Chapter 2 CBD Microscopic Simulation Model

2.1 Introduction

An area composed of Kivukoni and Mchafukoge is a center of the business activity (called Central Business District: CBD) in Dar es Salaam, where there are about 100 thousands job opportunities. According to the trip generation survey, office use including government offices, public agencies and private companies concentrate in the eastern part of CBD which is divided by India St. and Upanga Rd. In this area, some urban regeneration projects such as Mafta House (Maktaba St.), Bank of Tanzania (Shaaban Robert Rd.), NHC House (Samora Ave.) and EXIM Tower (Ghana Ave.) are underway as of late 2007 (Figure 2.1.1).

From left to right, Mafta House, Bank of Tanzania, NHC House and EXIM Tower

Figure 2.1.1 New Office Buildings in the City Center

These will be additional employees working at these new office buildings and at the same time these new buildings attract many visitors in near future. While, the western part of the city center is dominated by small retail shops and residential buildings. Most of these buildings are aged low-rise buildings, however, some redevelopment projects including some high-rise commercial residences are progressing in this area also.

It is generally expected that there will be a need for some form of high-order public transport system accordance to cope with such increasing demand in the city center. One of such systems is Bus Rapid

Transit (BRT). BRT Phase 1 has been committed by the Government of Tanzania, and which will open to public by the end of year 2009. This system runs on Morogoro road from the fish market, through Ubungo, up to Kimala. Since CBD is an already congested area, it is very important to assess the impact of BRT Phase 1 and develop a proper traffic circulation plan to avoid anticipated chaotic congestion problems.

2.2 Outline of the Micro Simulation for CBD

2.2.1 Model Area and Intersections

The modeling area for the microscopic simulation is defined that, a part of the central business district (CBD) called the "city center" which is bounded by Bibi Titi Mohamed Rd. and Ohio St. as shown in Figure 2.2.1.

Figure 2.2.1 Modeling Area and Intersections for Microscopic Simulation

2.2.2 The Target Year and Base Case

The base case of the microscopic simulation for the city center is the year 2009 when BRT Phase 1 starts its service. The base case road network and traffic management plan is based on the proposed street direction prepared by LOGIT for DART in 2007.

2.2.3 Modeling Software

Table 2.2.1 shows major microscopic simulation tools in the world. These models are commercial products and some of them have a compatibility with strategic model software. Compatibility among these microscopic simulation models is not guaranteed, that is, data transfer from a certain microscopic model to another one is difficult.

VISSIM is used for this analysis due to its excellent graphical capabilities and its ability to model traffic signal through user-defined parameters.

Table 2.2.1 Major Microscopic Simulation Software

Model	Developer	Compatibility with Strategic model software
Cube Dynasim	Citilabs, USA	Cube families (TRIPS, Voyager, etc.)
Dracula (Dynamic Route Assignment Combining User Learning and Micro-simulation)	Institute for Transport Studies, University of Leeds, UK	SATURN
PARAMICS (PARAllel MICroscopic Simulation)	The Edinburgh Parallel Computing Centre and SIAS Ltd, UK	-
TSIS-CORSIM (Traffic Software Integrated System / CORridor microscopic SIMulation)	Federal Highway Administration (FHWA), USA	-
VISSIM (Verkehr In Städten – SIMulation)	PTV System Software and Consulting GMBH, Germany	VISSUM

Source: JICA Study Team

The traffic flow model used by VISSIM is a discreet, stochastic, time step based microscopic model, with driver-vehicle-units (DVU) as single entities. The model contains a psycho-physical car following model for longitudinal vehicle movement and a rule-based algorithm for lateral movements (lane changing). The car-following model is based on the continuous work of Wiedemann (1974, 1991).

Vehicles follow each other in an oscillating process. As a faster vehicle approaches a slower vehicle on a single lane, it has to decelerate. The action point of conscious reaction depends on the speed difference, distance, and driver-dependant behavior. On multi-lane links, moved up vehicles check whether they can improve their position by changing lanes. If so, they check the possibility of finding acceptable gaps on neighboring lanes. Car following and lane-changing together form the traffic flow model, comprising the basis of VISSIM.

2.3 Existing Condition and Issues

2.3.1 Road Inventory

The first step in defining a network is to describe the network geometry. VISSIM uses the concept of links and connectors to define the road network. Links are one-directional segments of streets, and connectors are usually the intersection of two or more links. In the case of a two-way street, each roadway block would consist of two one-directional links. Existing road geometric and regulation and operation information was collected by field observation survey.

Figure 2.3.1 shows the current road condition as of July 2007 for VISSIM model in the city center.

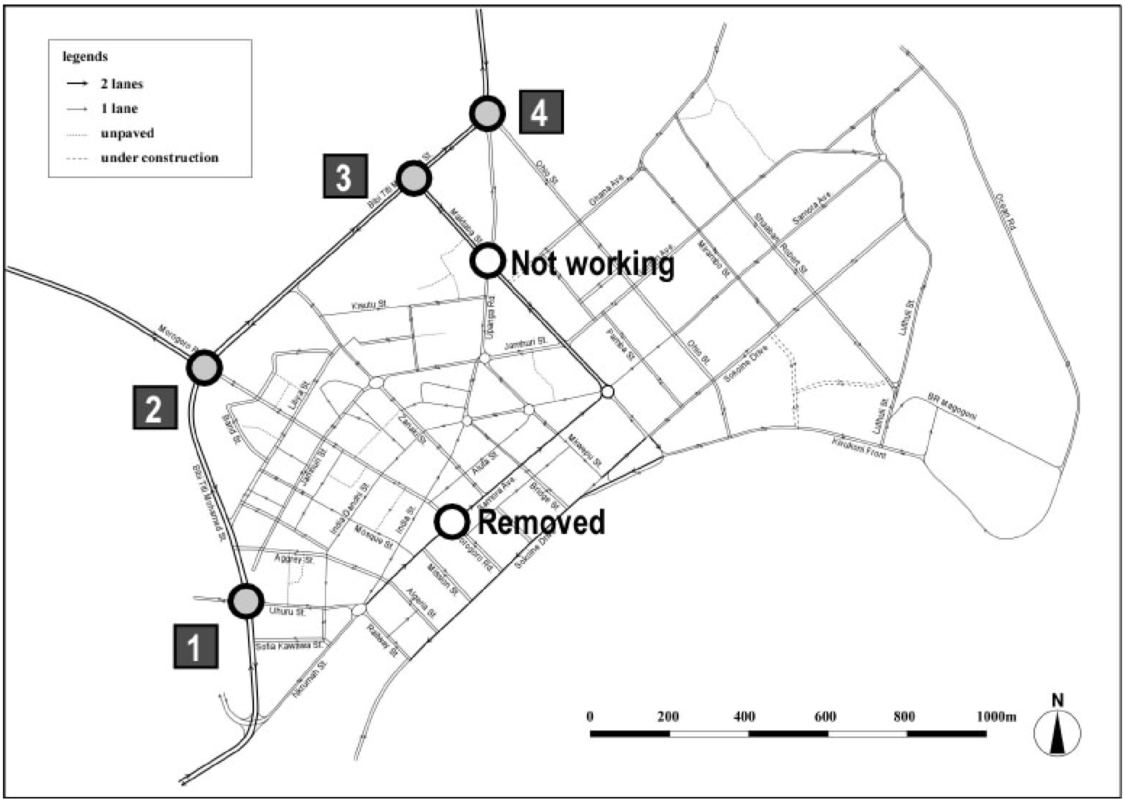
Source: JICA Study Team

Figure 2.3.1 Current Street Condition in Modeling Area

2.3.2 Traffic Signal

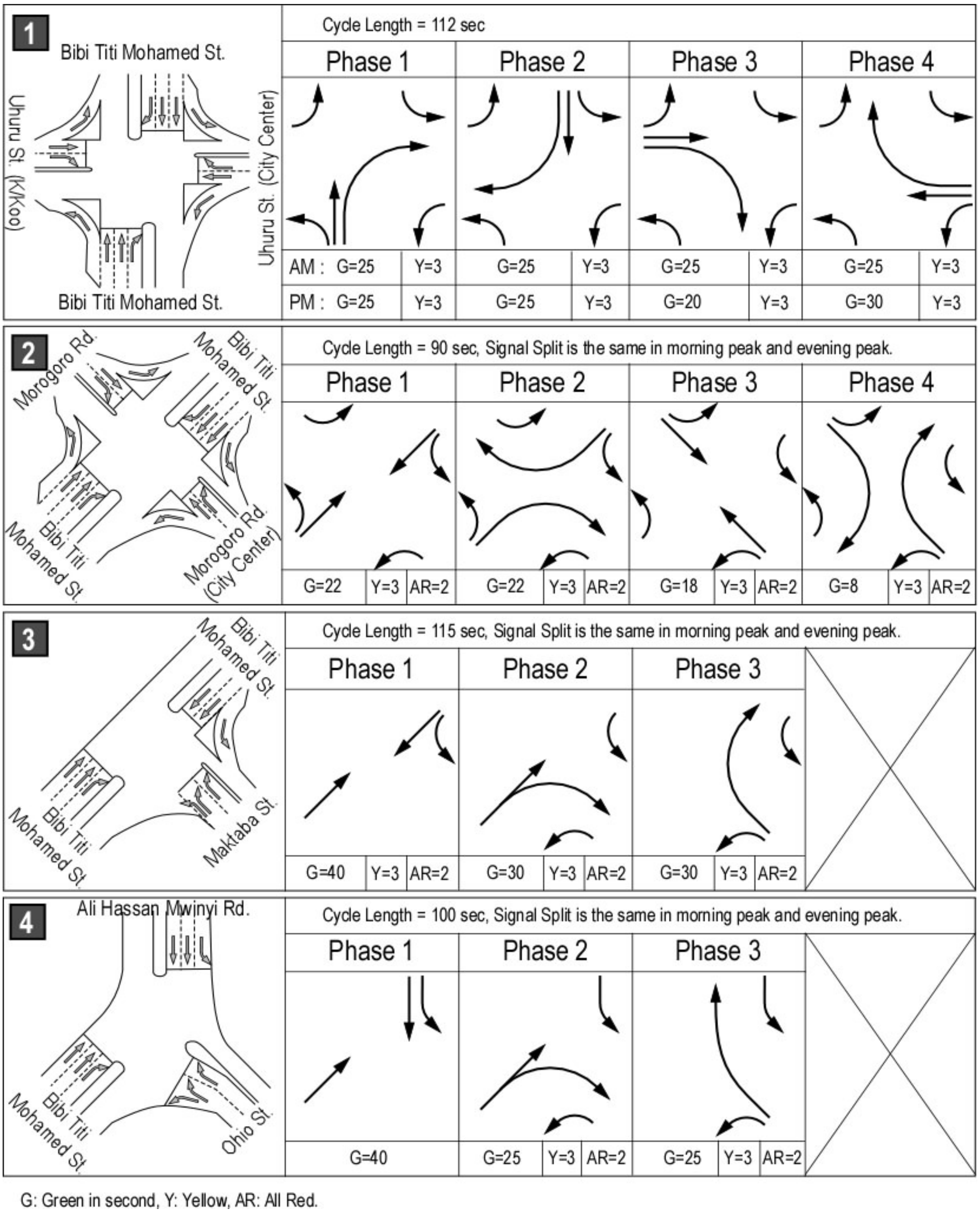
The existing conditions survey involved coding of traffic signal phasing and timing in case of traffic signal is operated. This traffic signal information is input into the VISSIM model to simulate the operation of existing signalized intersections. The existing condition of the intersection controlled manually by traffic police was observed, accordingly these information was also input into the VISSIM model. Most of the intersections in the city center are not signalized, thus a priority rule is adopted.

Figure 2.3.2 shows location of traffic signals including not-working ones at present, and Figure 2.3.3 shows the current pattern of operating traffic signals by the field observation survey. The traffic signals in operation are located only major intersections along the Bibi Titi Mohamed Rd. and there are no traffic signals in operation in the city center. All signals except Uhuru intersection are same phase and split in morning and evening.



Source: JICA Study Team

Figure 2.3.2 Location of Traffic Signal in the City Center



Source: JICA Study Team

Figure 2.3.3 Current Traffic Signal Operation

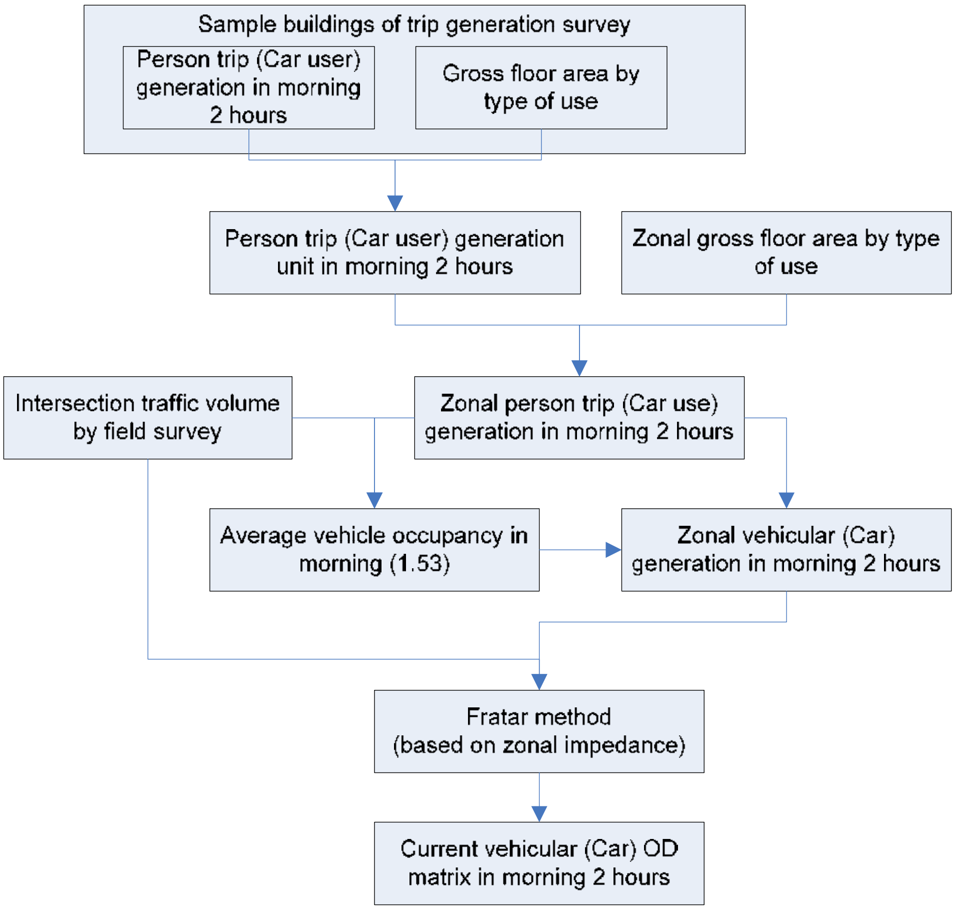
2.3.3 Traffic Volume

In VISSIM, two kinds of traffic volume input methods are prepared: One is a static routes and the other is dynamic assignment. In the static routes method, traffic volumes by each routes or proportion of turn movement at the intersection are required. This type of vehicle input method is used for the simulation of simple network such as isolated intersection or corridor including several intersections. In dynamic assignment, traffic volume should be prepared in a form of OD matrix, and vehicles on the network will search and choice an appropriate route based on the previous travel time and travel cost at every defined periods. For the simulation of the city center, the dynamic assignment was applied.

Traffic flow concerning to the city center consists three types of vehicle namely, passenger car, dala dala and truck. Dala dala is categorized into public transportation in the simulation and traffic volume of dala dala is calculated from route and headway.

Passenger car OD matrix is computed as shown in Figure 2.3.4. Based on the trip generation survey, zonal person trips using passenger car are estimated by each zone. The person trips using passenger car are converted vehicular trips by the total traffic volume collected by traffic count survey and total passenger trip crossing the boundary of the city center. As a result of the calculation, an average vehicle occupancy rate is estimated at 1.53 persons per passenger car in the morning peak 2 hours. The zonal vehicular trip generation of passenger car is estimated based on the car users' person trip generation and average vehicle occupancy rate. For estimation of the OD matrix, fratar method, which is a kind of a present pattern method, is adopted. In addition, with the assumption that the possibility of use of passenger car is in proportion of travel distance, distance between each zones are adopted as the present OD pattern.

For the estimation of the truck OD, fratar method is also used. In this case, vehicular trip generation is calculated in proportion to the total gross floor area of commercial use by each zone.

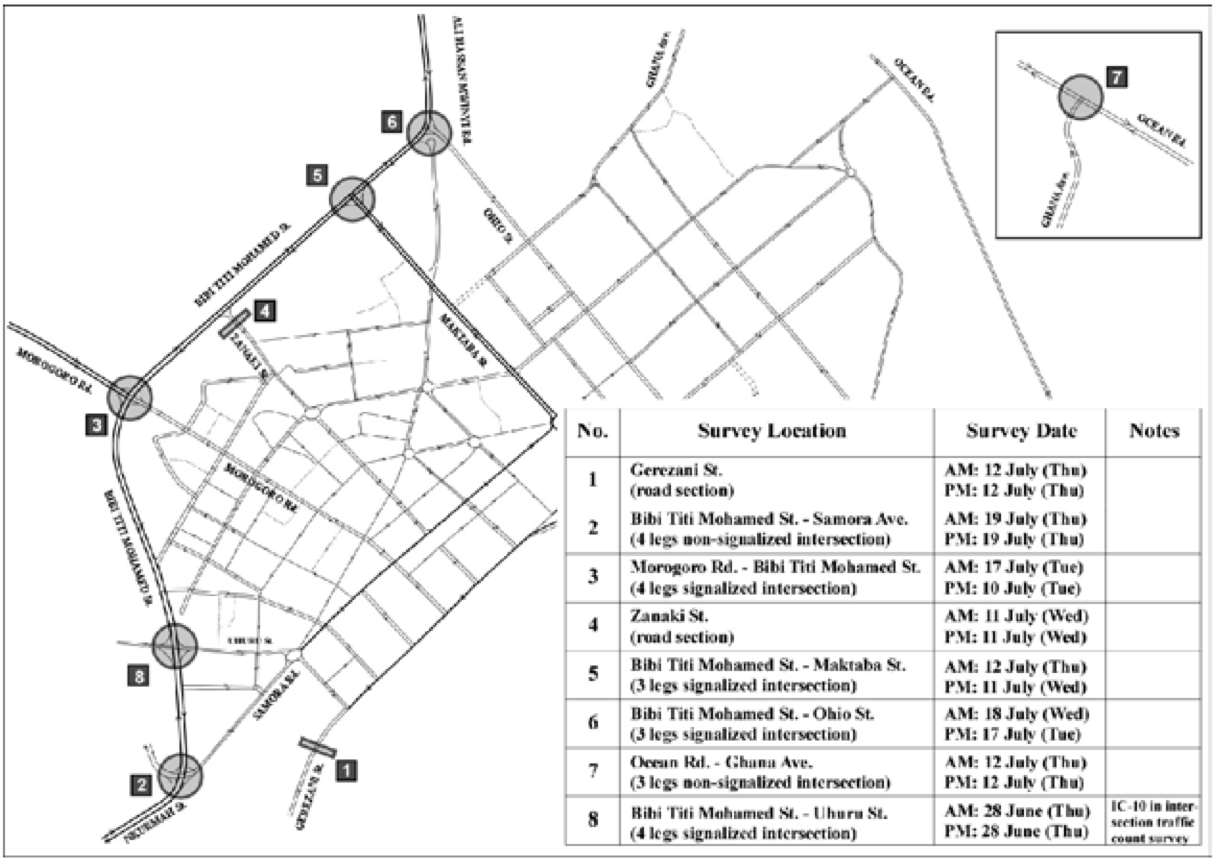


Source: JICA Study Team

Figure 2.3.4 Flow of Current Passenger Car OD Matrix Estimation

1) Traffic count survey

A turning movement and inflow / outflow traffic count survey was conducted during June to July 2007 at the study intersections and boundary of modeling area as shown in Figure 2.3.5 in the AM and PM peak hour in weekday.



