**Figure 7.7-3 Image of Bus Routes inside the 1st Ring Road**

Due to illegal roadside parking and street vendors in narrow streets, it was difficult to change the existing bus routes. However, the market relocation project enabled to make the re-alignment plan of bus routes inside the 1st Ring Road. Aroma Street is one of the existing bus routes, but the congestion is heavy due to street vendors around Los Posoz Market. As described in Chapter 3, the municipality of Santa Cruz de la Sierra plans to move street vendors around Los Pozos in the short-term period. After the market relocation

project, Quijarro Street, which is currently occupied by street vendors, can be used as a public transport route.




Source: JICA Study Team

**Figure 7.7-4 Location of Los Posoz Market and Bus Routes**

**(4) Fare Integration with Smartcard**

The fare system within Santa Cruz de la Sierra should be integrated with the modern technology such as IC smartcard in future. This is essential to achieve the radial and ring network of the public transport system that involves transfers between radial and ring lines. The fare integration is necessary to reduce the transfer cost, which can be implemented by using IC smartcard. The fare system is analyzed in 7.7.4.

**(5) Bus Location System**

It is recommended to introduce a bus location system to enhance the convenience for both users and operators. Through its introduction, users can obtain the current location of buses, making it become a reliable transportation method. Once public transportation utilization is promoted, total traffic demand is expected to reduce. Bus location information is used not only for the bus operator's operation interval management or user's judgment of utilization but also used for estimation of traffic conditions.

## 7.7.3 Proposed BRT Network

**(1) BRT Routes**

In principle, the proposed BRT network consists of radial routes, which pass the central area and go to the other end of Santa Cruz de la Sierra as shown in Figure 7.7-5. Since the Central Area forms grid pattern road network, east-west direction and north-south direction is easily connected with radial routes. On the other hand, the direct connection between the north-east and the south-west would be difficult and so does between the north-west and the south-east. Therefore, the routes from the south-west make an anticlockwise round operation on the first ring road. Similarly, Avenida- 1st Ring Road route also make anticlockwise round operation on the 1st Ring Road.

In the Central Area, left turn of BRT on 1st Ring Road and 2nd Ring Road is avoided since at present the municipality of Santa Cruz de la Sierra has made efforts to restrict left-turn at several intersections to give longer green phase time for vehicles going straight. To support the current efforts to alleviate traffic congestion by such traffic controls, left-turn of BRT fleets on 1st and 2nd Ring Roads are avoided as illustrated in Figure 7.7-6.

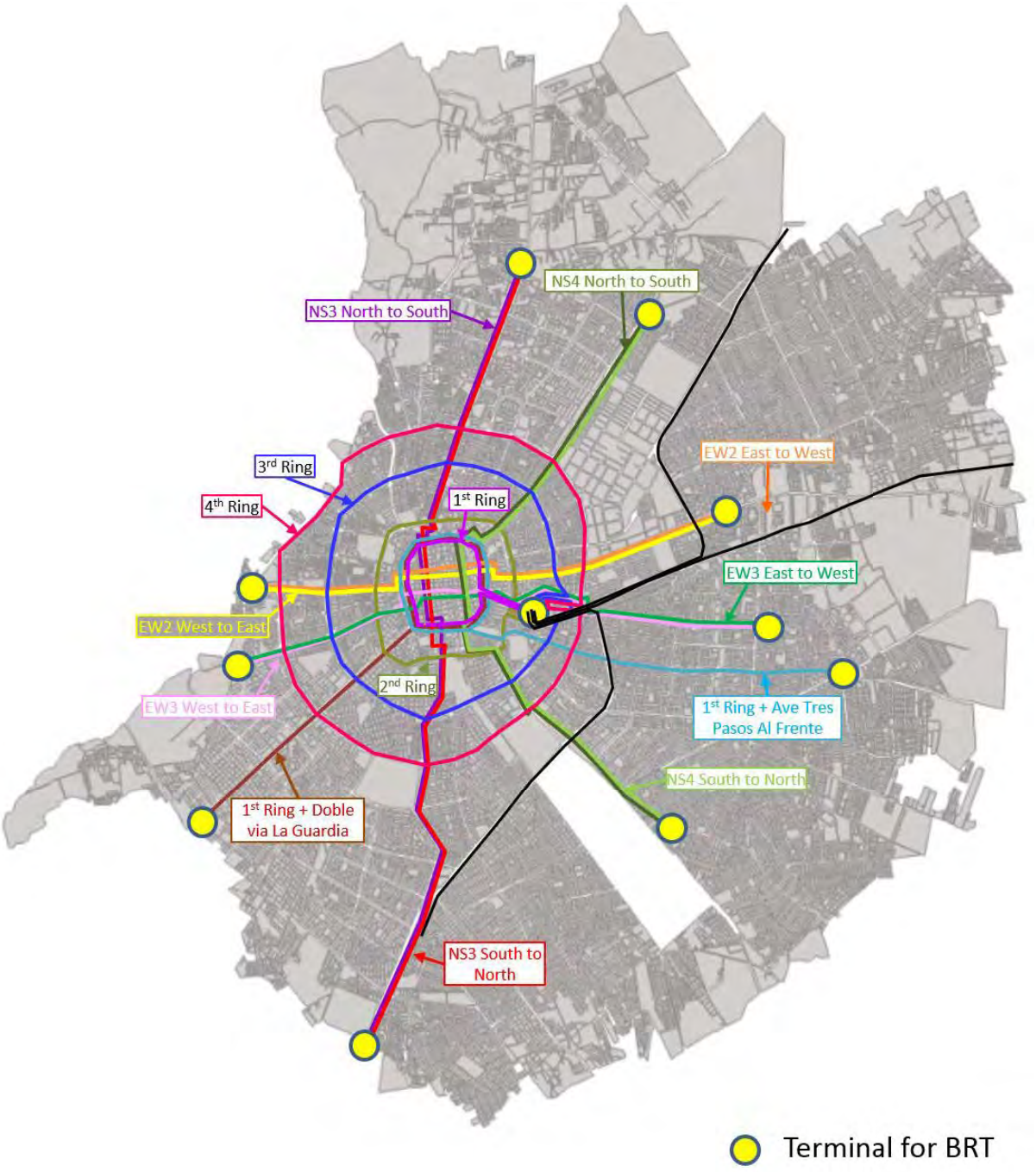
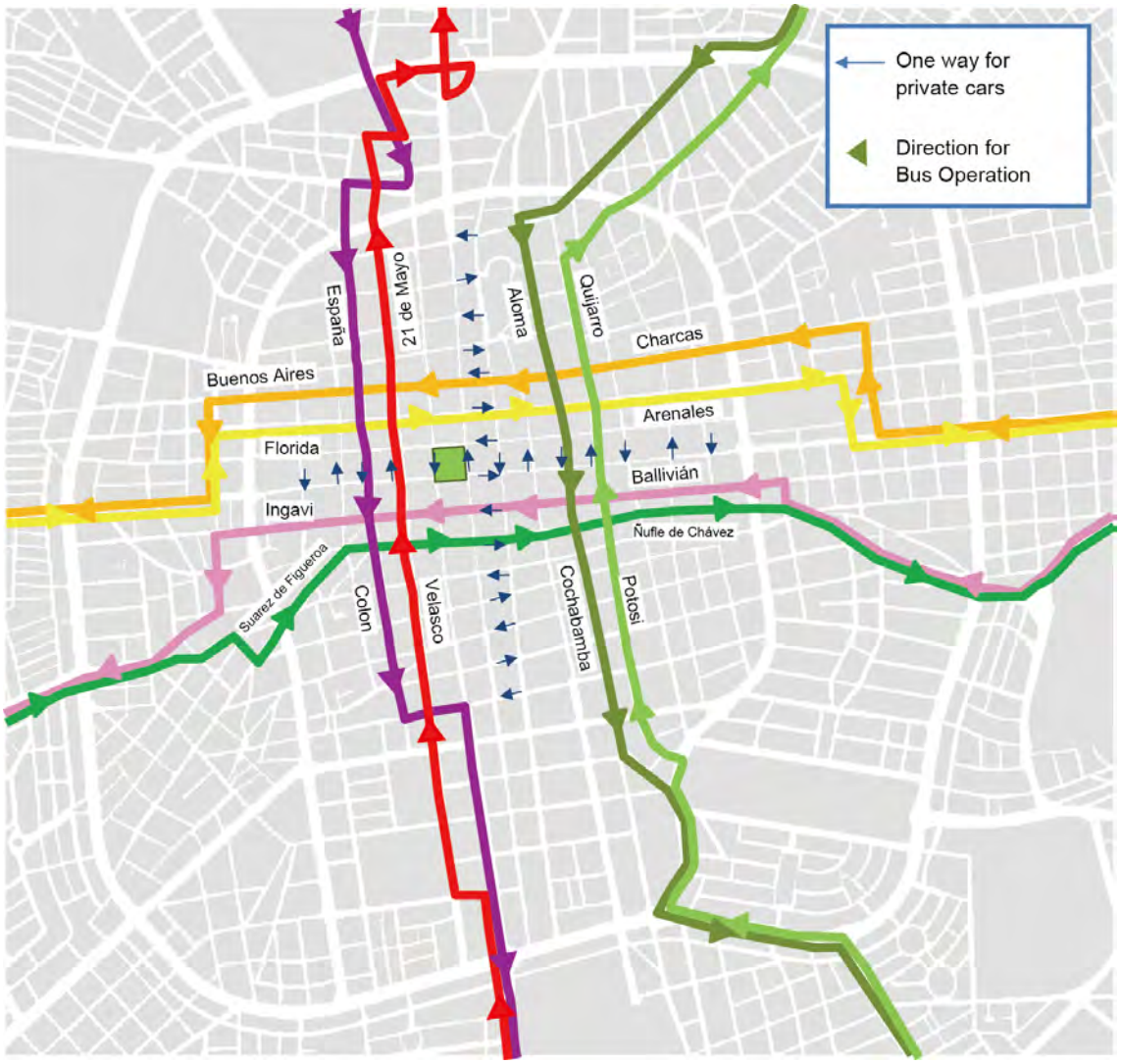



**Figure 7.7-5 Proposed BRT Routes in Santa Cruz de la Sierra**




Source: JICA Study Team

**Figure 7.7-6 Proposed BRT Routes in Central Area**

### (2) BRT Routes in Santa Cruz de la Sierra

It is proposed to alter BRT service according to the passenger demand and road conditions on the corridor. The following two BRT routes explain the different treatment in accordance with the situation of the section.

#### 1) North-South (West) BRT Route (Route Length: 17.0 km)

This BRT route is divided into three sections as shown in Figure 7.7-7, and each section shall be differently treated in the BRT operation.

a) Northern Section

Buses run on a lane next to the sidewalk, and passengers are boarding and alighting from the curbside.

When feeder bus services on 5th, 6th, 7th and 8th Ring Roads start operation, transfer at intersections should be considered. Some buses are operated as conventional bus and bus passengers should board and alight from the curb near the intersections. On the other hand, express buses can be operated in the middle of the road and pass the

flyovers. In this case, no passenger can get on and off at the intersections with these ring roads.

b) From 4th Ring Road to 1st Ring Road:

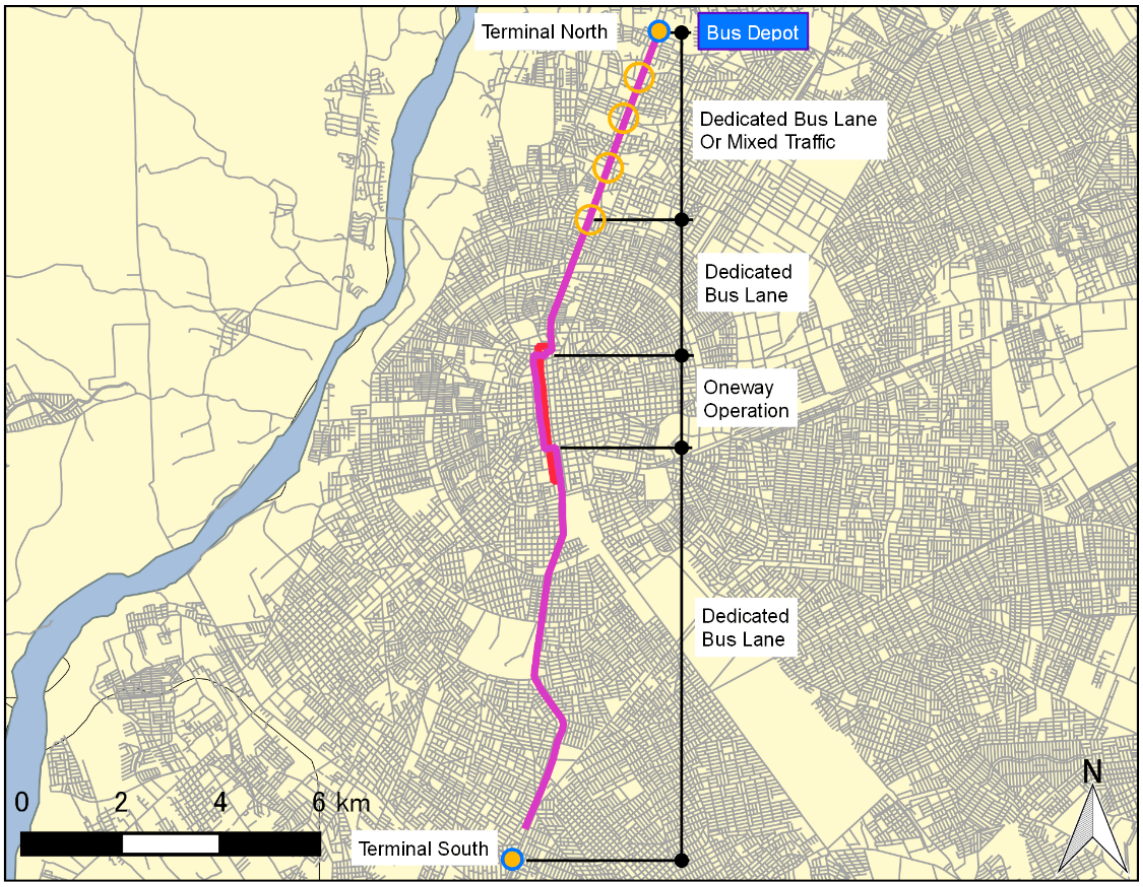
BRT shall run on a dedicated bus lane near median

c) Within 1st Ring Road

Bus passenger board from the curbside and bus operation shall be contraflow to the ordinary traffic to preserve priority for BRT.

d) Section from 1st Ring Road to the south

BRT buses run on a dedicated bus lane near the median, and passengers are boarding from the platform of bus shelters in the median.

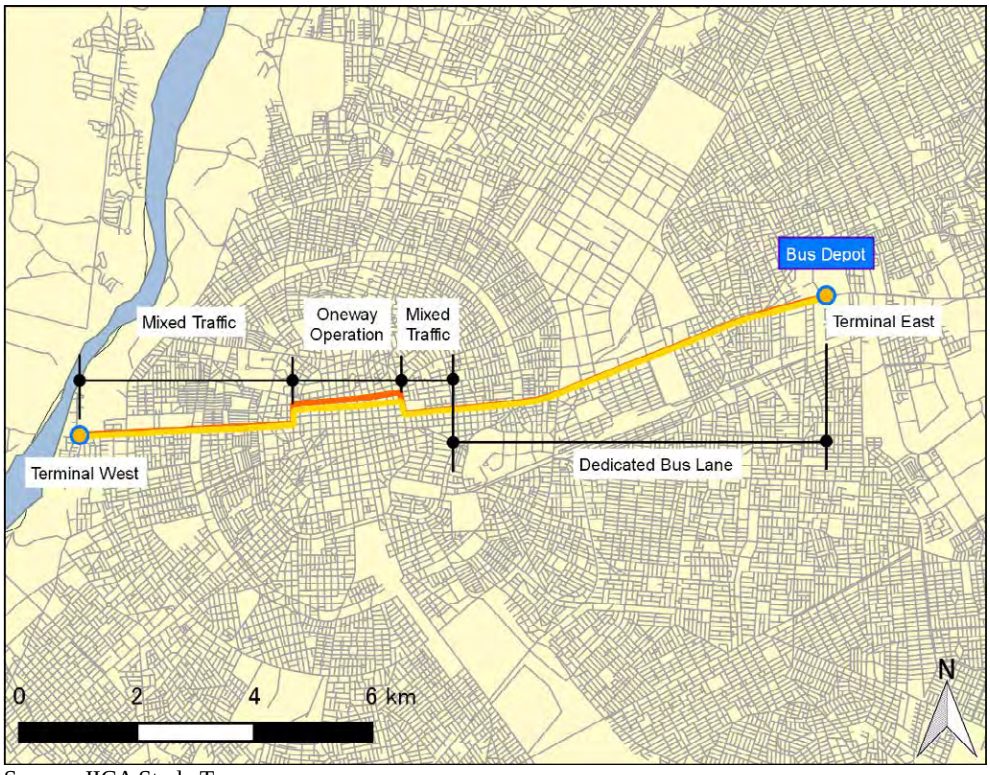



Source: JICA Study Team

**Figure 7.7-7 North-South (West) BRT Route**

**2) East-West Bus Route (Route Length: 13.5 km)**

BRT operation is different according to the section as shown in Figure 7.7-8.

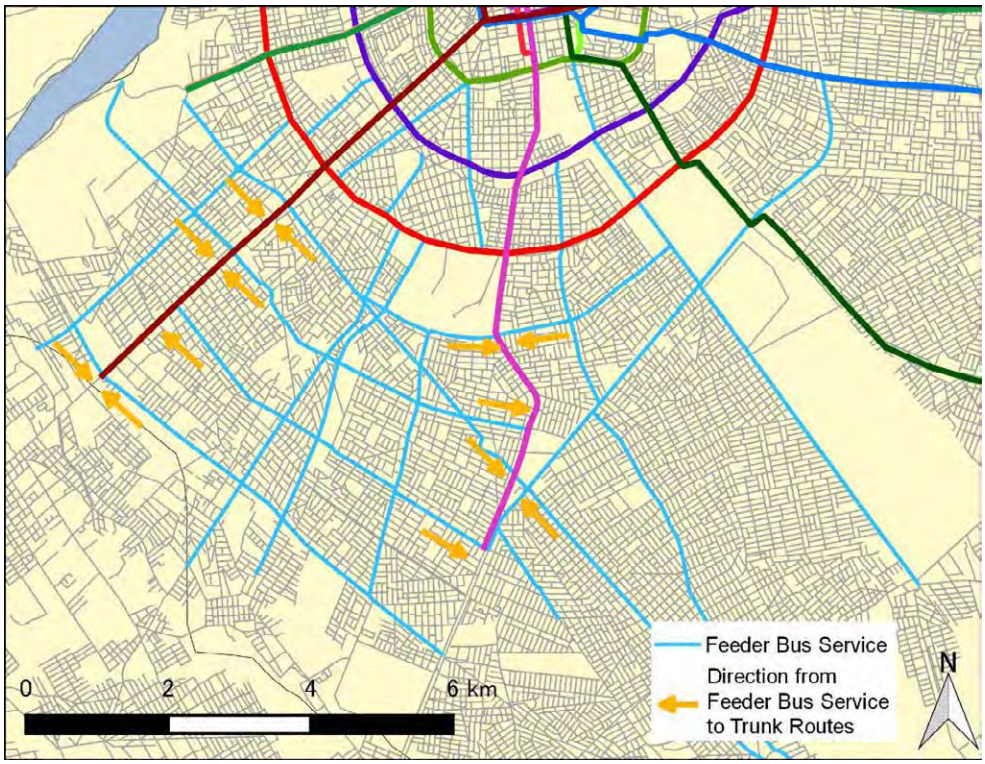



Source: JICA Study Team

**Figure 7.7-8 East-West BRT Route**

### (3) Trunk Bus Routes and Feeder Bus Routes

Trunk bus routes mainly operated as BRT in radial directions are supported by feeder bus services in circular directions as shown in Figure 7.7-9.

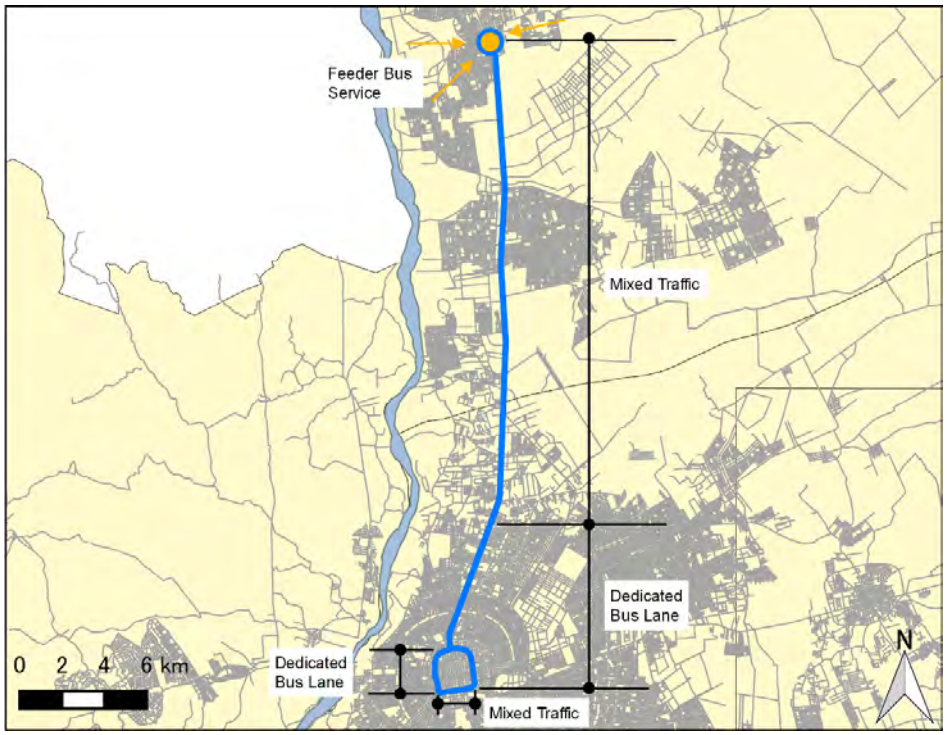



Source: JICA Study Team

**Figure 7.7-9 Feeder Service for BRT System**

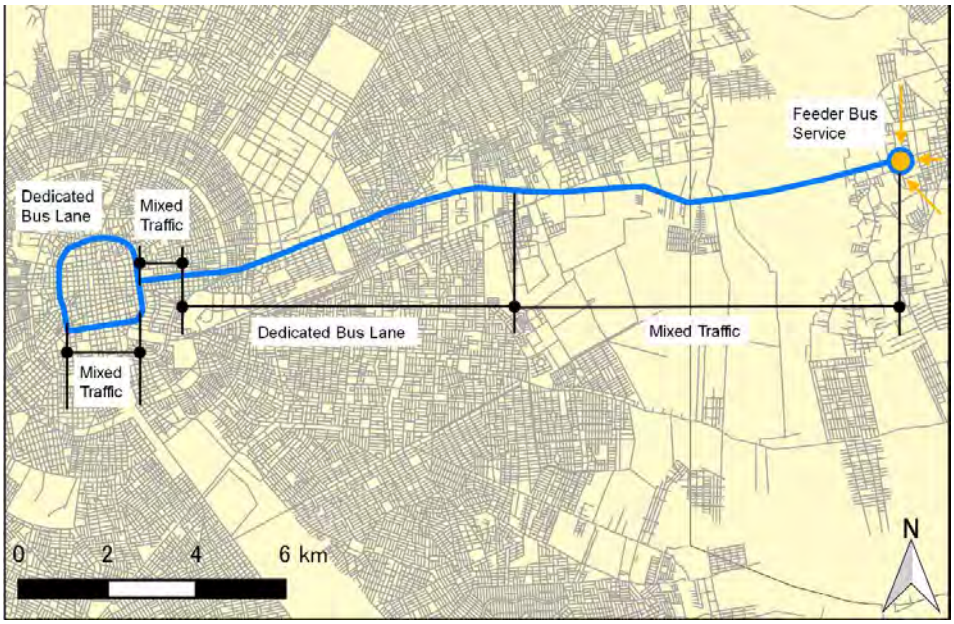
### (4) Inter-Municipality BRT System

BRT system shall be applied for inter-municipality transport for comfort and convenience for passengers. At present minibuses and trufis are operated between the surrounding municipalities and Municipality of Santa Cruz de la Sierra. When travel demand increase, fast and larger capacity bus service is desired. BRT system shall be introduced between these urban centers in the surrounding municipalities and the central area. The intermunicipal BRT system is shown in Figure 7.7-10, Figure 7.7-11, Figure 7.7-12, and Figure 7.7-13.



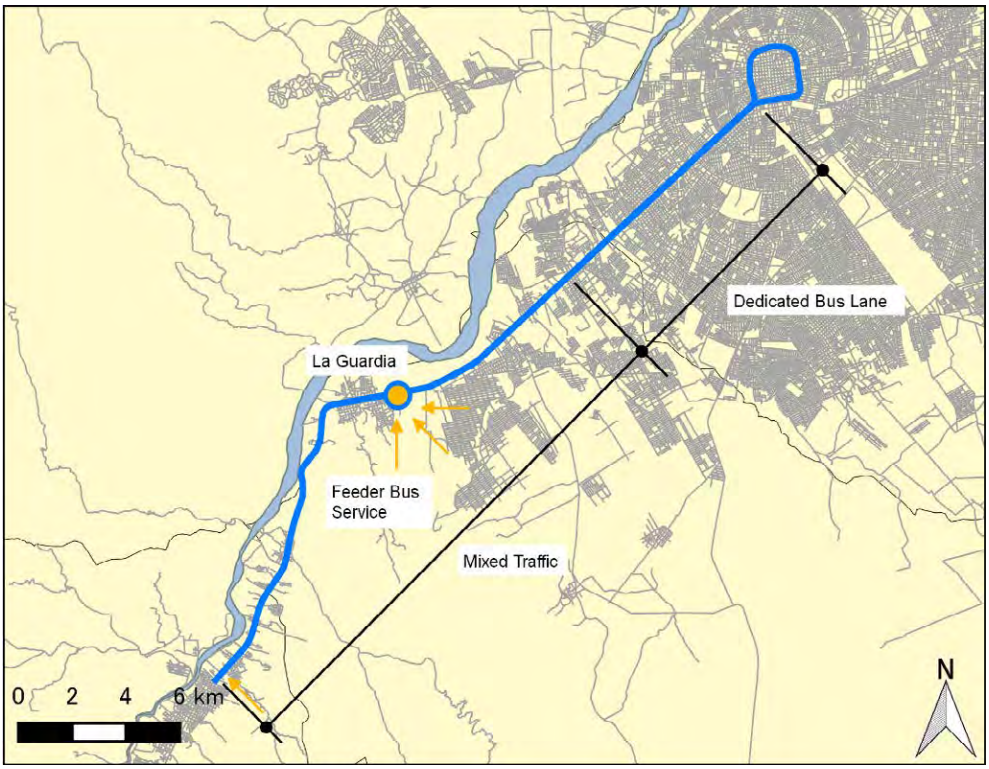

Source: JICA Study Team

**Figure 7.7-10 BRT System between Satelite Norte and Santa Cruz de la Sierra**



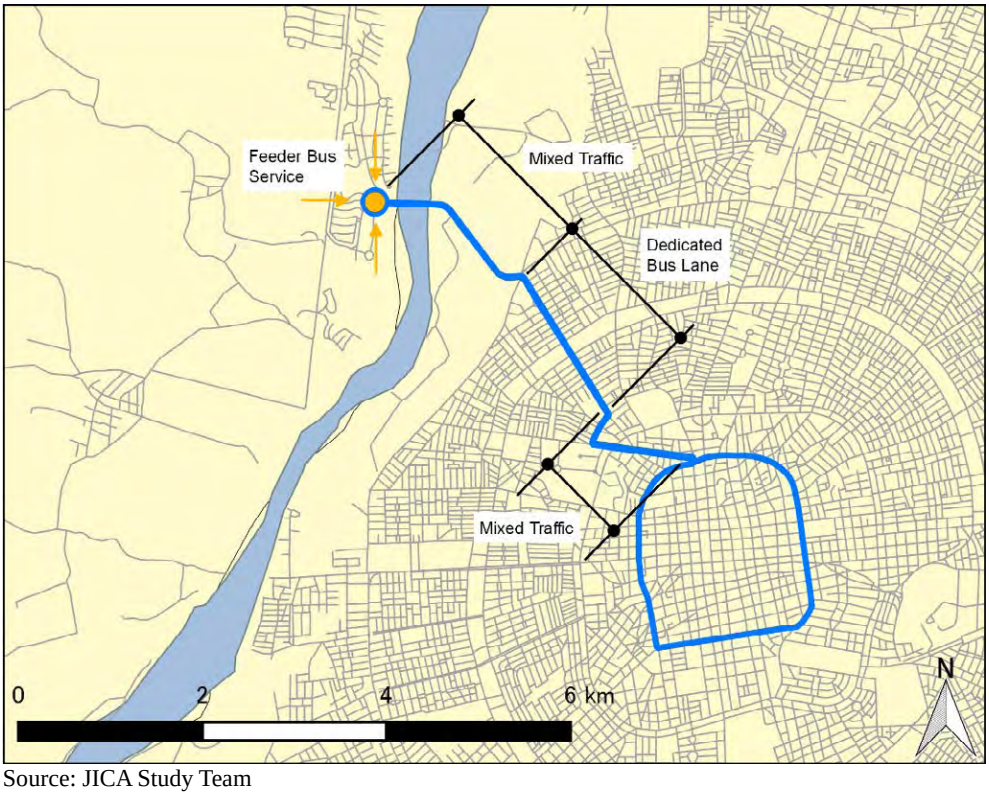

Source: JICA Study Team

**Figure 7.7-11 BRT System between Cotoca and Santa Cruz de la Sierra**




Source: JICA Study Team

**Figure 7.7-12 BRT System between La Guardia/El Torno and Santa Cruz de la Sierra**




Source: JICA Study Team

**Figure 7.7-13 BRT System between Porongo and Santa Cruz de la Sierra**

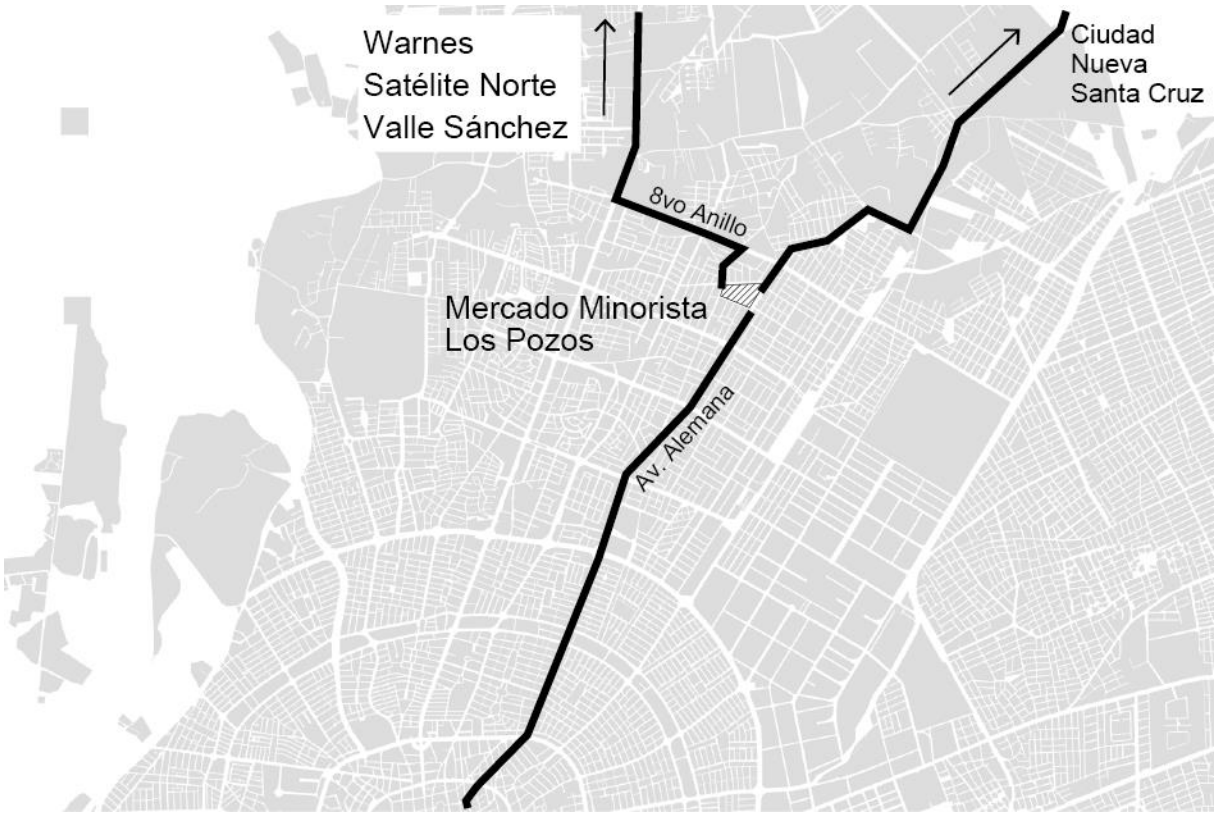
**(5) Access to New Markets**

The proposed BRT routes are not connected to the new markets directly because the BRT routes run along the Fundamental Road while the new markets are located along different avenues. Providing public transport services for the new markets is necessary.