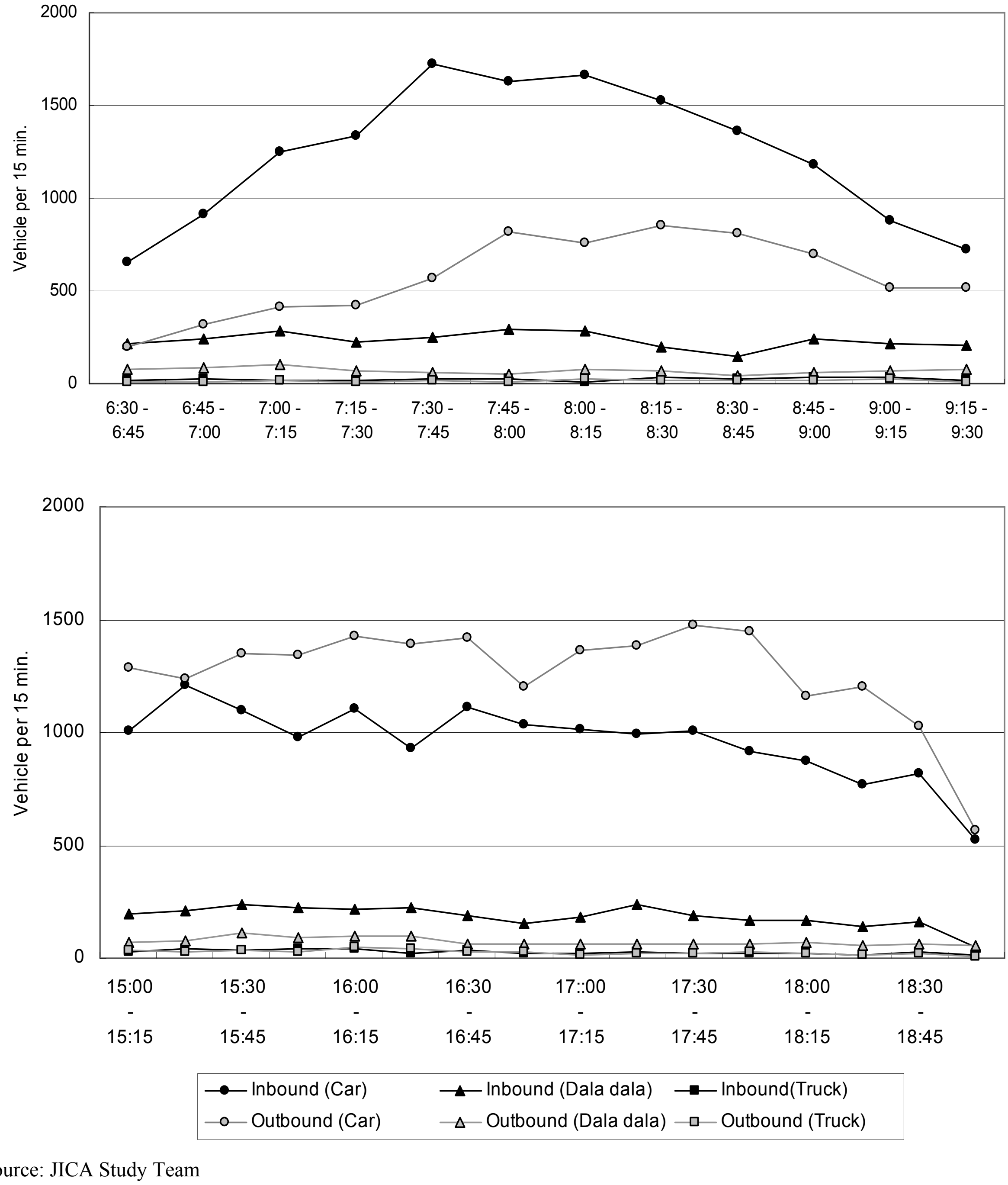
No.	Survey Location	Survey Date	Notes
1	Gerezani St. (road section)	AM: 12 July (Thu) PM: 12 July (Thu)	
2	Bibi Titi Mohamed St. - Samora Ave. (4 legs non-signalized intersection)	AM: 19 July (Thu) PM: 19 July (Thu)	
3	Morogoro Rd. - Bibi Titi Mohamed St. (4 legs signalized intersection)	AM: 17 July (Tue) PM: 10 July (Tue)	
4	Zanaki St. (road section)	AM: 11 July (Wed) PM: 11 July (Wed)	
5	Bibi Titi Mohamed St. - Maktaba St. (3 legs signalized intersection)	AM: 12 July (Thu) PM: 11 July (Wed)	
6	Bibi Titi Mohamed St. - Ohio St. (3 legs signalized intersection)	AM: 18 July (Wed) PM: 17 July (Tue)	
7	Ocean Rd. - Ghana Ave. (3 legs non-signalized intersection)	AM: 12 July (Thu) PM: 12 July (Thu)	
8	Bibi Titi Mohamed St. - Uhuru St. (4 legs signalized intersection)	AM: 28 June (Thu) PM: 28 June (Thu)	IC-10 in intersection traffic count survey

Source: JICA Study Team

Figure 2.3.5 Traffic Volume Count Survey Location on the border of Modeling Area

Figure 2.3.6 shows the hourly inbound and outbound traffic volume by type of vehicle. A morning peak of the inbound traffic is observed during 7:30 – 8:30, while, the evening peak of outbound traffic is not remarkable. Accordingly, the microscopic simulation for the analysis of traffic circulation in the city center focuses the morning peak hours.

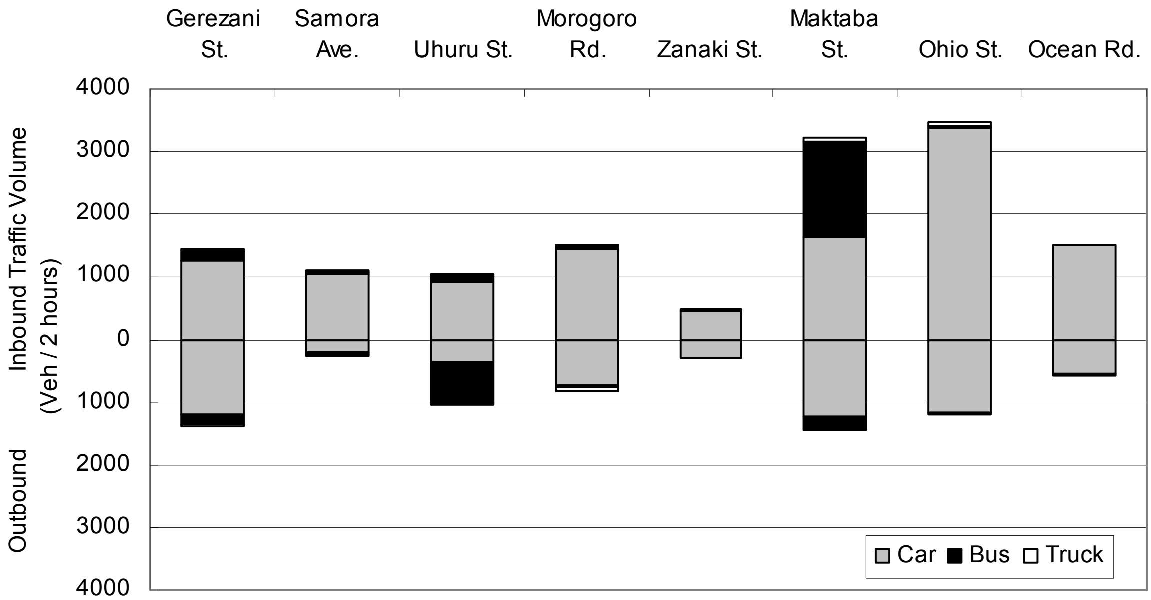
Hourly fluctuation of dala dala including other buses is not significant, the inbound and outbound traffic volumes in morning and evening are almost steady. The number of trucks entering or outgoing from the city center is quite few.



Source: JICA Study Team

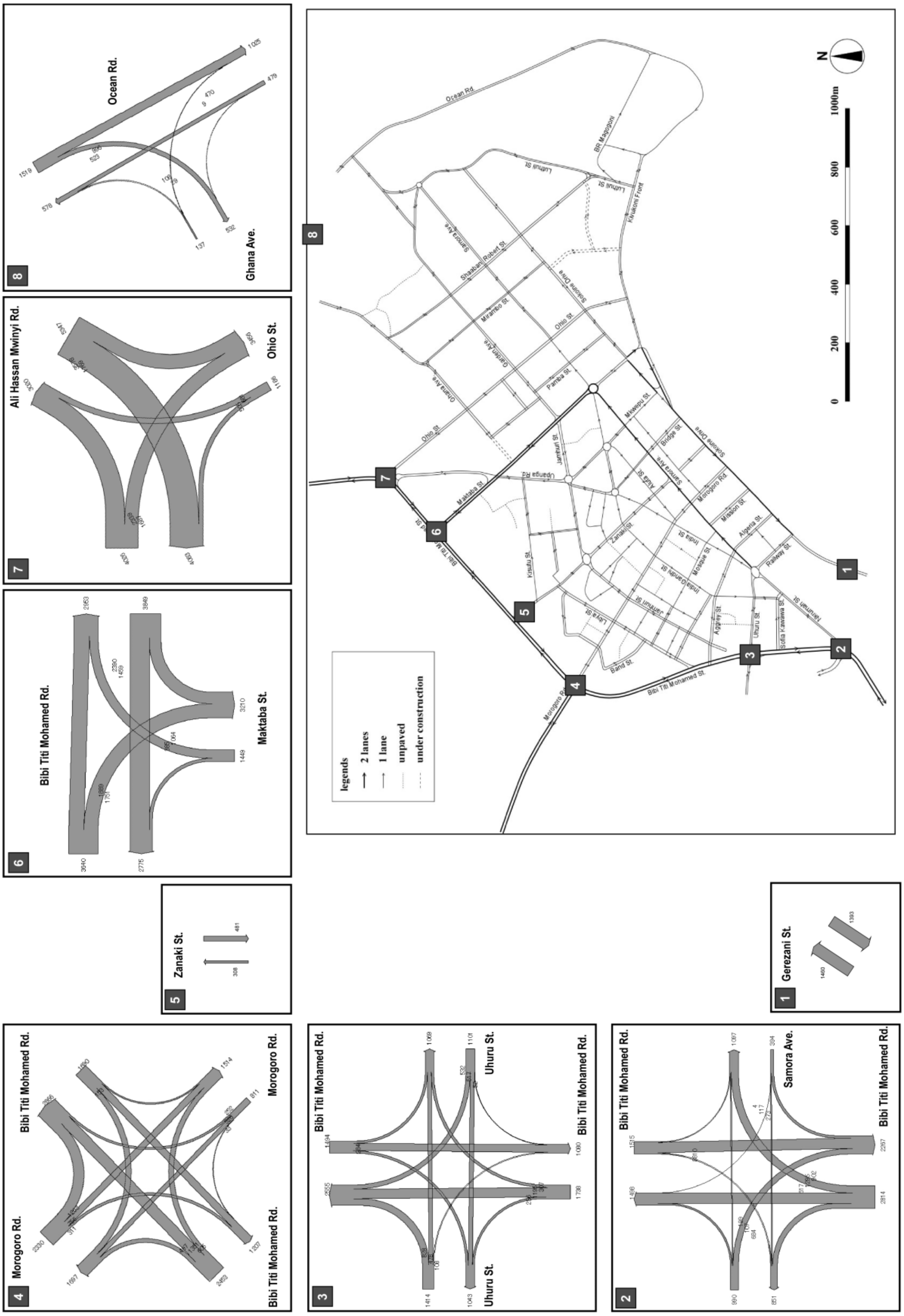
Figure 2.3.6 Hourly Traffic Volume by Direction

Figure 2.3.7 and 2.3.8 shows the traffic volume in morning 2 hours from 7:00 – 9:00. The largest inbound traffic volume is observed on Ohio St. and it was dominated by passenger cars. The secondary largest inbound traffic volume is observed at Maktaba St. and half of them is occupied by dala dala including other buses. The outbound traffic in the morning peak is lower than that of the inbound traffic except Gerezani St. and Uhuru St. Especially, Uhuru St. is the only exit route of dala dala and more than half of the outbound traffic volume is occupied by dala dala.



Source: JICA Study Team

Figure 2.3.7 Inbound and Outbound Traffic Volume in 7:00 – 9:00

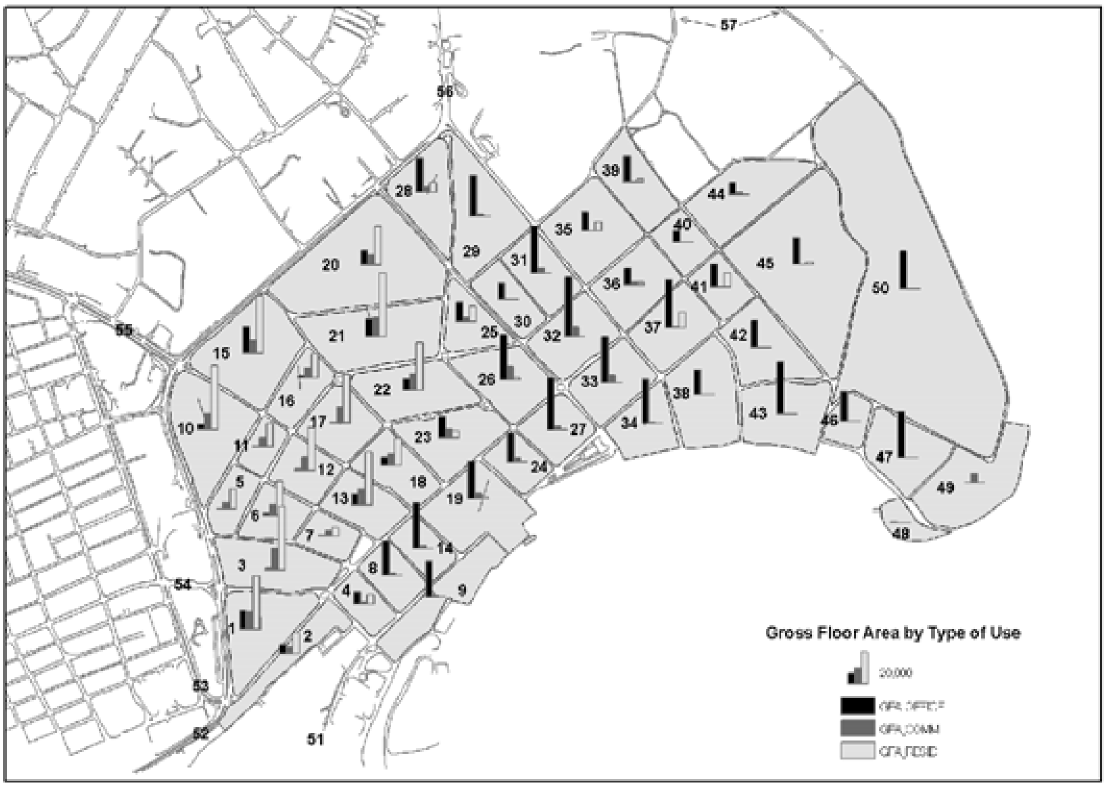


Source: JICA Study Team

Figure 2.3.8 Turning Traffic Volume in total of all vehicle type in 7:00 – 9:00

2) Zoning and feature of zone

For the microscopic simulation, the city center is divided into 50 internal zones and 7 external zones as shown in Figure 2.3.9. Figure 2.3.9 also shows a gross floor area collected by the land use inventory survey. According to the result of land use inventory survey, the east side of the city center is dominated by office use including private companies and government or public agencies, and the west side is mainly residential and commercial use.



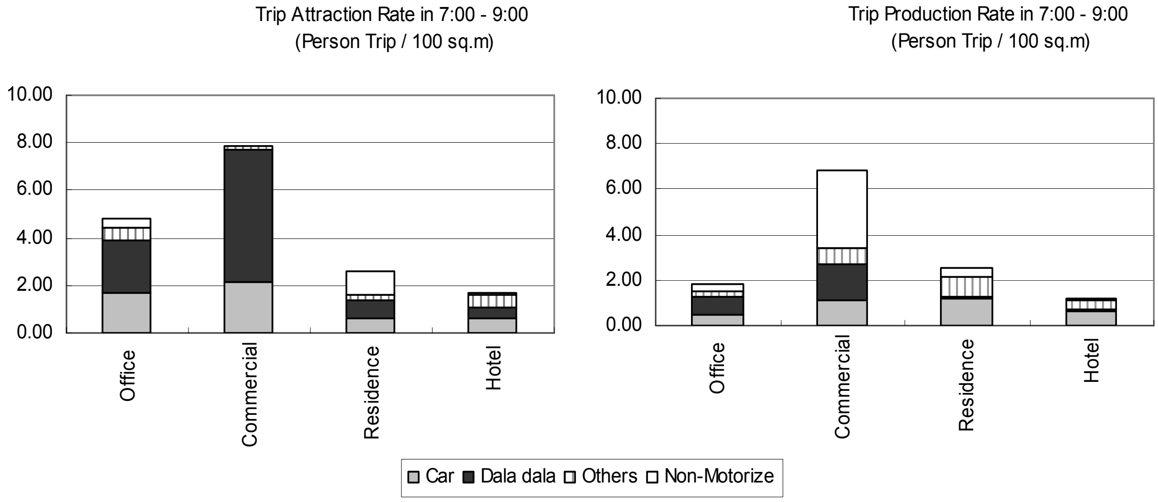
Source: JICA Study Team

Figure 2.3.9 Gross Floor Area by Zone

3) Estimation of vehicular trip generation

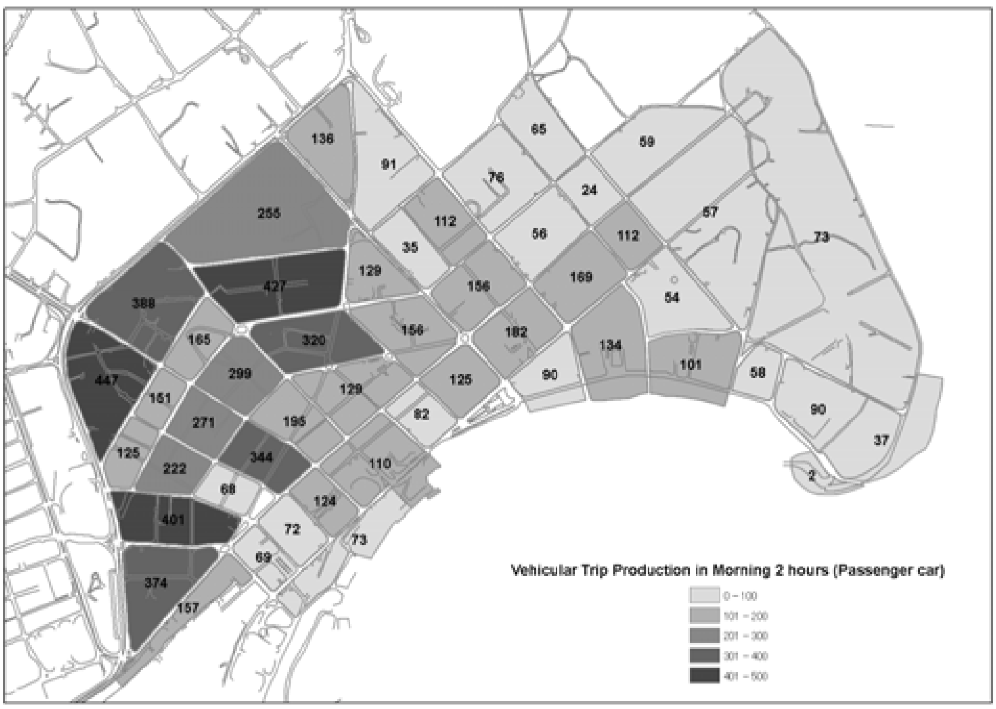
Figure 2.3.10 shows the person trip generation unit by type of land use in the morning peak hours: 7:00 – 9:00, that are estimated based on the trip generation survey. Based on the trip generation units and gross floor area by type of land use and by zone, car users (person) trip generations are computed, consequently which are converted into vehicular figures by using the average vehicle occupancy rates. The vehicle occupancy rate by type of vehicle for this analysis is calculated based on the traffic count survey at the cordon line of CBD.

The estimated vehicular trip production (outbound traffic from CBD) of passenger car in the city center is estimated at about 7.6 thousands and trip attraction (inbound traffic to CBD) is about 13.0 thousands in the morning 2 hours from 7:00 – 9:00. Figure 2.3.11 and 2.3.12 shows the vehicular trip production and attraction volume in the morning 2 hours, which suggests the estimated parking demand of residents and employees in the city center respectively.



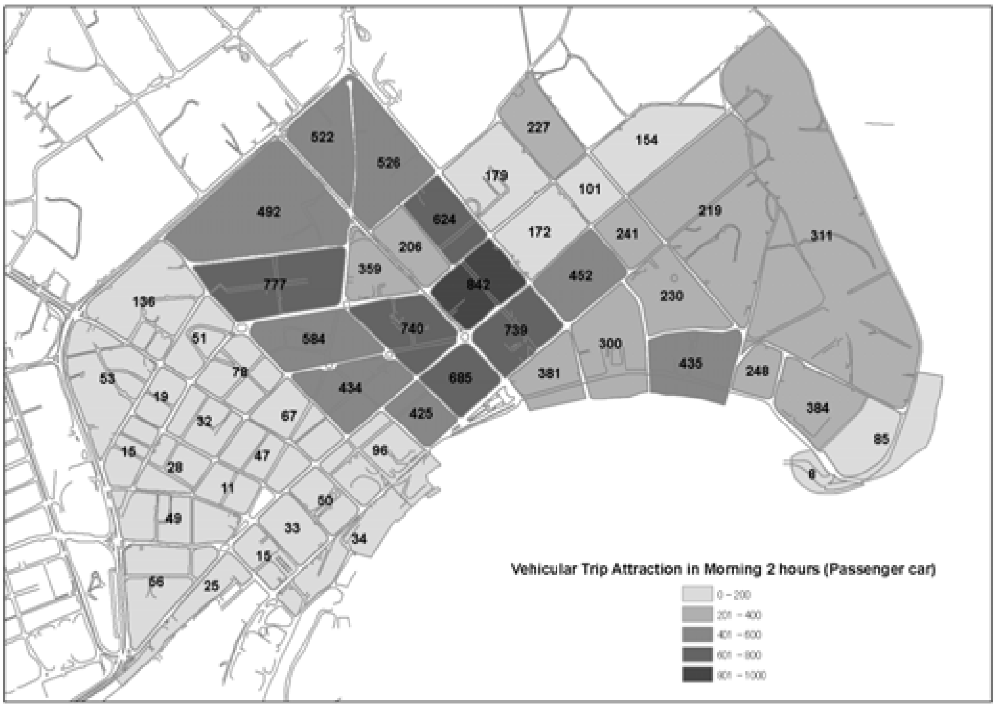
Source: JICA Study Team

Figure 2.3.10 Person Trip Generation Units in 7:00 – 9:00



Source: JICA Study Team

Figure 2.3.11 Vehicular Trip Production in Morning 2 hours

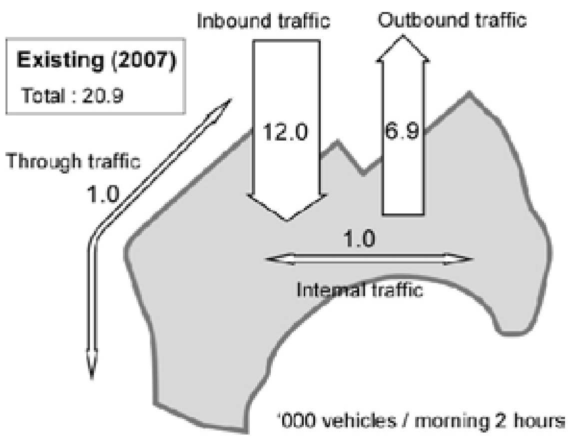


Source: JICA Study Team

Figure 2.3.12 Vehicular Trip Attraction in Morning 2 hours

4) Estimation of Origin-Destination Matrix

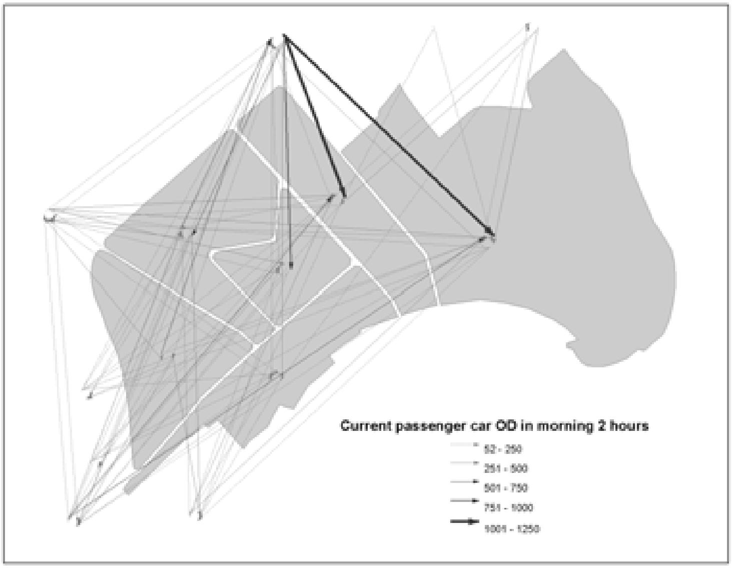
By employing the conventional fratar method, the year 2007 passenger car OD matrix in 7:00 – 9:00 is estimated. Figure 2.13 summarizes the year 2007 passenger car flow generated in CBD. The inbound passenger car volume in morning 2 hours is about 12.0 thousands vehicles, whilst the outbound traffic is estimated at 6.9 thousands. Internal (within CBD) traffic volume and through traffic is about 1.0 thousands respectively.



Source: JICA Study Team

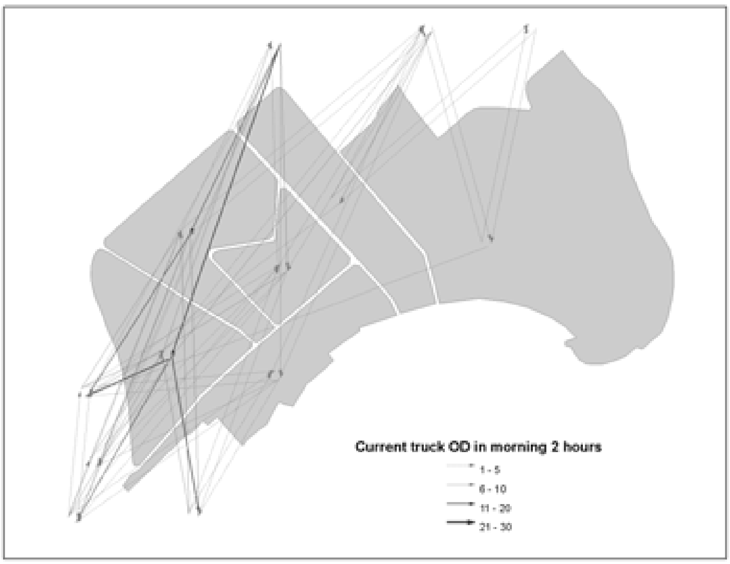
Figure 2.3.13 The Year 2007 Passenger Car Trip Generation in 7:00 – 9:00

Figure 2.3.14 shows the 2007 passenger car OD by super zone in CBD, whilst Figure 2.3.15 shows that of trucks. Major traffic flows (travel demands) are observed from Ali Hassan Mwinyi Rd. to several zones along Ohio St. along which there are several high-rise office buildings. Truck travel demand is dominated in the western part of CBD, where there are a lot of shop houses and small retailers.



Source: JICA Study Team

Figure 2.3.14 Estimated Car OD Volume in 7:00 – 9:00

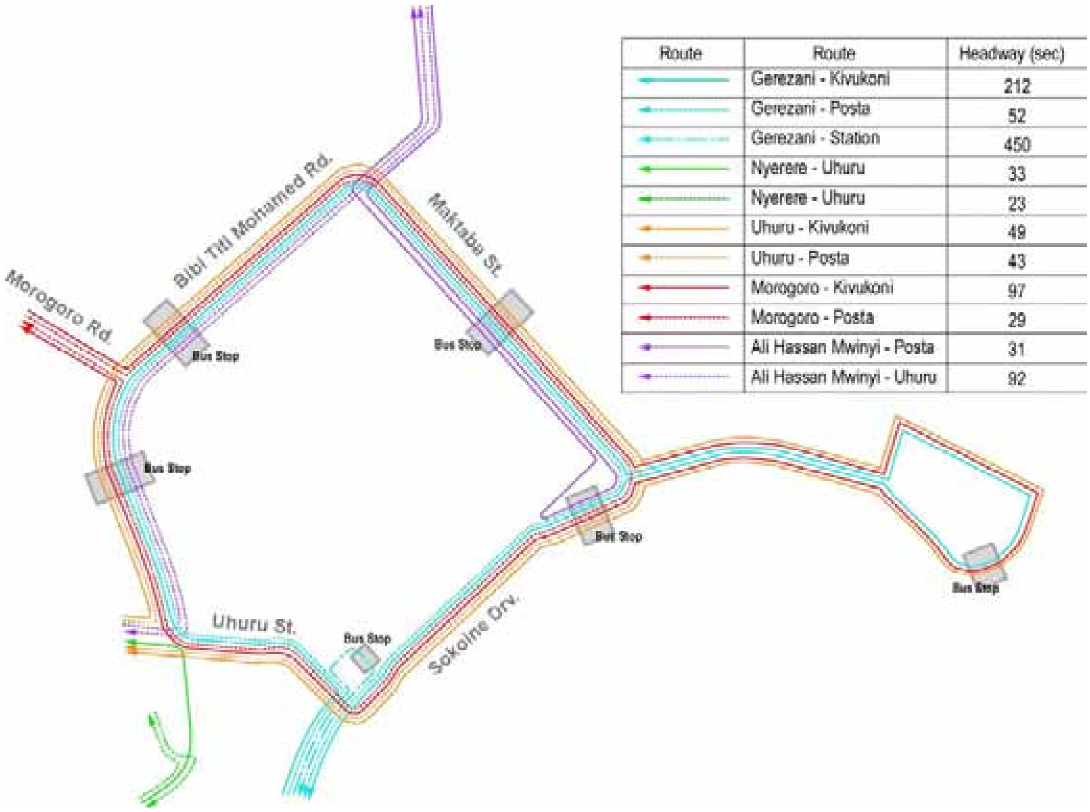


Source: JICA Study Team

Figure 2.3.15 Estimated Truck OD Volume in 7:00 – 9:00

2.3.4 Dala dala Routes and Services

Information of dala-dala routes and services in the year 2007 was given by SUMATRA, which are coded as VISSIM network: a total of 11 routes as the existing conditions model of year 2007. There are approximately 6 bus stops within CBD, which are also coded as part of VISSIM network as shown in Figure 2.3.16.



Source: JICA Study Team

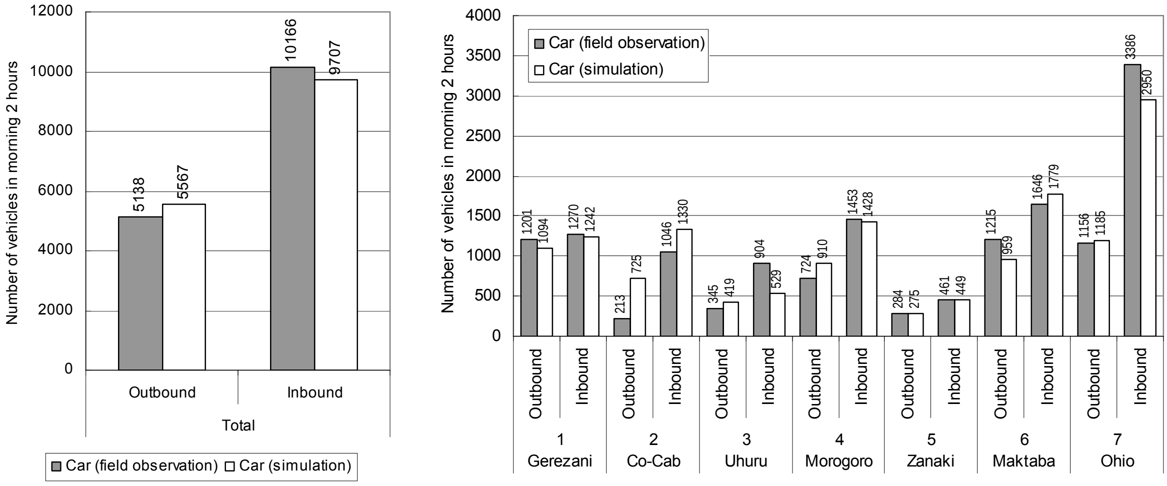
Figure 2.3.16 Dala dala Routes and Services Information used in Simulation

2.3.5 Model Calibration

The route decision model was calibrated using the traffic volume data (screen line traffic volume) collected in the site. Figure 2.3.17 shows estimated traffic by the calibrated microscopic simulation model and actual traffic count data in 7:00 – 9:00 for comparison. As seen in Figure 2.3.17, the model can well explain the current travel behavior of passenger cars.

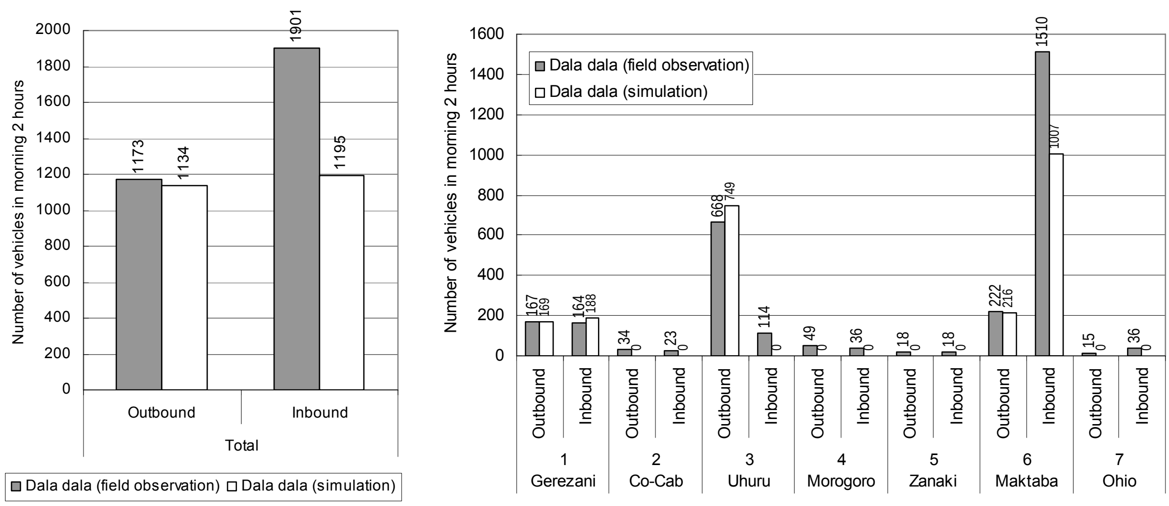
On the other hands, a slightly big difference is observed in the inbound Dala Dala traffic on Maktaba st., which exceeds more than 500 vehicles per 2 hours. While, there is no significant difference in the outbound traffic.

Another traffic count survey (directional traffic count data at major intersections in 2007 by the JICA study team) suggests that there might be no big difference between the estimated traffic and the actual traffic counts in 2007.



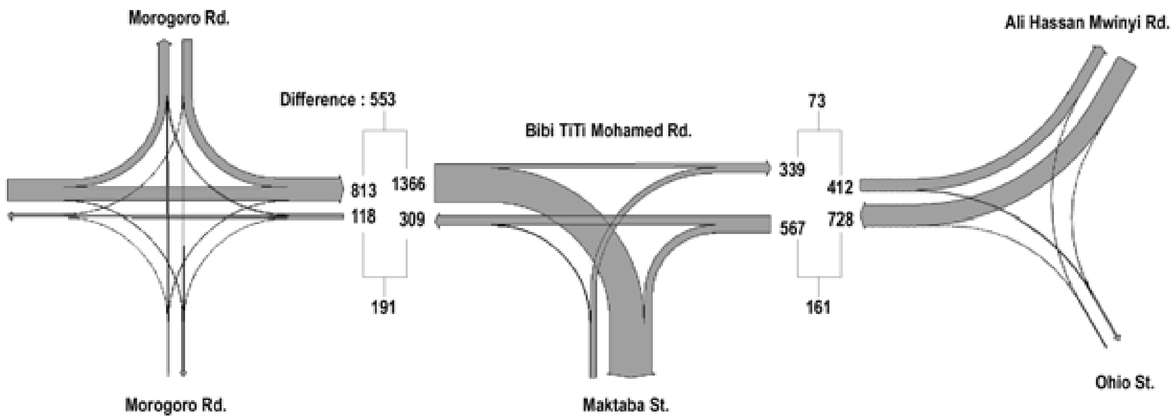
Source: JICA Study Team

Figure 2.3.17 Passenger Car Traffic Volume in 7:00 – 9:00



Source: JICA Study Team

Figure 2.3.18 Dala dala Traffic Volume in 7:00 – 9:00



Source: JICA Study Team

Figure 2.3.19 Dala dala traffic at Intersections surrounding CBD in 7:00 – 9:00

2.3.6 Evaluation of Current Traffic Management

Table 2.3.1 shows the performance of the existing network with the existing demand. An average travel speed is estimated at 27.7 km/h and about 30% of the travel time is delay time such as stops at intersections.