The new Los Pozos Market is located at a strategic place along 8th Ring Road which can function as a transfer point for public transport routes between urban transport services and suburban (or inter-municipality) services. The market will be connected to the central area with a bus route along Av. Alemana, which is a branch route of the north-south BRT corridor. Although the route does not have the section of exclusive lanes, it can play a part of the BRT network.

The new Abasto Market is expected to function as the terminal point for bus routes in District 6. The bus routes connecting to the market are planned as the feeder routes of the BRT network. A bus route which uses the east-west corridor of the BRT network along Ave. Virgen de Cotoca will be directly connected to the market.

The feeder network in the south of Santa Cruz de la Sierra (District 8, 10, 12) is planned in such a manner that these bus routes are connected to the new La Ramada Market. The locations of the new Plan 3000 Market and Abasto Wholesales Market are also considered in the planning of the bus routes.




Source: JICA Study Team

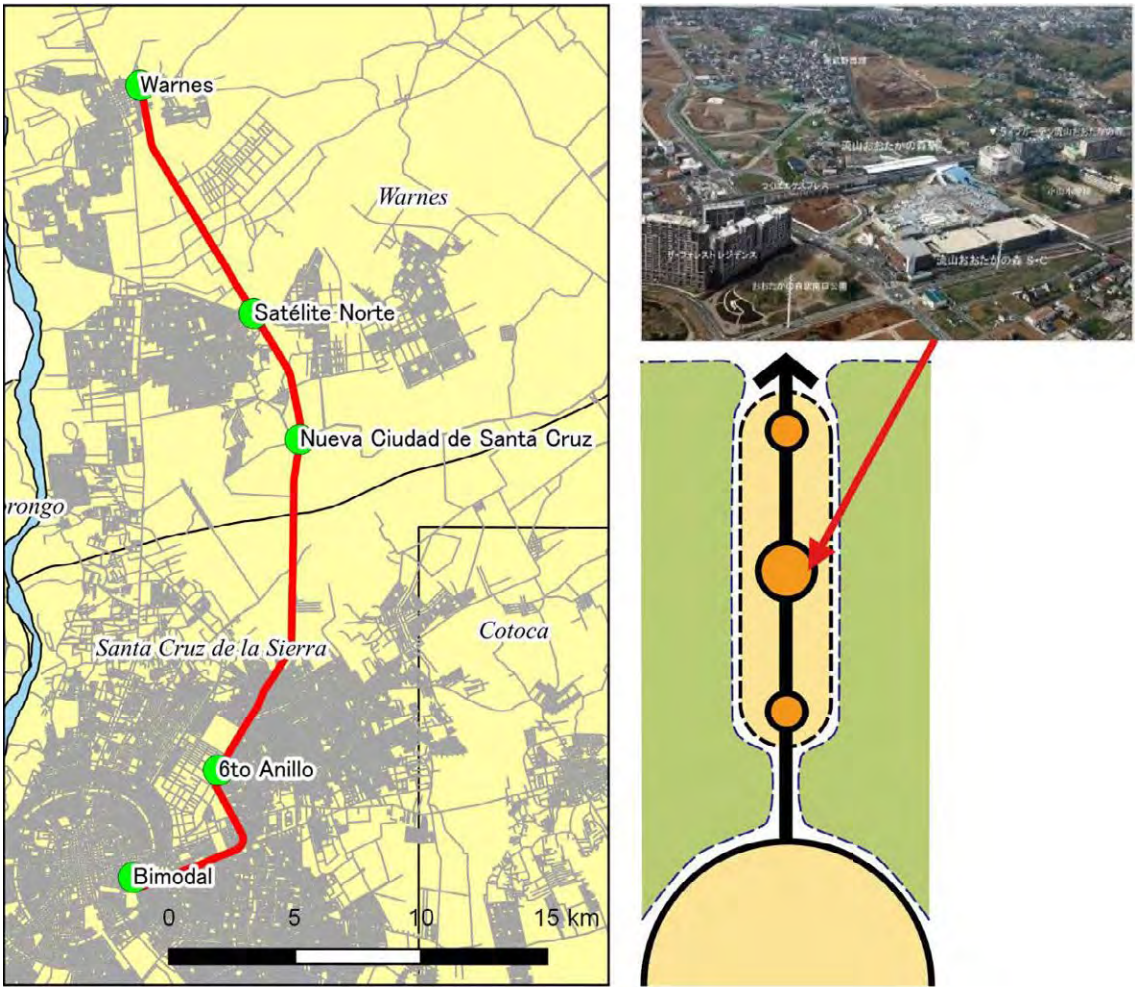
**Figure 7.7-14 Public Transport Access to New Los Pozos Market**

### (6) Warnes – Santa Cruz Transit Corridor

Large-scale urban developments are planned to the east of Viru Viru International Airport between Santa Cruz de la Sierra and Warnes. The municipality of Warnes has already approved these urbanizations. Although the road network in the Master Plan considers the future traffic demand of these urbanizations, a mass transit system is necessary to formulate the sustainable urban structure. The formulation of a public transport corridor with the Transit-Oriented Development is expected to prevent the expansion of low-density areas.

The mass transit corridor should be developed along the existing railway line where the Warnes-Santa Cruz Road would be developed. The demand forecast shows that the modern type BRT system can carry the passengers along the corridor. The figure illustrates the location of the line and its stations.

The present demand is very small because the new urbanization area is not populated. Therefore, it is necessary to develop this corridor in cooperation with the urban development. The TOD approach should be considered for the development.




Source: JICA Study Team

**Figure 7.7-15 Warnes–Santa Cruz Transit Corridor with TOD**

## 7.7.4 BRT Operation and Facilities

### (1) Tariff System

#### 1) Type of Tariff System

Typical fare systems for public transport are:

a) Flat Tariff System (Existing System in Santa Cruz de la Sierra)

The fare is constant for the trips using a bus and passengers pay every time they ride a bus. This is a common system for city bus transport since the number of passengers is large and flat tariff reduce the time for ticketing.

b) Distance-Proportional Tariff System

The fare is determined by distance traveled by a passenger. The railway system often utilizes this system because an average travel distance is relatively long compared to that of city bus transport.

c) Zone Tariff System

In this system, the service area is divided into several zones. The fare is determined for each pair of zones.

d) Time-based tariff system

Passengers can use public transport systems under the tariff system within a predefined period.

Since the BRT system includes long-distance lines, the distance-proportional system is proposed.

#### 2) Payment Method

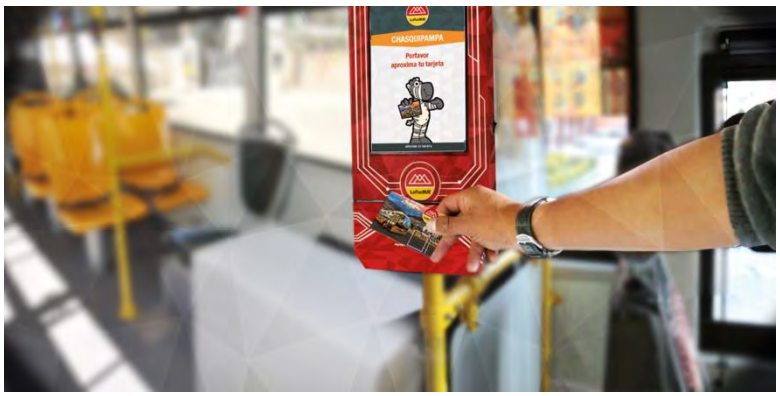
A smartcard system should be introduced to the BRT system as the payment method, although it is one of the challenging reforms of the present transport system because it is necessary to consider the payment by cash. The experience of La Paz shows this situation.

La Paz has introduced a smartcard system named PumaKatari IC Card to its modern bus system. The experience shows that passengers prefer cash payment regardless the advantage of IC Card. At the beginning of the operation of the bus, only 9% of passengers used the IC Card, and it has increased to 20% after a discount of the fare (Bs. 2.0 for IC Card, and Bs. 2.3 for cash) was applied. A passenger should purchase an IC Card at Bs. 20 (Bs. 10 for the IC Card and Bs. 10 for the initial charge) in the beginning, and it is necessary to charge to use the IC Card.

A ticket system is necessary for the fare integration if the cash payment is accepted because the information on boarding can be validated by the ticket when the fare integration (fare discount) is applied to the transfer of lines.

In case that fares are collected inside buses, a ticket machine should be installed in addition to the smartcard device; otherwise, a conductor should ride the bus to deal with the ticket. Since the BRT system includes the routes where onboard fare collection is required, only the smartcard and pre-purchased tickets should be accepted.

The picture below shows the IC Card Recorder in buses of PumaKatari bus system in La Paz.



Source: http://www.lapazbus.bo/

**Figure 7.7-16 Onboard IC Card Recorder**

To apply the distance proportional tariff system, both boarding and alighting information should be recorded. The information is recorded when the passenger passes through the gates of bus stations (bus shelters) by touching the IC Card to the IC Card Recorder. However, some lines need to install two devices inside the buses to record both boarding and alighting.

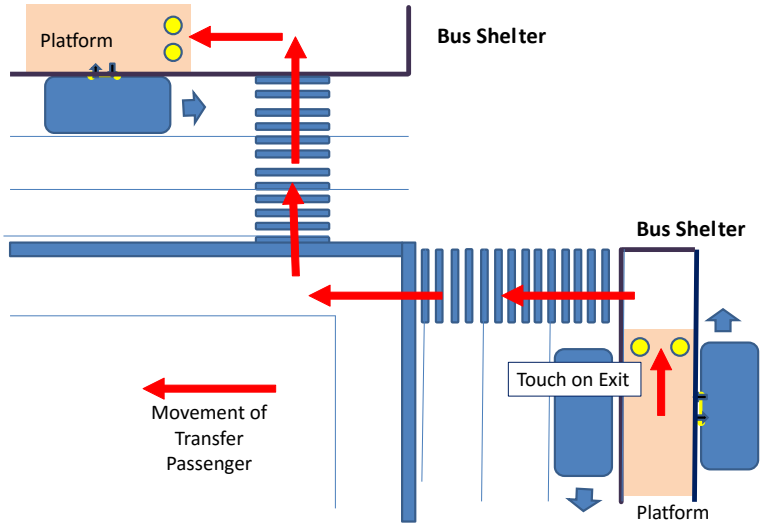
Recording at boarding time

Recording at alighting time

Source: http://5931bus.com/routebus/pasmo/

**Figure 7.7-17 Recording at boarding and alighting inside a bus**

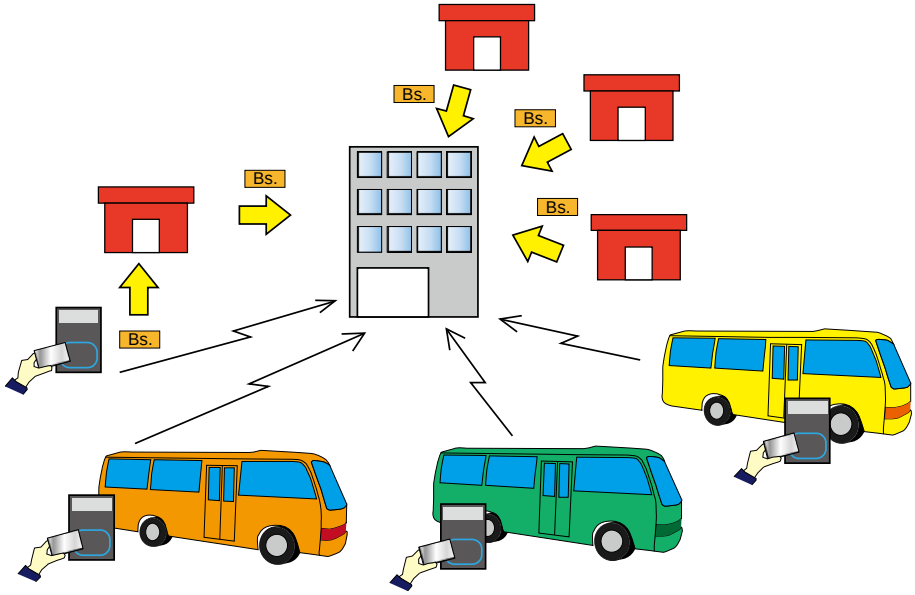
In case of transfer to another line, the boarding to the first line and alighting from the second line can be validated through the information of the record of the IC Card. Therefore, passengers can get off at a bus shelter and walk on the zebra crossing to move to another bus shelter.




Source: JICA Study Team

**Figure 7.7-18 Transfer between lines with IC Card**

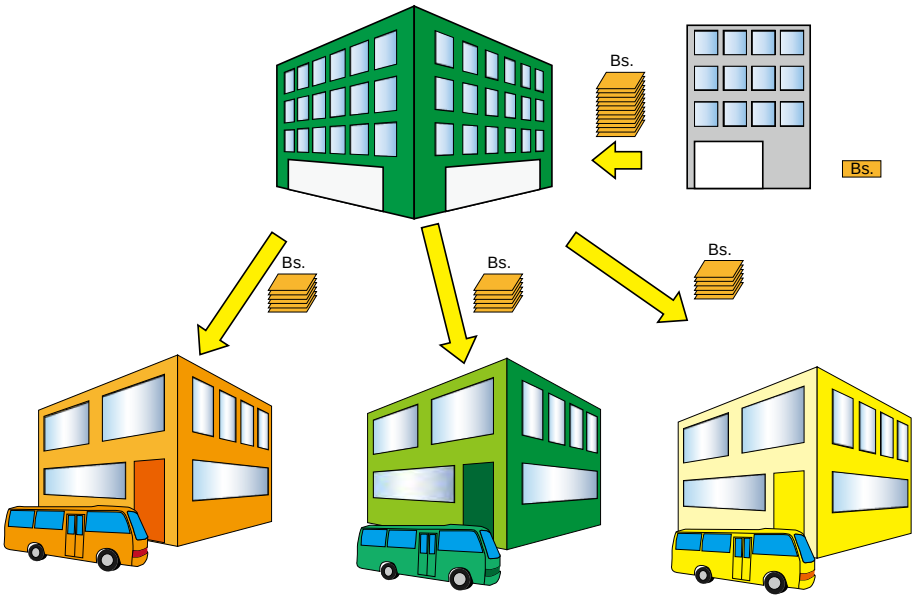
In the smartcard system, passengers charge the fare to the IC Card in advance, and the money is collected to a center of the fare integration system, which is generally named as the Clearing House. The charge devices are located at large stations, offices of the fare integration system, or shops which have the contract with the authority. The information on the boarding of passengers on the buses is recorded through IC recorders and sent to the Clearing House.




Source: JICA Study Team

**Figure 7.7-19 Fare collection from passengers**

The collected money is distributed to bus operators under contracts between the authority and the operators. There are some methods to calculate the proportion of the distribution such as calculation based on vehicle-kilometers, the number of passenger boarding, passenger-kilometers, or pre-defined contract price that is agreed between the authority and the operators. The method should be analyzed and decided before the implementation of the project.



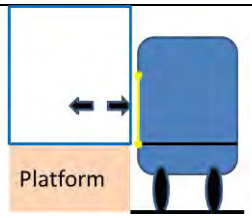
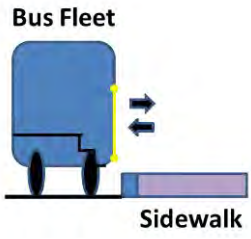
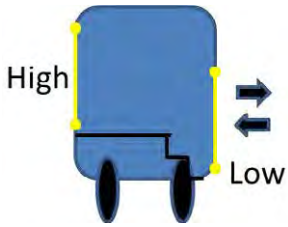
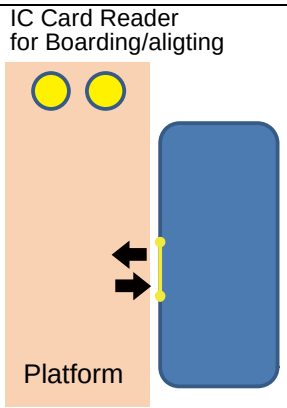
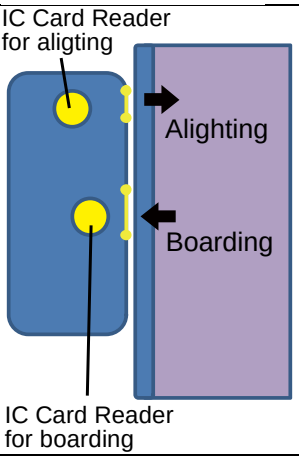
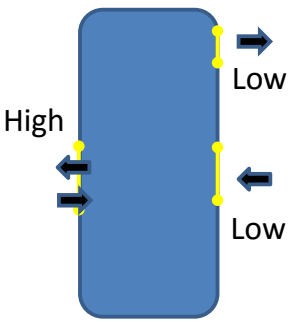

Source: JICA Study Team

**Figure 7.7-20 Distribution of fare revenue**

### (2) Stations

Two types of bus shelters are proposed for the BRT. One is a bus stop on the curbside, and another is a bus shelter on the median. A bus shelter on the median is needed for the section where bus passenger demand is high. Bus fleet for conventional bus service uses right-side doors at a low level in the countries where traffic is on right-hand. In contrast, a bus fleet with the left-side door at a high level is commonly used in BRT system since bus shelter is located on the median. The dedicated lane is not necessary for BRT in suburban areas where the traffic is not heavy because a bus on the section can be operated as an ordinary bus. Since the BRT system passes through the central area, where the streets are too narrow to construct bus shelters with high platform, it is proposed that passengers get on a bus from curbside. To deal with this issue, it is recommended to introduce a compatible bus fleet as illustrated in the table below.

**Table 7.7-2 Type of BRT Fleet**

| | BRT System (1) | BRT System (2) | BRT System (3) |
|---|---|---|---|
| Passenger Demand | Heavy Demand Corridor | Medium Demand Corridor | Medium/Heavy Demand Corridor |
| Corridor | 1st Ring Road,<br>2nd Ring Road and<br>3rd Ring Road<br>Major radial corridors | Suburban areas of Major Radial Corridors | Corridors connecting Suburban and Central Area |
| Bus lanes | Dedicated lanes | Mixed traffic | Dedicated lane/ mixed traffic |
| Bus Shelter | Median with platform | Curbside | Median in the central area and curbside in suburban |
| Bus Fleet: | Doors on Left-hand side and the same height with platform | Doors on Right-hand side and the same height as ordinary buses | Buses should have a high door on left-hand side and a low door on right-hand side |
| IC Card Validator Device: | Device is set in Bus shelter; No validation on buses | One for boarding and another for alighting | One for boarding and another for alighting |
| Vertical |  |  |  |
| Horizontal |  |  |  |

Source: JICA Study Team

BRT bus fleets with both side doors are operated in 20 cities in Latin American countries as listed in Table 7.7-3.

**Table 7.7-3 BRT Systems with Left and Right-hand doors in Latin America**

| Country | Cities |
|---|---|
| Brazil | Belo Horizonte, Brasília, Campinas, Goiânia, Porto Alegre, Recife, Rio de Janeiro*, São Paulo, Sumaré, Uberlândia |
| Colombia | Cali, Medellín |
| Ecuador | Quito |
| El Salvador | Gran San Salvador |
| Guatemala | Guatemala |
| Mexico | Guadalupe, Juárez, Mexico City, Monterrey |
| Venezuela | Caracas |

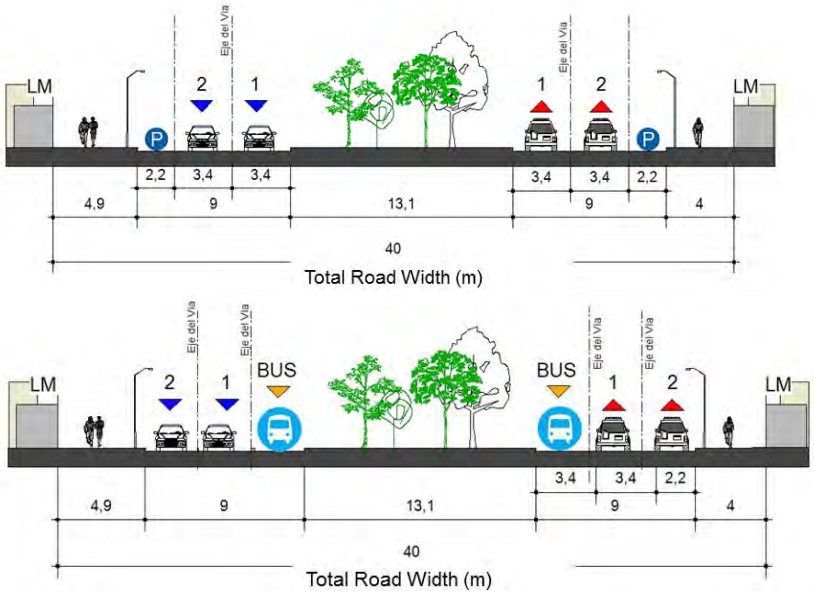
Note*: 2015, left only in corridors TransOeste, TransOlímpica and TransCarioca
Source: Global BRT Data, POSITION OF BUS DOORS, http://brtdata.org/indicators/systems/position_of_bus_doors

The picture below shows the example of both side door vehicles operated in Ahmedabad, India.


**Figure 7.7-21 Examples of Compatible Bus in Ahmedabad, India**

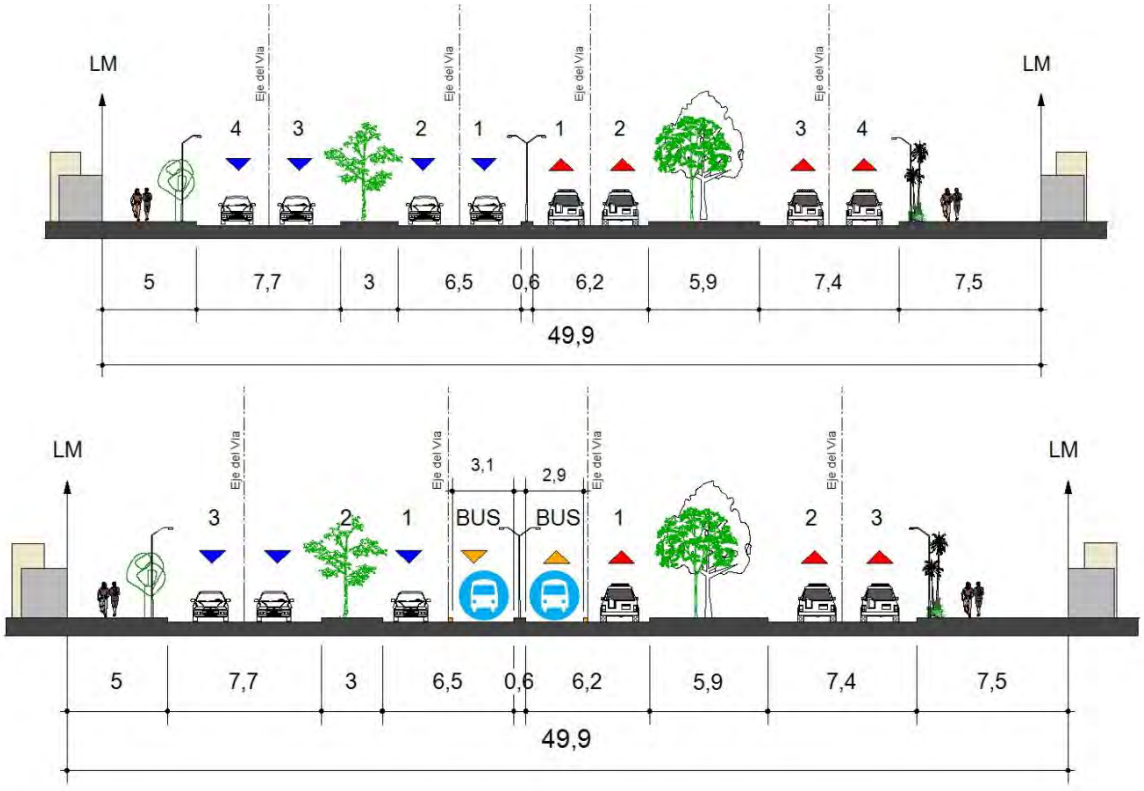
### (3) Cross Section of BRT System

It is recommended to introduce dedicated bus lane in the median of a roadway to avoid conflict with access traffic to land use along the road. The existing cross section of the 1st Ring Road and the cross section for introducing bus dedicated lane in the median are illustrated in Figure 7.7-22, which are prepared by the municipality of Santa Cruz de la Sierra. Figure 7.7-23 also indicates the cross sections before and after installation of BRT system.




Source: Municipality of Santa Cruz de la Sierra

**Figure 7.7-22 Existing Cross Section and New Cross Section for BRT System on 1st Ring Road**




Source: Municipality of Santa Cruz de la Sierra

**Figure 7.7-23 Existing Cross Section and New Cross Section for BRT System on 2nd Ring Road**

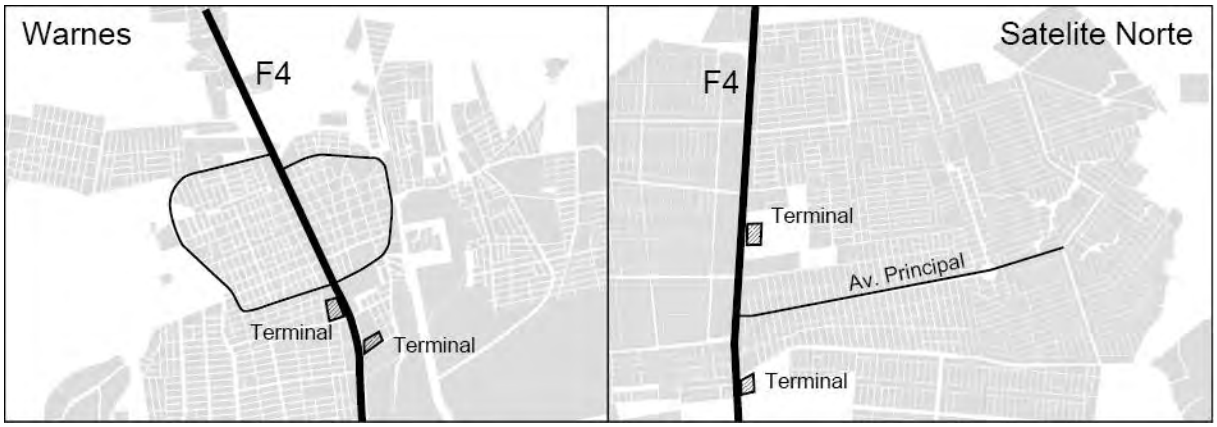
**(4) Road Development and Improvement for BRT System Development**

Road widening and new road construction are required at some missing link sections for the BRT system. For instance, the eastern part of the 3rd Ring Road has missing links where the road is not connected, or the road width is much narrower than the other part. The road should be widened or newly constructed to make the 3rd Ring Road as a complete circular road.

**(5) Development of New Bus Terminals for BRT**

The terminal for international and inter-provincial buses are relocated from Bimodal terminal to the new terminal on radial roads, and the space of Bimodal terminal could be utilized for a terminal for BRT operated on the 1st and the 2nd Ring Roads.

The bus terminals in Warnes and Satelite Norte should be developed along the Fundamental Road 4 as shown the figure below. The locations in the figure are candidate locations. The terminal should be large enough to function as the transfer point between the trunk lines and feeder lines.




Source: JICA Study Team

**Figure 7.7-24 Location of Bus Terminals in Warnes and Satelite Norte**

## 7.7.5 Phased Development of Public Transportation System

**(1) Short-term Public Transport System Development Plan (-2020)**

The municipality of Santa Cruz de la Sierra has started preparation for developing BRT system in the municipality.