Table 2.3.1 Results of Simulation in 7:00 – 9:00

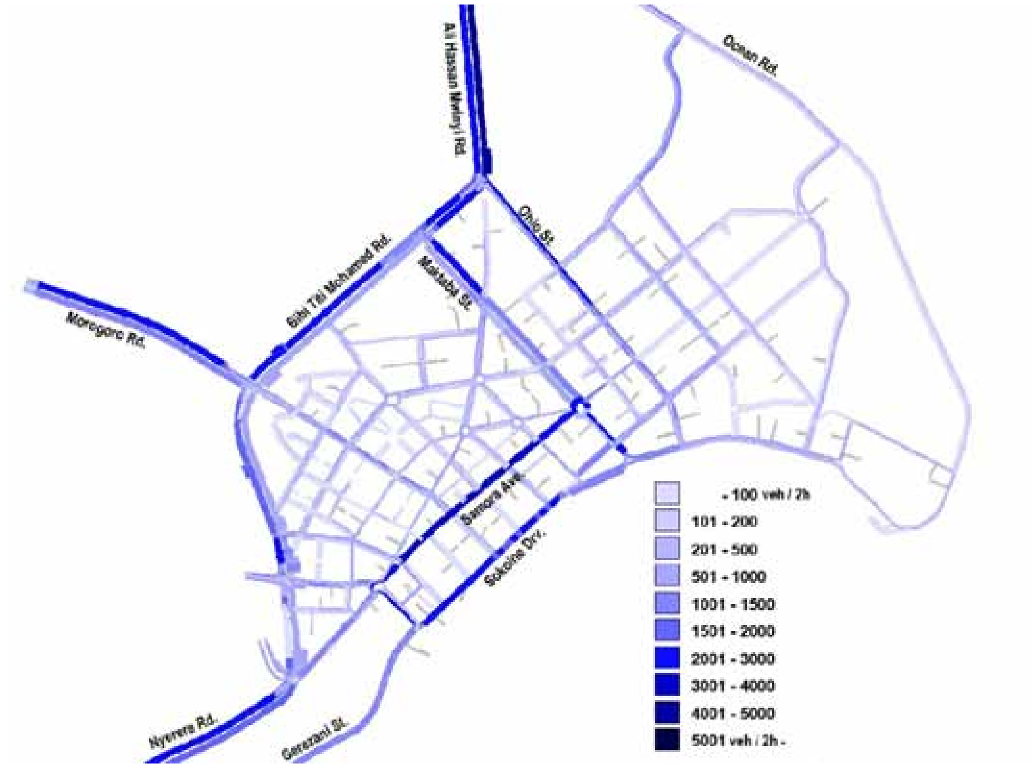
Number of Vehicles	22,424
Total Distance Traveled (km)	45,392
Average Distance Traveled (km)	2.02
Total Travel Time (hour)	1,638
Average Travel Time (min)	4.38
Average Network Speed (km/h)	27.7
Total Network Delay (hour)	485
Average Delay (min)	1.30

Note: Above figures are taking into account only vehicles that reached their destinations.
Source: JICA Study Team

Figure 2.3.20 shows the simulated traffic volume from 7:00 to 9:00 (assigned traffics on the network within the simulated two hours). The traffic volumes on Samora Ave., Sokoine Drv., Maktaba St. and Ohio St. are remarkable in the city center.

Figure 2.3.21 shows the simulated average travel speed by road segment from 7:00 to 9:00. Lower travel speeds are simulated on road segments near the major intersections and dala dala stops along the Bibi Titi Mohamed Rd.

Within CBD, low travel speeds are observed on the approaches to Askari monument roundabout, Clock tower roundabout, and westbound of Sokine drive from the intersection with Station St., which is lower than 15 km/h.



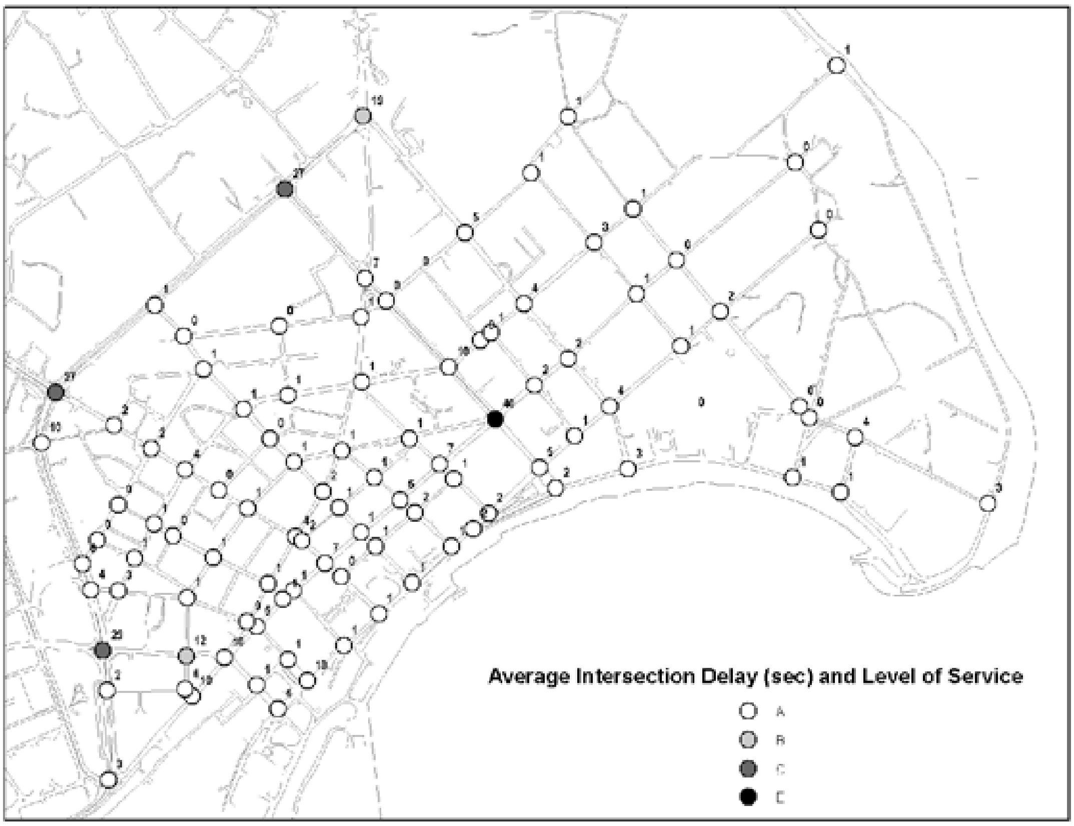
Source: JICA Study Team

Figure 2.3.20 Simulated Traffic Volume in 7:00 – 9:00 in 2007

Source: JICA Study Team

Figure 2.3.21 Simulated Average Travel Speeds in 7:00 – 9:00 in 2007

Figure 2.3.22 shows the intersection delay and the level of service (LOS) based on the Highway Capacity Manual as shown in Table 2.3.2. The most congested intersection is Askari Monument Roundabout which shows LOS "E" and the average delay is 40 seconds per vehicle. The LOS "C" intersections are observed at signalized intersections along the Bibi Titi Mohamed Rd.



Source: JICA Study Team

Figure 2.3.22 Level of Service of Major Intersections in 7:00 – 9:00 of Current Condition

The microscopic simulation prepared for the year 2007 (exiting) condition and site observations suggest several issues/problems which can be improved immediately (see Figure 2.23).

First, traffic signals installed along the Bibi Titi Mohamed should be fine-tuned in accordance with actual traffic volumes, otherwise traffic police should continue the manual traffic control to meet the changing travel pattern.

The existing dala dala stops along the Bibi Titi Mohamed are located lay-by, however, many dala dala buses make stops in the carriageway for loading and unloading passengers and block other traffics. This phenomena indicates a shortage of lay-by bus stop capacity.

At the dala dala stop in front of the post office called "Posta", a lot of dala dala make stops for loading and unloading by using one lane of Maktaba St. Accordingly the capacity of Maktaba St. is reduced to half.

There are no operating traffic signals inside CBD, therefore, speed reductions and delays are observed at many intersections along artery streets such as Samora Ave.

Table 2.3.2 Level-of-Service Definitions for Intersections

Level-of-Service	Control Delay (second / vehicle)		Description
	Signalized intersections	Unsignalized intersections	
A	≤ 10.0	≤ 10.0	Very low vehicle delays, free traffic flow, signal progression extremely favorable, most vehicles arrive during given signal phase.
B	10.1 to 20.0	10.1 to 15.0	Good signal progression, more vehicles stop and experience higher delays than for LOS A.
C	20.1 to 35.0	15.1 to 25.0	Stable traffic flow, fair signal progression, significant number of vehicles stop at signals.
D	35.1 to 55.0	25.1 to 35.0	Noticeable traffic congestion, longer delays and unfavorable signal progression, many vehicles stop at signals.
E	55.1 to 80.0	35.1 to 50.0	Limit of acceptable vehicle delay, unstable traffic flow, poor signal progression, traffic near roadway capacity, frequent cycle failures.
F	>80.0	> 50.0	Unacceptable delay, extremely unstable flow, heavy congestion, traffic exceeds roadway capacity, stop-and-go conditions.

Source: Highway Capacity Manual, Transportation Research Board, 2000

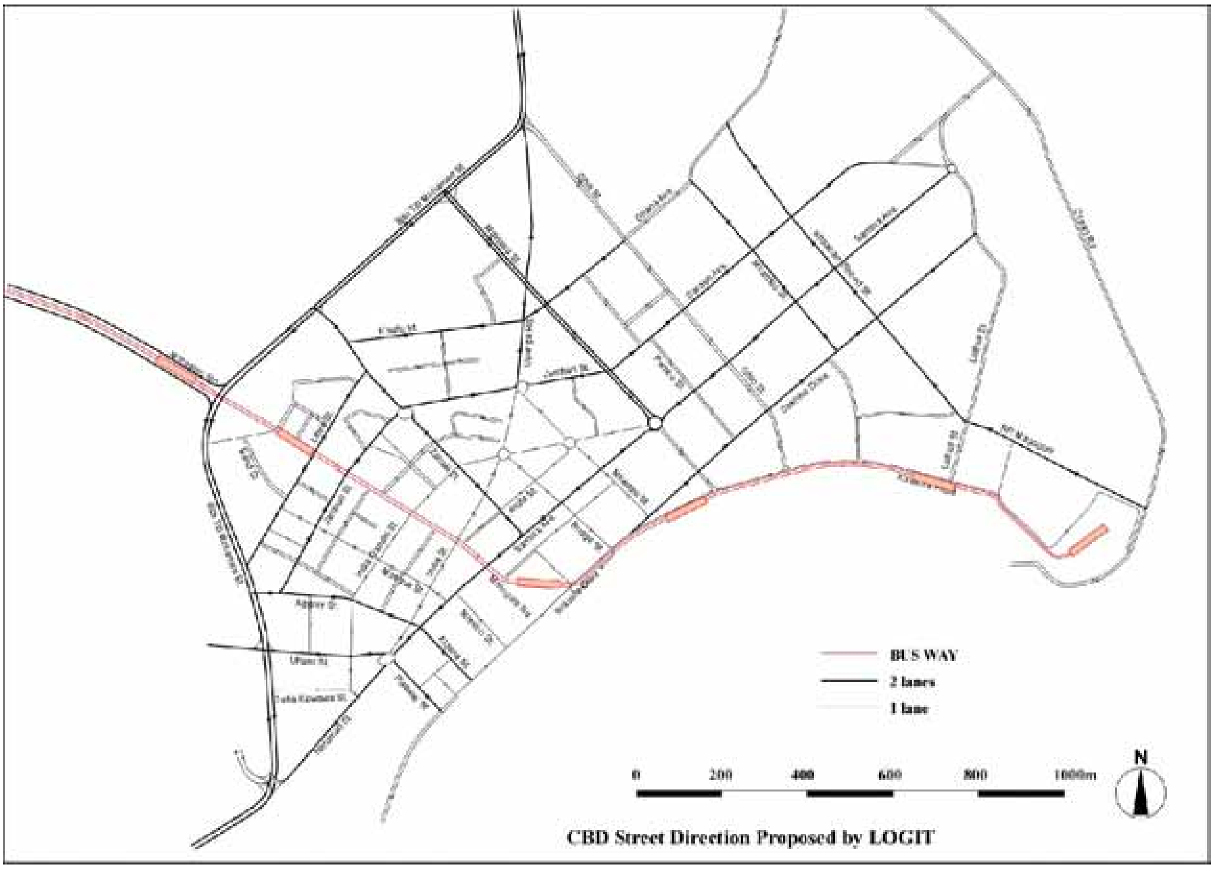
Figure 2.3.23 Problems of Existing Traffic Flow in 7:00 – 8:00

2.4 BRT Phase 1 Base Case Simulation

2.4.1 Road Network

The VISSIM base case road network including BRT phase 1 operation was prepared based on the proposed road operation by LOGIT for DART (Figure 2.4.1). There are two major features in this network and operation plan as follows:

- Most of the streets in CBD are operated by one-way system, and
- Four missing link (Upanga Rd. – Ali Hassan Mwinyi, Ghana Ave. – Kisutu St., Jamhuri St. – Garden Ave. and BR Magogoni – Shaaban Robert St.) are connected.



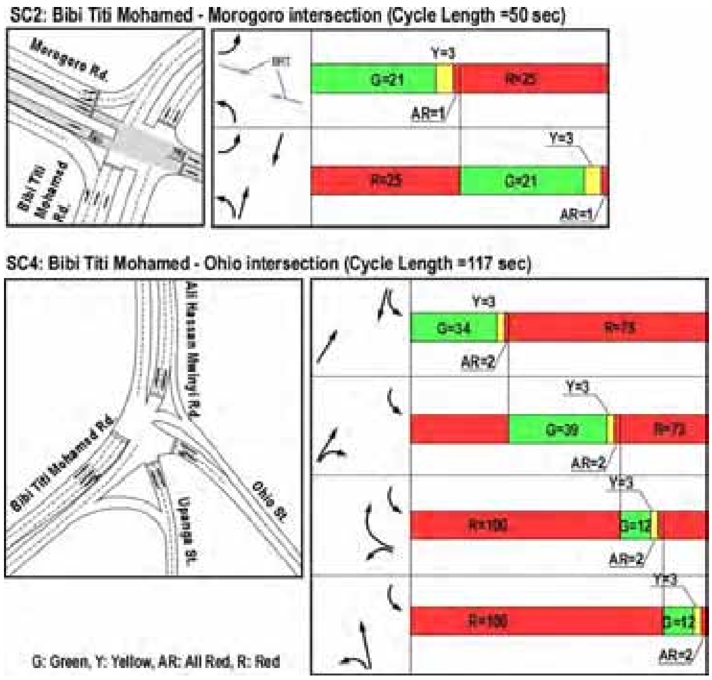
Source: Street Direction by LOGIT

Figure 2.4.1 BRT Base Case Network (DART original plan)

2.4.2 Traffic Signal

According to the operation plan of BRT phase 1, the traffic signal at the Morogoro Rd. – Bibi Titi Mohamed Rd. intersection will be changed as shown in Figure 2.4.2.

The traffic signal at the Ohio intersection includes an additional phase for Upanga Rd. Concerning other signalized intersections, nothing is changed from the current signal timing in this case.

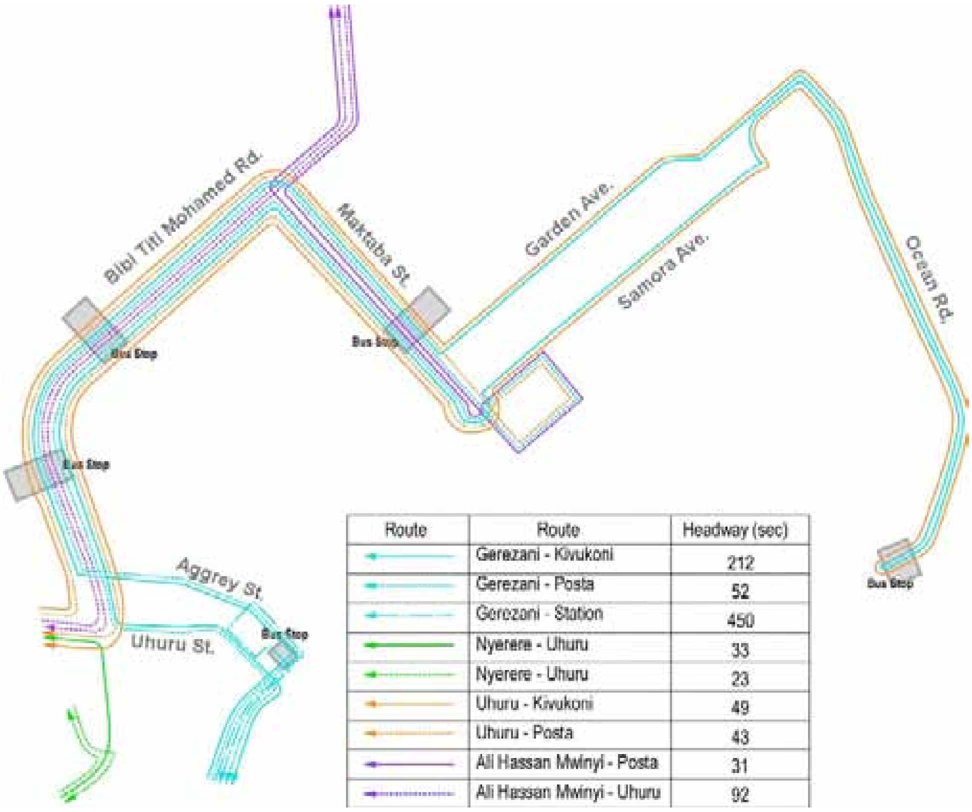


Source: Signal configuration at SC2 is based on the BRT Phase 1 Design.
Signal configuration at SC4 is considered by JICA Study Team based on the current configuration

Figure 2.4.2 Planned Traffic Signal in BRT Phase 1 (AM)

2.4.3 BRT and Re-routed Dala dala

Figure 2.4.3 shows the proposed Dala dala re-routing plan by LOGIT. There is no Dala dala buses on Morogoro road with the BRT Phase 1 operation through Morogoro Rd. to Kivukoni Front. The BRT services are provided with 1 minute headway with significant reduction of Dala dala bus services: 30% of dala dala operation from the current operation in the city center.



Source: Based on the LOGIT Plan

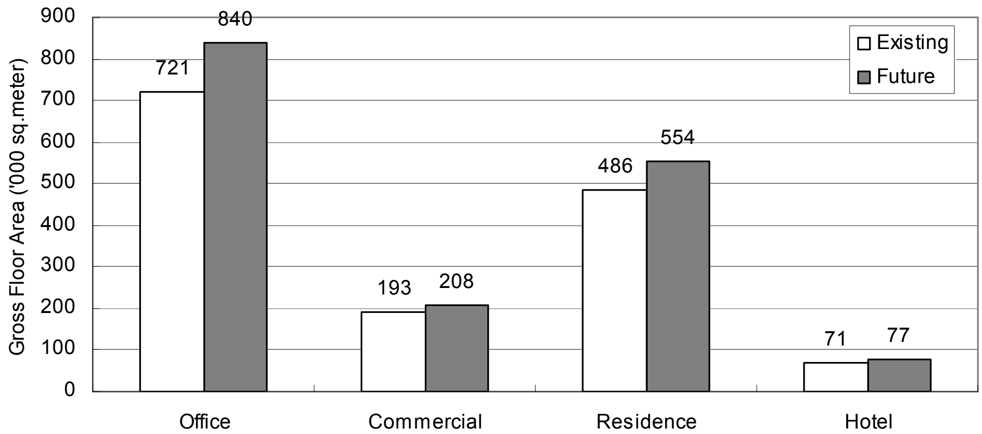
Figure 2.4.3 Re-routed Dala dala Services

2.4.4 Estimation of Year 2009 Car OD

The BRT Phase 1 is scheduled to open to public in March 2009. In order to test the impact of BRT Phase 1 operation, the year 2009 OD matrix is estimated.

The year 2009 car OD matrix is estimated by combining the current passenger car OD (2007) and additional trip generation by the existing under-construction building in the city center. Figure 2.4.4 shows the existing and estimated future gross floor area. The gross floor area of office use in the city center will increase by 119 thousans to 840 thousands sq. meter and residential use will increase by 68 thousands to 554 thousands sq. meter. The increase of gross floor area of commercial use and hotel are lower than office and residence.