In addition to the preparation of the BRT system, existing microbus routes should be simplified and realigned because it is necessary for changing the existing public transport network to the radial and circular system.

Presently, 92 microbus lines run through the central area. The number of lines exceeds the demand in the central area because each minibus carries passengers whose origin or destination is not necessarily the central area. Many lines run through the central area and connect markets or education facilities along ring roads. On the other hand, passengers can reach such destinations by transferring to the BRT routes on ring roads in the future. Furthermore, the travel demand relating to the market is expected to be reduced after the market relocation project. The reduction in the number of microbus lines in the central area and realignment of the route can be started in the short-term period.

**(2) Medium-Term Public Transport System Development Plan (-2025)**

Bus routes should be completely examined and restructured from scratch by the relevant authority of public sector. Bus service should cover all the urbanized areas in the municipality with trunk routes and feeder routes. The comprehensive route restructuring shall be implemented in the medium-term. During the short-term period, information on bus passenger demand shall be collected and analyzed, and it should be utilized for the medium-term development plan of the public transport system.

At the same time, inter-municipality bus transport shall be enhanced by the introduction of BRT system. When the BRT service is provided, integration of bus services shall be managed by the organization at the metropolitan level which can deal with urban transport planning, development, and control and management of the operation.

**(3) Long-term Public Transport System Development Plan (-2035)**

As urban population increase and the urbanized area would be expanded, higher transportation demand is expected. If the travel demands between suburban areas and the central area increase significantly, suburban railway shall be developed. Since the railway has the ROW of 30m, a new railway system can be developed if the land for the railway is maintained.

### 7.7.6 Business Plan

The municipality of Santa Cruz de la Sierra should be the implementation agency of the BRT project including the investment in the infrastructure. On the other hand, the BRT system should be operated by a private company or private companies under concession contracts. The operators receive the amount of contract price while the municipality receives the fare revenue. This means that the municipality takes the risk of the revenue.

# 7.8 Traffic Management Plan

## 7.8.1 Policies

Policies of the traffic management were established so that they can contribute to achieving the objectives as shown in Table 7.8-1.

To ensure traffic safety, it is important to consider the solutions from the viewpoint of the 3E approach: "Engineering, Enforcement, and Education". It is necessary to develop a traffic accident database which forms the basis for considering countermeasures.

To ensure smooth traffic flow, a comprehensive parking management is necessary. Bottleneck points must be improved after analyzing the causes of problems and examining possible improvement measures, which may include intersection geometry improvement and signal improvement.

**Table 7.8-1 Policies on Traffic Management for Traffic Safety**

| General Objectives | Specific Objectives | Policy |
|---|---|---|
| Ensure Traffic Safety | • Eliminate fatal traffic accidents<br>• Reduce the number of traffic accidents | • Identify locations with a high risk of traffic accidents (black spots) and analyze their causes<br>• Install proper traffic signs and road markings |
| | • Raise awareness of traffic safety and compliance with traffic rules | • Introduce an electronic violation detection system to maintain discipline in obeying traffic rules.<br>• Establish continuous education system of road safety |
| Ensure smooth traffic flow | • Relieve traffic congestion in the Historic Center | • A tariffed control system should be implemented, while the street parking in spaces outside of the designated area should be prohibited.<br>• Off-street parking should be prepared.<br>• Installation of taxi stands or public taxi parking lots<br>• Regulate taxies through a proper registration system |
| | • Ensure mobility around markets, schools, and other facilities having high trip generation | • Introduce regulations for the loading and unloading of goods around the markets<br>• Introduction of the Traffic Impact Study for new development |
| | • Eliminate bottlenecks in road network | • All major intersections should be signalized.<br>• Roundabouts with high traffic volume should be changed to compacted intersections with traffic signals. |
| | • Optimize the traffic flow using modern technology | • Introduction and expansion of coordinated signal system and central signal control system with traffic detectors in consideration of the increases in traffic volume<br>• Introduction of a parking guidance system, such as electric boards and smartphone, etc., to reduce vehicles searching for parking space<br>• Coordinate private sectors for effective use of probe data and road information<br>• Promote program of mobility management through varied office start times<br>• Introduce and expand ITS in the metropolitan area such as provision of traffic information |

Source: JICA Study Team

### 7.8.2 Traffic Safety Program

The traffic safety program consists of the following projects.

- Traffic Accident Database
- Accident Black Spot Analysis
- Road Safety Audit
- Traffic Safety Education
- Traffic Signals for Traffic Safety
- Improvement at Intersection with Traffic Signs and Road Markings
- Electronic Violation Detection System
- Common Universal Design Guidelines and Improvement of Sidewalks

#### (1) Traffic Accident Database

An information sharing system about traffic accidents should be established between the municipality and the National Police, and a traffic accident database should be developed.

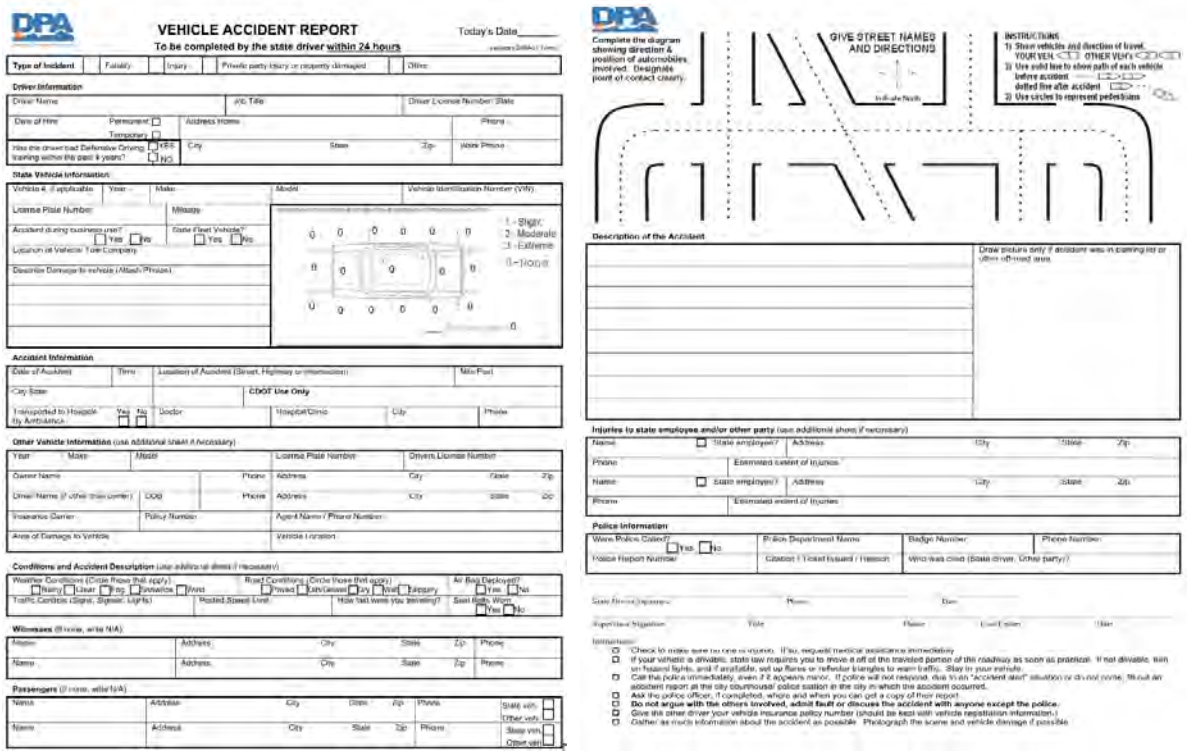
D.S.S. has discussed with National Police regarding collaborating on an accident form. This is proposed as a system where forms are prepared and aggregated to a database by Santa Cruz de la Sierra and National Police fill in the form when the accident occurs. If this effort is realized, the municipality of Santa Cruz de la Sierra can develop a database and analyze accident statistical data with locations to consider solutions.

Figure 7.8-1 shows a sample of a traffic accident report form, which includes information on the type of incident, driver, vehicle, time, location, weather, road, seat belts, speed, traffic control, and others with a diagram of the accident.

#### (2) Accident Black Spot Analysis

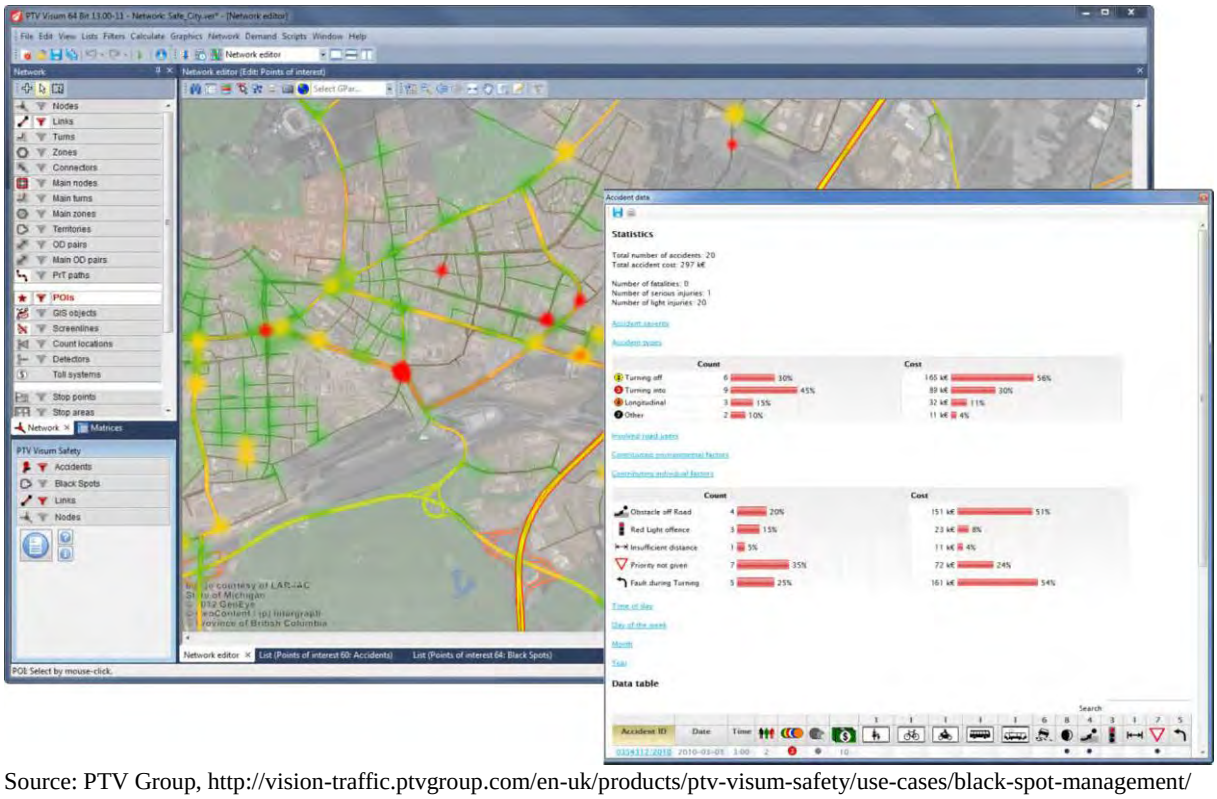
A traffic accident management system using the visualization of accident occurrence conditions should be developed to identify traffic accident occurrence locations and causes of accidents. This system can help to conduct effective countermeasures against the frequent occurrences of accidents by assembling accident records with GPS location data as statistical data. For instance, they can utilize the system to identify the priority of intersections for developing an improvement plan for road safety and evaluating the effect of traffic safety measures by comparing the frequency of accidents before and after the implementation of road improvements to reduce accidents.

A sample result of the analysis in the form of a heat map of the accident occurrence locations is shown in Figure 7.8-2. By using a heat map, black spots can be clarified. It may offer a perspective that leads to the engineering of measures to reduce traffic accidents. Position coordinates are required to obtain the accident location identification. For this purpose, it is also recommended to utilize tablet-type PCs with GPS for identifying the accident occurrence locations on the map.




Source: Colorado Department of Transportation, URL; https://www.codot.gov/library/forms/fhwa-other-forms/DRM-01

**Figure 7.8-1 Sample of Vehicle Accident Report Form**




Source: PTV Group, http://vision-traffic.ptvgroup.com/en-uk/products/ptv-visum-safety/use-cases/black-spot-management/

**Figure 7.8-2 Sample of Traffic Management System by Visualization of Accident Occurrence Condition**

### (3) Road Safety Audit

The Road Safety Audit process should be introduced to minimize the future traffic accidents. Traffic safety measures need an objective and comprehensive overview considering the

needs of all road users including car drivers, pedestrians, and cyclists. A road safety audit is a formal safety performance examination of an existing or future road or intersection by an independent audit team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users.

The features of a road safety audit are:

- A safety audit uses a 3–5 persons interdisciplinary team.
- Safety audit team members are usually independent of the project.
- The field review is a necessary component of the safety audit.
- Safety audits use checklists and field reviews to examine all design features.
- Safety audits are comprehensive and attempt to consider all factors that may contribute to an accident.
- Safety audits consider the needs of pedestrians, cyclists, large trucks as well as automobile drivers.
- Safety audits are proactive. They look at locations before the development of accident patterns to correct hazards before they happen.

RSAs may be conducted practically at every stage in the lifecycle of a transportation facility[1]. When applied early in the planning and preliminary (functional design) of the roads, the RSA process offers the greatest opportunity for beneficial influence. As a design progresses into detailed design and construction, changes that may improve safety performance typically become more difficult, costly, and time-consuming to implement. Figure 7.8-3 illustrates a method of grouping RSAs by phase (pre-construction, construction, and post-construction) and by stage (planning, preliminary design, etc.).


Source: FHWA https://safety.fhwa.dot.gov/rsa/guidelines/chapter3.htm

**Figure 7.8-3 Types of Road Safety Audits by Phase and Stage**

It is necessary to develop a manual and human capacity (road safety auditors) so that the municipality may carry out this RSA. Currently, many road safety audit manuals or guideline are issued in developing countries as well as developed countries. For instance, "New Roads and Schemes: Road Safety Audit," by African Development Bank or "Road Safety Audit for

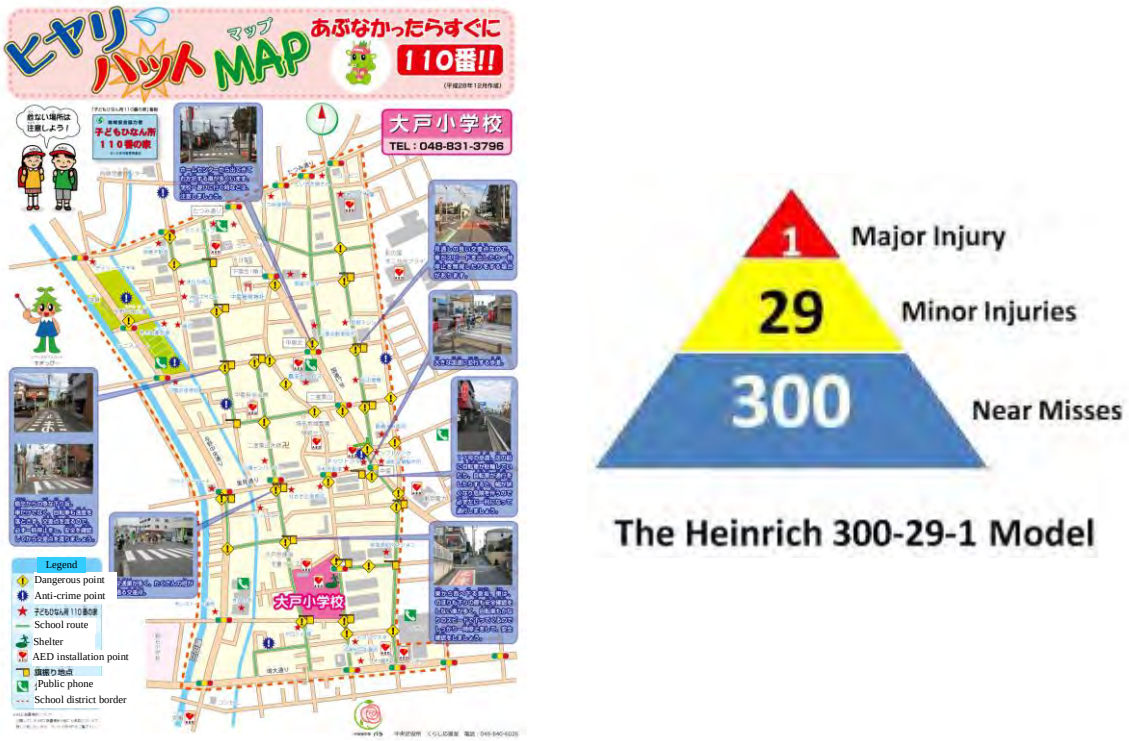
[1] The Road Safety Audit Guidelines by the FHWA (Federal Highway Administration of the U.S.A.),

Road Projects- An Operational Tool Kit," by Asian Development Bank, Manila, is helpful references for Santa Cruz de la Sierra in developing their manual. The government should incur the cost of the road safety audits.

### (4) Traffic Safety Education

The municipality proposed to the central government about setting a schedule of traffic education in primary and secondary school starting from 2018. This effort and these activities should continue to be conducted while simultaneously making step-by-step improvements and new ideas are often taken into consideration. For instance, a near miss map that students and their parents identified the critical points around the school in a workshop in Japan is as shown on the left side of Figure 7.8-4.

William Heinrich, an American engineer, suggested the Heinrich 300-29-1 model: that for every 300 near-misses there might be 29 minor injuries and one major injury (as reference Figure 7.8-4 right). Heinrich's "Safety Triangle" implies that traffic accidents and fatalities would eventually be able to be reduced by eliminating near-miss events. Therefore, it is important for not only drivers but also other road users, such as pedestrians and cyclists, to take preventive measures such as traffic safety education.




Source: (Left) Saitama city URL http://www.city.saitama.jp/chuo/001/001/003/p036723.html
(Right) URL http://etraintoday.com/blog/near-miss-vs-an-accident/

**Figure 7.8-4 Near-miss Map by Opinion of School Students (left) and Heinrich 300-29-1 Model (right)**

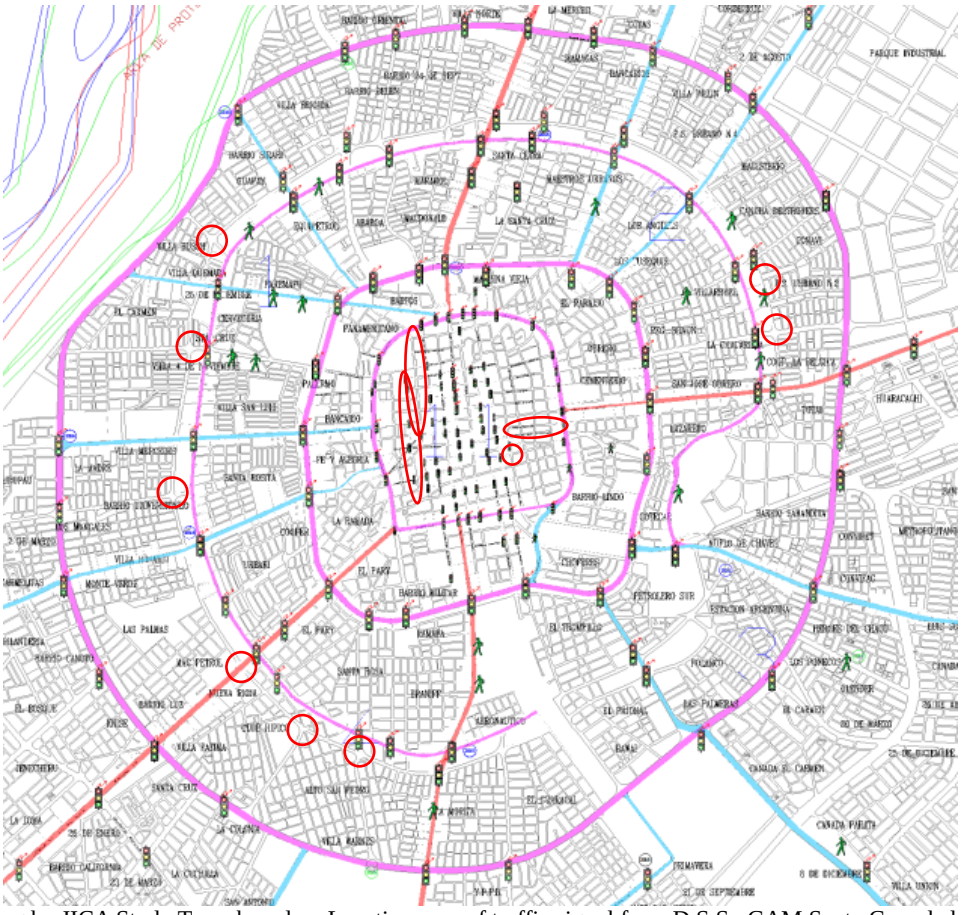
### (5) Penalty Point System

It is proposed to introduce a penalty point system for traffic offenses. This system tracks individual driving records through a point system that assigns points for each traffic violation, moving or otherwise. When the driver commits a traffic violation, it is recorded on the driving record of his driver's license. When a driver is charged with a traffic violation, in many cases the driver can avoid receiving points, but once the points are on their driver's license, they cannot be removed. In the case of a few violation points and guilt, the violator

must plead guilty, pay the full fine, and attend a traffic school course. In the case of many violation points, the violator's driver's license is curtailed. Although the driver's license system is a nationwide system, the penalty point system is expected to enhance awareness regarding traffic safety.

**(6) Traffic Signals for traffic safety**

Intersections should be signalized along the 3rd Ring Road (exterior) and the exclusive bus lanes of the 1st Ring Road. Also, intersections near large educational and public facilities should be signalized. The RSA should be conducted for the selection of intersections to be signalized.



Source: Editing by JICA Study Team based on Location map of traffic signal from D.S.S., GAM Santa Cruz de la Sierra

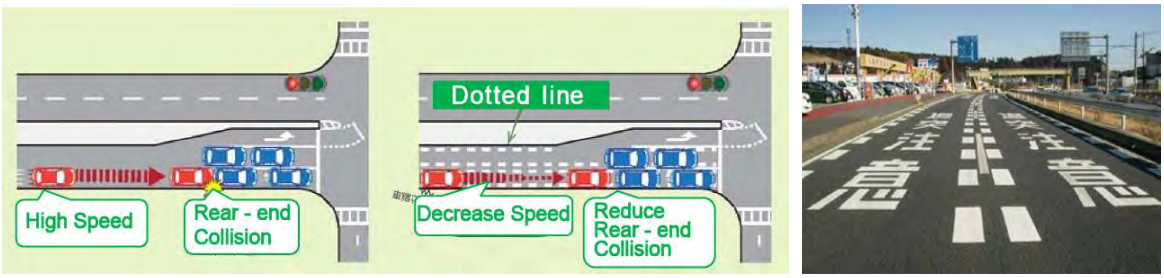
**Figure 7.8-5 Proposal Intersections for Introduction of Traffic Signals**

**(7) Improvement at Intersection with Traffic Signs and Road Markings**

Traffic signs and road making that are intuitively recognized by drivers should be installed at intersections properly so that drivers maintain the safe driving and obeying the traffic rules.

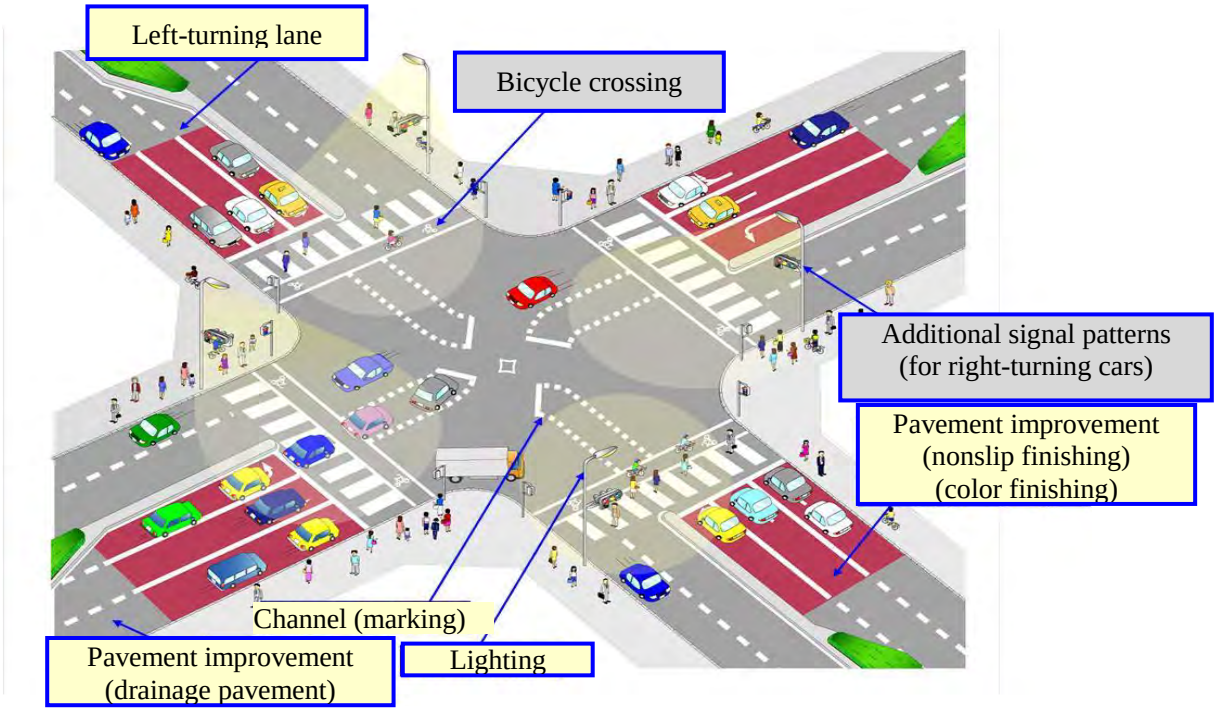
For instance, installation of "dotted line" road marking is proposed as shown in Figure 7.8-6. This marking gets drivers to feel that the width of the lane is narrowing and make them reduce the speed. Colored pavements also draw drivers' attention at intersections. Figure 7.8-7 shows some examples of road marking at an intersection.

This countermeasure is relatively low-cost, has a short construction time, and doesn't require significant changes in layout.




Source: JICA Study Team

**Figure 7.8-6 Image-1 of Road Markings at an Intersection**




Source: Editing by JICA Study Team based on figure of MLIT in Japan

**Figure 7.8-7 Image-2 of Road Markings at an Intersection**

There are many speed bumps to reduce the speed in residential areas of Santa Cruz de la Sierra; however, the noise from the cars driving over them is a nuisance for residents. As measures against this problem, installation of the "three-dimensional slowdown indication" is proposed. This marking does not only have the effect of slowing down vehicles but also the effect of alerting the driver by utilizing optical illusions.

Source: Sekisui Jushi Corporation http://www.sekisuijushi.co.jp.e.tp.hp.transer.com
(Right: Netherlands, Left: Shizuoka Prefecture, Japan)

**Figure 7.8-8 Images of Optical Illusion Bumps in Residential Areas**

**(8) Electronic Violation Detection System**

As mentioned in Section 2.6, the municipality is considering introducing the Electronic Violation Detection System (DEI). This system is called Foto Multa and is defined as an electronic system that captures a vehicle at the actual time of committing an offense, producing automatic photographs, video, or digital images of each vehicle that violates a traffic rule. The process of introduction is being conducted in 3 phases (regulation, bidding, and implementation). At first, a public consultation was conducted to determine the amount to penalize the driver who does not respect the traffic signals. The cameras are planned to be installed for the Foto Multa system at 22 intersections preferably located on the main avenues; i.e., the Cristo Redentor, Virgen de Cotoca, Santos Dumont and the road to La Guardia. The intersections were chosen based on:

- Daily vehicle volume that is greater than 5,000
- Observation of high speeds and school zones
- Frequency of accidents


Source: D.S.S., GAM Santa Cruz de la Sierra

**Figure 7.8-9 Image of System Configuration for an Electronic Violation Detection System (DEI)**

The notice of violations recorded by the Electronic Violation Detection System (DEI) is sent by any of the following: text message to a mobile number, Email, printed notification to the vehicle owner, or information through a consultation portal and citizen information desk. D.S.S. is currently discussing cooperation with the ANH (National Hydrocarbons Agency) to use the B-SISA SYSTEM so that the notification of violation is also typed out on the receipt when the driver gases up because it is difficult to identify the address of the vehicle driver in Bolivia. The violators must confirm the notification on the internet site.

## 7.8.3 Parking Management Program

A proper parking management program should be formulated to increase the traffic capacity. It consists of six components, as follows.

- Parking Facility Development Policy and Planning
- On-street Parking Management

- Enforcement of Illegal Parking
- Parking Guidance System
- Public Taxi Facilities in Historic Center
- Control of Taxi by Proper Registration System and Public Taxi Facilities in Historic Center

### (1) Parking Facility Development Policy

New policies or guidelines regarding parking management should be developed. It should be clearly determined in which areas parking facility development is promoted or restricted. The policy should cover the following:

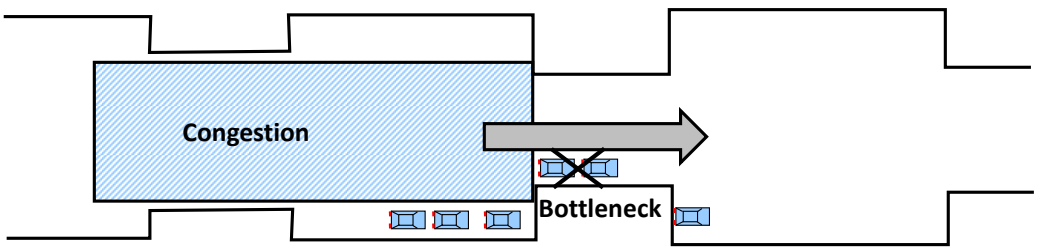
- Definition and classification of parking
- Coordination and linkage with land use plan and new bus route network
- Role of on-street and off-road parking facility
- Development of regulation regarding system of tariffed control and prohibition of on-street parking outside of the designated area within the 1st Ring Road
- Role sharing between public and private sectors
- Control and support of parking facility development by private sector

### (2) On-street Parking Management

The results of the parking survey indicated that on-street parking lasting 15 minutes or less is the most common, meaning that vehicles parking for a long period would disturb many vehicles that would otherwise be able to park in that space for short periods of time. In principle, vehicles should be parked in off-street parking facilities if the parking time is long (over 30 minutes). On-street parking for a long period (i.e., for over 30 min) should be prohibited, or a parking fee should be set higher than the fee for off-street parking. The following policies should be applied to the on-street parking management.