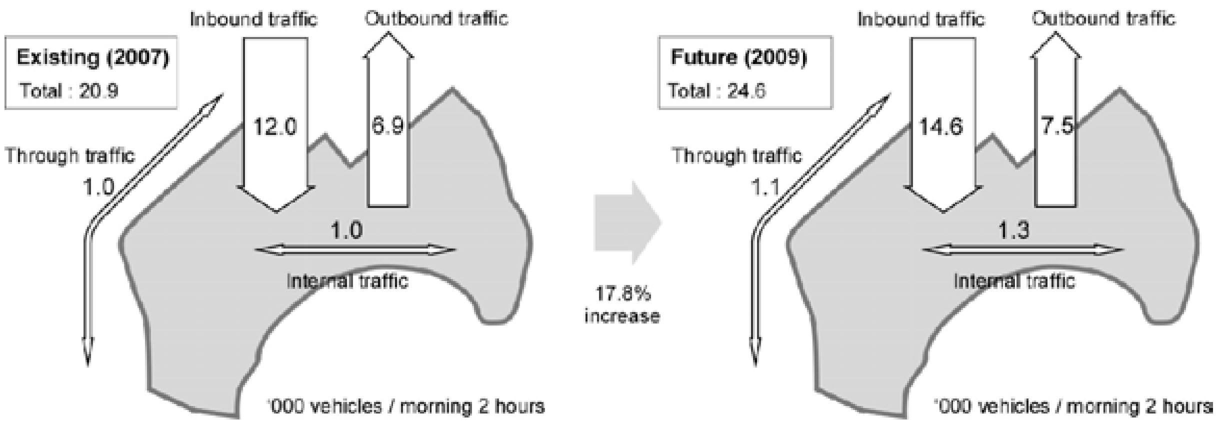
A future truck OD matrix (year 2009) is calculated based on the increase of gross floor area of commercial use and the present truck volume. The increase of gross floor area of commercial use is not remarkable in comparison with the office and residence use, accordingly, the future truck traffic is not increase conspicuously.



Source: JICA Study Team

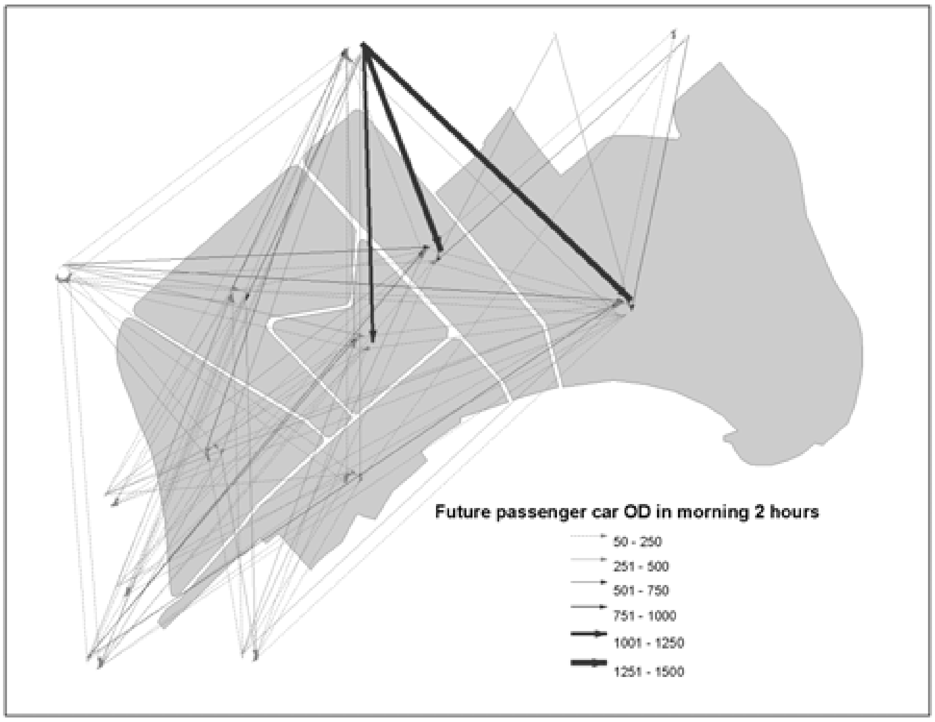
Figure 2.4.4 Estimated Gross Floor Area in CBD by year 2009

As the results, a total number of passenger car volume concerning the city center increases by 17.8% of the current volume or up to 24.6 thousands vehicular trips in total in the morning 2 hours of 2009. The inbound traffic volume is forecasted to increase to 14.6 thousand vehicles in the morning 2 hours, which means additional 2.6 thousand vehicular trip will add to the current traffic volume. To maintain the current level of service in the city center, therefore, at least one or more additional lanes in both of inbound / outbound direction is required at the boundary of the city center.



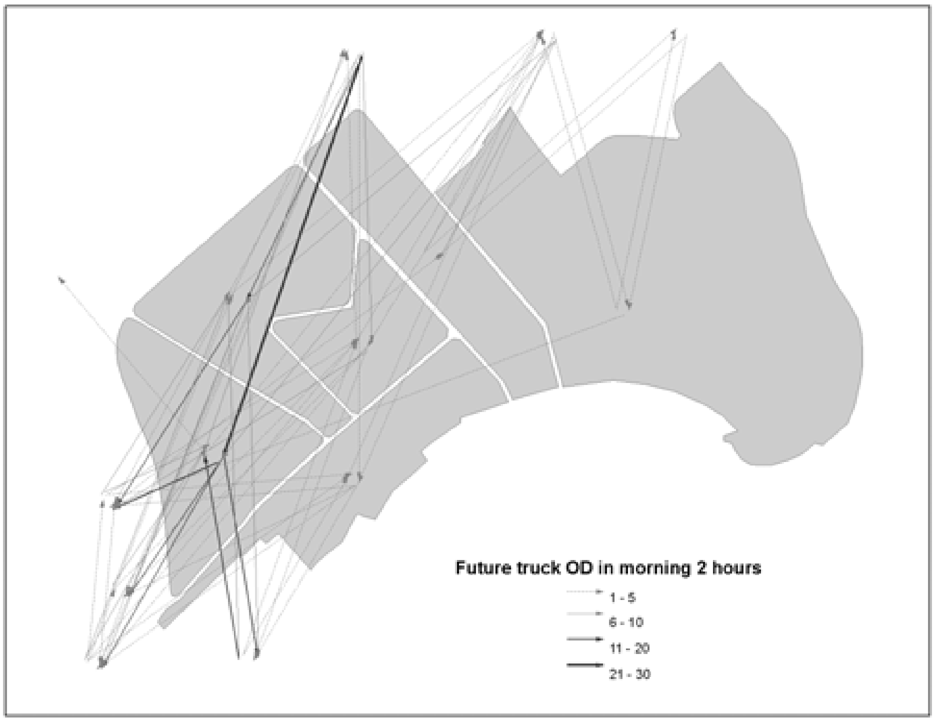
Source: JICA Study Team

Figure 2.4.5 Estimated Passenger Car Trip Generation in the morning peak in 2009



Source: JICA Study Team

Figure 2.4.6 Estimated Passenger Car OD Volume in 2009



Source: JICA Study Team

Figure 2.4.7 Estimated Truck OD in the morning peak in 2009

2.4.5 Evaluation of CBD traffic management with BRT Phase 1

Table 2.4.1 shows performance of the existing case and the BRT phase 1 base case. In the BRT phase 1 simulation case, the proposed road network (original DART plan) cannot accommodate all the traffic demand within the morning 2 hours, which means, the estimated morning peak traffic demand in the 2009 exceeds the ultimate capacity of the CBD network already.

For the consequent analysis, accordingly, 85% of the year 2009 matrix, which is almost equivalent to the existing traffic volume, is used to identify other problems of the proposed network.

As suggested in Table 2.4.1 the performance of the proposed road network and operation plan with BRT Phase 1 may become worse in comparison with the existing condition.

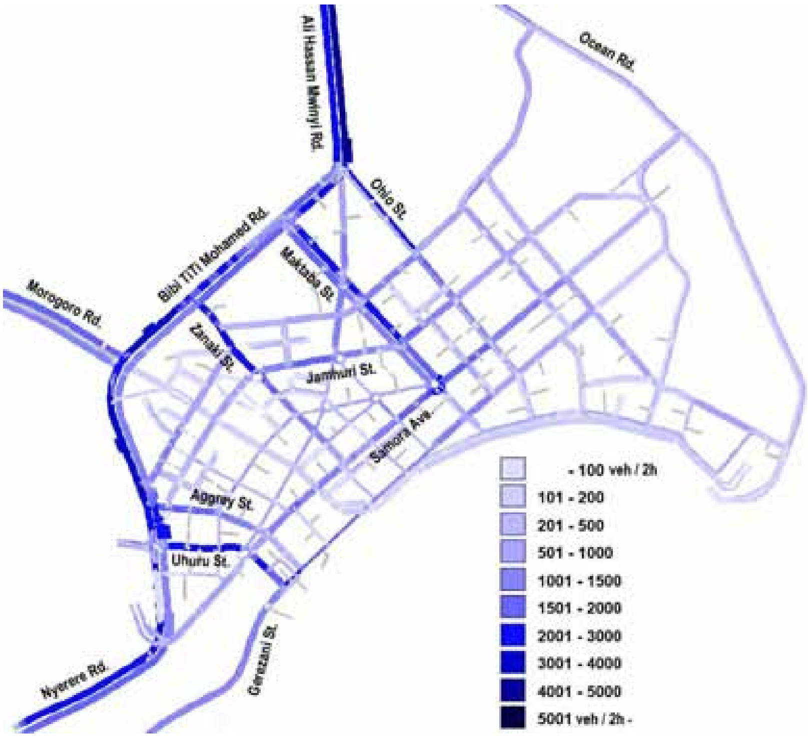
Table 2.4.1 Results of Simulation in 7:00 – 9:00

	Existing Case (2007)	BRT phase1 Base Case (85% volume)
Number of Vehicles	22,424	21,037
Total Distance Traveled (km)	45,392	45,851
Average Distance Traveled (km)	2.02	2.18
Total Travel Time (hour)	1,638	1,905
Average Travel Time (min)	4.38	5.43
Average Network Speed (km/h)	27.7	24.1
Total Network Delay (hour)	485	730
Average Delay (min)	1.30	2.08

Note: Above figures are taking into account only vehicles that reached their destinations.
Source: JICA Study Team

Figure 2.4.8 shows the two-hour traffic volumes from 7:00 to 9:00 in BRT phase 1 base case (85% volume assignment). The traffic volumes on the Uhuru St. Ave., Zanaki St., Maktaba St. and Ohio St. are remarkable in the city center.

Figure 2.4.9 shows the average travel speeds from 7:00 to 9:00. Some speed reduction segments observed in the existing case are improved such as Askari monument roundabout and Clock tower roundabout. However, it should be noted that the former case is due to the planned reduction of the number of dala dala operation in the city center, while the latter case is due to the change of one-way operation of Samora Ave. The speed reduction at the intersection of Bibi Titi Mohamed Rd. and Libya St is caused by right-turn traffic from / to Morogoro Rd. shifted from the intersection with Bibi Titi Mohamed Rd. and the traffic generated in the west side of BRT phase 1 route (Morogoro Rd.).



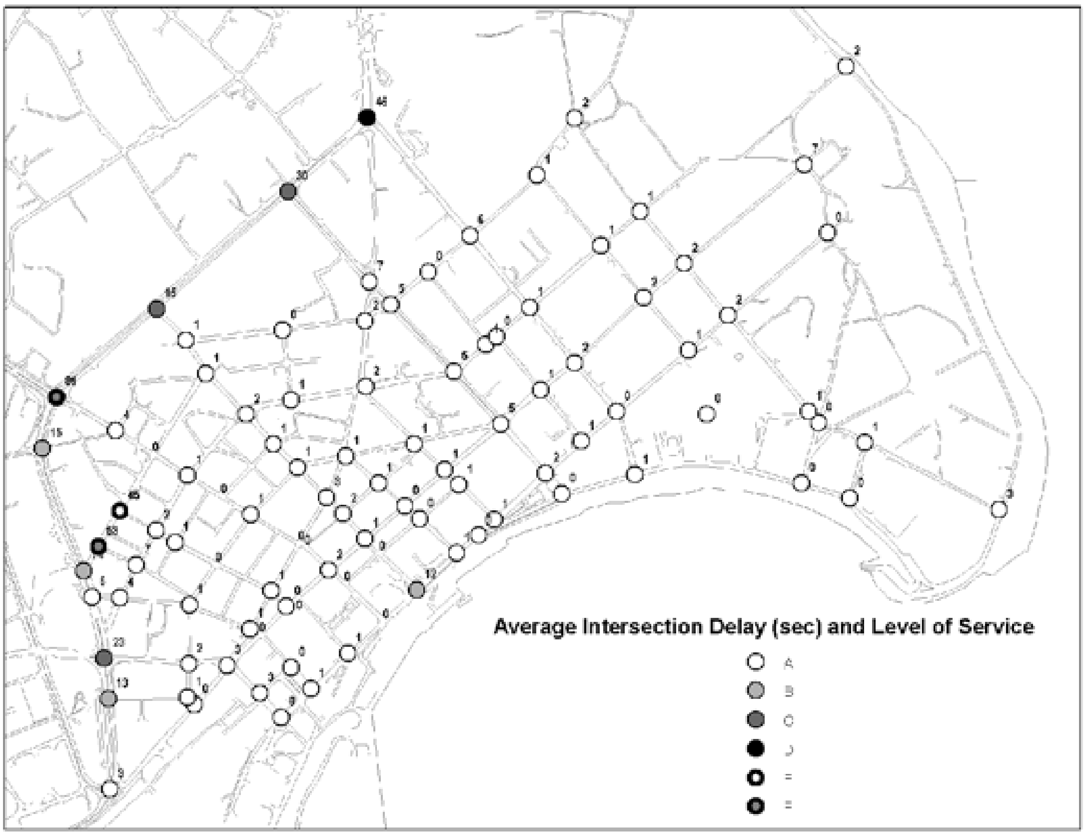
Source: JICA Study Team

Figure 2.4.8 BRT Phase 1 Original Plan - Traffic Volume in 7:00 – 9:00 with 85% Demand of Year 2009

Source: JICA Study Team

Figure 2.4.9 Average Travel Speed in 7:00 – 9:00 of 85% Volume on BRT Base Case Network

Figure 2.4.10 shows the level of service and delay at major intersections. The LOS of the intersection of Bibi Titi Mohamed Rd. and Morogoro Rd. is “F” and almost other intersections on the Bibi Titi Mohamed are also worsen than the existing situation. Libya St. is highly congested street in the city center. This traffic congestion is caused by the outbound traffic made by residence along this street and the through traffic bound for Morogoro Rd.



Source: JICA Study Team

Figure 2.4.10 LOS of Major Intersections in 7:00 – 9:00 of 85% Volume on BRT Base Case Network

The major cause of the gridlock problem in the with-BRT Phase 1 original network plan is insufficient capacity of access roads to the CBD and BRT lanes. The traffic demand in 2009 will increase by 18% of the current traffic demand, while, the number of traffic lanes for the inbound traffic at the boundary of the city center decreases as shown in Table 2.4.2. As the results, almost of intersections along the Bibi Titi Mohamed Rd. will be over saturated and a considerable number of vehicles will not be able to enter the city center in morning peak hour within an expected time duration.

The total number of lanes at the BRT section is the same with the existing case, while the traffic volume crossing the section will increase in the future, accordingly the volume-capacity ratio will be worsen than the current situation.

The other problem is introducing of one-way system on major streets in the city center. In general, one-way system enables to increase capacity of streets by increasing travel speeds. However, in case of CBD, which is in fact a small area having narrow streets, one-way system makes uneconomic detour and increase travel distance and travel time. The longer travel distance and travel time means increase of on-street running vehicles, which causes traffic congestion.

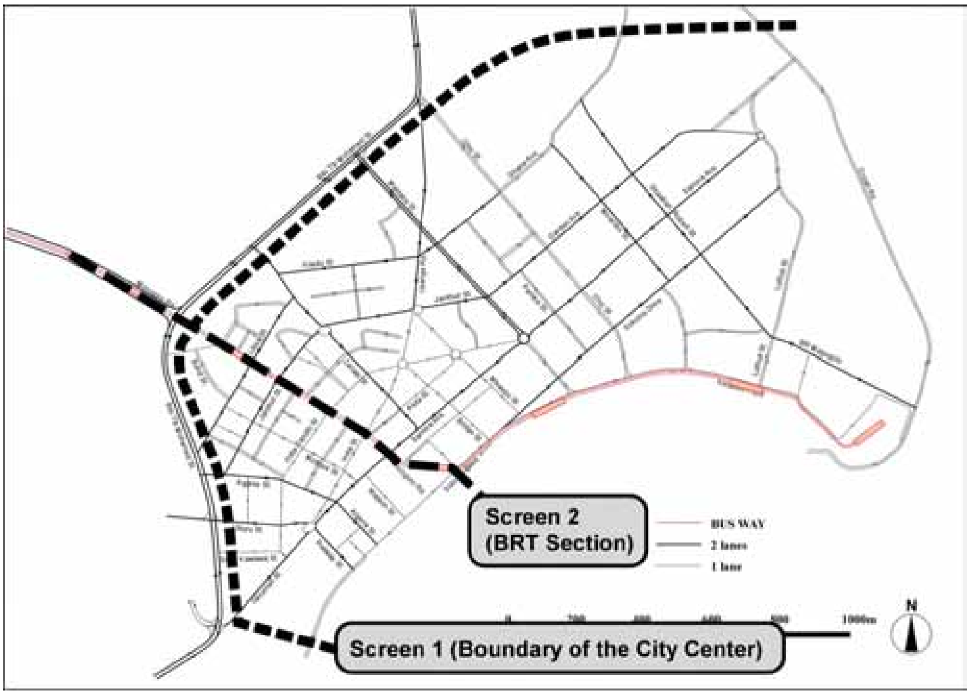


Figure 2.4.11 Screen Line in the City Center

Table 2.4.2 Traffic Demand and Lanes in the Morning Peak Hour at Screen 1

	Existing Case			BRT Phase 1 Base Case		
	Number of lanes	Demand (PCU/hour)	Volume / hour / lane	Number of lanes	Demand (PCU/hour)	Volume / hour / lane
Inbound	13	6,648	511	12	7,834	652
Outbound	13	4,126	317	14	4,303	307

Source: JICA Study Team

Table 2.4.3 Traffic Demand and Lanes in the Morning Peak Hour at Screen 2

	Existing Case			BRT Phase 1 Base Case		
	Number of lanes	Demand (PCU/hour)	Volume / hour / lane	Number of lanes	Demand (PCU/hour)	Volume / hour / lane
Eastbound	7	3,531	504	7	3,863	552
Westbound	7	1,780	254	7	252	307

Source: JICA Study Team

2.5 Minor Improvement Case with BRT Phase 1

2.5.1 Concept and Improvement Point

The most critical problem of with-BRT Phase 1 case is insufficient capacity of roads forming the boundary of the city center: severe traffic congestion at the intersections along the Bibit Titi Mohamed Rd. is anticipated.

In order to improve the road capacity at the peripheral area of the city center and to maintain smooth traffic flow inside of the city center, following minor modifications were considered as the "Minor improvement case":

- Two-lane right-turn intersections to increase inbound traffic capacity on Bibi Titi Mohamed Rd. at the intersections with Maktaba St. and Ohio St.
- Turnaround of one-way at Upang St. between Ohio St. and Maktaba St.
- Installation of traffic signals at the intersection of Bibi Titi Mohamed Rd. with Samora Ave.
- Removal of Askari monument roundabout and installation of traffic signal.
- Removal of roundabout at clock tower (non-signalized intersection).
- Installation of traffic signal at the intersection of Maktaba St. with Ghana Ave. and Garden Ave.
- Two-way street operation in the eastside area of Ohio St.