1) Existing off-street parking facilities are utilized adequately
2) Introduction of tariffed control system on-street parking at the designated area
3) Prohibition of on-street parking outside of the designated area

The municipality should design the locations of on-street parking which have little impact on traffic congestion. Parking spaces should not be located before a potential bottleneck point as shown in Figure 7.8-10. The design of on-street parking should be easy to understand for everyone.




Source: JICA study team

**Figure 7.8-10 Relation between Bottleneck Point and On-street Parking Space**

Source: (Left): Manual for Street Department for Transport London city
(Right): Luton England, JICA Study team,

**Figure 7.8-11 Design of On-street Parking and Picture of On-street Facility**

### (3) Development of New Parking Facility

Multistory parking facilities should be developed to increase the parking capacity. Recent parking lots do not require as much space as previously designed ones through the utilization of automated and mechanical operation.

Figure 7.8-12 shows a plan of a multi-story parking having a capacity of 130 vehicles with an automated parking system proposed in "Elaboracion de una propuesta de estacionamiento vertical inteligente en el area central de Santa Cruz de la Sierra, Lic. Romer Mollo Pedraza".



Source: Proyecto de estacionamiento vertical inteligente-SCZ: Universidad Autónoma Gabriel Rene Moreno

**Figure 7.8-12 Image of Proposal for Architectural Design of New Parking Facility**

### (4) Enforcement of Illegal Parking

To conduct proper on-street parking management as mentioned above, stricter parking enforcement is necessary, including the following actions.

#### (a) Clear and visible indication of no parking section

Placing more traffic signs along the prohibited section together with colored marking on

the pavement improves the visibility of the indication of parking regulation. At the same time, on-street parking spaces should be marked clearly with paint as rectangular boxes.

**(b) Attaching stickers, clamps, or other devices to illegally parked vehicles**

Previously D.T.T. placed a clamp on illegally parked vehicles and confiscated license plates of the illegally parked vehicles. National Police also place clamps on illegally parked vehicles and charged a fine. These devices prevent drivers from moving their cars without the penalty. At the same time, anti-bribery laws must be more strictly enforced, to prevent parking enforcement officers from accepting bribes.

**(c) Monitoring through video shooting**

Surveillance cameras installed along the prohibited section can be used to monitor illegal parking. If an illegally parked vehicle is found, a warning message can be announced through the public addressing system or police nearby can be called to the site for warning or apprehension. Although it might be difficult to change the law, the enforcement can be deputized to a private organization of suitable qualification as practiced in some countries. Enforcement procedure must be defined clearly, and staff must be trained.

Source: (Left): Surveillance camera for illegal parking, Tokyo metropolitan government
(Right): Ashima Co., Ltd. URL: http://www.e-asima.com/parking.html

**Figure 7.8-13 Enforcement Measure for Illegal Parking Utilizing Surveillance Camera and Deputized to a Private Organization**

**(5) Parking Guidance System**

A parking guidance system should be introduced to encourage more efficient use of the existing parking facilities. Figure 7.8-14 shows the parking guidance system through the internet, parking information boards and a mobile phones app developed as a social experiment in Istanbul, Turkey. This system provides information about locations, availability, and parking fees of parking lots outside the most congested area.

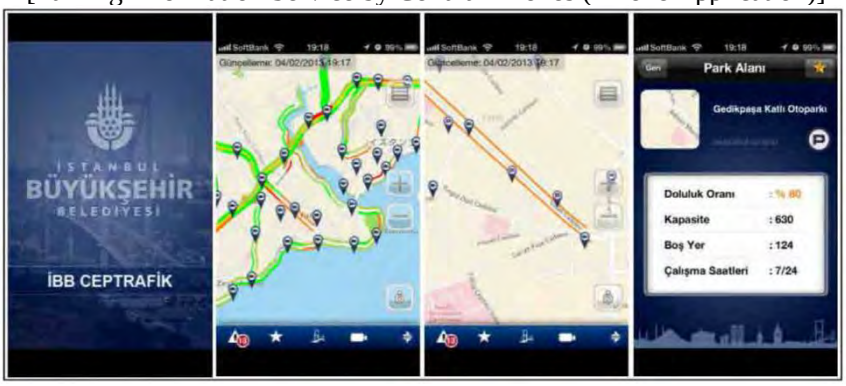
It should be introduced not only for on-street parking but also for off-street parking in collaboration with private parking operation companies.

It is also recommended to set up parking information boards at the entrance to the central area and provide information about parking locations and free spaces in real-time so that vehicles searching for parking space and needless traffic volume is reduced within the 1st Ring Road. This system also has the advantage for private parking operation companies so that their free spaces are displayed on board, website, smartphone app, helping to draw in customers.

[Parking Information Service by the Website]

[Parking Information Service by Information Boards]

[Parking Information Service by Cellular Phones (iPhone Application)]




Source: Traffic Demand Management of Historical Area in Istanbul (iSTDM) Final Report, JICA

**Figure 7.8-14 Parking Information Service by various media**

### (6) Control of Taxi by Proper Registration System and Public Taxi Facilities in Historic Center

Although the municipality has instituted an ordinance about the registration of taxies that requires the installation of a taxi meter, taxi associations and drivers do not follow the ordinance. The municipality authorized each taxi company to have taxi stands, which are called "parada", and they can have two vehicles parked in the space of 25 square meters along the arterial road outside the 1st Ring Road.

It is also suggested to set up large taxi stands for the public in the Historic Center.

Figure 7.8-15 shows large taxi stands for the public in Japan. Two or three taxis are waiting at taxi stands, and remaining taxis are waiting at parking lots near taxi stands. It limits the number of taxis waiting for passengers on the road.

Source: Tokyo metropolitan government; http://www.toshiseibi.metro.tokyo.jp/kiban/honbun/6-5.pdf

**Figure 7.8-15 Large Taxi Stands for Public Parking Lots**

Taxis can park in the dedicated parking stand near the Plaza principal to wait for customers and customers can then always find a taxi at the entrance. This system can achieve a reduction in taxies searching for customers in the Historic Center.

### 7.8.4 Bottleneck Point Improvement

#### (1) Signal Control System Upgrading

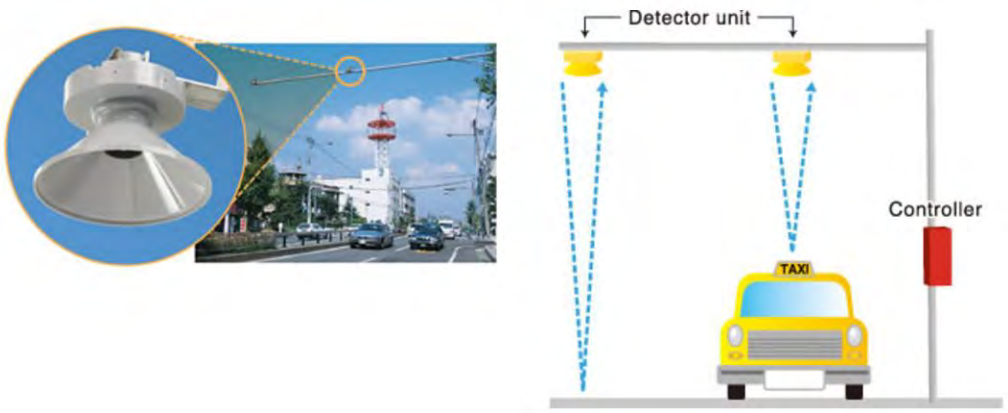
"Offset Adjustment" (coordinating traffic signals) should be expanded to reduce travel times, stops and delays.

Presently, loop coils or traffic cameras are installed at 40 intersections among a total of 214 intersections where the signal phases are adjusted in real time. On the other hand, the signal phases of other intersections are adjusted manually based on the past experiences or traffic information in the Google Map.

More vehicle detectors should be installed at major signalized intersections to expand the road sections with the automatic signal phase adjustment. It is recommended to use an ultrasonic vehicle detector (as shown in Figure 7.8-16) because of its advantages as shown in Table 7.8-2.

The loop coil (inductive loop) or video image processor with traffic cameras have some weakness in terms of maintenance and accuracy at nighttime. Traffic cameras are also expensive. Therefore, it is difficult to expand the use of sensors to all intersections.

This device can detect vehicles based on the difference in arrival time of the waves reflected from vehicles and roads surface by transmitting ultrasonic wave towards roadways. This sensor costs less than a video image device, and its installation and maintenance is easy. It cannot measure the spot speed, but that is not required for adjusting signal timing.




Source: Sumitomo Electric Industries, Ltd. http://global-sei.com/its/products/uvd.html

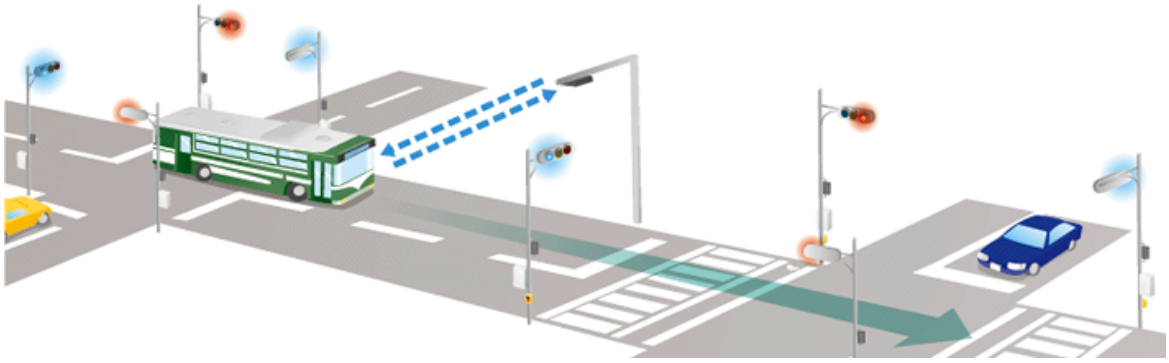
**Figure 7.8-16 Ultrasonic Vehicle Detector**

**Table 7.8-2 Strengths and Weaknesses of Commercially Available Sensor Technologies**

| Technology | Strengths | Weaknesses |
|---|---|---|
| Inductive Loop (Loop coil) | • Mature, well-understood technology.<br>• Large experience base<br>• Provides basic traffic parameters (e.g., volume, presence, occupancy, speed, headway, and gap)<br>• Insensitive to inclement weather such as rain, fog, and snow<br>• Provides the best accuracy for count data as compared with other commonly used techniques<br>• Common standard for obtaining accurate occupancy measurements | • Installation requires pavement cut<br>• Decreases pavement life<br>• Installation and maintenance require lane closure<br>• Wire loops subject to stresses of traffic and temperature<br>• Multiple detectors usually required to monitor a location<br>• Detection accuracy may decrease when design requires detection of a large variety of vehicle classes |
| Video Image Processor by Traffic camera | • Monitors multiple lanes and multiple detection zones/lane<br>• Easy to add and modify detection zones<br>• Rich array of data available<br>• Provides wide-area detection when information gathered at one camera location can be linked to another | • Installation and maintenance, including periodic lens cleaning, require lane closure when camera is mounted over roadway<br>• Performance affected by inclement weather such as fog, rain, and snow; vehicle shadows; vehicle projection into adjacent lanes; occlusion; day-to-night transition; vehicle/road contrast; and water, salt grime, icicles, and cobwebs on camera lens<br>• Requires 9- to 15-m camera mounting height for optimum presence detection and speed measurement<br>• Reliable nighttime signal actuation requires street lighting<br>• Sensor purchase cost is high |
| Ultrasonic | • Multiple-lane operation available<br>• Capable of overheight vehicle detection<br>• Large Japanese experience base | • Spot speed cannot be measured<br>• Environmental conditions such as temperature change and extreme air turbulence can affect performance<br>• Temperature compensation is built into some models<br>• Large pulse repetition periods may degrade occupancy measurement on freeways with vehicles traveling at moderate to high speeds |

Source: Edited by JICA Study team based on "A Summary of Vehicle Detection and Surveillance Technologies used in Intelligent Transportation Systems Funded by the Federal Highway Administration's Intelligent Transportation Systems Program Office", The Vehicle Detector Clearinghouse

If the bus operation is made with other vehicles, securing punctual operation would be difficult. As a solution to this issue, introducing Traffic Signal Control System for Public Transportation prioritization on the exclusive lane is recommended as shown in Figure 7.8-17. The present traffic signal software has this optional function.



Source: Sumitomo Electric System Solutions Co., Ltd., http://global-sei.com/its/products/utms.html

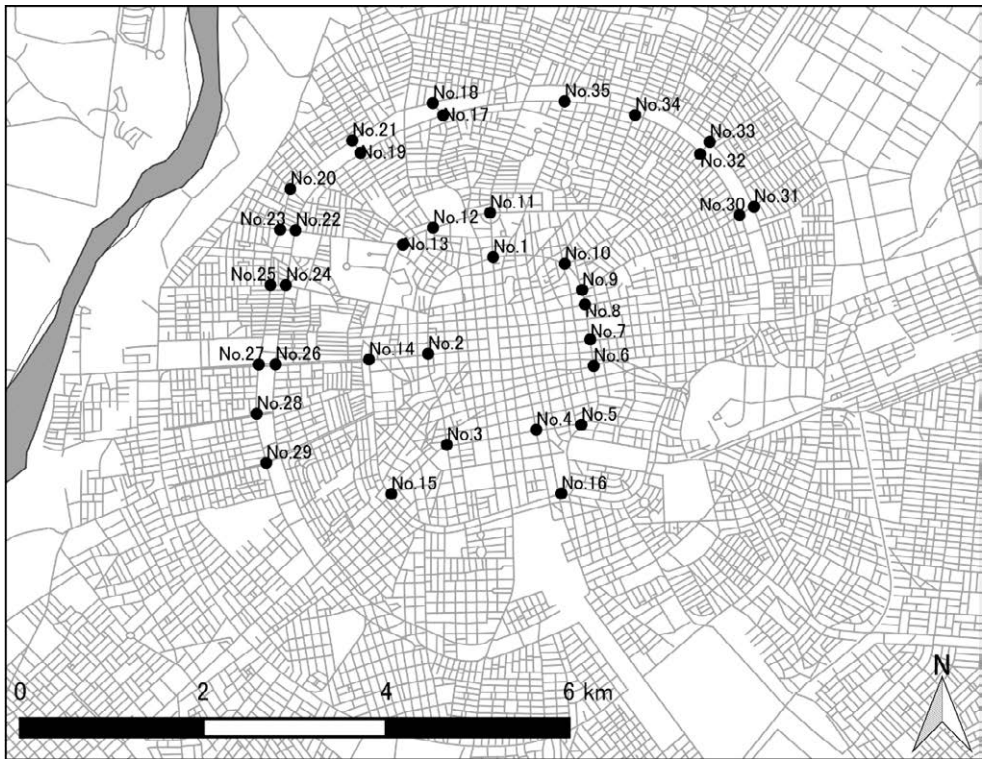
**Figure 7.8-17 Case of Public Transportation Priority System**

### (2) Conversion of Roundabouts to Traffic Signal-Controlled Intersections

Roundabouts can be an appropriate design alternative to both "stop sign controlled" and signal-controlled intersections, as they have fewer conflict points than cross intersections. However, in cases with very high traffic volumes, traffic signal control may be more suitable because roundabouts cannot handle high traffic volumes. According to "Roundabouts: An Informational Guide", FHWA, USA, the maximum daily service volume of a single-lane roundabout varies between 20,000 and 26,000 vehicles per day, depending on the left-turn percentages and the distribution of traffic between the major and minor roads. A double-lane roundabout may service 40,000 to 50,000 vehicles per day

Traffic volume of most of the roundabouts on main roads in Santa Cruz de la Sierra exceeds the above figures. These intersections on main roads should be changed from roundabouts to traffic signal-controlled intersections.

Figure 7.8-18 shows the roundabouts that should be converted to signalized intersections.




Source: JICA study team

**Figure 7.8-18 Locations of Roundabouts to be converted to Signalized Intersections**

**(3) Introduce Regulations and Build Facilities for the Loading and Unloading of Goods around the Markets**

New regulations should be introduced to control the loading and unloading of goods around existing markets because parking of trucks and delivery cars for loading and unloading of goods is one of the causes of the traffic congestion.

## 7.8.5 Transportation Demand Management

Transportation Demand Management (TDM) is the application of strategies and policies to reduce travel demand or to redistribute this demand in space or in time instead of taking supply-side measures such as the construction of flyovers, improving intersections, and widening of roads.

Typical TDM approaches and measures are shown in Table 7.8-3. These measures intend to reduce the number of private vehicle trips or their peak directly by restricting vehicle use or indirectly promoting the attractiveness of other modes of transport.

**Table 7.8-3 TDM Approach and Measure**

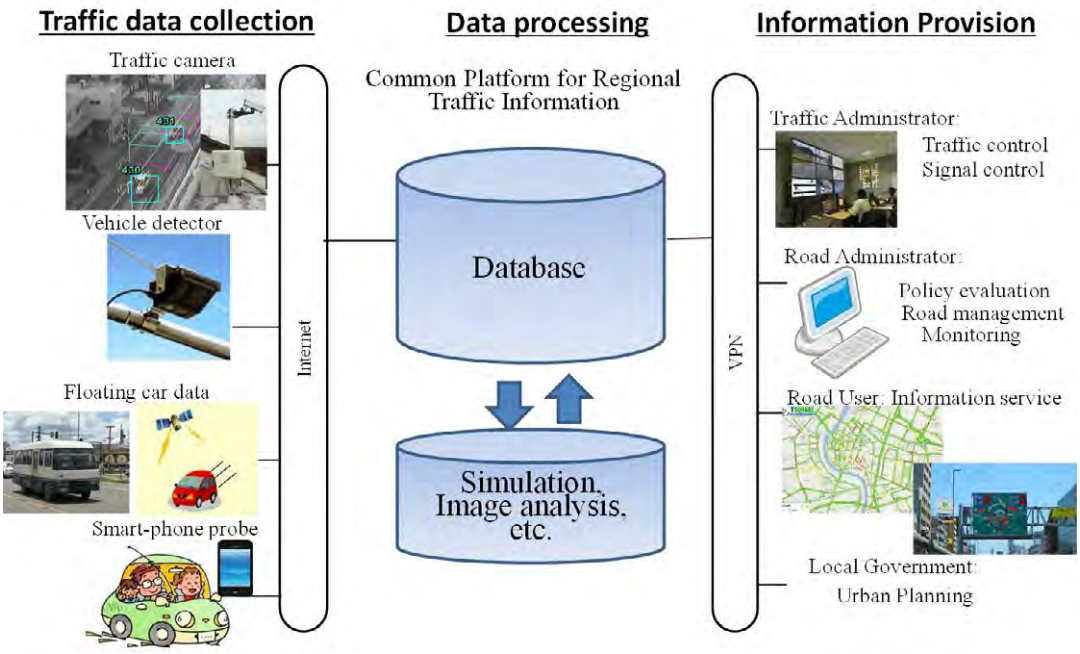
| Approaches | Measures |
|---|---|
| Route Change | • Strengthening of traffic information system |
| Peak Hour Change (Departure-Time Change) | • Mobility management/ Shift traffic demands from peak hours |
| Efficient Car Use | • Reversible (tidal) flow lanes, HOV lane<br>• Car sharing<br>• Efficient freight system |
| Trip Reduction Change | • Road pricing (Congestion charging)<br>• Restriction of vehicle use<br>• Parking management |

Source: JICA study team

**(1) Strengthening of Traffic Information System（Route Change)**

Drivers who try to avoid congested sections select the route depending on their experiences. Although traffic conditions change in real time, nobody knows the current conditions. Thus traffic tends to concentrate on one section of the road network. To optimize the traffic demand at road network, it is necessary to disperse traffic flow from congested areas to other areas of the road network.

Figure 7.8-19 shows a concept image of comprehensive traffic information system in Santa Cruz de la Sierra. It is composed of three phases: traffic data collection, data processing, and information provision.




Source: JICA Study Team

**Figure 7.8-19 Concept of Comprehensive Traffic Information System**

## Traffic Data Collection

To provide traffic information, the system should be strengthened in terms of coverage area, type of data, collection frequency, data processing and information dissemination to media. The same arterial road network for signal system upgrading is the coverage area of the traffic information system. In the traffic information system, arterial roads in the network are divided into links of the same traffic condition, and vehicle detectors are installed at each link to collect traffic data. The number of vehicle detectors should be much more than the number in the existing system.

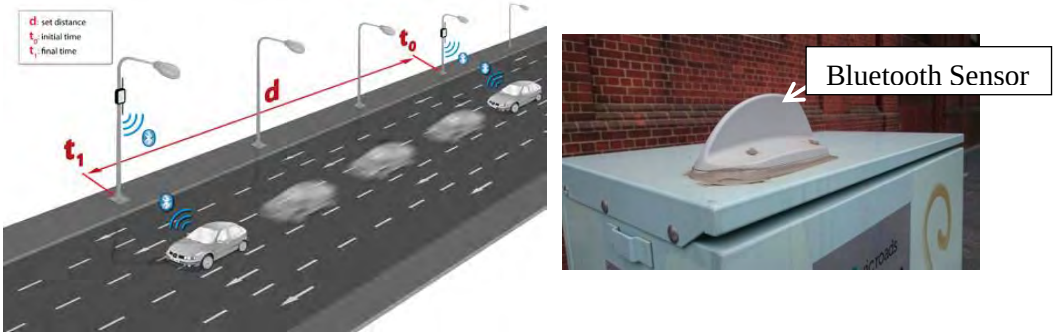
However, the installation of vehicle detectors at each link is costly, and thus it may be a long-term measure. As a short-term measure, the utilization of micro bus and bus or taxi GPS data (floating car data) is proposed. Currently, microbuses have GPS installed for operation by their owner or syndicate. If they provide or sell the data to the municipality, the municipality may collect and process the data to create the traffic information. Since the microbus network covers almost all arterial road networks in Santa Cruz de la Sierra w, the microbus data is helpful although special care should be taken in the processing of data from microbuses, as they frequently stop in places other than bus stops.

Figure 7.8-20 shows a traffic information system utilizing floating car data from taxies and trucks. In this system, GPS data is collected from taxies and trucks and is processed, and then the traffic congestion information is distributed through various media such as internet websites, smartphone app, and car navigation systems. By utilizing micro buses' GPS data, the same system may be developed.


Source: Toyota Tsusho Electronics (Thailand) Co.,LTD
http://www.itu.int/en/ITU-T/Workshops-and-Seminars/drnrr/201305/Documents/S2P1_Thanomsak_Ajjanapanya.pdf

**Figure 7.8-20 Case of Traffic Information System**

Alternatively, monitoring by utilizing Bluetooth sensors was recently developed and implemented in Australia as shown in Figure 7.8-21. The system can sense the flow of Bluetooth devices on a given street, roadway or passageway differentiating hands-free car kits from pedestrian phones. Sensor data is then transferred by multi-hop radio communication, via an internet gateway, to a server. The traffic measurements can then be analyzed to address congestion of either vehicle or pedestrian traffic. By utilizing this technology, the flow and congestion of vehicular traffic can be understood. The monitoring system can also be used to calculate the average speed of the vehicles which transit over a roadway by taking the time mark at two different points.




Source: (Left) http://www.libelium.com/vehicle_traffic_monitoring_bluetooth_sensors_over_zigbee/
(Right) JICA Study Team

**Figure 7.8-21 Traffic monitoring system by utilizing Bluetooth Sensor**

**Data Processing**

The collected data shall be sent to the data server in the control center in real-time through the data communication system. The traffic condition of each link is determined every 5 minutes and the link travel time is calculated. Once data about the traffic condition of each link is obtained, it can be used in many ways including determination of service level, queue length, and link travel time. The data is processed in the format suitable for the media to be used for information dissemination. Also, if information such as a traffic condition map on a smartphone app or message at VMS is to be provided, it is necessary to conduct data cleansing and visualization via software. It may also predict traffic condition through simulations by storing the past data.

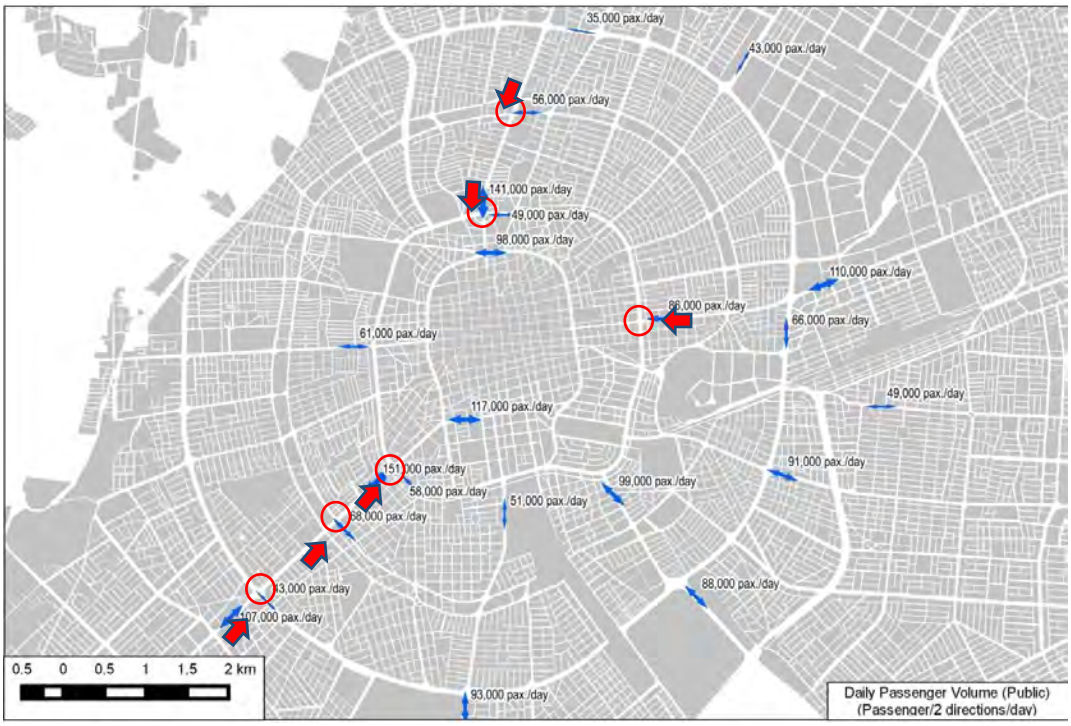
**Information Provision**

By processing data, the system can provide traffic information through the internet, smartphone app and VMS on arterial roads. Figure 7.8-22 shows traffic information provision utilizing VMS in Japan. This sign board is installed before a fork in a road and provides traffic congestion information, traffic incident information (such as road closings and accidents), and travel time to the main points. Drivers can estimate the travel time and know the traffic condition at that time. Then the drivers can select the optimal and quickest routes, and it is expected that traffic disperses so that each driver choose their destination carefully to suit their needs.


Source: (Left) JICA Study Team; (Right) Tokyo metropolitan government

**Figure 7.8-22 Case of Graphic Variable Message Sign in Japan**

Figure 7.8-23 shows the proposed locations of the variable message signs.




Source: JICA Study Team

**Figure 7.8-23 Proposal on Installation Location of Graphic Variable Message Sign**

The issue with traffic information equipment is the cost of maintenance. As one of the solutions, an information system which rents out advertisement space is recommended, as shown in Figure 7.8-24, which is the case of traffic information system with an advertisement in India. This system can get a part of the maintenance cost from advertisement, and then the administrator can reduce the maintenance cost and sustain good service.


Source: Zero-Sum, Ltd. Japan, Zero-Sum ITS Solutions India Pvt. Ltd.

**Figure 7.8-24 Case of Traffic Information System with Advertisement in India**

**(2) Shift of departure time from peak hours to off-peak hours**

According to the results of the traffic count survey, the traffic peaks occur during lunchtime (12:00-14:00), in addition to the morning (7:00-8:00) and evening peak (18:00-19:00) times, at some locations.

Currently, government or non-government offices open around 8:00-9:00 and finish around 17:00-18:00. Even the school timing is overlapping in Santa Cruz. At lunchtime, most people go back home or go to restaurants by vehicle and return to their offices at the same time.

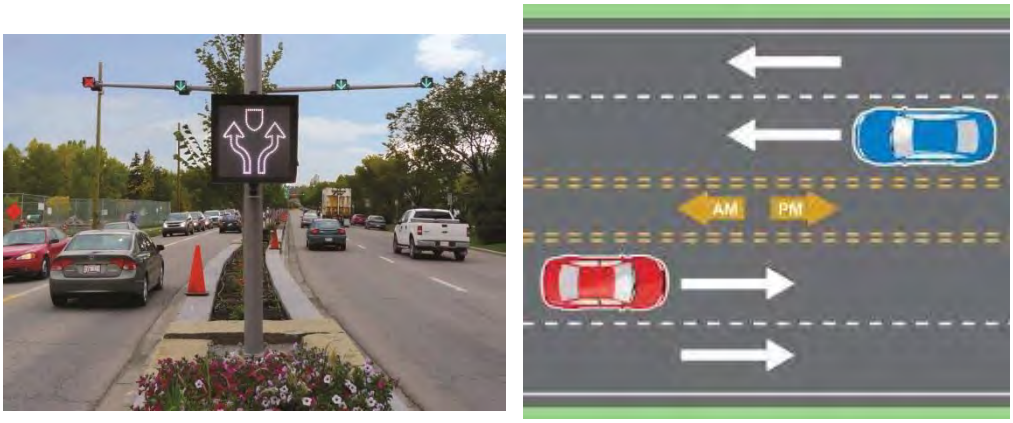
If the work hours and school hours are diversified, the concentration of the travel demand in the peak hours is expected to decrease.

The municipality conducted interviews with some schools and parents of their students about traffic problems during the commute hours. As a result, it was understood that traffic congestion was caused by commuting to the elementary school and secondary school which was located next to each other. The municipality asked the schools to adjust commute time to avoid traffic congestion. As a result, traffic congestion was relieved by this measure.

Shifting of departure time from peak hours to off-peak hours should be encouraged. It is necessary to collaborate with private companies, and the municipality should campaign for flextime and encourage companies located in business areas to agree to this measure.

**(3) Reversible Traffic Lanes**

The direction toward the center of Santa Cruz de la Sierra is crowded during the morning peak time, and the direction toward the suburban areas are crowded, and opposite lanes have comparatively available space during evening time. The implementation of reversible lanes on main radial roads in Santa Cruz de la Sierra has been proposed and is viewed to be an effective solution for peak-hour congestion. Figure 7.8-25 shows an image of reversible lanes. It adds peak-direction capacity to a two-way road and decreases congestion by temporarily borrowing available lane capacity from the other (off-peak) direction or middle lane.




Source: (Left) ISL Engineering https://islengineering.com/~islengi1/index.php/transportation/reversible-lane-control-systems
(Right)http://www.aarp.org

**Figure 7.8-25 Example of Reversible Lanes**

**(4) Restriction of Vehicle Use**

There are various effective measures to restrict the use of vehicles. For instance, road pricing (congestion charge) is a system of direct charges levied for entering an urban area, which has been introduced in big cities such as London and Singapore, etc. Road space rationing such as alternate day travel which is based on license numbers has been implemented in cities with serious air quality problems such as Santiago, São Paulo, Bogotá, and La Paz.

The Master Plan includes the following three traffic measures: 1) tariffed control system for

on-street parking at the designated area, 2) prohibition of on-street parking outside of the designated area, and 3) control of taxies by proper registration system and public taxi facilities in Historic Center.

## 7.9 Non-motorized Transport

### 7.9.1 Policies

In the Metropolitan Area, the non-motorized transport consists of trips by walk and by bicycle, then the policy focuses on pedestrian and cyclists. There is no animal transport, animal-drawn carts, and bicycle or tricycle carts.

Policies of the public transport were established so that they can contribute to achieving the objectives as shown in Table 7.9-1.

Construction of bicycle lanes and improvement of sidewalks are the major policies of non-motorized transport. Since there is no guideline of bicycle lane which is applied to all the municipalities, it is necessary to establish a common guideline for the construction of bicycle lanes. For the pedestrian network, it is necessary to consider wheelchair users.

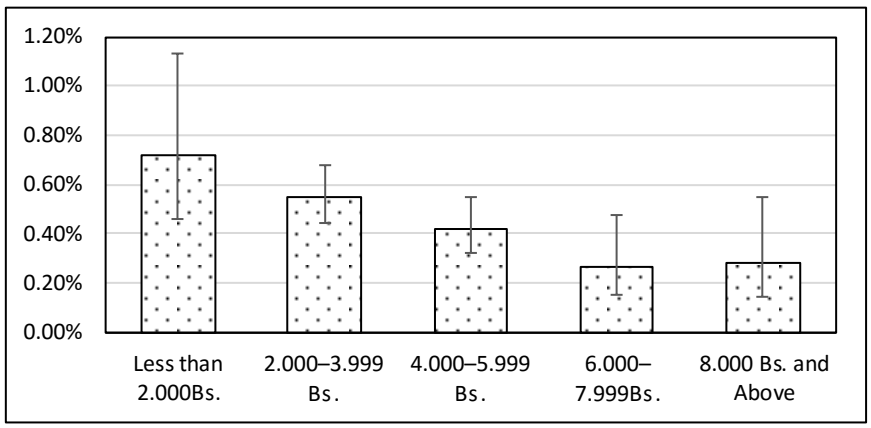
**Table 7.9-1 Policies on Non-Motorized Transport**

| General Objectives | Specific Objectives | Policy |
|---|---|---|
| Provide Good Environment for Non-Motorized Transport | • Develop a safe and comfortable bicycle network | • Establish a common guideline of bicycle lanes for the Metropolitan Area<br>• Construction of bicycle lanes |
| | • Improve the pedestrian network | • Construction and improvement of sidewalks<br>• Establish a common guideline for wheelchair usage in the Metropolitan Area.<br>• Pedestrian crossing should be provided with a long enough signaling phase between major intersections where the distance is long |

Source: JICA Study Team

### 7.9.2 Bicycle Network

Presently, the number of commuter trips by bicycle is very small. Figure 7.9-1 shows the percentage of bicycle use as the transport mode of commuter trips by household income level. The result shows that bicycle is used by people of low-income households although the percentage is less than 1%.




Source: JICA Study Team

**Figure 7.9-1 Share of Bicycle Use as the Mode of Commuter Trip**

The following reasons can be identified: 1) Infrastructure for bicycle use is insufficient. 2) It rains heavily in the rainy season. 3) Summer in the Metropolitan Area is a very hot season. 4) The density of the public transport routes is high. The first problem can be solved by improving the infrastructure, but other reasons remain.

The modal shift to bicycle contributes to solving urban transport problems in some cities where the modal share of trips by bicycle is very high, but the impact on the traffic problems in the Metropolitan Area may be very small. Since public transport can carry more people than bicycles, the modal shift to bicycle from public transport cannot reduce the traffic congestion. If car drivers change their mode to bicycles, it may reduce the traffic on roads. However, the bicycle is not the attractive alternative mode for most car users because cars are still faster than bicycles even during the peak hours. From this, the bicycle is not considered as the major mode of commuter transport in the Master Plan.

On the other hand, the bicycle is an alternative mode for short distance trips within communities. The promotion of the bicycle use can contribute to alleviating the chaos around the local markets. The bicycle use by school children instead of micro can reduce the traffic on local streets.


Source: Photo taken by JICA Study Team

**Figure 7.9-2 Infrastructure of Bicycle in Lima, Peru**

In the Master Plan, the major ring and circular roads are proposed to be used as the BRT corridors, where the available space is planned to be converted to bus lanes. On the other hand, many roads have the median where trees and pedestrian way exist. The bicycle network should be formulated using such roads.

### 7.9.3 Pedestrian Facilities

Improvement of sidewalks is one of the important projects in the Master Plan. Sidewalks should be continuous, as smooth as possible, and separated from vehicle lanes physically and visually. A design guideline of pedestrian facilities should be developed considering the universal design. The proposed common guideline should be developed with the participation of wheelchair users and should be used not only in Santa Cruz de la Sierra but also other municipalities.

Pedestrian crossing facilities along the arterial roads should be developed, and they are included in the road improvement projects and the traffic management program. A pedestrian crossing should be provided with a long enough signaling phase between major intersections where the distance is long. The design should consider public opinions, especially of women and wheelchair users.

It is proposed to formulate the pedestrian network in the historical center by making use of

the manzanas. A typical manzana in the historical center is a square of 100m x 100m, having an inner court. Some commercial buildings allow people to pass through the corridors inside the manzana. By connecting such kind of open spaces inside manzanas with the public and private partnership, the attractive pedestrian network can be formulated.

# 7.10 Evaluation of the Master Plan

## 7.10.1 Economic Benefits

### (1) Contents of Economic Benefits of the Master Plan

The economic benefits of the Master Plan are calculated only for the benefits that are measurable in monetary unit. Congestion relief, which is one of the most important benefits of infrastructure development of the transport sector, can be evaluated in terms of the reduction in travel time. Valuation of travel time in a monetary unit is popular in transport planning. Following two benefits are calculated to evaluate the Master Plan.

- Reduction in travel time
- Saving in vehicle operating costs (VOCs)

Traffic management is an important part of the Master Plan, but the impacts of most of the projects in the traffic management sector are not measurable. For example, the reduction in traffic accidents by implementing the enhancement of education in traffic safety cannot be predicted. This is one of the reasons to implement the project of the traffic accident database. The Master Plan includes the structural improvement of the drainage system, but the drainage project is excluded from the evaluation because the methodology of evaluating drainage system is different than that of transport projects.

The economic benefits are calculated based on the results of the demand forecast, which consists of the following output data:

- Vehicle kilometers
- Passenger hours

The economic benefits are calculated by comparing these output values of "with project case" and "without project case".

### (2) Without Case

The "Without Case" is the case if no project in the master plan is implemented. Although this is an unrealistic case, the projection of the case is necessary for the calculation of the economic benefit.

The case is analyzed in Chapter 3 as "Option 1A", which assumes the present trend in the development of urbanizations continue and low density urbanized area expand. However, "Option 1A" does not necessarily assume that there be no new roads. If no road project is implemented, new urbanizations will not be populated. "Option 1A" assumes some roads be constructed to support the development of new urbanizations.

If no transport project is implemented, the future urbanization area would be smaller than that of "Option 1A". The nearest case of the "Without Case" in the scenario analysis would be the "Option 2A", where the future urbanized area is limited to the area in the urbanizations that have been already approved. Although "Option 2A" is the case of the road development, its socioeconomic assumption can be considered as that of the "Without Case" because the approved urbanized area can be accessed with existing infrastructure. The socioeconomic condition of "Option 2A" is as same as that of "Option 2B", which is equal to the socioeconomic framework of the master plan.

### (3) Estimation of vehicle-kilometers and passenger-hours

The traffic demand forecast is carried out for the morning peak hour and the morning off-peak hour. To estimate the total vehicle-kilometers and passenger-hours in a day, those numbers in the morning peak hour is multiplied by six while those of the off-peak hour is multiplied by nine. Table 7.10-1 shows the estimated numbers.

**Table 7.10-1 Vehicle-kilometers and Passenger-hours per day in 2035**

| Year | Case | Vehicle-kilometers (000) | | Passenger-hours (000) | |
|---|---|---|---|---|---|
| | | Private cars | Buses | Private cars | Buses |
| 2020 | Without Case (A) | 9,518 | 2,638 | 340 | 752 |
| | With Case (B) | 9,520 | 2,394 | 336 | 732 |
| | Difference (A-B) | -1 | 244 | 4 | 20 |
| 2025 | Without Case (A) | 10,959 | 2,679 | 429 | 887 |
| | With Case (B) | 10,272 | 1,581 | 321 | 581 |
| | Difference (A-B) | 687 | 1,099 | 108 | 306 |
| 2035 | Without Case (A) | 22,916 | 3,116 | 991 | 2,173 |
| | With Case (B) | 18,598 | 2,355 | 472 | 1,281 |
| | Difference (A-B) | 4,317 | 761 | 520 | 892 |

Source: JICA Study Team

### (4) Estimation of Travel Time Cost

A value of time represents an equivalent monetary value per a certain unit of time. It is the monetary value which can be saved if the travel time is reduced, or it is also the monetary value that a person can pay to reduce the travel time.

There are some methods to estimate a value of time. The average hourly salary is one of the most appropriate estimations. According to INE, the average monthly income of Bolivian families is estimated at Bs. 4,234 in 2016. On the other hand, the average monthly income in the Metropolitan Area was estimated at Bs. 4,257 from results of the Commuter Survey and the Household Interview Survey as shown in Table 7.10-2.

**Table 7.10-2 Household Income Distribution**

| | Median | Samples |
|---|---|---|
| Less than Bs. 2,000 | 1,000 | 1,604 |
| Bs. 2,000–3,999 | 3,000 | 6,955 |
| Bs. 4,000–5,999 | 5,000 | 4,458 |
| Bs. 6,000–7,999 | 7,000 | 1,455 |
| Bs. 8,000 –9,999 | 9,000 | 505 |
| Bs. 10,000–11,999 | 11,000 | 230 |
| Bs. 12,000–13,999 | 13,000 | 115 |
| Bs. 14,000 and Above | 15,000 | 160 |
| Weighted Average | | 4,257 |

Source: JICA Study Team (CS & HIS)

The monthly income is converted to the hourly income by applying 176 working hours per month as Bs. 4,234 / 176 = Bs. 24.06 per hour. It is popular in transport planning that the hourly income is used as the value of time for trips relating working. The value of time for other purposes is lower although it is difficult to estimate the values. It is assumed that the average value of time is 50% of the hourly income. From this, the value of time is calculated at Bs. 12 per hour. The value of time is also estimated from the parameters of the logit model developed based on the Opinion Survey. In case of public transport users, it is Bs. 12.5 for the commuter trips and Bs. 14.6 for private trips. Since the results are very

close to the calculated value of time (Bs. 12), these values (Bs. 12.5 and Bs 14.6) are used.

Table 7.10-3 shows the result of the calculation of the benefit of the travel time reduction.

**Table 7.10-3 Benefit of Travel Time Reduction**

| Year | Mode | Travel time Reduction (000 hours) | Value of time (Bs./hour) | Benefit of travel time reduction (Bs. in million) | |
|---|---|---|---|---|---|
| | | | | Day | Year |
| 2020 | Private cars | 4 | 15 | 0.06 | 19 |
| | Public transport | 20 | 13 | 0.25 | 81 |
| | Total | 24 | | 0.30 | 100 |
| 2025 | Private cars | 108 | 15 | 1.58 | 522 |
| | Public transport | 306 | 13 | 3.82 | 1,262 |
| | Total | 414 | | 5.41 | 1,784 |
| 2035 | Private cars | 520 | 15 | 7.59 | 2,505 |
| | Public transport | 892 | 13 | 11.15 | 3,679 |
| | Total | 1,412 | | 18.74 | 6,183 |

Source: JICA Study Team

### (5) Estimation of Vehicle Operating Cost (VOC)

The modal shift from private cars to public transport systems is expected to save the vehicle operating costs in the Metropolitan Area because the number of reduced private cars is estimated to be larger than the number of increased public transport vehicles.

The cost of fuel or electricity (in case of electric trains) is the major component of VOCs because whichever vehicle is used, energy is consumed. The procurement cost, which is dispersed over the period vehicle life as depreciation and interest, also essential component of the VOCs. Other components of VOCs are replacement costs of parts such as tires, payments to drivers, and costs of repair and maintenance.

The average age of vehicles in the Metropolitan Area is as old as 14.7 years, according to the Traffic Surveys. This is because vehicles of the models of 1990s are still typical in the Metropolitan Area. It is expected that these 1990s cars would be replaced with new cars in next five years due to the life of cars. Therefore, for the estimation of VOCs in the master plan period, the fuel efficiency of modern cars can be used.

Table 7.10-4 shows the results of the VOC calculation.

**Table 7.10-4 Benefit of VOC Reduction**

| Year | Mode | Vehicle-kms Reduction 1000 | VOC per 1000 km (Bs./1000km) | Benefit of VOC reduction (Bs. in million) | |
|---|---|---|---|---|---|
| | | | | Day | Year |
| 2020 | Private cars | -1 | 1,654 | 0.00 | -1 |
| | Public transport | 244 | 4,918 | 1.20 | 397 |
| | Total | 243 | | 1.20 | 396 |
| 2025 | Private cars | 687 | 1,654 | 1.14 | 375 |
| | Public transport | 1,099 | 4,918 | 5.40 | 1,784 |
| | Total | 1,785 | | 6.54 | 2,158 |
| 2035 | Private cars | 4,317 | 1,654 | 7.14 | 2,357 |
| | Public transport | 761 | 4,918 | 3.74 | 1,235 |
| | Total | 5,078 | | 10.89 | 3,592 |

Source: JICA Study Team

## 7.10.2 Greenhouse Gas Effect

### (1) Methodology and Units

The methodology to estimate the volume of vehicle emissions is described in Chapter 4. The carbon dioxide equivalent (CO2e) is calculated from vehicle-kilometer by using the following conversion factors.

- Private cars: 0.2388 CO2e-kg per 1000 vehicle-kilometer
- Buses: 0.5878 CO2e-kg per 1000 vehicle-kilometer

### (2) Reduction in Carbon Dioxide

The reduction in CO2e by the Master Plan was calculated at 1.5 tons per day (488 tons per year) in 2035 as shown in Table 7.10-5.

**Table 7.10-5 Reduction in Carbon Dioxide Equivalent**

| Year | Mode | Vehicle-kms Reduction 1000 | CO2e-kg per 1000 km (kg/1000km) | Reduction in CO2e (ton) Day | Year |
|---|---|---|---|---|---|
| 2020 | Private cars | -1 | 0.2388 | 0.00 | 0 |
| | Public transport | 244 | 0.5878 | 0.14 | 47 |
| | Total | 243 | | 0.14 | 47 |
| 2025 | Private cars | 687 | 0.2388 | 0.16 | 54 |
| | Public transport | 1,099 | 0.5878 | 0.65 | 213 |
| | Total | 1,785 | | 0.81 | 267 |
| 2035 | Private cars | 4,317 | 0.2388 | 1.03 | 340 |
| | Public transport | 761 | 0.5878 | 0.45 | 148 |
| | Total | 5,078 | | 1.48 | 488 |

Source: JICA Study Team

## 7.10.3 Project Cost

The project costs of the Master Plan are summarized as follows.

**Table 7.10-6 Estimation of the Project Cost**

(Unit: US$ Million)

| Sector | Short-term | Mid-term | Long-term | Total |
|---|---|---|---|---|
| Road Infrastructure | 85.6 | 423.2 | 902.4 | 1,411.1 |
| Public Transport | 60.7 | 64.1 | 0.0 | 124.8 |
| Traffic Management | 9.2 | 25.4 | 0.0 | 34.6 |
| Drainage | 5.0 | 103.3 | 206.6 | 309.9 |
| Total | 160.5 | 616.0 | 1,109.0 | 1,880.4 |

Source: JICA Study Team

In addition to the project cost above, maintenance costs of the road infrastructure need to be considered for the evaluation. The maintenance costs of roads are assumed at 1% of the project cost every year. For the operation and maintenance costs of the proposed BRT system, US$ 1.6 per vehicle-kilometer is assumed[2].

Since the benefits of the Master Plan was calculated for transport projects, the project cost of the drainage sector was excluded from the evaluation.

[2] Influences of operational issues on the operational cost of BRT buses and BRT systems, Nicolai, Joaquin C.; Weiss, Dieter M. 27th Annual Southern African Transport Conference 2008

In an economic evaluation, the cost should represent the economic cost, which means that tax and other transfer costs should be excluded. However, since the cost estimates in the Master Plan does not consider whether it contains tax or not, it is assumed that the project cost is equal to the economic cost.

### 7.10.4 Cost-benefit Analysis

The economic internal rate of return (EIRR) of the Master Plan was calculated at as high as 35%, using the flow of the difference between the benefit and cost. The period of the evaluation is from 2018 to 2035. The result shows that the Master Plan is expected to generate high economic benefit effectively.

**Table 7.10-7 Benefit and Cost Flow of the Master Plan**

(Unit: Bs. Million)

| Year | Benefit | | | Cost | Cash Flow |
|---|---|---|---|---|---|
| | VOC Reduction | Travel Time Saving | Total | | |
| 2018 | | | | 869 | -869 |
| 2019 | | | | 882 | -882 |
| 2020 | 396 | 100 | 496 | 979 | -484 |
| 2021 | 216 | 178 | 394 | 908 | -514 |
| 2022 | 460 | 445 | 905 | 1,521 | -616 |
| 2023 | 978 | 1,066 | 2,044 | 1,795 | 249 |
| 2024 | 1,553 | 1,863 | 3,416 | 1,843 | 1,573 |
| 2025 | 2,158 | 1,784 | 3,943 | 1,232 | 2,711 |
| 2026 | 2,302 | 2,224 | 4,526 | 1,063 | 3,463 |
| 2027 | 2,445 | 2,664 | 5,109 | 1,148 | 3,961 |
| 2028 | 2,588 | 3,104 | 5,693 | 1,236 | 4,456 |
| 2029 | 2,732 | 3,544 | 6,276 | 1,225 | 5,051 |
| 2030 | 2,875 | 3,984 | 6,859 | 1,096 | 5,763 |
| 2031 | 3,019 | 4,424 | 7,443 | 1,026 | 6,416 |
| 2032 | 3,162 | 4,864 | 8,026 | 1,188 | 6,837 |
| 2033 | 3,305 | 5,304 | 8,609 | 1,044 | 7,565 |
| 2034 | 3,449 | 5,744 | 9,192 | 850 | 8,342 |
| 2035 | 3,592 | 6,183 | 9,776 | 490 | 9,286 |

35%

Source: JICA Study Team

# 7.11 Institution and Legal Framework

## 7.11.1 Coordination at the Level of Metropolitan Area

### (1) Necessity of the Coordination

#### 1) Road Network

The master plan includes the construction of roads that go through two or more than two municipalities. In principle, the Department of Santa Cruz is responsible for the construction and maintenance of inter-municipal roads, which means that the Department should provide a mechanism for the coordination among municipalities. On the other hand, there are some roads which should be constructed and maintained by municipalities even if the road is located in two or more municipalities when the major function of the road is to provide local access rather than the connection between municipalities. In such case, the coordination between municipalities is very important to formulate the proper road network.

Bridge construction along Pirai River requires the coordination at the level of the Metropolitan Area. The coordination between the municipalities of both side of the bridge is not sufficient because the construction of a bridge affects the plan of other bridges.

#### 2) Urban Development

The road network and public transport system of the Master Plan assume the future land use in the Metropolitan Area, which is discussed in Chapter 3. If more urbanizations than those considered in the Master Plan are approved and developed, other arterial roads would be necessary. If the population in urbanizations do not increase as expected, the demand forecast should be reviewed, and some road projects should be canceled.

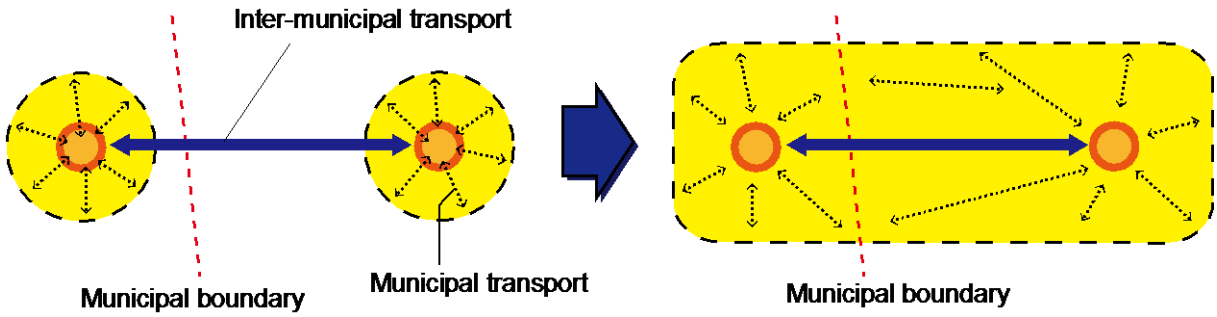
During the Master Plan Project, the issue of the control of the urban development to avoid the urban sprawl has been discussed, but it was found that the introduction of an integrated control mechanism to the six municipalities is challenging, although all municipalities have reached the same opinion that the further urban sprawl with low-density development without a transport plan should be avoided.

#### 3) Drainage Development

Since the pavement of unpaved roads is one of the most important projects in the Master Plan, the capacity of the drainage system should be expanded simultaneously to avoid floods of paved roads. As described in Chapter 8, construction of a canal from Santa Cruz de la Sierra to the Rio Grande through Cotoca is one of the drainage projects. Implementation of the project requires high-level coordination among the municipalities, the Department of Santa Cruz, and the central government.

#### 4) Public transport

The present institute system for the demarcation of public transport system assumes that the local transport, which is managed by municipalities, and inter-city transport, which is managed by the department government are separated as illustrated in the left figure. The urbanized area of municipalities has expanded, and the demand for local transport crossing the municipal boundary is increasing.




Source: JICA Study Team

**Figure 7.11-1 Jurisdiction of Public Transport System**

**5) Update and Maintenance of the Traffic Database**

The demand forecast model developed in the Project focuses on the Metropolitan Area, but it is necessary to develop more detail model for the transport analysis at the municipal level. Since the transport analysis using the demand forecast model requires high skill and knowledge of urban transport, and the model should be maintained as an integrated, uniform model, it is recommended that an organization take the demand forecast model and use it for the transport analysis of all municipalities in the Metropolitan Area.

**(2) The Region Metropolitan**

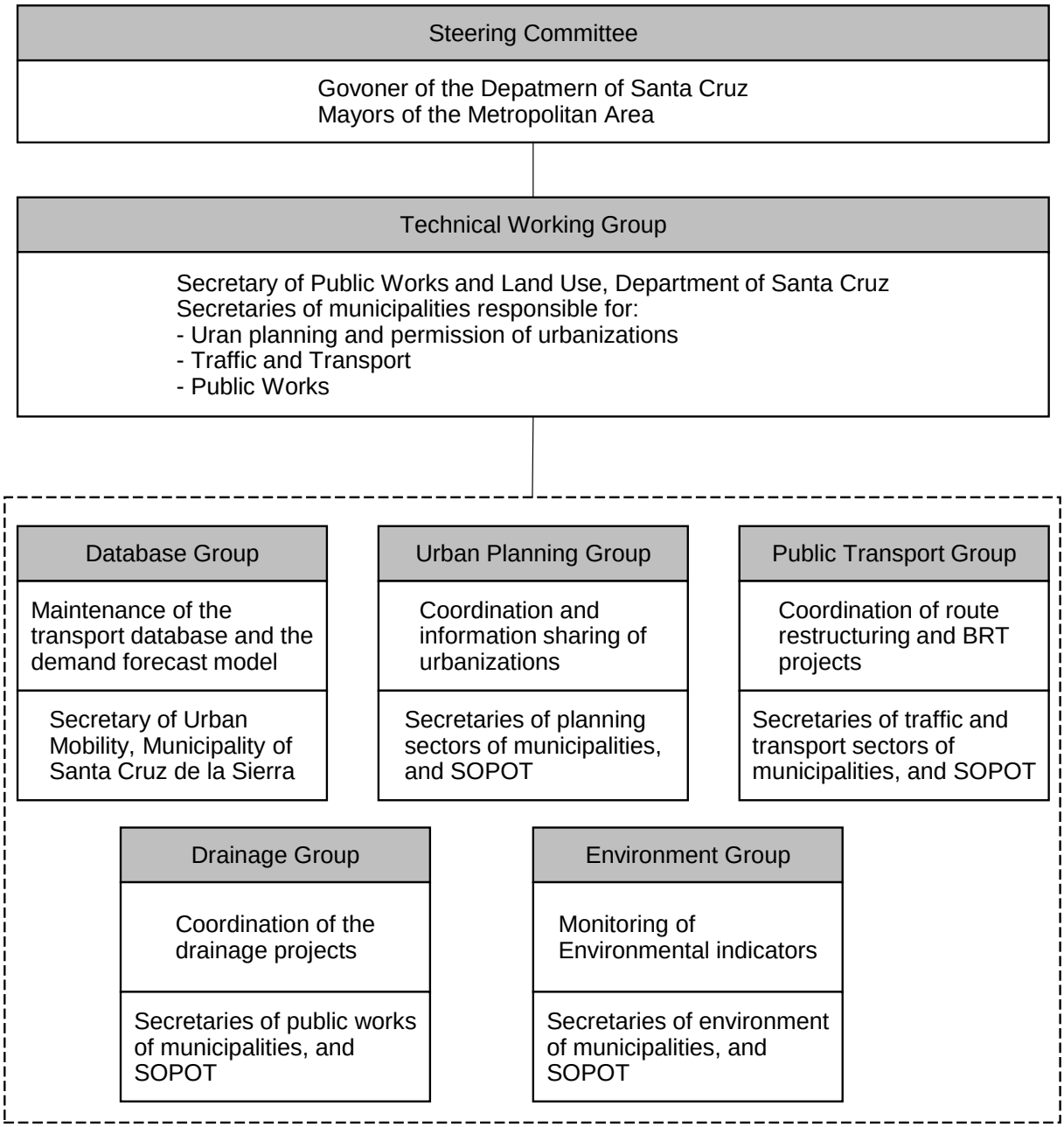
The Department of Santa Cruz has been working on the establishment of the Region Metropolitan of Santa Cruz and held many public meetings in 2016 and 2017. The Region Metropolitan is one of the autonomies stipulated in Law 031. It is expected that the Region Metropolitan have the function of the planning of the transport master plan because the necessary budget and powers are given to the organization. However, since it takes time to establish the Region Metropolitan, and it is proposed to establish an organization for the Santa Cruz Metropolitan focusing on the implementation of the Master Plan.

**(3) Establishment of the Metropolitan Coordination Committee for Transport**

It is proposed that an organization for the coordination of the Metropolitan Area to monitor and implement the Master Plan. The organization can succeed the structure of the Project as shown in Figure 7.11-2. It has the following functions:

- Coordination and information sharing of urban development
- Coordination of road network development
- Coordination of route restructuring of public transport system
- Coordination of BRT projects
- Coordination of the drainage projects
- Monitoring of the environmental indicators
- Maintenance of the transport database

It is expected that members who participated in the training in Japan in 2016 participate and take the initiative of the organization.




Source: JICA Study Team

**Figure 7.11-2 Structure of the Metropolitan Coordination Committee for Transport**

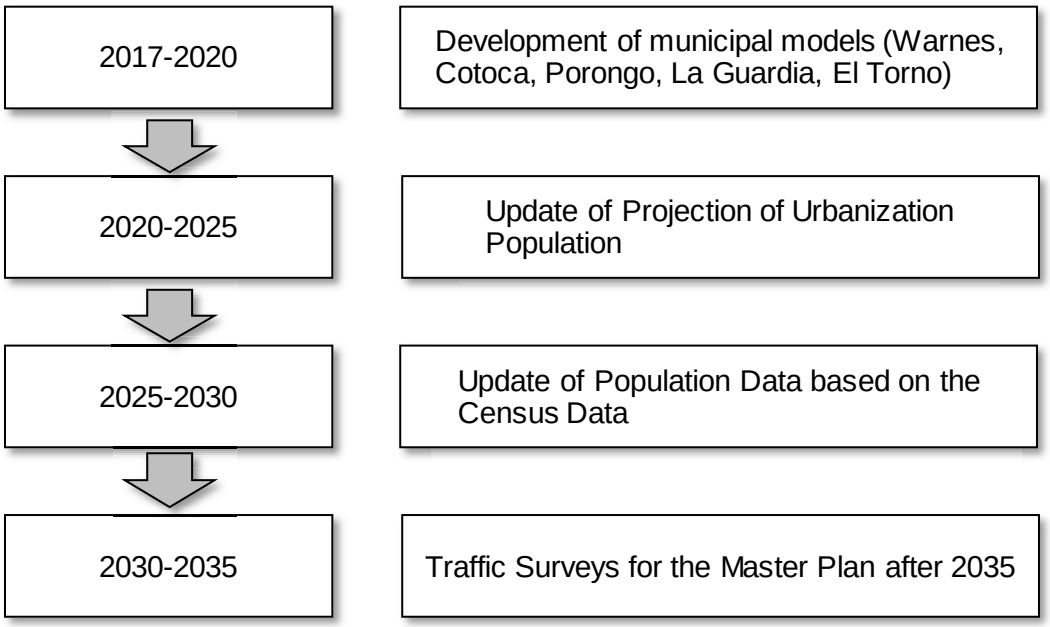
## 7.11.2 Enhancement of Research in Transport Sector

The experience of the Project shows that the capacity of both private and public sector to carry out traffic surveys in the Metropolitan Area is low level. This is due to the lack of demand of public sector to carry out such surveys. Since the business opportunity of the traffic surveys and analysis in the Metropolitan Area is small, few companies can carry out traffic surveys. The need for acquiring traffic data is increasing as the traffic demand is increasing. Enhancing the capacity of surveys in the transport sector is necessary.