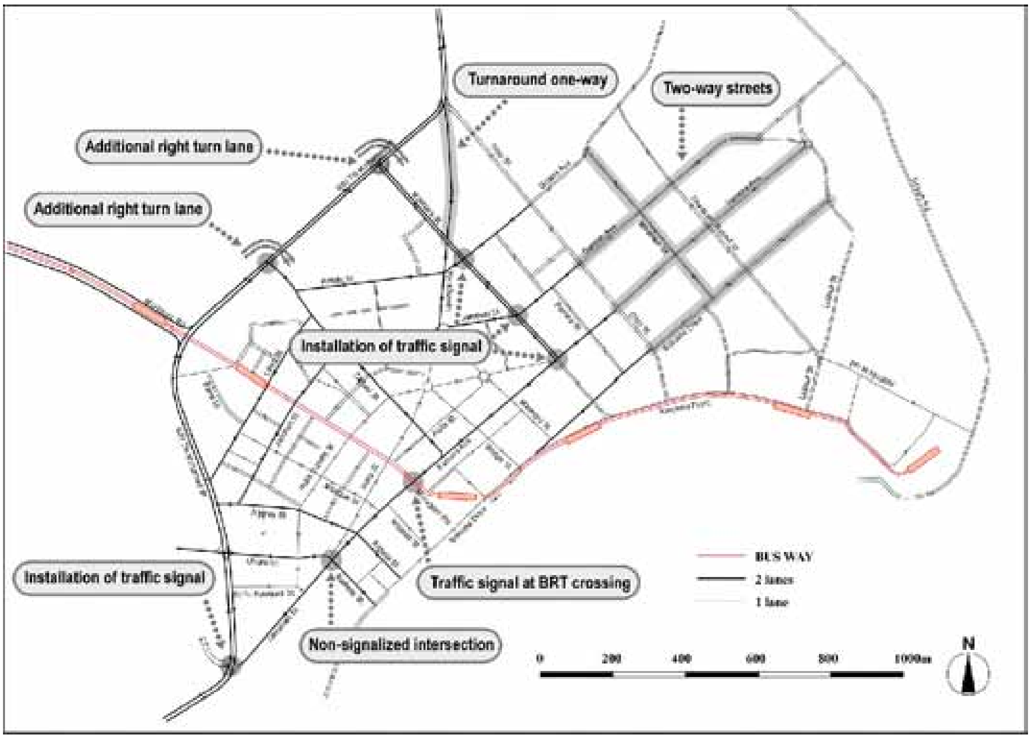


Figure 2.5.1 Modifications as Minor Improvement

2.5.2 Evaluation of Minor Improvement Case

Table 2.5.1 shows a summary of the simulation of the Minor Improvement Case. An average travel distance in this case is same with the BRT Phase 1 Base case, but the average delay is improved slightly. This minor improvement case shows a slightly better performance in comparison with the BRT Phase 1 Base Case.

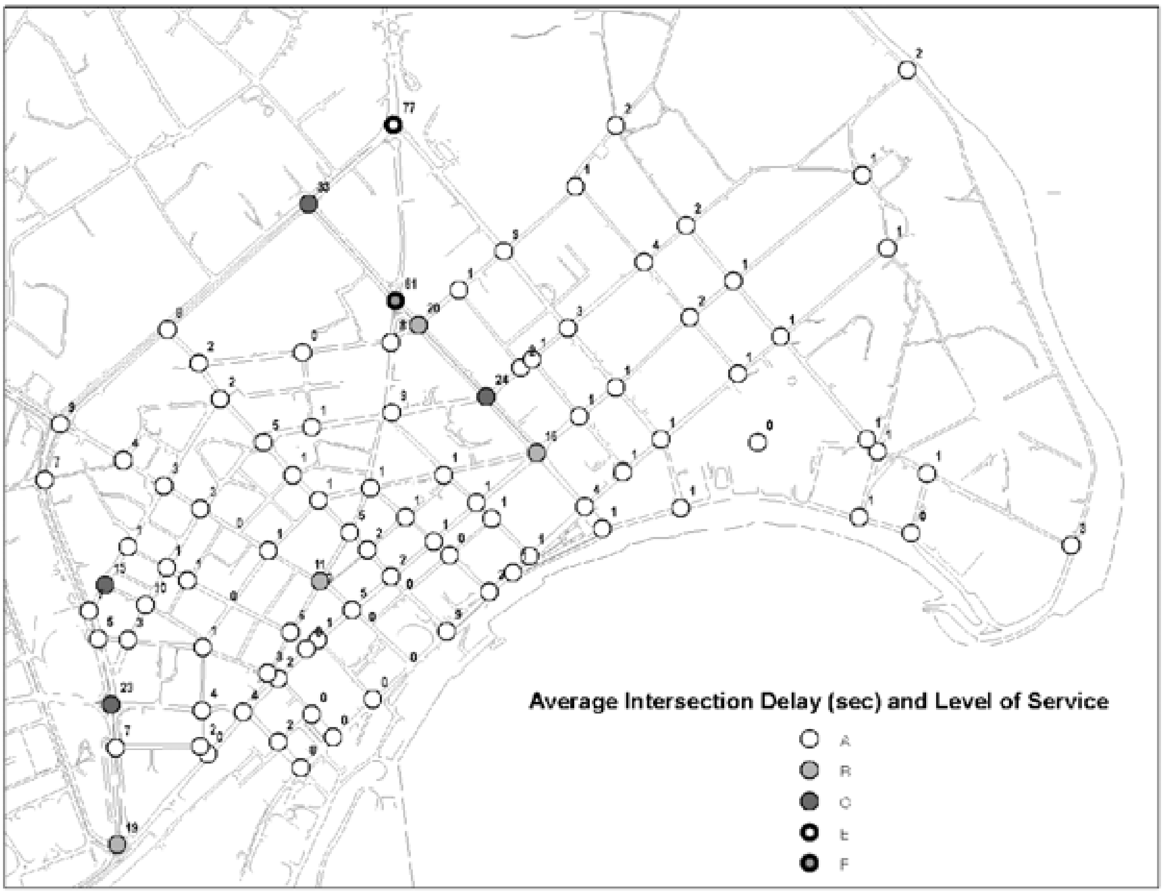
Table 2.5.1 Results of Simulation in 7:00 – 9:00

	Existing Case (2007)	BRT phase1 Base Case (85% volume)	Minor Improved Case (85% volume)
Number of Vehicles	22,424	21,037	20,407
Total Distance Traveled (km)	45,392	45,851	44,649
Average Distance Traveled (km)	2.02	2.18	2.18
Total Travel Time (hour)	1,638	1,905	1,833
Average Travel Time (min)	4.38	5.43	5.38
Average Network Speed (km/h)	27.7	24.1	24.4
Total Network Delay (hour)	485	730	688
Average Delay (min)	1.30	2.08	2.02

Note: Above figures are taking into account only vehicles that reached their destinations.
Source: JICA Study Team

Because of the capacity enhancement at the two entrance points to the city center, a considerable traffic will flow into the Maktaba St. and Ohio St. As the results, traffic congestion is observed at intersections along these two streets inside CBD.

By applying the Minor Improvements, the traffic congestion points at the boundary of the city center will be improved, however, it can be said that the congested points will just shift from the entrance points to the inside area of the city center. It clearly suggests that the future problem cannot be solved by just enhancing the capacity at the entrance points of the city center, and at the same time, the capacity of the street system inside the city center should be improved.



Source: JICA Study Team

Figure 2.5.2 LOS of Major Intersections in 7:00 – 9:00 of 85% Volume on Minor Changed Network

2.6 Traffic Management Improvement Plan

2.6.1 Principal Improvement Concept and Alternatives

Principal concepts in considering the future street and traffic circulation system in the city center with BRT Phase 1 operation are:

i) To maintain high mobility and accessibility by shorter travel distances for all drivers and avoiding long detour, and

ii) To achieve the most efficient (capacity increase) and economical utilization of the existing street by some minor improvements such as removal of on-street parking, signalization of intersection and widening of some designated streets.

Based on these two concepts, several test networks for the simulation are prepared. After a million of simulation works of possible ideas, one recommendable idea has been as shown in Figure 2.6.1. The major improved points are;

i) Improvement of Ohio St. intersection with Bibi Titi Mohamed St. including connection of

Upanga St. to the intersection of Ali Hassan Mwinyi Rd.

ii) Connection Jamhuri St. to Garden Ave.

iii) Connection BR Magogoni St. to Shaaban Robert St.

iv) One way system at Railway St. and Algeria St.

v) Removal of on-street parking and obtain two lane street at India St., Indira Gandhi St., Mosque St. and a part of Sokoine Drive.

vi) Improvement of intersections with traffic signal as shown in Figure 2.6.2 and 2.6.3.

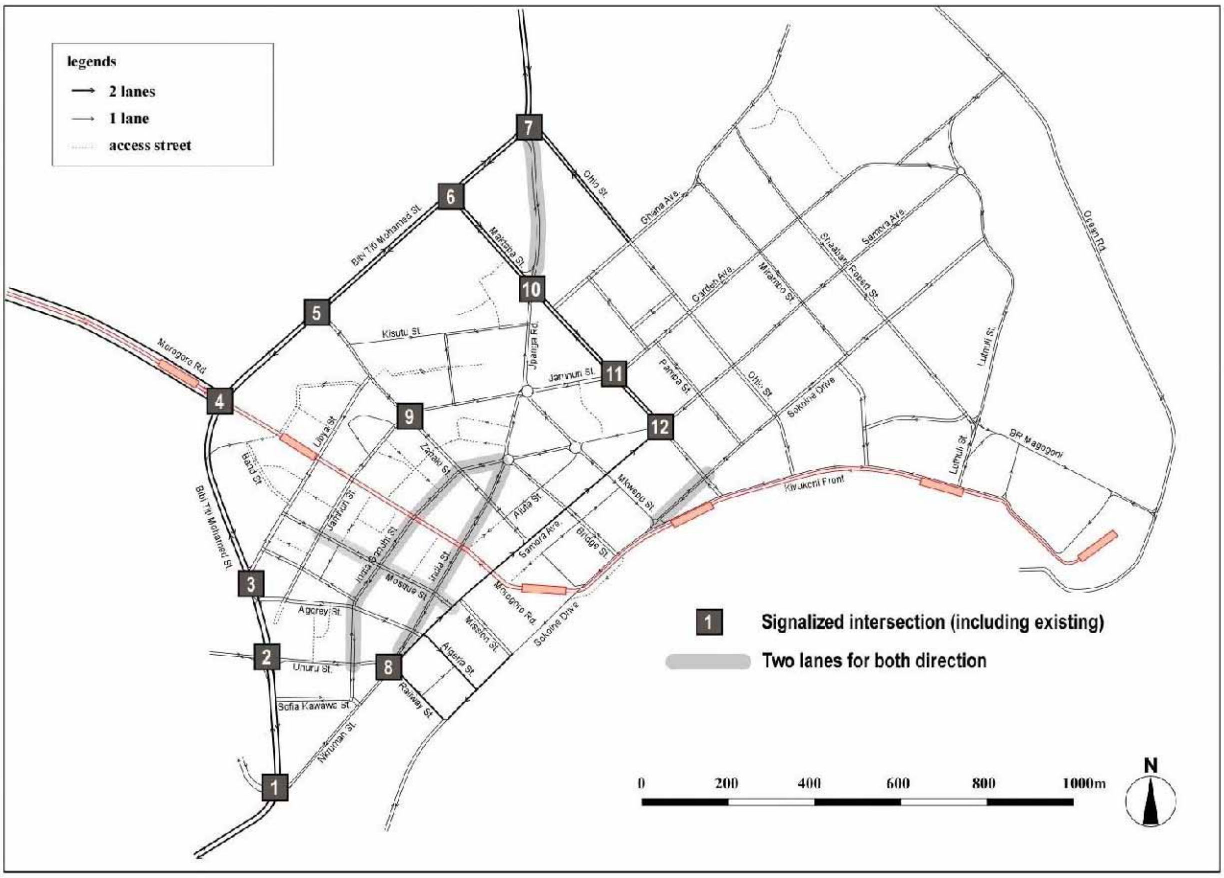


Figure 2.6.1 Improvement Point

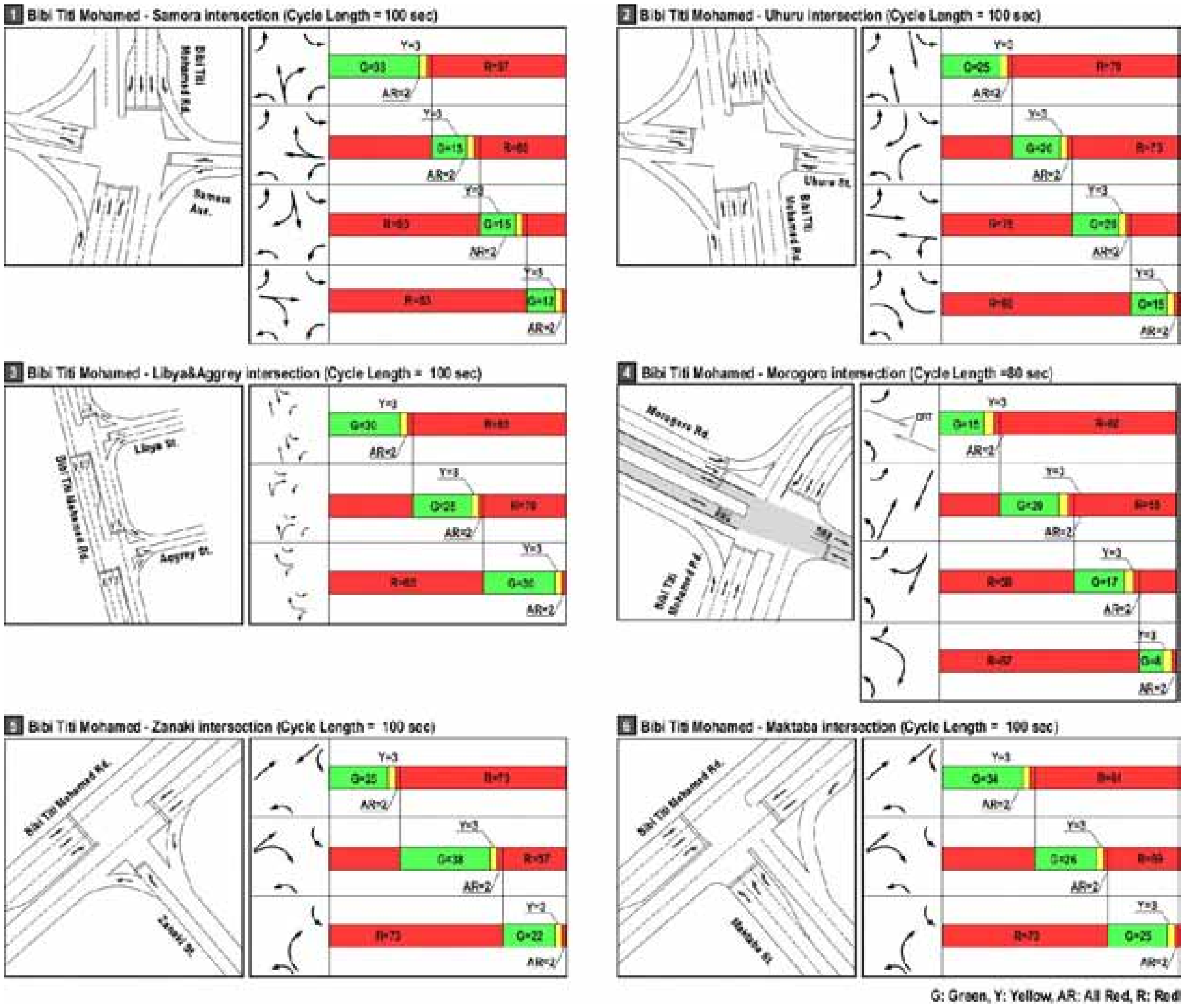


Figure 2.6.2 Intersection Improvement Plan (Morning peak)

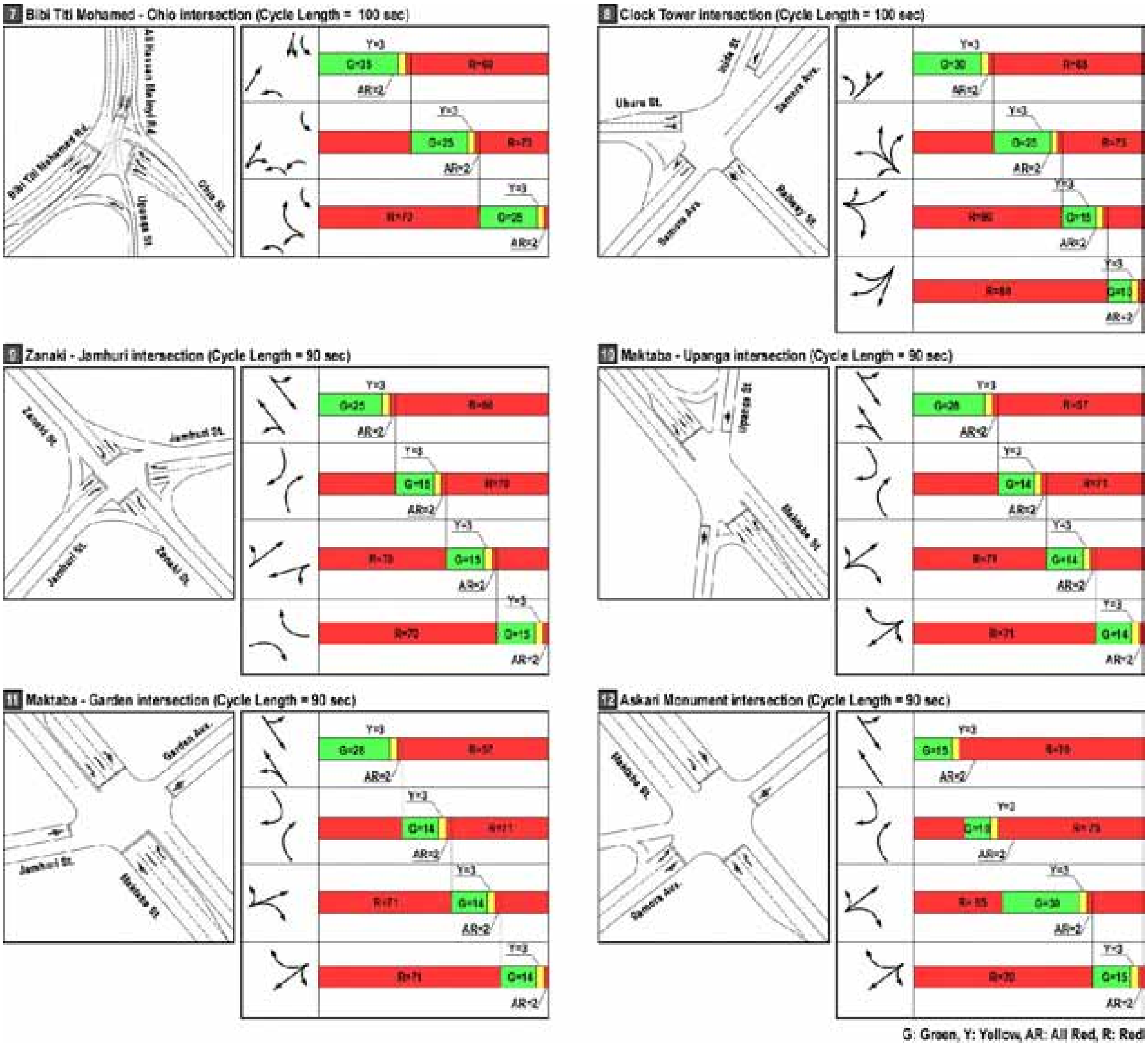


Figure 2.6.3 Intersection Improvement Plan (cont'd)

Dala dala route for this case is based on the original BRT phase 1 plan and modified as shown in Figure 2.6.4. The existing Posta dala dala route will touch BRT at the Old Posta station and the existing Kivukoni route at Kivukoni terminal. The operation of these modified routes and other routes are same with the BRT phase 1 original plan.