It is proposed to establish a research center in the Metropolitan Coordination Committee for Transport. In the beginning, the Secretary of Urban Mobility of the municipality of Santa Cruz de la Sierra is expected to function as the research center, using its human resources.

### 7.11.3 Update of the Transport Database

The demand forecast model in the Project is developed based on not only the traffic surveys but also the statistics of 2012 Census and the information of the urbanization in the Metropolitan Area. The demand forecast model will be used for the feasibility studies of new projects, analysis of public transport and road traffic for the works by municipalities, and academic analysis, and small modifications will be done in demand for the new demand forecasts. In addition to such opportunities, it is recommended to update the database when there is a change in the plan of urbanizations. When the next census is conducted, the demand forecast model should be reviewed.




Source: JICA Study Team

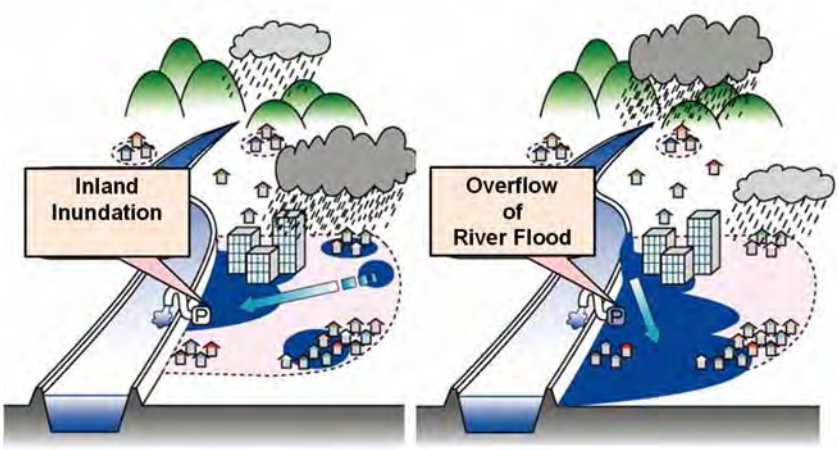
**Figure 7.11-3 Update of Traffic Demand Forecast**

# Chapter 8 Drainage

## 8.1 Present Conditions

### 8.1.1 General

The flood disasters in the Santa Cruz Metropolitan Area can be classified into two types, i.e., i) inland inundation and ii) overflow of river flood. The inland inundation occurs when the rainfall exceeds the flow capacity of the drainage systems in the land or water level of outer side of the land is higher than that of the drainage systems in the land. The overflow of river flood occurs when flood's force exceeds the strength of the river banks. Once the river flood overtops or scours the river banks, it causes severe damages in the inland.




Source: Prepared by the JICA Study Team based on the information from http://www.ajiko.co.jp/product/detail/ID4TCIA3FBT

**Figure 8.1-1 Types of Flood Disasters**

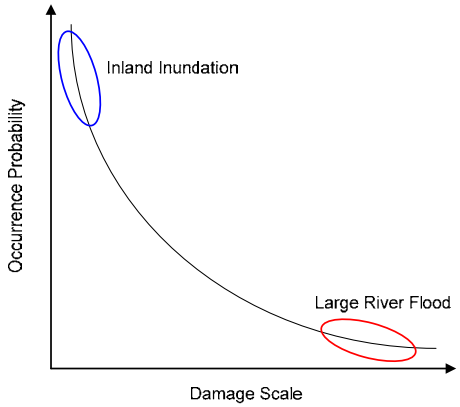
Normally, disasters that cause large damages tend to occur less frequently and disasters with small damages tend to occur more frequently, as shown in Figure 8.1-2. "Infrequent Disaster with Large Damages" and "Frequent Disaster with Small Damages" are distinctly treated in the Disaster Management Policy. In general, measures for "Infrequent Disaster with Large Damages" are considered to be more important than that for the "Frequent Disaster with Small Damages" from the view point of disaster management. In the Metropolitan Area, large river flood can be categorized as "Infrequent Disaster with Large Damages" and inland inundation can be categorized as "Frequent Disaster with Small Damages".

The Pirai River experiences regular flash floods because of its location along the edge of Andes. In March 1983, a flash flood occurred in the basin of the Pirai River which inundated the rich part of Santa Cruz de la Sierra, the most important economic center of the country. This event affected 9,500 houses in the Santa Cruz Department and 5,000 houses in the rural areas, producing damages estimated at US$37 million and 900 people were reported missing. Thanks to the efforts on defensive works along the Pirai River and the *Rio Grande*, together with the reforestation on the upstream basin of both rivers by *Servicio de Encauzamiento de Aguas y Requlariz*ació *n del Río Piraí* (SEARPI), the Metropolitan Area has been relatively safer against river floods since the 1983 flood incident. However, the maximum river water level recorded in the Pirai River on 23 February 2014 was estimated to be around 3.75 m/s in flood velocity with approximately 5,000 $m^3$/s of the flood discharge. SEARPI is increasingly wary about the recent abnormal heavy rainfalls.

For the urban transport in the Santa Cruz Metropolitan Area, inland inundations are an issue despite its relatively small damages. The rainwater drainage facilities are planned, designed,

and constructed by the Drainage Department of GAM Santa Cruz. The protection of public and private properties against flood and the monitoring of flood scale are carried out by SEARPI. The response on catastrophic disaster is operated by the Civil Defense.

This study diagnosis present condition of inland water drainage in Santa Cruz de la Sierra and suggests effective measures for inland water drainage to contribute in urban traffic resilience against inland inundation in the municipality.




Source: JICA Study Team

**Figure 8.1-2 Theory of Flood Disaster Risk**

## 8.1.2 Present Conditions of the Inland Water Drainage

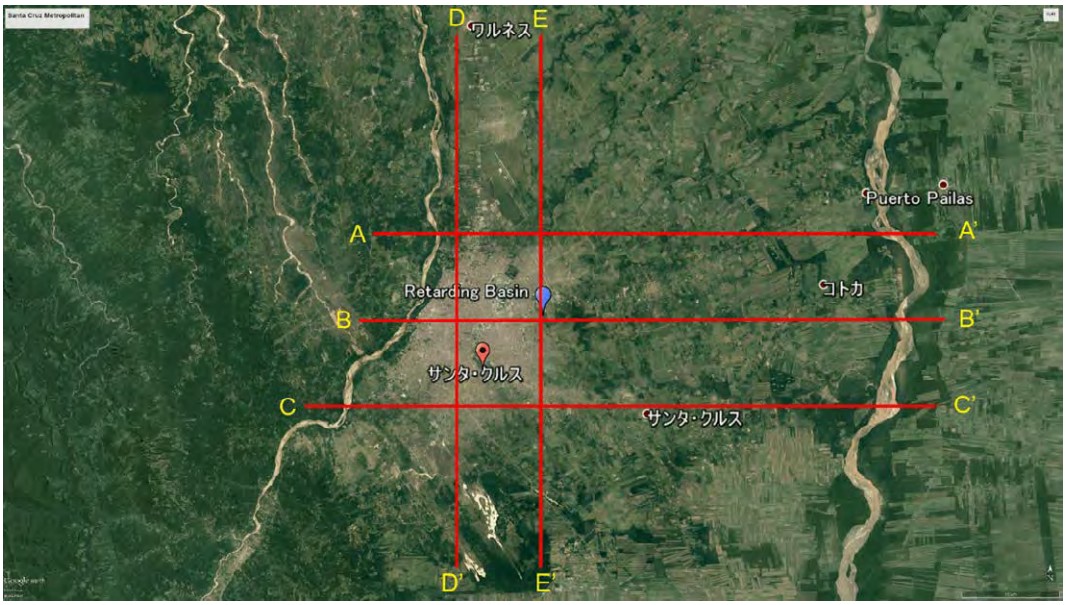
### (1) Natural Features

This section describes the natural features related to the inland water drainage in Santa Cruz de la Sierra.

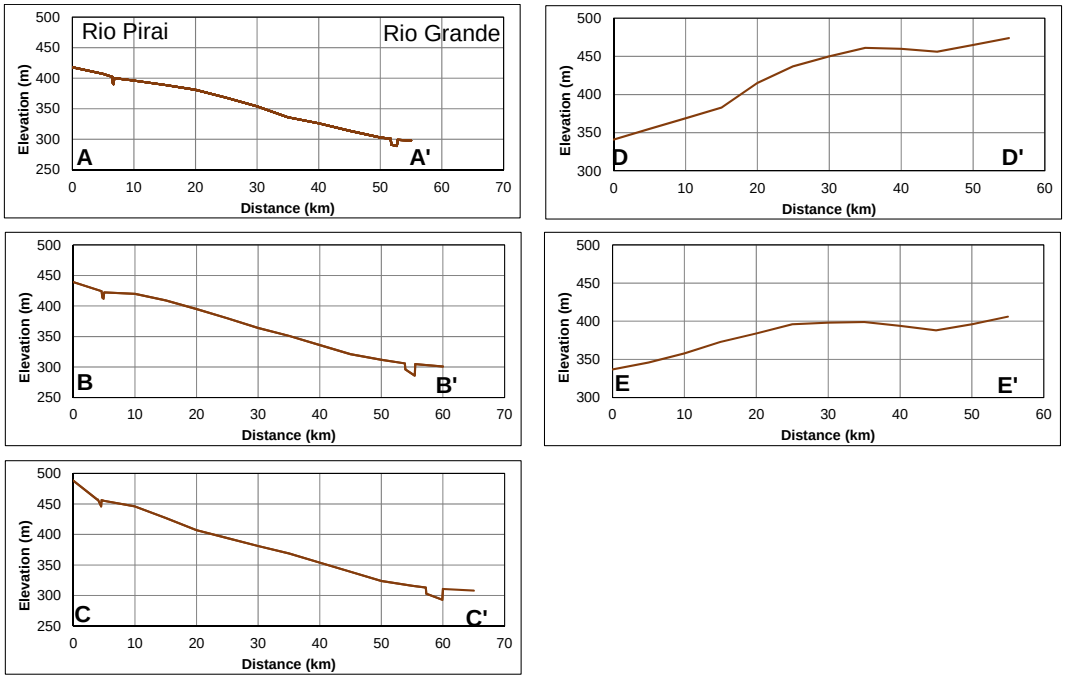
#### 1) Topographic Condition

Figure 8.1-3 shows the cross sections of the ground surface in and around Santa Cruz de la Sierra. Point elevations on the cross sections are measured in a 5-km interval using a satellite image website, Google Earth Pro. This measurement method has no high accuracy but may grasp general topography. The cross sections of A, B, and C are from west to eastward, D and E are from north to southward.

The elevation difference between the Pirai River and the *Rio Grande* is approximately 100 m in cross section A and approximately 150 m in cross section C. Distance from the Pirai River to the *Rio Grande* is approximately 50 km in cross sections A, B, and C. Therefore, the slope gradient of the ground surface from west to eastward ranges from 1:500 to 1:300. The cross section D, which is from *Warnes* to Santa Cruz de la Sierra, shows an approximate slope gradient of 1:300, while the south side of Santa Cruz de la Sierra is slightly lower than the municipality. The cross section E, which is from *Warnes* to Santa Cruz de la Sierra, has a 1:500 slope gradient. Thus, the ground surface in and around Santa Cruz de la Sierra slopes down to the northeastward direction.




**Locations of the Cross Sections**

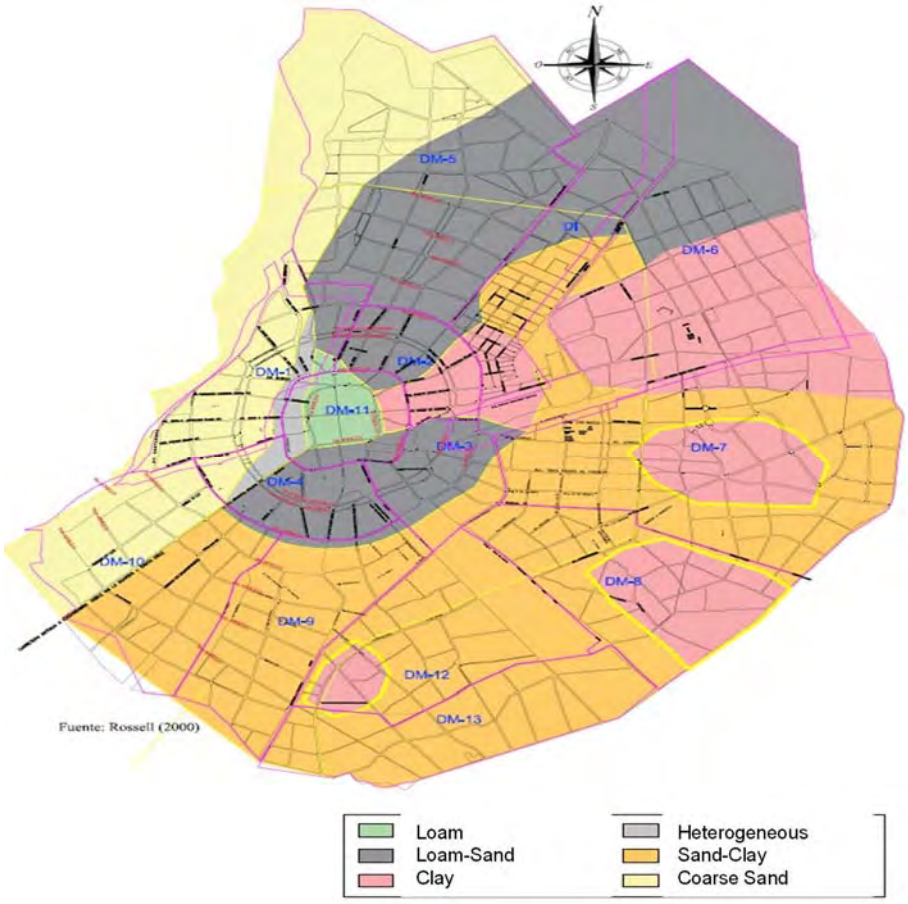



Source: JICA Study Team. Prepared based on the information from Google Earth Pro.

**Figure 8.1-3 Cross Sections of the Ground Surface in and around Santa Cruz**

## 2) Geological Condition

Figure 8.1-4 shows the surface geological condition of Santa Cruz de la Sierra. It was prepared based on information from thesis papers from a university and the Road Department of Santa Cruz de la Sierra, which showed the geological conditions of the 2 m depth. The west part of the municipality, which is along the Pirai River, has a coarse sand surface which are accumulated sediments from the river. The down town of the municipality located in the center is surfaced loam layer. The loam is a highly viscous soil, and refers to one having silt and clay contents of about 25% to 40%.

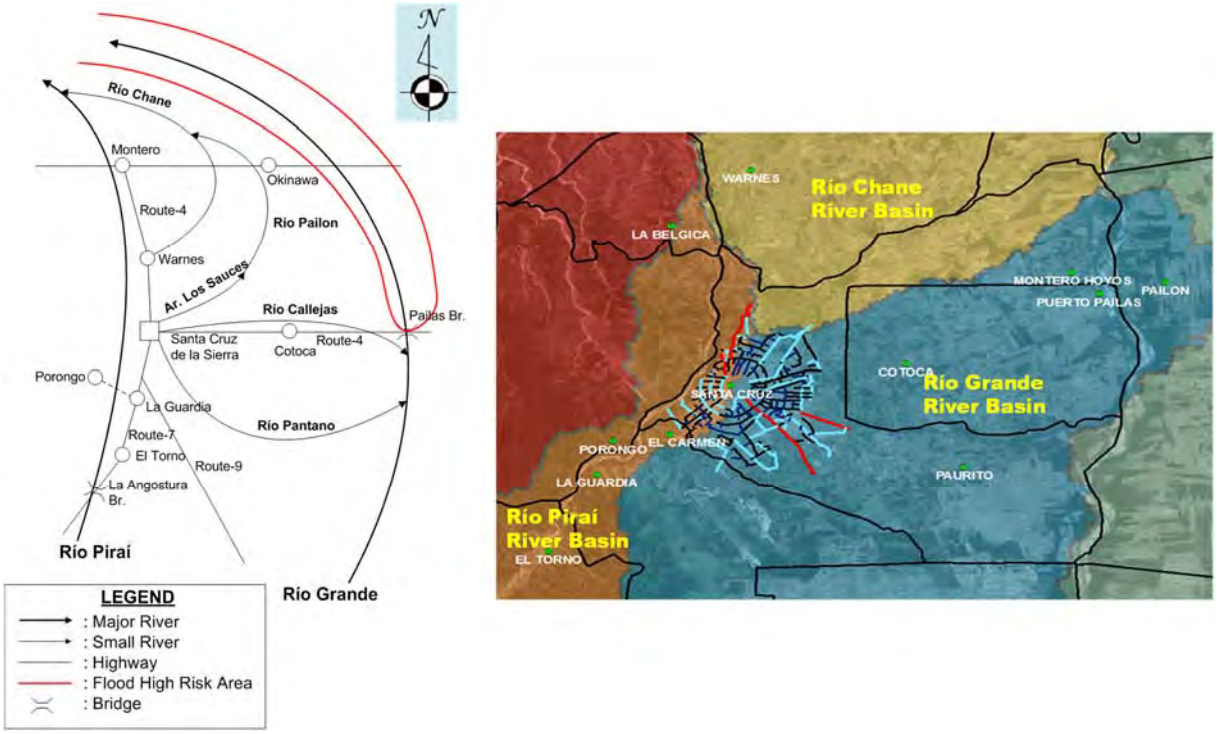



Source: JICA Study Team. Prepared based on the "Plan Maestro De Drenaje Pluvial, Secretaria Municipal De Obras Publicas Direccion De Drenaje, February 2017"

**Figure 8.1-4 Surface Geological Condition of Santa Cruz de la Sierra**

### 3) River System in and around the Metropolitan Area

The river system in and around the Metropolitan Area is schematically shown on the left side of Figure 8.1-5. This schematic map is slightly modified from the map in the "Final Report, Data Collection Survey on Urban Transport for Santa Cruz Metropolitan Area (2015)". As shown in the figure, inland water in the north part of Santa Cruz de la Sierra drains out to the *Arroyo La Sauces* (*Arroyo* is an appellation of a small river in Bolivia), the *Rio Pailon*, the *Rio Chane*, and finally flows out to the Pirai River. The east and south part of Santa Cruz de la Sierra drain out to the *Rio Grande* through the *Rio Callejas* and the *Rio Pantano*, respectively. The inland water from the west part of the municipality drains out to the Pirai River. The right side of Figure 8.1-5 was prepared by the Drainage Department of Santa Cruz de la Sierra based on the topographical data storage from the municipality. The west part of the municipality is the Pirai River basin and the east part is the *Rio Grande* basin.




Source: JICA Study Team. Prepared based on the several information including the "Plan Maestro De Drenaje Pluvial, Secretaria Municipal De Obras Publicas Direccion De Drenaje, February 2017"

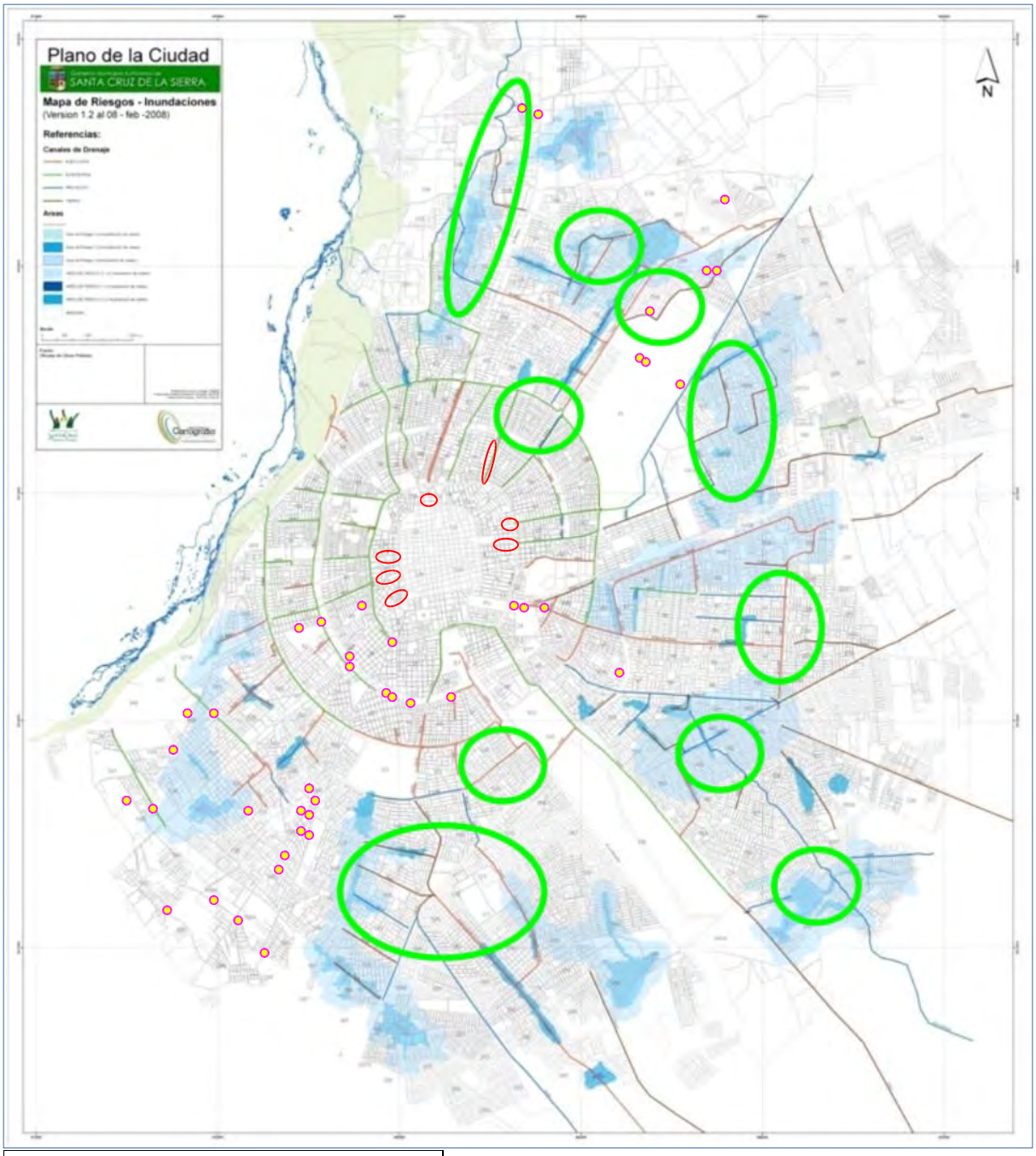
**Figure 8.1-5 River System in and around the Project Area**

### (2) Present Conditions of the Inland Inundation

The present conditions of the inland inundation in Santa Cruz de la Sierra is described in Subsection 5.1.3 in the "Final Report, Data Collection Survey on Urban Transport for Santa Cruz Metropolitan Area (2015)". This section discusses additional information on inland inundation.

#### 1) Inland Inundation Areas in Santa Cruz de la Sierra

Figure 8.1-6 shows the inland inundation areas in Santa Cruz de la Sierra. The green and red colored circles are inundation areas indicated by the Drainage Department of Santa Cruz de la Sierra in 2014, and was later on confirmed by the JICA Survey Team for the "Final Report, Data Collection Survey on Urban Transport for Santa Cruz Metropolitan Area (2015)". Recently, the Drainage Department carried out an interview survey on the inundation areas. The yellow and pink colored circles indicate the newly identified inundation areas from the interview survey. As shown in the figure, most of the green colored areas are not detected as an inundation area in the recent interview survey. It can be assumed that the inundation conditions have been changed because of the new drainage constructions. For example, 90% of the area of District 7 became inundation free because of the new drainage constructions according to a staff of the Drainage Department.

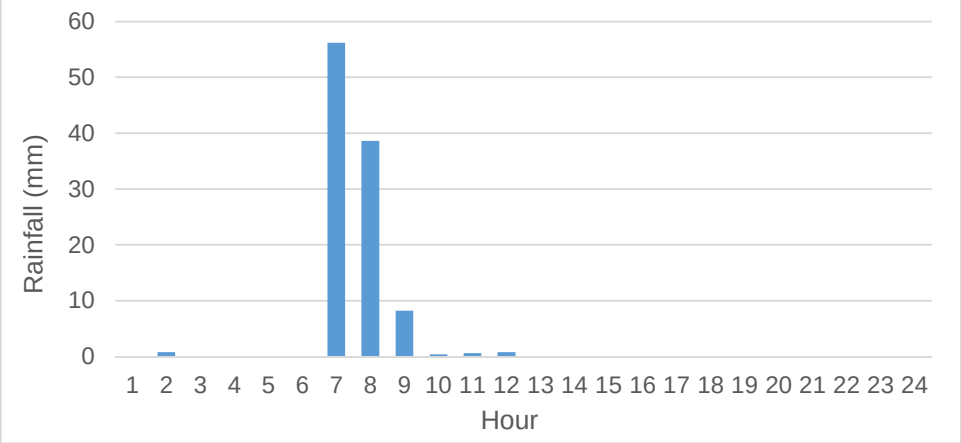



Source: JICA Study Team

**Figure 8.1-6 Inland Inundation Areas in Santa Cruz de la Sierra**

### 2) Situation of Flood on 11th February 2017

A short intense rainfall in Santa Cruz de la Sierra caused severe inland water inundation on 11 February 2017. The intense rainfall caused problems in the different sectors of the municipality. Traffic is one the most affected sector, the streets and avenues were impassable in many places. Figure 8.1-7 shows the hourly rainfall on 11 February 2017 observed at the Drainage Department Office in the municipality. The two-hour rainfall from 6:00 to 8:00 was recorded as 94.8 mm. Some local people testified that the rainfall started on 10 February 2017 and continued until the morning of 11 February, but the rainfall station observed that there was no rainfall on 10 February 2017. Locational situation of the rainfall may be different. The rainfall volume far exceeded the existing drainage capacity as shown in the bottom right photograph in Figure 8.1-8. Statistical damage data by the flood was not available from the Drainage Department.



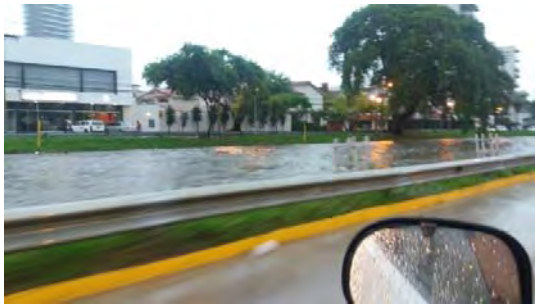

Source: JICA Study Team. Prepared based on the information from the Drainage Department.

**Figure 8.1-7 Hourly Rainfall at SMOP-Drainage on 11 February 2017**

Effect on Pedestrians

Effect on Vehicular Traffic

Effect on Vehicular Traffic



Due to Limited Drainage Capacity

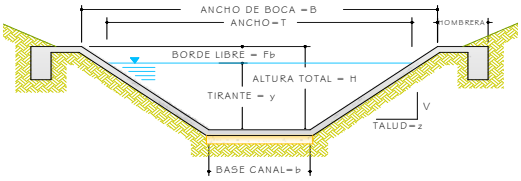
Source: JICA Study Team. Prepared based on the EL DEBER website (http://www.eldeber.com.bo/santacruz/Al-menos-un-muerto-tras-torrencial-lluvia-en-Santa-Cruz-20170211-0008.html)

**Figure 8.1-8 Impacts of the Intense Rainfall on 11 February 2017 on the Citizens**

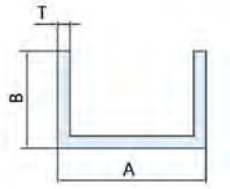
### (3) Design Standards of the Drainage System

The design flood of the drainage system in Santa Cruz de la Sierra is estimated using the rational method. The design scale is a 10-year probable flood but the Drainage Department of the municipality will use the 20-year probable flood for priority channels as shown in Table 8.1-2. The drainage plan and the structural designs are carried out by the civil engineers in the Drainage Department.

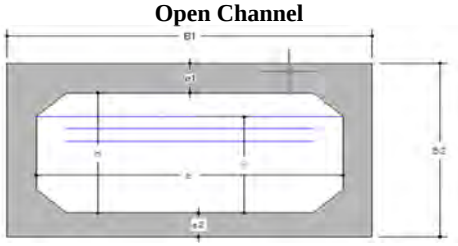
Figure 8.1-9 shows the typical cross sections of the drainage and there are three types of structures. Most of the drainages use the open channel type because this type is the most economical. The rectangular reinforced concrete (RC) open channel is used where the space for drainage installment is narrow, this type is more expensive than the open channel because of its reinforced concrete structure. The box culvert is used when crossing or below some public facilities such as road. This type is the most expensive among the three types because of the required reinforced concrete volume.




**Open Channel**




**Rectangular RC Open Channel**



**RC Box Culvert**

Source: JICA Study Team. Prepared based on the information of the Drainage Dept. GAM Santa Cruz

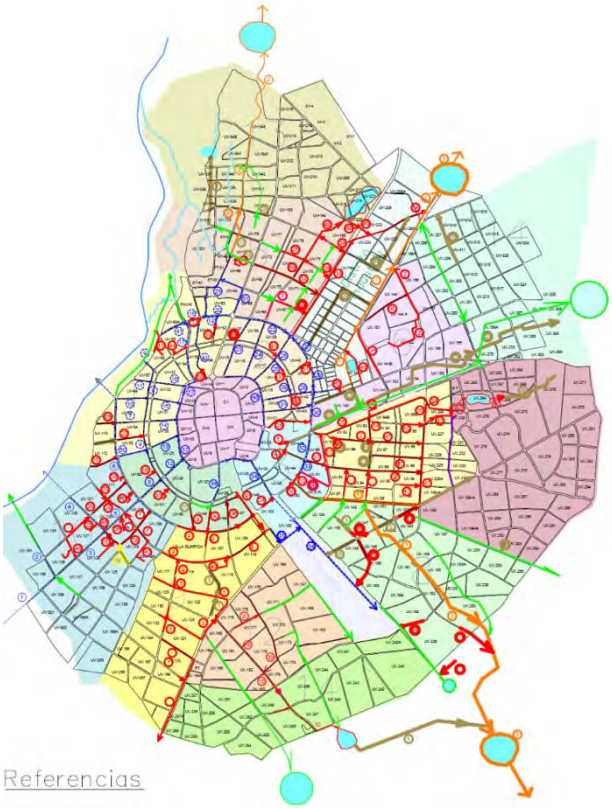
**Figure 8.1-9 Typical Cross Sections of the Drainage**

### (4) Present Conditions of the Existing Structures

Figure 8.1-10 shows the drainage system in Santa Cruz de la Sierra. Inside the 2nd ring road is an underground drainage network consisted of pipes and box culverts (i.e., cross section size: 1.8 m x 1.8 m).

The maintenance works on the underground drainage network inside of the 2nd ring road had been carried out by SAGUAPAC two years ago but recently the drainage department supervises the maintenance works by another contractor. The drainage network in the historical area inside the 1st ring road will be rehabilitated in the near future according to the Drainage Department. Therefore, the pavement will also be replaced by the Road Department of the municipality.

The outside of the 2nd ring road basically has an open channel drainage system. The underground drainage network connects to the open channel drainage system as shown in the photograph located on the upper right part of Figure 8.1-11. The open channel drainages are designed based on flow capacity estimate in a uniform flow condition (i.e., no backwater effect at end of the downstream). However, three outlets to the Pirai River shown in Figure 8.1-11, frequently have backwater of the river, which disturb the flowing out of inland water during river floods. Therefore, rainwater congestion often happens during the rainy season even if the open channel drainage systems are wide enough.




**Open Channel Drainage System**

**Underground Drainage Network inside of the 2nd Ring Road**

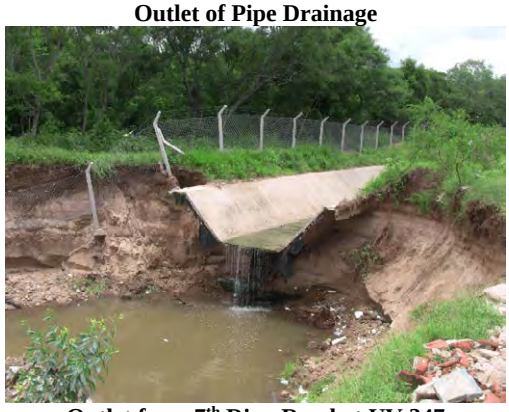
Source: Drainage Department of Santa Cruz de la Sierra and SAGUAPAC

**Figure 8.1-10 Drainage System in Santa Cruz de la Sierra**

**Typical Open Channel (*Canal Isuto*)**

**Outlet of Pipe Drainage**

**Outlet of *Canal Isuto***



**Outlet from 7th Ring Road at UV-347**

Source: JICA Study Team

**Figure 8.1-11 Outlets of the Drainage System in Santa Cruz de la Sierra to the Pirai River**

Other open channels flow out flood water outside of the municipality via retarding basins (*laguna*). Some small ponds are expanded and deeply excavated to storage inland water temporary as *lagunas* by CAF financed projects. Nine *lagunas* were planned but only three locations were completed due to the difficulties in land acquisitions.

Figure 8.1-12 shows two *lagunas* in Santa Cruz de la Sierra. Some *lagunas* are artificially enlarged and are maintained by the Drainage Department to be able to increase storage capacity of inland water.

The *Laguna Claracuta* is located in the downstream end of the *Canal Alemania*. Most of the parts of the *Canal Alemania* was improved as for the design flood, but the downstream part remains in its original condition due to land availability. The *laguna*, originally a small pond, was expanded in 2010 using the CAF fund. The entire *laguna* land was acquisitioned and was registered as a municipal property. Lots of garbage were left illegally around the inlet of the *laguna*. A municipality staff suggested to improve the *laguna* as a public park to protect the land against the illegal dumping. The reserved water in the *laguna* flows out to *Canal Chivito* (flow capacity =150 $m^3/s$), *Laguna Los Sauces*, *Arroyo Los Sauces*, and then finally to the Pirai River as shown in Figure 8.1-5.

The *Laguna Guapilo* is located in the east part of the municipality. A part of the peripheral zone of the *laguna* was improved and was turned into a public park, and is shown in the lower photographs in Figure 8.1-12. The reserved water in the *laguna* flows out to the *Rio Grande* via the *Rio Callejas* in Cotoca (see Figure 8.2-2).

***Laguna Claracuta (1)***

***Laguna Claracuta (2)***

***Laguna Guapilo (1)***

***Laguna Guapilo (2)***

Source: JICA Study Team

**Figure 8.1-12 Lagunas in Santa Cruz de la Sierra**

### (5) Ongoing and Planned Projects

#### 1) Budgetary Plan of the Drainage Department of Santa Cruz de la Sierra for Year 2017

Table 8.1-1 shows the budgetary plan of the Drainage Department of Santa Cruz de la Sierra for year 2017. The budget is composed of the local budget of the municipality and the loan from the CAF, which is B$175.41 million in total. Some construction and improvement works for drainage canals and rainwater storage *lagunas* are ongoing.

**Table 8.1-1 Budgetary Plan of the Drainage Department for Santa Cruz de la Sierra for Year 2017**

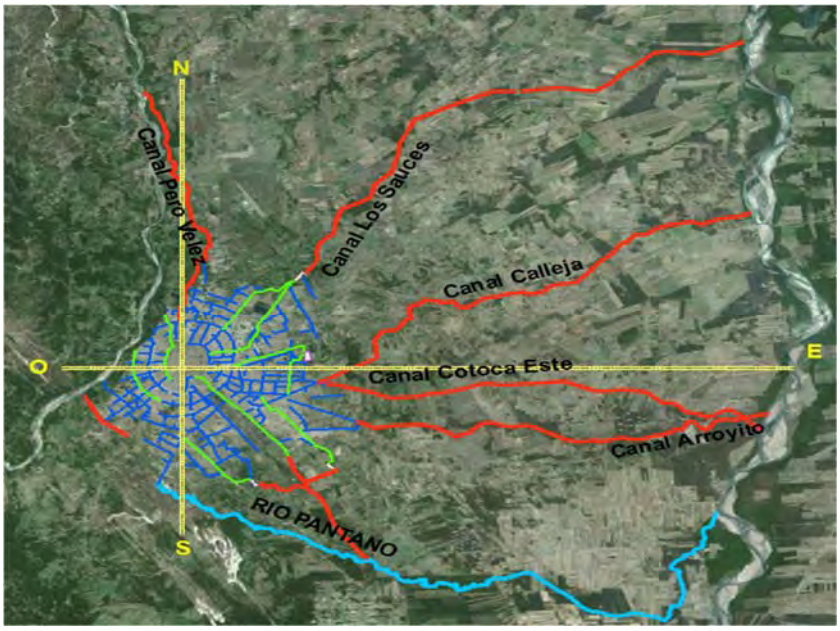
| Type | Amount (million, B$) | Major Works |
|---|---|---|
| Local Budget | 80.30 | - Construction of drainage canals of 6th Ring Road – Canal *Cotoca*, 7th Ring Road, *Villa Tranquila, Icarai*<br>- Improvement of drainage canals of *Av. Pedro Casal – Av. Moscu*, 7th Ring Road – *Av. Moscu* |
| Loan from CAF | 95.11 | - Construction of *Laguna de Los Sauces, Laguna de Esperanza* Phase II, drainage canals of *Barrio el Fuerte – Canaveral, Pero Velez* Phase II, *Cotoca* Phase II |
| Total | 175.41 | - |

Source: JICA Study Team. Prepared based on the "Formulario De Consolidacion Del Presupuesto", Gobierno Autonomo Municipal De Santa Cruz De La Sierra Secretaria Municipal De Admistracion Y Finanzas, Departamento De Presupuesto, August 2016.

#### 2) Drainage Master Plan of Santa Cruz de la Sierra

The Drainage Master Plan of the municipality has been studied since July 2016. The study has three phases: i) diagnosis, ii) concept design, and iii) final design. It will be completed in July or August 2017. The study is funded by the municipality's own budget. Local consultants are procured. The Master Plan also covers the areas outside Santa Cruz de la Sierra because drainage conditions of the upstream (Santa Cruz de la Sierra) and the downstream areas affect each other. Therefore, the study is discussed with the surrounding municipalities, such as *Cotoca* and *Warnes*, regarding the plan. The budgetary arrangement of Santa Cruz de la Sierra will cover only the inside of the municipality. Other municipalities shall expect support from the Santa Cruz Department (i.e., SEARPI). The coordination system for the Drainage Master Plan study is not established. Firstly, Santa Cruz de la Sierra will discuss with related municipalities on the master plan contents and then they will discuss with SEARPI.

The Drainage Department announced the concept of the master plan last February 2017. Eight existing *emisarios* (rivers) shown in Figure 8.1-13 were planned to be improved in the master plan. It requires a huge budget and an implementation period, but the integration of some existing *emisarios* is difficult because of their amount for design flow discharges and the difficulties in land acquisition for the integrated large drainage according to the Drainage Department. *Ar. Los Sauces* flows out to the Pirai River via the *Rio Chane* and the *Rio Pilon* as shown in Figure 8.1-5. The *Rio Chane* has huge sedimentation in the river. Therefore, it is concept that *Ar. Los Sauces* directs to the *Rio Grande* by newly constructed drainage.




Source: JICA Study Team. Prepared based on the "Plan Maestro De Drenaje Pluvial, Secretaria Municipal De Obras Publicas Direccion De Drenaje, February 2017"

**Figure 8.1-13Concept of the Outlet Channel from Santa Cruz de la Sierra to the *Rios* in the Master Plan**

Rainfall intensity formulas are newly prepared in the master plan. The annual maximum daily rainfall data in *Trompillo* from 1943 to 2015, and the short time rainfall record observed in their office ground are used for the preparation. The observation of the short time rainfall (5-minute interval) have been carried out since last December. The formulas are compared with the existing two formulas prepared in 1968 and 1988 by a German consulting film and SEARPI, and it was confirmed that the newly prepared formula has similarities with them. The formulas are under modification with observed short time rainfall.

Design scale for drainage channels are set as shown in Table 8.1-2.

**Table 8.1-2 Design Scale of the Drainage Canal Planned in the Master Plan**

| Canal Type | Design Scale (Return Period) |
|---|---|
| *Emisarios* (River) | 20 |
| Main Drainage Canal | 20 |
| Secondary Drainage Canal | 10 |
| Tertiary Drainage Canal | 5 |

Source: JICA Study Team. Prepared based on the "Plan Maestro De Drenaje Pluvial, Secretaria Municipal De Obras Publicas Direccion De Drenaje, February 2017".

Implementing agencies and funding sources for the construction of the *emisarios* will be decided through discussions among the central government, the Santa Cruz Department, and related municipalities. Santa Cruz de la Sierra often discusses with the *Cotoca* municipality. Santa Cruz de la Sierra also discussed with a CAF staff from La Paz. The CAF expects that the master plan will be a good direction for the drainage system in the Santa Cruz de la Sierra, and commented that they will evaluate the results of the ongoing study. Korea is also interested in supporting the construction stage.

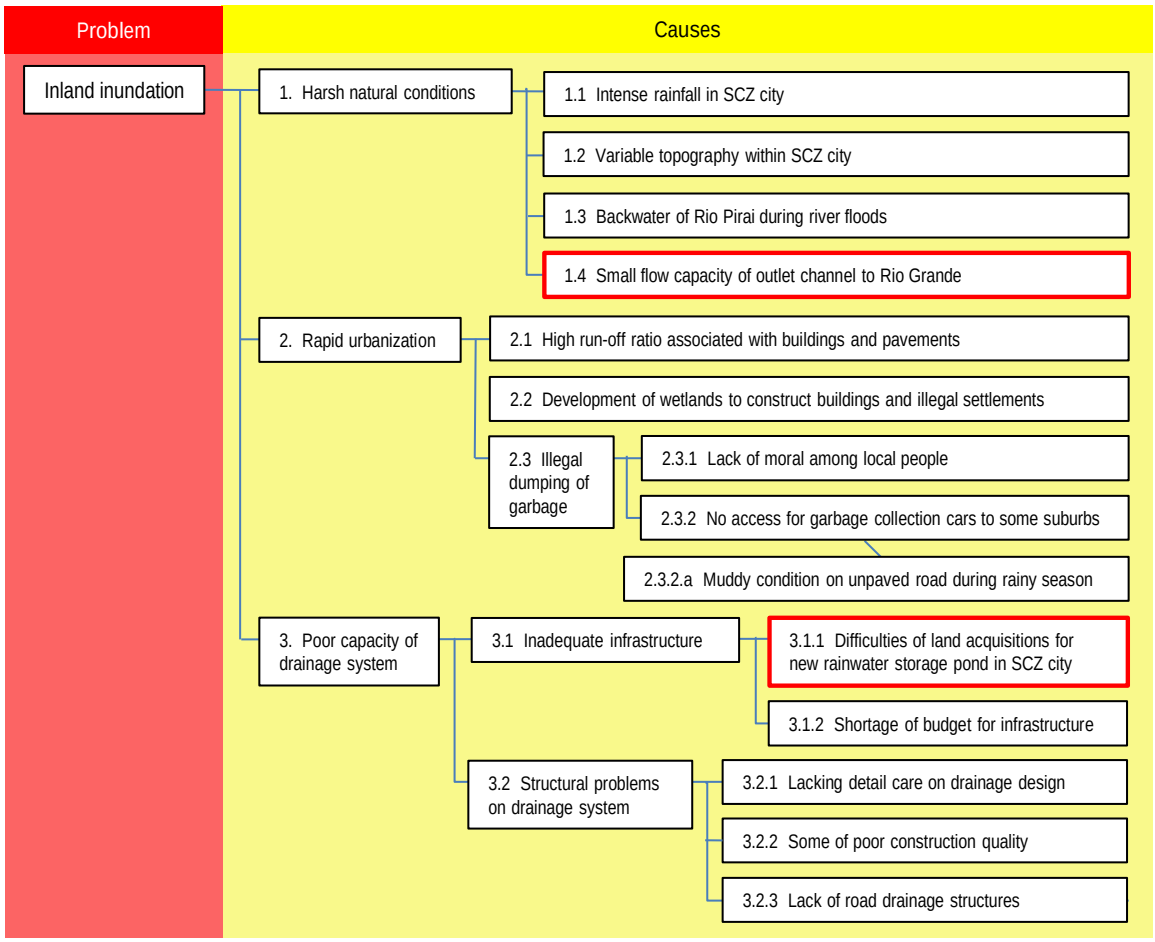
The Drainage Department told that the right-of-way (ROW) of *emisarios* will be widened as 100 m width. Therefore, space for the highway along the *emisarios* are available. They also mentioned that the introduction of the drainage pumping system is good for the west part of Santa Cruz de la Sierra. Japan can support not only the plan, design, and construction stages, but also the operation and maintenance stages since they have lots of experiences in and out of the country.

# 8.2 Preliminary Study on Drainage Improvement

## 8.2.1 Diagnosis of Inland Inundation Issues in Santa Cruz de la Sierra

### (1) Problem and Causes of Inland Inundation in Santa Cruz de la Sierra

The inland inundation problem in the urban area of Santa Cruz de la Sierra is complicated. Several conditions i.e., i) harsh natural conditions, ii) rapid urbanization, and iii) poor capacity of drainage system, can cause the problem as shown in Figure 8.2-1. In addition, small flow capacity of the outlet channel to the *Rio Grande* and the difficulties in land acquisitions for the new rainwater storage pond in Santa Cruz de la Sierra are considered as important issues as well. The root causes of the structural problems on the drainage system can be categorized into three: i) lacking detailed care on drainage design, ii) some poor construction qualities, and iii) lack of road drainage structures. This subsection will suggest some improvement measures for the problems.




Source: JICA Study Team

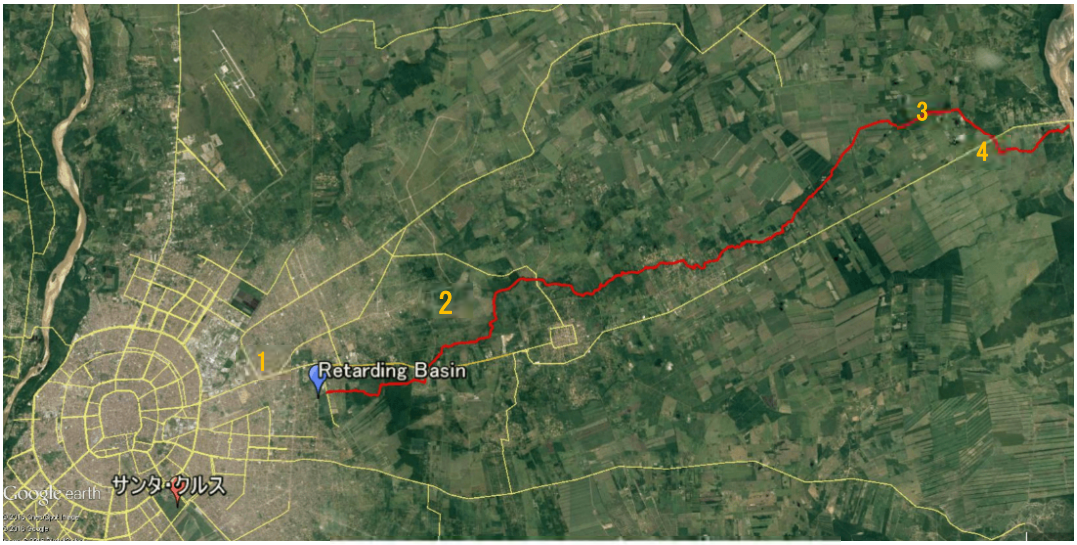
**Figure 8.2-1 Problem and Causes of Inland Inundation**

### (2) Major Problems for Inland Inundation

#### 1) Small Flow Capacity of the Outlet Channel to *Rio Grande*

Figure 8.2-2 shows the *Rio Callejas*, which is one of the major outlet channels from Santa Cruz de la Sierra to the *Rio Grande*, with a length of approximately 46 km. As shown in the figure, the said *rio* is around 10 m wide, but has some bottleneck points that are on cross points

with the major transportation routes (i.e., railway and highway). The outlet channel has no enough capacity to flow out inland water from the east part of Santa Cruz de la Sierra which frequently inundates the lowland along its alignment.




**Alignment of the Present *Rio Callejas* (L = 46 km)**

***1. Outlet of Laguna Guapilo***

***2. Cross Point of Rio Callejas and a Railway***

***3. Cross Point of Rio Callejas and a Highway***

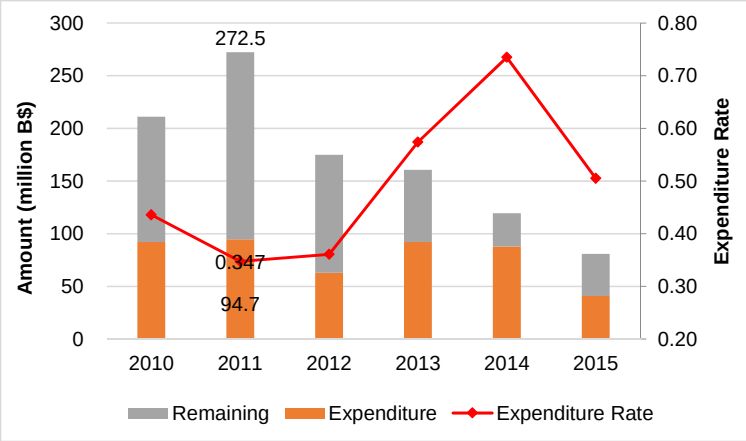
***4. Immediately Upstream of Rio Callejas - Rio Grande Junction***

Source: JICA Study Team. Prepared based on the information from the field investigation and Google Earth Pro.

**Figure 8.2-2 Present Conditions of *Rio Callejas***

**2) Difficulties in Land Acquisitions for the New Drainage Structures in Santa Cruz de la Sierra**

Figure 8.2-3 shows the budgetary plan and actual expenditure for the construction of the drainage structures in Santa Cruz de la Sierra. This figure implies that the drainage structures were not constructed following the plan. Especially, in the year of 2011, which expended only 34.7% of the original budget. The one main reason is the difficulties in land acquisitions for the structure constructions including rainwater retarding ponds. The poor capacity of the drainage system is not improved even if enough budget is already arranged by the municipality.




Source: JICA Study Team. Prepared based on the information from the Drainage Dept. Santa Cruz de la Sierra

**Figure 8.2-3 Budgetary Plan and Actual Expenditure for the Construction of the Drainage Structures**

## 8.2.2 Applicable Measures for Inland Water Drainage

Six applicable measures for the inland water drainage system in Santa Cruz de la Sierra are recommended and are as follows. All measures are quite costly and takes time, but without such measures future developments in the Metropolitan Area will be significantly affected by the inland inundation issues.

### (1) Construction of the Main Drainage Channel to *Rio Grande*

**1) Design Concept**

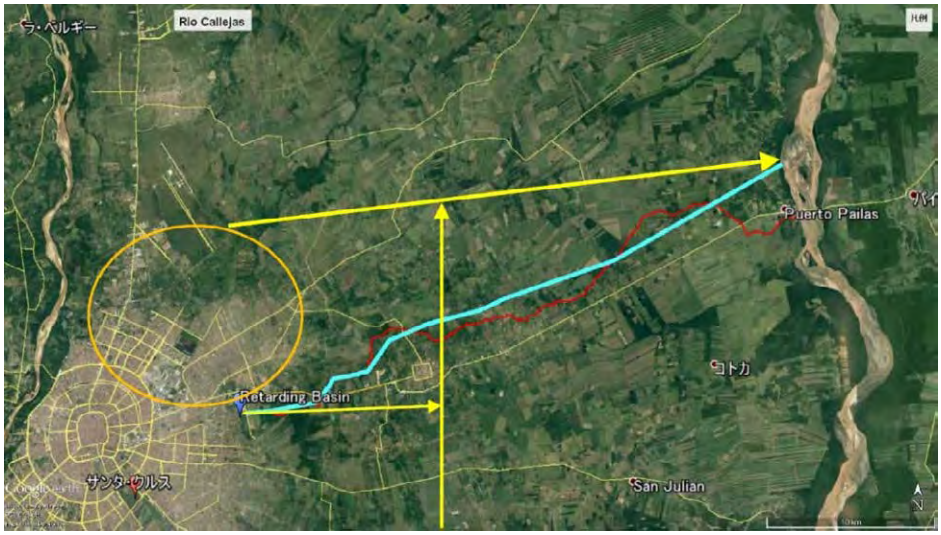
As shown in Figure 8.1-3, the ground surface in and around Santa Cruz de la Sierra slopes down to the northeastward direction. Thus, it is reasonable to flow out inland water to the northeastward direction if the municipality continues the current drainage method, which is the gravity flow method.

The light blue colored line in Figure 8.2-4 is the conceptual alignment of the *Rio Callejas* improvement with an approximate length of 36 km. The flow velocity in the *Rio Callejas* will increase because the length of the river will shorten from 46 km to 36 km after the improvement works. The alignment avoids the existing high value properties, such as houses, through a quick check on the satellite image obtained from a website.

The yellow colored line is the alignment that will be required if the drainage improvement of the north part of the municipality is considered. This option is more costly because it consists of tributary channels, but it can drain inland water in the south part of the municipality using an intercept channel directing from south to north.

The main drainage channel can flow out inland water in the urban area of the municipality of

*Cotoca*. Some staff of the Drainage Department pointed out that the construction works have some problems such as: i) costly measure for a short intensity rainfall, ii) involvement of environmental problems, and iii) it may be the responsibility of the central government or the Santa Cruz Department. Further discussions on it are required to formulate the master plan.




Source: JICA Study Team. Prepared based on the information from Google Earth Pro.

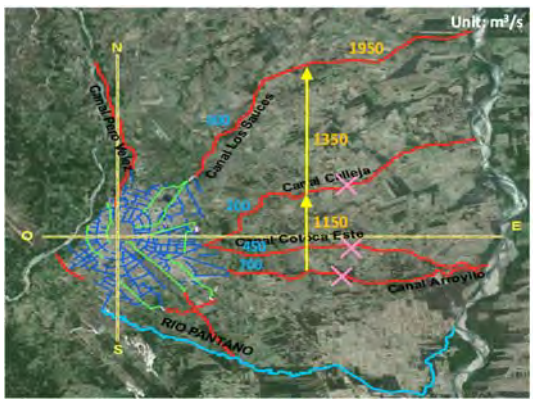
**Figure 8.2-4 Concepts of the Main Drainage Channel to *Rio Grande***

## 2) Preliminary Alternative Study

### (a) Alternatives

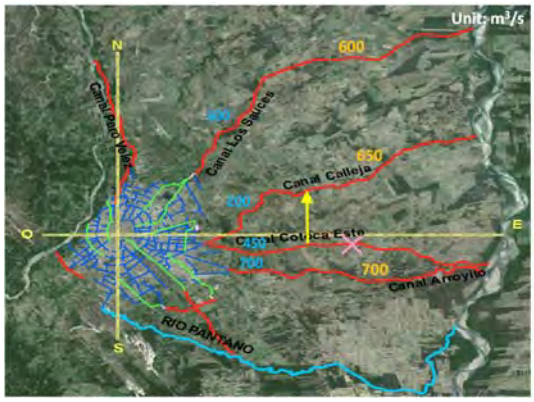
This subsection carries out a preliminary alternative study of the main drainage channel to the *Rio Grande* based on Figure 8.1-13. The design floods of the *Emisarios Los Sauces, Emisarios Callejas, Emisarios Cotoca Este,* and *Emisarios Arroyito* are estimated in the master plan in a 20-year return period flood. Actual peak time of each design flood is based on the flood lead time, which are different from each other, but this preliminary study simply adds these design floods. Three alternatives are described in the following list and are shown in Figure 8.2-5.

- Alternative-A: Design floods of *Emisarios Callejas, Emisarios Cotoca Este,* and *Emisarios Arroyito* flow down to *Emisarios Los Sauces*
- Alternative-B: Design floods of *Emisarios Cotoca Este* and *Emisarios Arroyito* flow down to *Emisarios Callejas*
- Alternative-C: Design floods of *Emisarios Cotoca Este* flow down to *Emisarios Callejas*




**Alternative-A**


**Alternative-B**



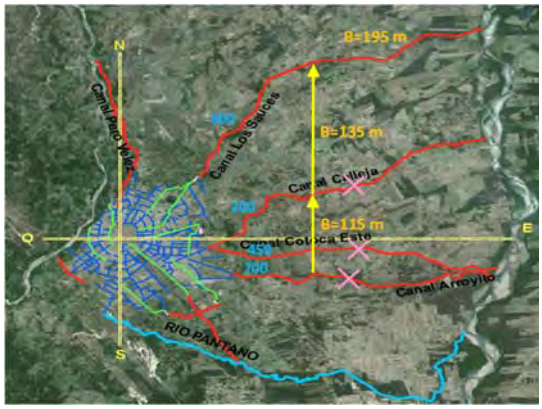

**Alternative-C**

Source: JICA Study Team. Prepared based on the "Plan Maestro De Drenaje Pluvial, Secretaria Municipal De Obras Publicas Direccion De Drenaje, February 2017"

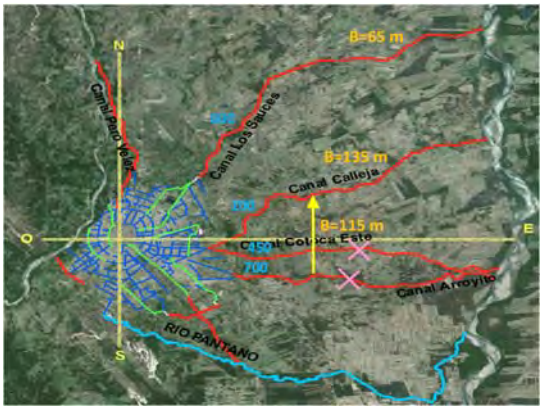
**Figure 8.2-5 Preliminary Alternative Study of the Main Drainage Channel to Rio Grande**

### (b) Estimate of the Design Width of the Main Drainage Channels

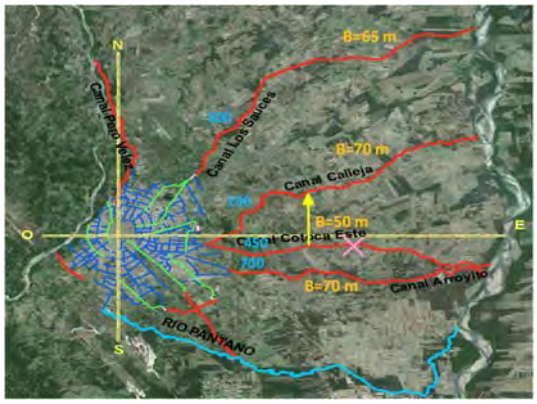
Two concrete retaining walls are designed for both bank sides of the main drainage channels as shown on the lower right side of Figure 8.2-6. The design widths of the drainage channels are determined by the flow capacity of the design floods estimated under a uniform flow condition. Roughness coefficient (n) = 0.030, while the channel longitudinal gradient (i) = 1/400, are set as estimates. The backwater effect of the *Rio Grande* is not considered in this preliminary study, but it should be considered in the further detailed study. Estimated design widths on each of the three alternatives are shown in Figure 8.2-6. Probably, some locations within the channels will require the consideration of scouring by floods on the front side of the walls. Therefore, some protective works, such as gabion mattress, shall be designed on the front side of the walls during the detailed design stage.



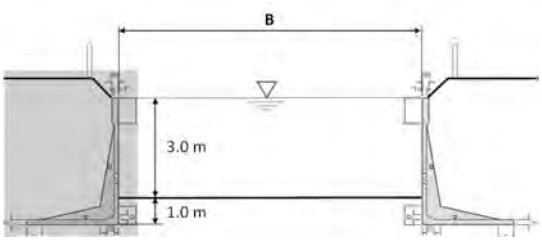

**Alternative-A**




**Alternative-B**




**Alternative-C**




**Concrete Retaining Wall for Drainage Channel**

Source: JICA Study Team. Prepared based on the "Plan Maestro De Drenaje Pluvial, Secretaria Municipal De Obras Publicas Direccion De Drenaje, February 2017" and a website of a catalogue of L-shape concrete retaining wall (http://www.landes.co.jp/product/38/2)

**Figure 8.2-6 Preliminary Alternative Study of the Main Drainage Channel to *Rio Grande***

### (c) Preliminary Cost Estimate of the Alternatives

Unit costs for the drainage channel construction are set using the information from the Drainage Department and the local land owners, as shown in Table 8.2-1. The Drainage Department of Santa Cruz de la Sierra mentioned that the assumed unit costs seem to be a relatively reasonable amount. Table 8.2-2 shows the cost estimate results on each of the alternatives. Alternative-A has the lowest cost, while Alternative-B and C have higher cost which are 109.8% and 133.4% of Alternative-A, respectively. The channel length and the number of required new bridge on the channel are critical points of the channel construction cost. Therefore, this study proposes to select Alternative-A.