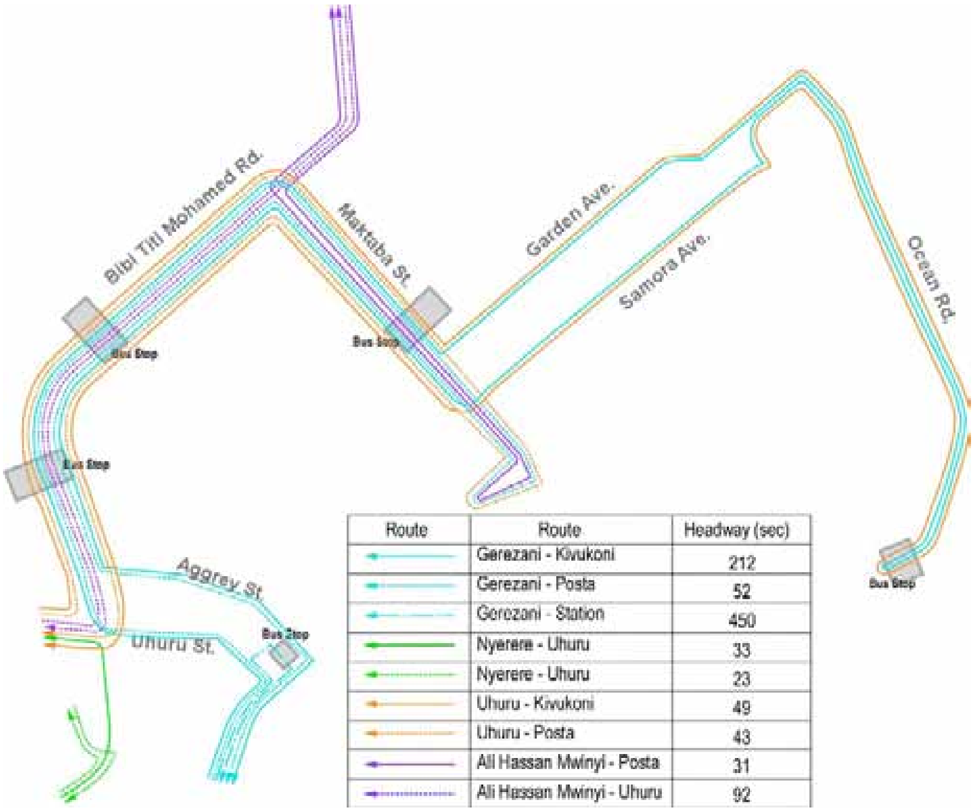


Figure 2.6.4 Dala dala Basic Routes

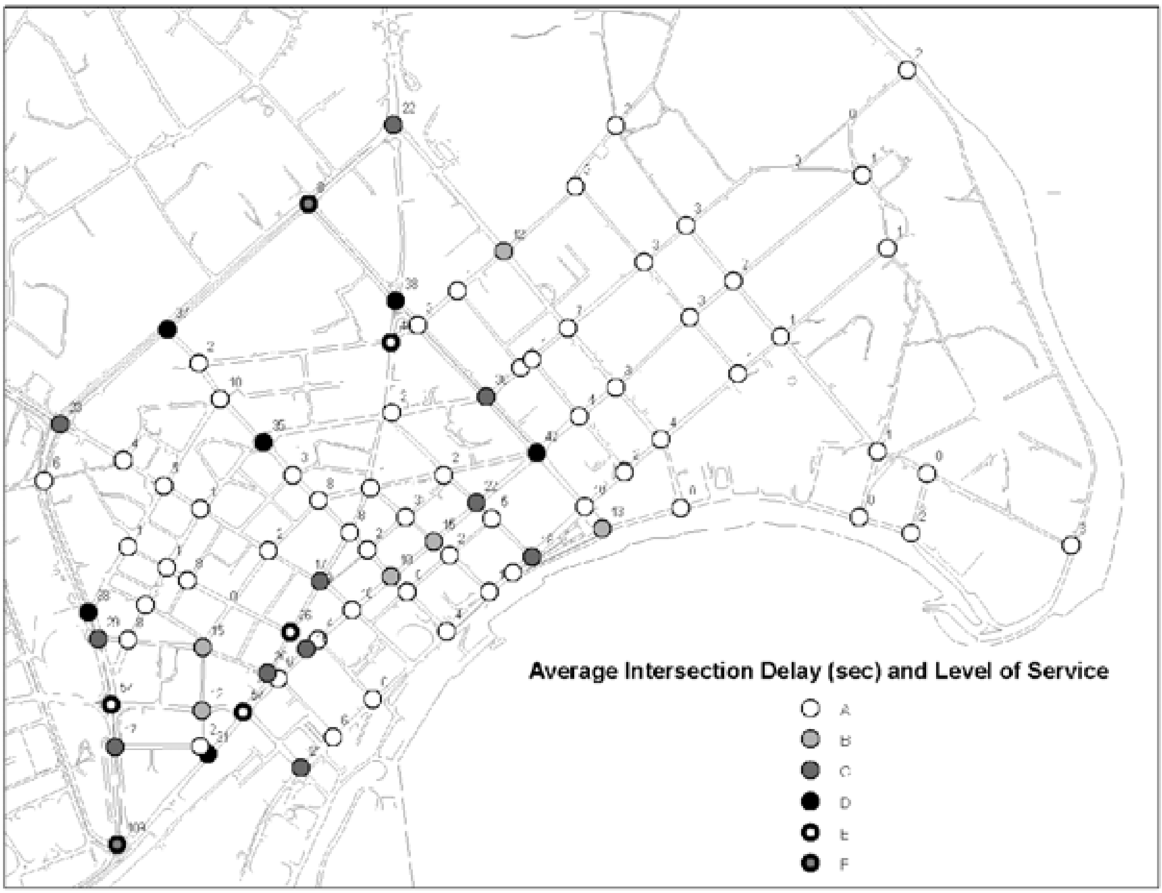
2.6.2 Evaluation of the improved case and further consideration

Table 2.6.1 shows results of the microscopic simulation for an improved case and other cases. The improved case can accommodate 100% of the demand in the morning peak hours from 7:00 to 9:00 including BRT, however, the average travel time and delay is longer than the current traffic condition. As shown in Figure 2.6.5, level of service at most of major intersections in western area of CBD are less than level "C".

Table 2.6.1 Results of Simulation in 7:00 – 9:00

	Existing Case (2007)	BRT phase1 Base Case (loading 85% of the demand)	Minor Improved Case (loading 85% of the demand)	Improved Case (loading 100% of the demand)
Number of Vehicles	22,424	21,037	20,407	24,011
Total Distance Traveled (km)	45,392	45,851	44,649	49,430
Average Distance Traveled (km)	2.02	2.18	2.18	2.06
Total Travel Time (hour)	1,638	1,905	1,833	2,635
Average Travel Time (min)	4.38	5.43	5.38	6.58
Average Network Speed (km/h)	27.7	24.1	24.4	18.8
Total Network Delay (hour)	485	730	688	1,371
Average Delay (min)	1.30	2.08	2.02	3.43

Note: Above figures are taking into account only vehicles that reached their destinations.
Source: JICA Study Team



Source: JICA Study Team

Figure 2.6.5 LOS of Major Intersections in 7:00 – 9:00 of Improved Network

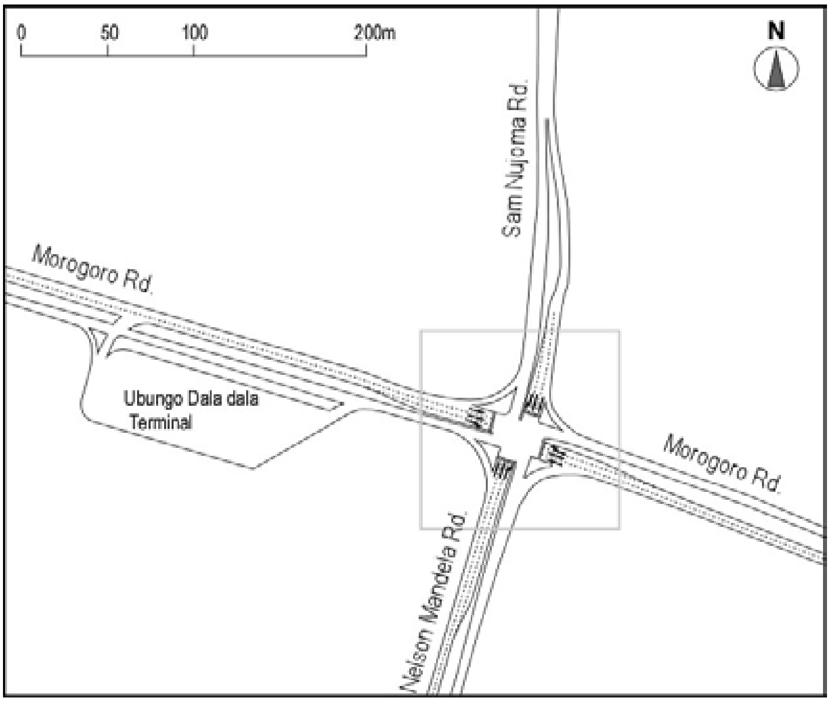
The result indicate that the passenger car traffic demand should be controlled at the level of 85% of the total passenger car demand in 2009 in order to maintain the current level of services. Otherwise considerable road improvement is required. The implementation of further road improvement such as road widening, however, is very difficult in a short term because of difficulties of land acquisition and other difficult factors in CBD. Therefore, use of (passenger car) traffic demand management technique is desirable with substantial development of public transport systems and associated pedestrian facilities. Detailed discussion on the traffic demand management is available in Technical Report 2.

Chapter 3 Ubungo Intersection Analysis

3.1 Current Traffic Condition

(1) Current Configuration of Intersections and Traffic Signal

Figure 3.1.1 shows the existing configuration of Ubungo intersection and its vicinity. Currently, composition of inflow traffic of each leg is consisted of two straight lanes and one lane for right turn. Dala dala terminal is located in close vicinity to this intersection to/from which the existing dala dala buses run through the Morogoro Rd.

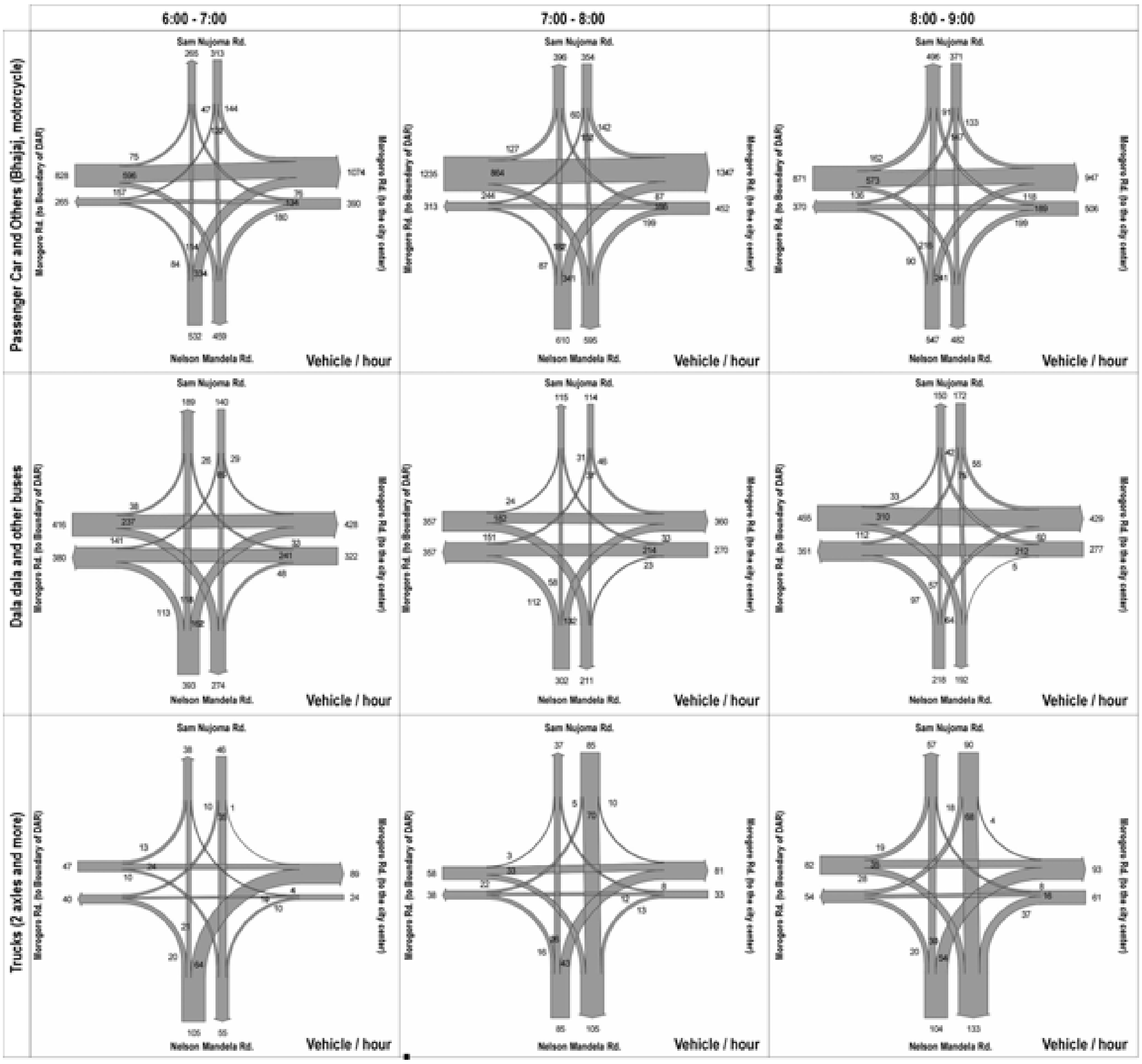


Source: JICA Study Team

Figure 3.1.1 Existing Configuration of Ubungo Intersection

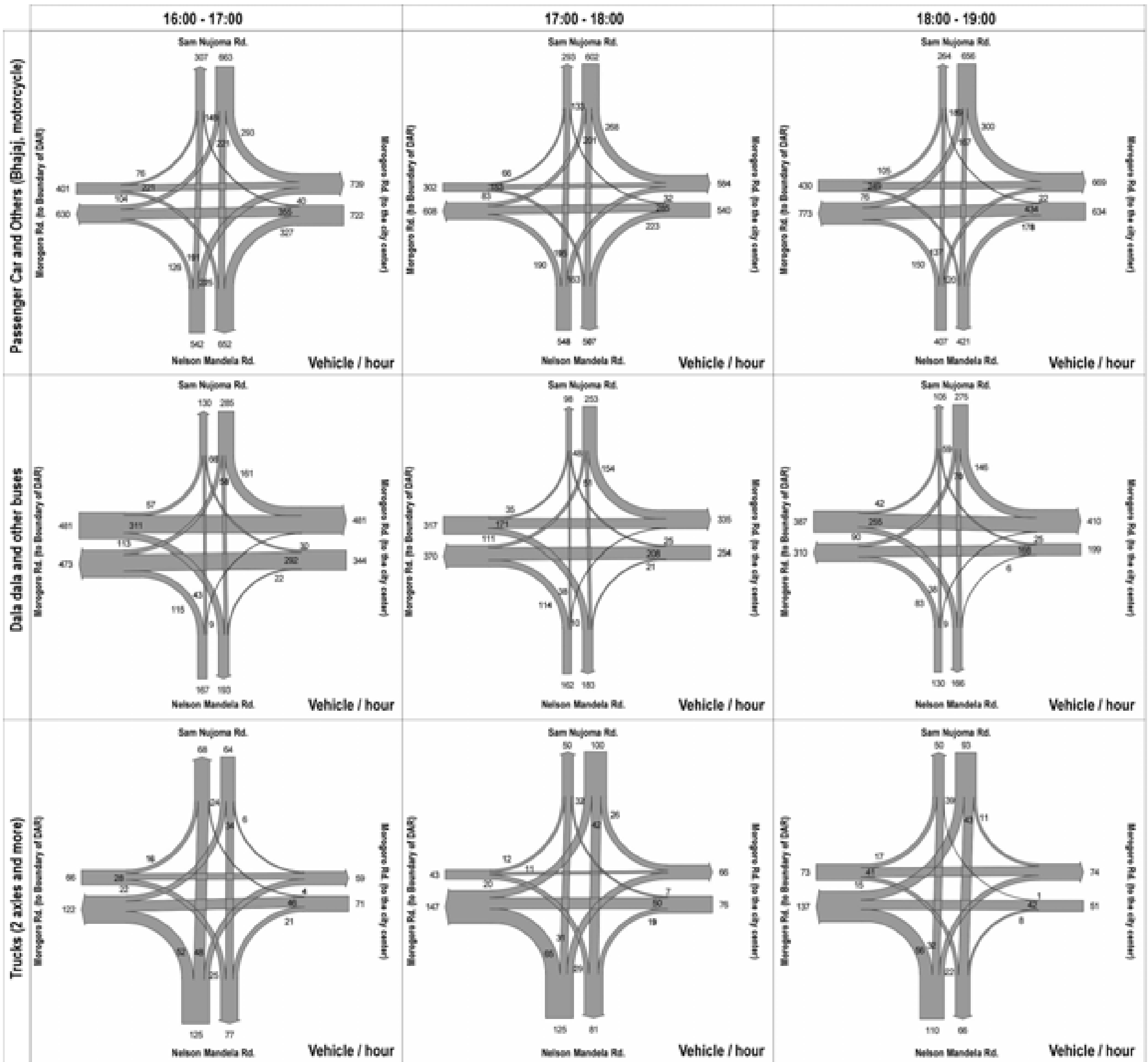
(2) Traffic Volume

Figure 3.1.2 and 3.1.3 show the current traffic volume at the Ubungo intersection in the morning and evening peak periods respectively. In the morning, major traffic flow is from Kimara to the city center, however, the traffic flow from the Nelson Mandela Rd. to the city center and from Kimara to the Nelson Mandela are not negligible volume. Sam Nujoma Rd. was under construction when the traffic count survey was conducted, therefore, the traffic volume is not remarkable. In the evening peak hour, the largest traffic flow is from the city center to Kimara, however, the traffic volume is not considerable in comparison with morning peak hour.



Source: JICA Study Team

Figure 3.1.2 Existing Traffic Volume in Morning Peak Hour



Source: JICA Study Team

Figure 3.1.3 Existing Traffic Volume in Evening Peak Hour

(3) Traffic Signal

Traffic flow control of this intersection is conducted by traffic polices in morning and evening peak periods currently. Based on the current traffic volume count data under the traffic police manual operation, a saturation level of this intersection is calculated as shown in Table 3.1.1 and 3.1.2, which suggest under utilization of the intersection capacity. In the morning peak hour, this intersection is almost saturated under the current signal operation consisting of combination of each opposite maneuvers (4 phases). It is suggested to combine a straight and right-turning phase into one phase (see Phase Pattern 2 in Table 3.1.1 and 3.1.2). As calculated in Table 3.1.1 and 3.1.2, the degree of saturation can be decreased by this phasing improvement.