However, the Drainage Department of Santa Cruz de la Sierra mentioned that Alternative-C is the most practical option because the local government can set ROW of 100 m in width along the existing rivers. On the other hand, the land price of the private lands will rapidly increase if they carry out the land acquisition on the channel route. They have such bitter experiences on construction of rainwater retarding ponds. Further detailed study to determine the channel routes is necessary on the next stage: a feasibility study in the near future.

**Table 8.2-1 Unit Costs for the Drainage Channel Construction**

| Item | Unit Cost |
|---|---|
| Concrete Retaining Walls for the Drainage Channel | US$1,006/m |
| Land Acquisition on the Agricultural Area | US$3,500/ha |
| Bridge on the Drainage Channel | US$3,018/m |

Source: JICA Study Team. Prepared based on the information from the Drainage Department and the local land owners.

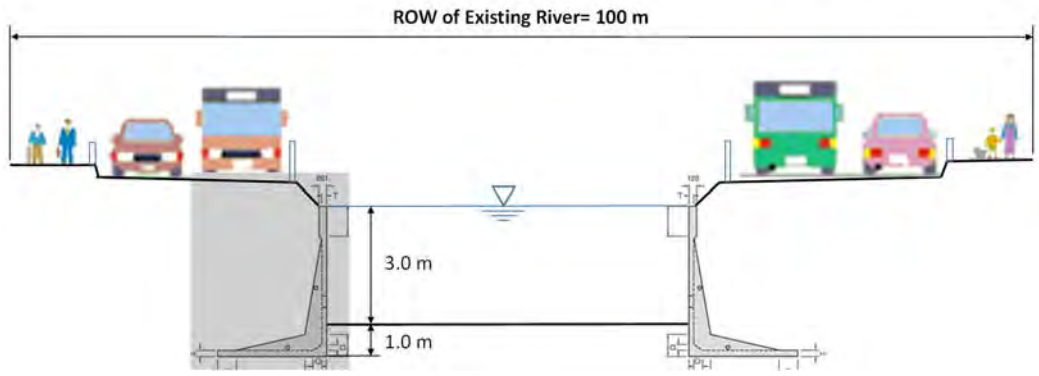
**Table 8.2-2 Preliminary Cost Comparison of the Alternatives**

| Item | Unit | Alternative | | |
|---|---|---|---|---|
| | | A | B | C |
| Channel Length | km | 46.4 | 53.4 | 67.0 |
| Land Acquisition | ha | 774 | 603 | 519 |
| nos. of Bridge | nos | 10 | 11 | 14 |
| **Approx. Cost** | **mil. USD** | **54.0** | **59.3** | **72.0** |
| | Ratio | 1.000 | 1.098 | 1.334 |

Source: JICA Study Team

### 3) Possible Usage along the Drainage Channels

As mentioned above, the Drainage Department of Santa Cruz de la Sierra explained that the local government can set ROW of 100 m in width along the existing rivers and a possible option to add highways on both sides of the newly constructed drainage channels from Santa Cruz de la Sierra to the fringe of Santa Cruz Metropolitan Area, as shown in Figure 8.2-7. The JICA Study Team cannot confirm how much ROW is effective or enforceable by the local government although it is physically possible or worth to conduct a further study and discussions.

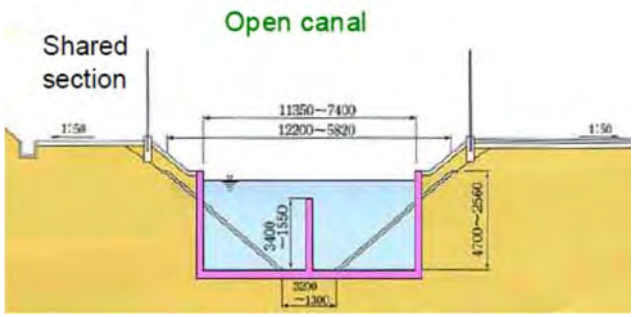



Source: JICA Study Team. Prepared based on the websites of a catalogue of an L-shaped concrete retaining wall (http://www.landes.co.jp/product/38/2) and MLIT, Japan (https://www.cgr.mlit.go.jp/hirokoku/south/summary.html)

**Figure 8.2-7 Concept of Possible Usage along Drainage Channels**

## (2) Improvement of the Existing Drainage Facilities and Small Rivers

It is important to monitor the constructed structures during the operational stage. Improvement of the existing drainage facilities and small rivers are required if their flow capacities are not enough to flow out the inland water. Due to the difficulties of land acquisitions, present public lands can be used as well. The RC open channel with rectangular cross section or box culvert can be constructed below public lands such as highways as shown in Figure 8.2-8. Such structures are already introduced on some parts of the drainage system in Santa Cruz de la Sierra.




**Renovation of the Existing Drainage Open Channel**

**Construction of a Box Culvert Channel below a Public Land**

Source: "Outline of the Aichi Irrigation Project" and http://www.asahi-concrete.co.jp/product/box-culvert

**Figure 8.2-8 Improvement Methods on the Existing Drainage Facility and the Use of Public Areas**

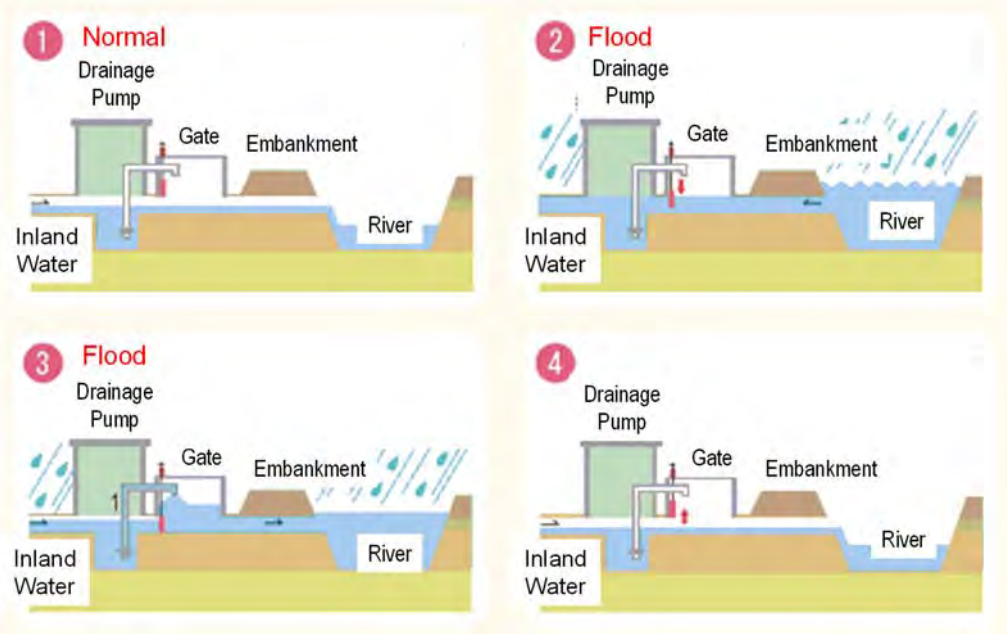
## (3) Introduction of the Drainage Pumping System

The mechanically forced drainage system (i.e., drainage pumping system) is required if the inland water on the lowland has to be drained out to a higher land or water body. As shown in

Figure 8.1-3, the elevation of the Pirai River is potentially higher than the lowlands in the municipality. Thus, it is difficult to drain out inland water if the Pirai River has a high-water level with river flood.

Figure 8.2-9 shows the concept of the drainage pumping system. The operation procedures of the system are as follows:

1) Inland water can normally flow out to the river.
2) During flood, when the river water level is higher than that of the inland, gate should be closed to prevent backwater from the river.
3) Inland water is pumped out if the inland water level increases and high water level condition of the river prolongs.
4) The pump operation is stopped and the gate is opened when the river water level decreases.




Source: JICA Study Team. Prepared based on the information from http://www.thr.mlit.go.jp/yamagata/river/enc/genre/03-kou/kou0203_002.html

**Figure 8.2-9 Concept of the Drainage Pumping System**

### (4) Introduction of Rainwater Retarding and Infiltration Structures

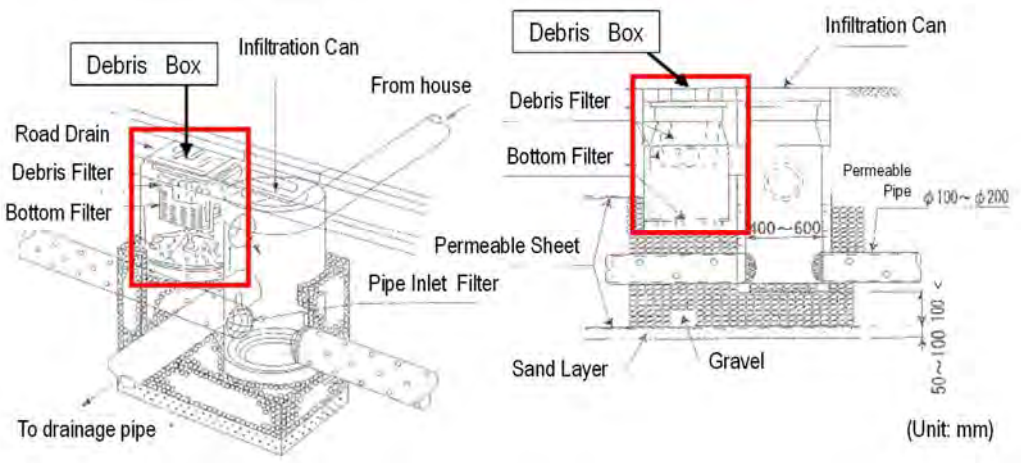
#### 1) Infiltration Structures on Road

An approach to reduce the run-off volume of rainwater is important because of the intense rainfall in the municipality and the limitation of the flow capacity of the drainage system. Recently, rainwater retarding and infiltration structures are gradually being developed and introduced in the Tokyo Metropolitan Area in Japan. It is a good opportunity to introduce such structures in the drainage network in the historical area inside of the 1st ring road which will be rehabilitated in the near future based on the Drainage Master Plan that is currently under preparation.

Figure 8.2-10 shows an example of the drainage pipe network with some infiltration structures. First, the rainwater from the road drain (side ditch) will flow into the debris box to capture the small garbage included in the rainwater. Secondly, the rainwater without small garbage will flow into the infiltration can and will then infiltrate the underground. Rainwater from buildings, such as houses, can also flow into the infiltration can to reduce the inundation on public roads.

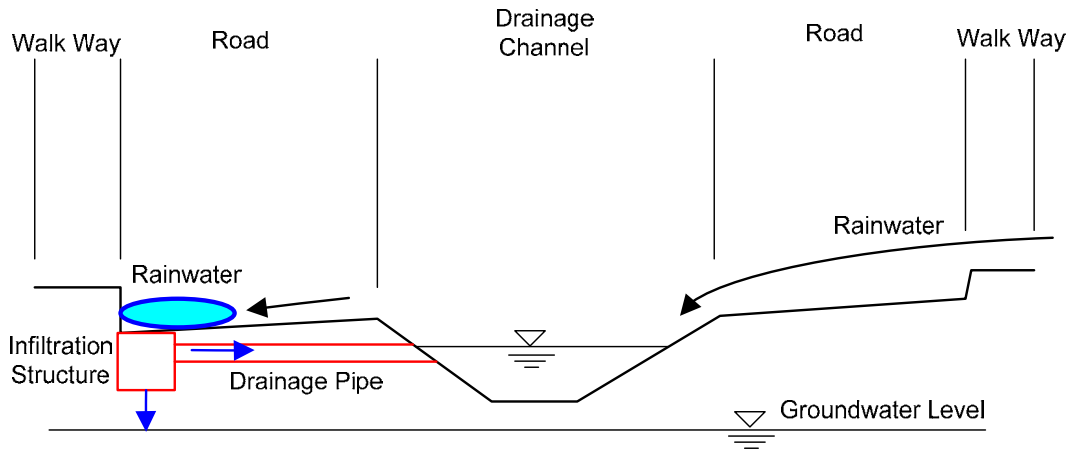
Excess water in the infiltration can will flow out to the drainage pipe. This structure highly requires periodical maintenance of extracting small garbage in the debris box.

Figure 8.2-11 shows an example of improvement of existing inland water problem using an infiltration structure. Most of the major highways in Santa Cruz de la Sierra comprise open drainage channels on the center of the highway without side ditches. Rainwater on some road sections directs to one side and makes paddle if the road section inclines to one side. Right side of a highway is rainwater free but opposite side on same cross section has rainwater paddle although the central drainage channel is still capable to flow water. Introduction of the infiltration structure explained above will improve such problem.




Source: JICA Study Team. Prepared based on the information from MLIT guidelines in Japanese

**Figure 8.2-10 Example of Drainage Pipe Network with Infiltration Structure**



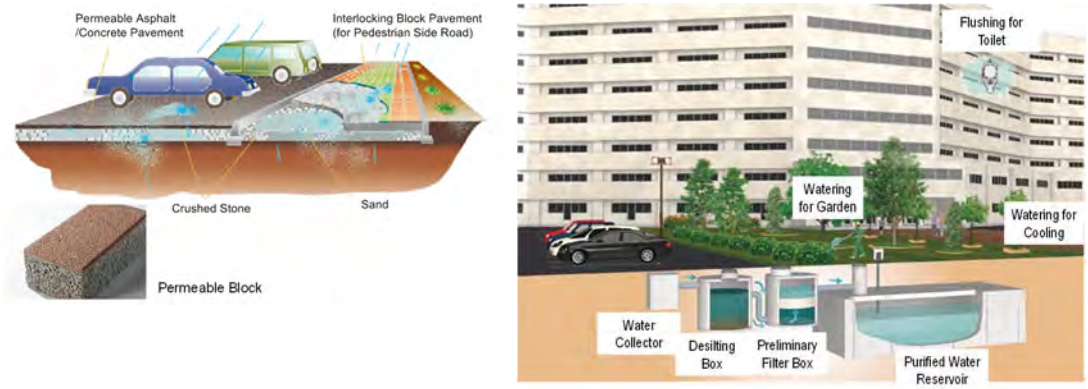

Source: JICA Study Team

**Figure 8.2-11 Example of Improvement in the Existing Inland Water Problem**

### 2) Permeable Pavement on Parking Lots and Pedestrian Roads

Figure 8.2-12 shows an example of permeable pavement applied on a parking lot and a pedestrian road. The permeable block is generally weaker than conventional pavement such as concrete and asphalt. Therefore, it can be applied in places where there are smaller loads and frictions from vehicles such as parking lots and pedestrian roads. Optionally, rainwater recycling system can be introduced on such permeable pavements which system contains the desilting box and the preliminary filter box to purify rainwater (right side of Figure 8.2-12). The purified rainwater is reserved in the purified rainwater reservoir located below the public land. The purified rainwater can be used for different purposes including watering for garden

and cooling, flushing water for toilets and car washing.




**Permeable Pavement** **Rainwater Recycle System**

Source: JICA Study Team. Prepared based on the documents of the Association for Rainwater Storage and Infiltration Technology, http://www.arsit.or.jp/ and http://www.hokukon.co.jp/business/rain/ra06.html

**Figure 8.2-12 Example of a Permeable Parking Lot and Pedestrian Road**

### 3) Applicability of Infiltration Structures

Only areas that satisfy the criteria mentioned in Table 8.2-3 can be applied with infiltration structures. Figure 8.1-4 shows the surface geological condition of Santa Cruz de la Sierra in this report, and implies that the west part of the municipality is covered with sandy materials with good permeability. Although, a more detailed in depth geological survey is required for their application. Therefore, pre-design survey such as topographical and geological survey and environmental survey, are required to study the suitability of the infiltration structures.

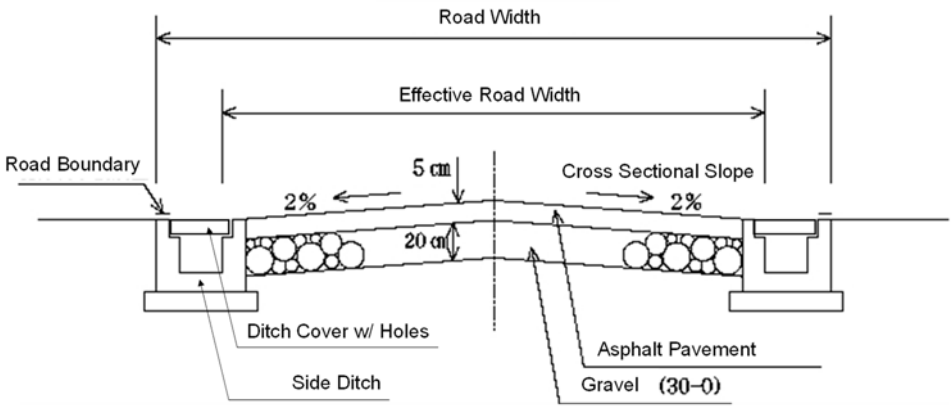
**Table 8.2-3 Criteria for the Construction of Infiltration Structures**

| Items | Suitable | Unsuitable |
|---|---|---|
| Topography | table land, terrace, alluvial fan, natural levee, hills, etc. | alluvial lowland, back filled land, cut slope, land slide protection area, steep slope area in danger of failure, sediment disaster potential area, etc. |
| Soil Conditions | permeable soil | percolation ratio < $10^{-7}$ m/s<br>porosity < 10%<br>Clay (d= 0.074 mm) > 40% |
| Groundwater | Distance from the structure to groundwater level > 0.5 m | High level groundwater |
| Environmental Impacts | - | Pollution to be expected by infirtlation of contaminants |

Source: JICA Study Team. Prepared based on the information from MLIT guidelines in Japanese.

## (5) Improvement of Road Drainage Structures

Some relatively small inundations on roads can be improved by the introduction of i) cross sectional slope on road and ii) side ditches on both sides of the road, although it is slightly costly. It is recommendable for the introduction of such structure in any central areas of the municipality as a pilot project. The side ditch connects to the drainage system. The disaster education shown in next page will assist the maintenance of the road side ditch through the reduction of illegal garbage dumping.




Source: JICA Study Team. Prepared based on the documents from a local government in Japan, http://www.city.shimanto.lg.jp/city-office/reiki_int/reiki_honbun/r101RG00000429.html

**Figure 8.2-13Typical Cross Section of the Road Drainage Structure**

### (6) Disaster Education

The illegal garbage dumping in the drainage open channel significantly reduces the flow capacity of the drainage system and the rainwater retarding capacity of the *lagunas*. The authority of Santa Cruz de la Sierra cleans up such garbage once a month using outsourcing basis but the illegal dumping is more often, which happens almost daily. The illegal dumping has increased inland inundation risk in the municipality.

Figure 8.2-14 shows examples of the campaign to maintain flow capacity of the drainage channel. Understanding the consequences of the illegal garbage dumping is one of the important contents of the disaster education. The campaign for a river clean up with the participation of the community is shown in the right-side photograph of Figure 8.2-14. This may change the participant's mind and indirectly effect reduction of the illegal garbage dumping.

Some community participates on cleaning activities on public lands (an activity of "*Minga*") which have been carried out in Santa Cruz de la Sierra according to the Drainage Department.

**A Campaign for Preventive Measure of Illegal Garbage Dumping on Drainage Open Channel**

**A Campaign for River Clean Up Based on Community Participation in Japan**

Source: JICA Study Team. Prepared based on the photograph taken by a Nippon Koei engineer in the Phnom Penh city, Cambodia for the JICA Preparatory Survey on the Project for Flood Protection and Drainage Improvement in the Municipality of Phnom Penh (Phase III) and http://www.koganei-kankyo.org/news.htm.

**Figure 8.2-14Examples of Campaigns to Maintain Flow Capacity of Drainage Channel**

## 8.2.3 Required Preparation Works for Applicable Measures of Inland Water Drainage

The six measures mentioned above require some preparation works as shown in Table 8.2-4.

Several alternative routes of 1) main drainage channel to the *Rio Grande* should be studied from multiple aspects. The selections of structure locations for 2) improvement of existing drainage facility, 3) introduction of drainage pumping system, 4) rainwater retarding and infiltration structures, and 5) improvement of road drainage structure are also important procedures. Some experienced local and international non-government organizations (NGOs) may be available in Santa Cruz de la Sierra to support the preparation and implementation of 6) disaster education.

**Table 8.2-4 Preparation Works for Applicable Measures of Inland Water Drainage**

| Preparation Works | Measures | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| | Main Drainage Channel to Rio Grande | Existing Drainage Facilities Improvement | Drainage Pumping System | Rainwater Retarding and Infiltration Structures | Improvement of Road Drainage Structures | Disaster Education |
| Topographical and Geological Survey | ○ | ○ | ○ | ○ | ○ | - |
| Probable Rainfall Analysis | ○ | ○ | ○ | ○ | - | - |
| Estimation of design flood of structures through hydrological analysis | ○ | ○ | ○ | - | - | - |
| Alternative study of channel routes | ○ | - | - | - | - | - |
| Selection of structure locations | - | ○ | ○ | ○ | ○ | - |
| Structural design by hydraulic analysis | ○ | ○ | ○ | ○ | ○ | - |
| Economical evaluation | ○ | ○ | ○ | ○ | ○ | ○ |
| Preparation of education materials | - | - | - | - | - | ○ |
| Environmental Impact Assessment | ○ | ○ | ○ | ○ | ○ | ○ |

Source: JICA Study Team

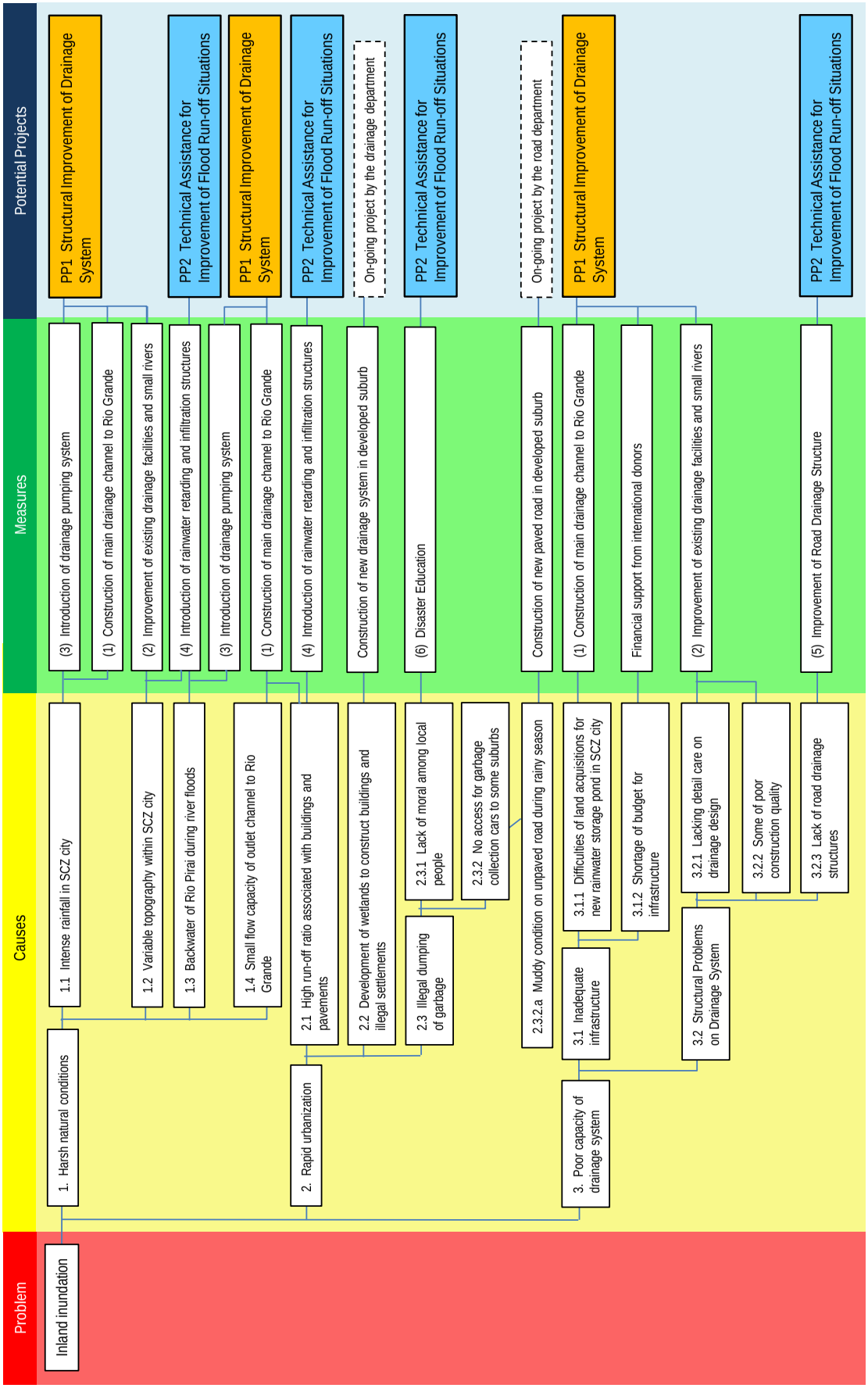
# 8.3 Potential Projects for Drainage System

## 8.3.1 Fault Tree Analysis on Drainage System

The causes and measures of the problem of the potential projects on the drainage system are summarized in Figure 8.3-1. Major causes of the problem shown in the middle column of the figure are described in detail on Subsection 8.2.1 of this report. Measures shown in the next column in the figure are effective activities for each cause of the problem. Some measures do not become potential projects in this sector because they are already carried out by some ongoing projects. Construction of the new drainage system and the new paved road in the developed suburb are ongoing, which are handled by the departments of drainage and road of Santa Cruz de la Sierra, but rapid progress in the construction is required. Some measures are combined as “potential project”. Two potential projects for the drainage system in Santa Cruz de la Sierra are extracted as follows.

- PP1: Structural Improvement of Drainage System
- PP2: Technical Assistance for Improvement of Flood Run-off Situations

The next subsection describes the profiles of the two potential projects.




Source: JICA Study Team

**Figure 8.3-1 Fault Tree Analysis on Drainage**

## 8.3.2 Description of Potential Projects

### (1) Structural Improvement of Drainage System

#### 1) General Profile

**Background:** The inland inundation problem in the urban area of Santa Cruz de la Sierra is caused by several conditions such as i) harsh natural conditions, ii) rapid urbanization, and iii) poor capacity of drainage systems. Small flow capacity of the outlet channel to the *Rio Grande* and the difficulties in land acquisitions within Santa Cruz de la Sierra for the new drainage structures are considered as important issues. It is highly required for a large-scale infrastructural investment to improve the situation of inland water inundation in Santa Cruz de la Sierra.

**Purpose:** Mitigation of inland water inundation in Santa Cruz de la Sierra

**Beneficiary:** Local people living and transporting within Santa Cruz de la Sierra

**Location:** Santa Cruz de la Sierra and *Cotoca* for the construction of the drainage system

#### 2) Components

**1. Construction:** Main drainage channel from Santa Cruz de la Sierra to the *Rio Grande* (approx. 111.4 km in total), bridge (23 nos.), drainage structures within Santa Cruz de la Sierra (approx. 20.0 km in total), and drainage pumping stations (2 nos.)

**2. Procurement:** Drainage pumps

**3. Institution and Organization:** Establishment of an operation and maintenance (O&M) section for the drainage pumping station under the Drainage Department of Santa Cruz de la Sierra

**6. Study:** A feasibility study on the project will identify the priority areas and components and will prepare phase plan.

#### 3) Implementation Plan

**Target:** Long and Mid. term

**Period:** 18 years (2018 – 2035)

**Cost:** US$309.9 million

**EIA:** Necessary

**Environmental Impact:** Social environment (land acquisition, resettlement, agriculture, others), Natural environment (flood, biodiversity, water quality)

**Implementation Agency:** Santa Cruz de la Sierra, *Cotoca*

**Operator/ Maintenance:** Santa Cruz de la Sierra, *Cotoca*

**Funding Source:** Loan from international donors

### (2) Technical Assistance for the Improvement of the Flood Run-off Situations

#### 1) General Profile

**Background:** The rapid urbanization has increased the run-off ratio. Most of the urban area is covered by concrete and asphalt except for limited gardens, public parks, and assigned retarding basin in the suburb area of the Santa Cruz de la Sierra. Rainwater does not infiltrate to the ground and goes to lower land immediately. An approach to reduce run-off volume of rainwater is important because of the intense rainfall in the municipality and the limitation of the flow capacity of the drainage system. On the other hand, the root causes of the structural problems on drainage system are: i) lacking detailed care on the drainage design, ii) some poor construction qualities, and iii) lack of road drainage structures. The illegal garbage dumping in the drainage open channel significantly reduces the flow capacity of the drainage system and the rainwater retarding capacity of the *lagunas*. Such practices of local people shall be improved.

**Purpose:** Mitigation of inland water inundation in Santa Cruz de la Sierra

**Beneficiary:** Local people living and transporting within Santa Cruz de la Sierra

**Location:** Santa Cruz de la Sierra

#### 2) Components

**Construction:** Pilot projects of rainwater retarding and infiltration structures on public areas and road drainage structures

**Institution and Organization:** Technical assistance on survey, plan, design, and construction of pilot project

**Other "Soft" Measures:** Technology transfer on the rainwater retarding and infiltration structures, establishment of database on spatial suitability map for the structure, disaster education including campaign for preventive measure of illegal garbage dumping on the drainage open channel

**Study:** Preparatory study on the technical assistance for improvement of flood run-off situations

#### 3) Implementation Plan

**Target:** Mid. term

**Period:** 5 years (2021 – 2025)

**Cost:** US$5 million

**EIA:** Necessary

**Environmental Impact:** Natural environment (flood, water quality)

**Implementation Agency:** Santa Cruz de la Sierra

**Operator/Maintenance:** Santa Cruz de la Sierra

**Funding Source:** Grant aid from international donors