For the further analysis, the existing traffic control is optimized as shown in Figure 3.1.4 as the base case.

Table 3.1.1 Traffic Signal Saturation in Morning Peak Hour

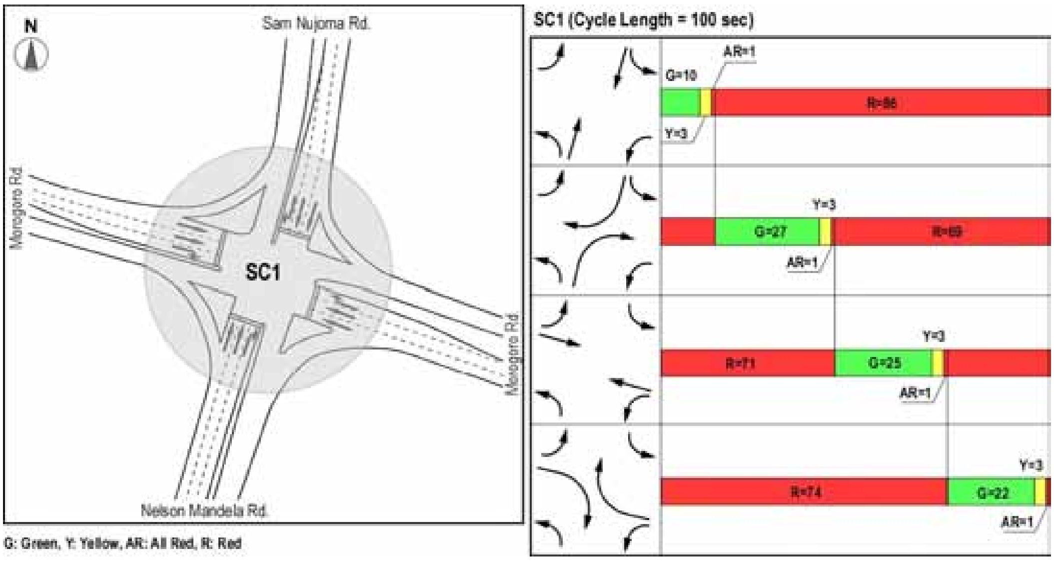
Period: AM Peak (6:45 - 7:45)

Approach	1			2			3			4				
	Sam Nujoma Rd			Morogoro Rd.			Nelson Mandela Rd.			Morogoro Rd.				
				From City Center						From DAR border				
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT		
Basic value of saturation flow rate	1800	2000	1800	1800	2000	1800	1800	2000	1800	1800	2000	1800		
Number of lane	1	2	1	1	2	1	1	2	1	1	2	1		
Lane width (m)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0		
and adjustment factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
Share of bus (%)	22.9%	19.0%	34.4%	11.4%	57.9%	24.2%	50.9%	34.3%	28.1%	24.2%	19.8%	37.2%		
and adjustment factor	0.96	0.96	0.94	0.98	0.90	0.95	0.91	0.94	0.95	0.95	0.96	0.93		
Share of truck (%)	3.2%	19.0%	8.9%	6.2%	3.1%	6.8%	8.4%	10.2%	8.8%	5.4%	2.5%	4.8%		
and adjustment factor	0.97	0.84	0.92	0.94	0.97	0.94	0.92	0.91	0.92	0.95	0.98	0.95		
Share of left turn (%)														
and adjustment factor														
Share of right turn (%)														
and adjustment factor														
Saturation flow ratio	1668	3238	1547	1658	3476	1607	1507	3396	1566	1630	3753	1599		
Total traffic volume (vehicle/hour)	188	263	90	211	382	132	214	254	545	149	1069	417		
- Passenger Cars	135	163	51	174	149	91	87	141	344	105	830	242		
- Dala dala and buses	43	50	31	24	221	32	109	87	153	36	212	155		
- 2 axles Trucks	5	22	4	11	10	9	10	14	31	8	21	12		
- 3 and more axles	1	28	4	2	2	0	8	12	17	0	6	8		
- Others	5	15	3	5	0	3	1	21	42	10	39	9		
Flow ratio	0.113	0.081	0.058	0.127	0.110	0.082	0.142	0.075	0.348	0.091	0.285	0.261	λi	Σλ
Phase ratio phase1		0.081						0.075					0.081	0.975
phase2			0.058						0.348				0.348	
phase3					0.110						0.285		0.285	
phase4						0.082						0.261	0.261	
Required Green phase1		7						7						
phase2			30						30					
phase3					25						25			
phase4						22						22		
Current Cycle Length	100													
Capacity	1,668	227	464	1,658	869	354	1,507	238	470	1,630	938	352		
V/C	0.122	1.536	0.234	0.141	0.505	0.423	0.172	1.343	1.413	0.105	1.248	1.361		
Phase Pattern 2														
Flow ratio	0.113	0.081	0.058	0.127	0.110	0.082	0.142	0.075	0.348	0.091	0.285	0.261	λi	Σλ
Phase ratio phase1		0.081	0.058										0.081	0.824
phase2											0.285	0.261	0.285	
phase3								0.075	0.348				0.348	
phase4					0.110	0.082							0.110	
Required Green phase1		7	7											
phase2											25	25		
phase3								30	30					
phase4					9	9								
Cycle Length	100													
Capacity	1,668	227	464	1,658	869	354	1,507	238	470	1,630	938	352		
V/C	0.122	1.536	0.234	0.141	0.505	0.423	0.172	1.343	1.413	0.105	1.248	1.361		

Table 3.1.2 Traffic Signal Saturation in Evening Peak Hour

Period: PM Peak (16:15 - 17:15)

Approach	1			2			3			4				
	Sam Nujoma Rd			Morogoro Rd.			Nelson Mandela Rd.			Morogoro Rd.				
				From City Center						From DAR border				
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT		
Basic value of saturation flow rate	1800	2000	1800	1800	2000	1800	1800	2000	1800	1800	2000	1800		
Number of lane	1	2	1	1	2	1	1	2	1	1	2	1		
Lane width (m)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0		
and adjustment factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
Share of bus (%)	35.4%	19.7%	29.3%	5.5%	39.9%	46.9%	38.0%	14.6%	3.7%	39.5%	55.6%	47.8%		
and adjustment factor	0.93	0.96	0.94	0.99	0.93	0.91	0.93	0.97	0.99	0.93	0.90	0.91		
Share of truck (%)	3.4%	12.1%	9.0%	4.7%	8.6%	6.3%	17.6%	15.9%	9.6%	10.9%	5.1%	8.0%		
and adjustment factor	0.97	0.89	0.92	0.96	0.92	0.94	0.85	0.86	0.91	0.90	0.95	0.93		
Share of left turn (%)														
and adjustment factor														
Share of right turn (%)														
and adjustment factor														
Saturation flow ratio	1625	3434	1560	1701	3412	1549	1422	3354	1631	1505	3424	1522		
Total traffic volume (vehicle/hour)	497	290	222	383	619	64	329	315	219	129	487	251		
- Passenger Cars	164	198	137	344	319	30	146	219	190	64	191	111		
- Dala dala and buses	176	57	65	21	247	30	125	46	8	51	271	120		
- 2 axles Trucks	16	28	15	12	36	3	9	26	16	10	19	13		
- 3 and more axles	1	7	5	6	17	1	49	24	5	4	6	7		
- Others	187	32	16	5	10	0	4	9	30	2	8	1		
Flow ratio	0.306	0.084	0.142	0.225	0.181	0.041	0.231	0.094	0.134	0.086	0.142	0.165	λi	Σλ
Phase ratio phase1		0.084						0.094					0.094	0.583
phase2			0.142						0.134				0.142	
phase3					0.181						0.142		0.181	
phase4						0.041						0.165	0.165	
Required Green phase1		14						14						
phase2			21						21					
phase3					26						26			
phase4						24						24		
Current Cycle Length	100													
Capacity	1,625	481	328	1,701	887	372	1,422	470	343	1,505	890	365		
V/C	0.338	0.757	0.823	0.242	0.831	0.200	0.309	0.837	0.778	0.104	0.646	0.819		
Phase Pattern 2														
Flow ratio	0.306	0.084	0.142	0.225	0.181	0.041	0.231	0.094	0.134	0.086	0.142	0.165	λi	Σλ
Phase ratio phase1		0.084	0.142										0.142	0.623
phase2											0.142	0.165	0.165	
phase3								0.094	0.134				0.134	
phase4					0.181	0.041							0.181	
Required Green phase1		21	21											
phase2											24	24		
phase3								19	19					
phase4					26	26								
Cycle Length	100													
Capacity	1,625	481	328	1,701	887	372	1,422	470	343	1,505	890	365		
V/C	0.338	0.757	0.823	0.242	0.831	0.200	0.309	0.837	0.778	0.104	0.646	0.819		



Source: JICA Study Team

Figure 3.1.4 Optimized Signal Phase Based on the Current Traffic Volume (AM Peak Hour)

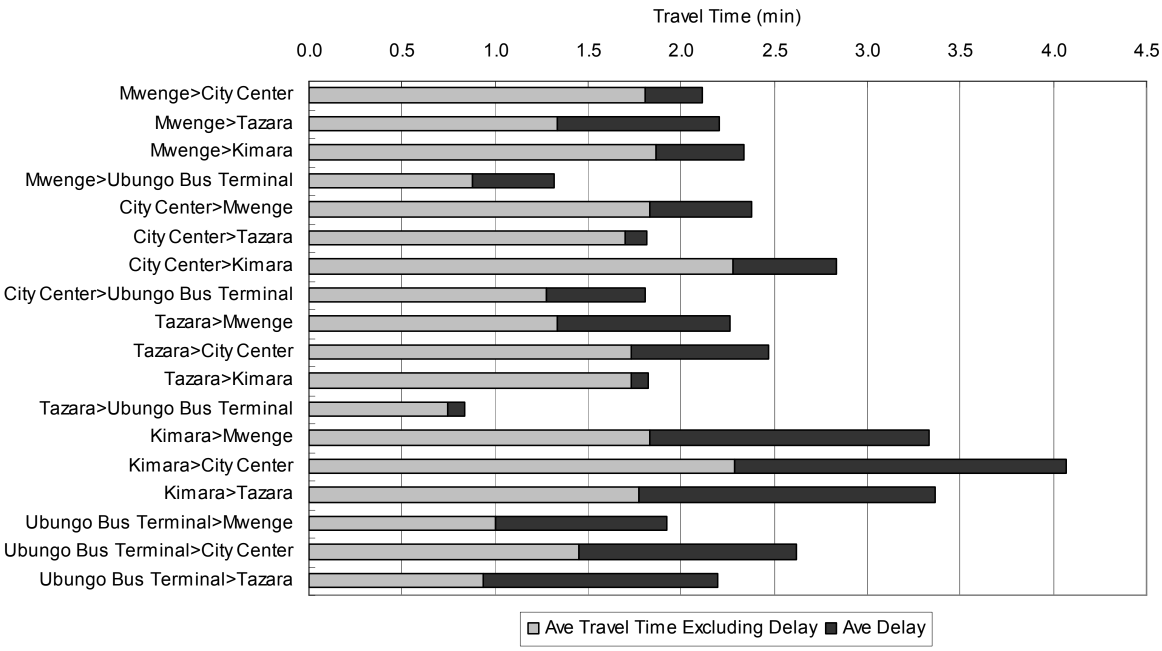
(4) Evaluation of the Current Condition

Table 3.1.3 shows a summary of the microscopic simulation for the current traffic condition. Average delay of all vehicles at the intersection is 32.6 seconds per vehicle and LOS is "C". Figure 3.1.5 shows the average travel time and delay by direction. The traffic from Kimara which indicates the largest traffic volume in the morning peak includes considerable delay more than 1 minute because of shortage of green time at the intersection.

Table 3.1.3 Network Performance in Existing Case in 6:00 – 9:00

Indicators	Existing Case
Number of Vehicles (arrived at destination)	11,071
Total Distance Traveled (km)	17,850
Ave. Travel Distance (km)	1.61
Total Travel Time (hour)	520
Ave. Travel Time (min)	2.82
Ave. Network Speed (km/h)	34.3
Total Network Delay (hour)	180.3
Ave. Delay (min)	0.98

Note: Above figures are taking into account only vehicles that reached their destinations.
Source: JICA Study Team



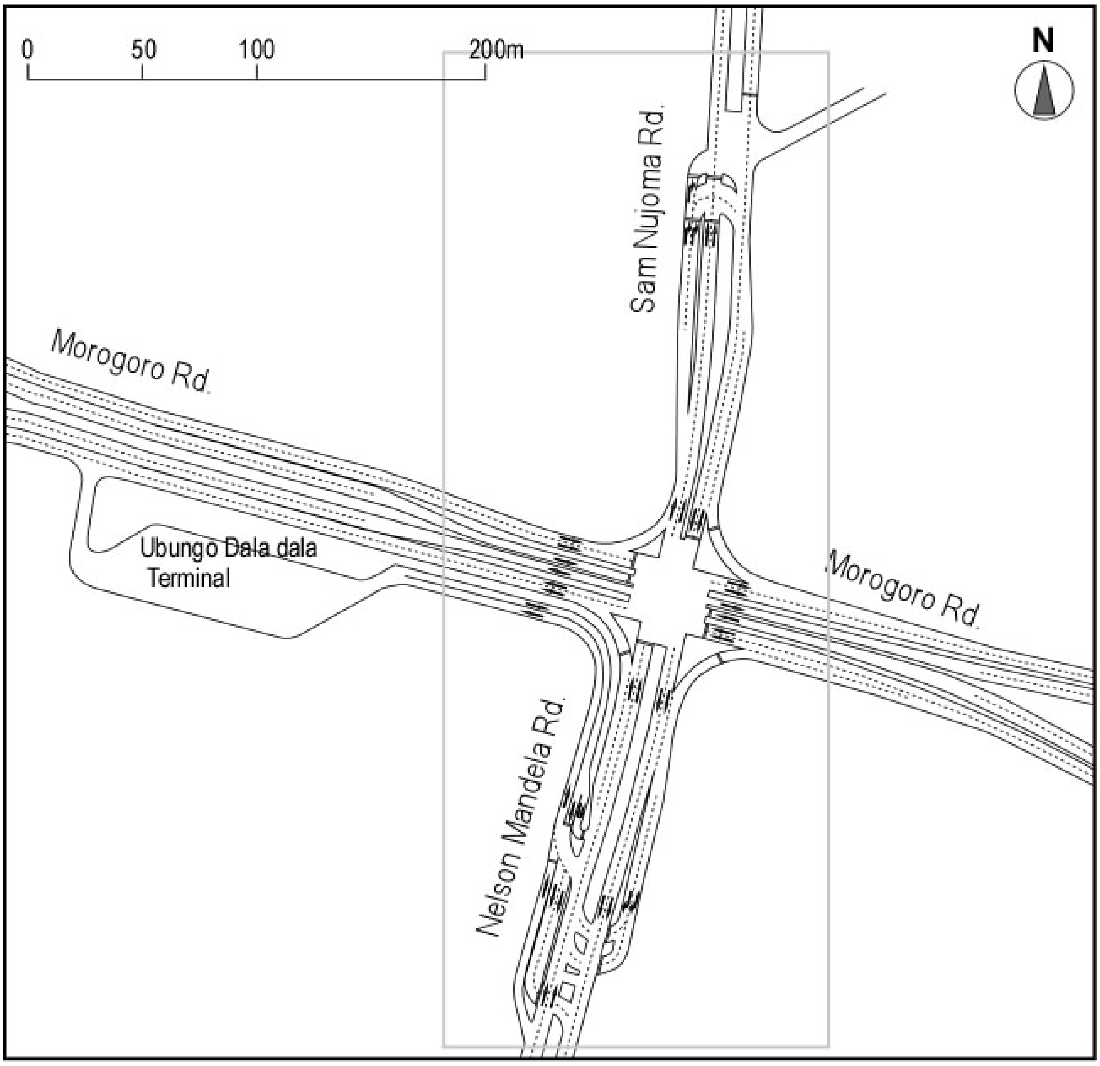
Source: JICA Study Team

Figure 3.1.5 Composition of Average Travel Time by Direction in 6:00 – 9:00

3.2 BRT Phase 1 Original Case

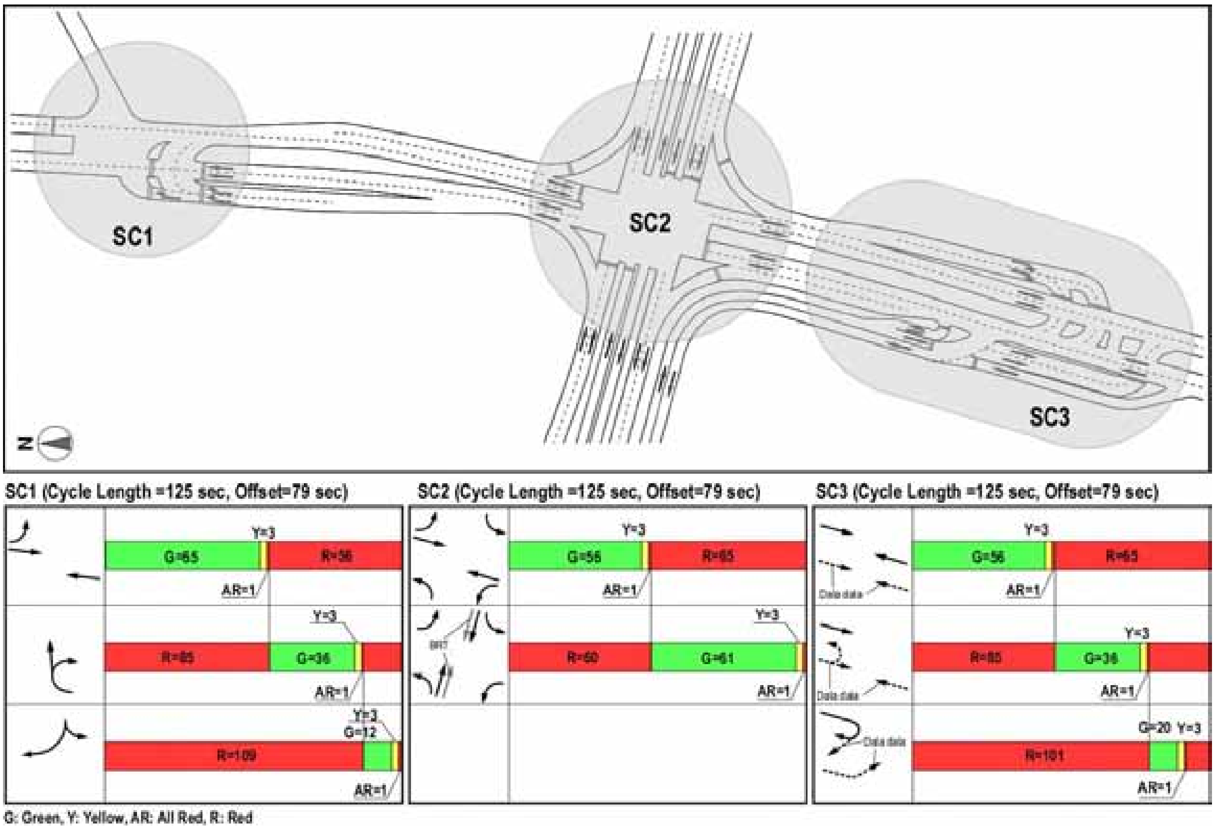
(1) Configuration of Intersections and signals

Ubungo intersection will be improved by the BRT Phase 1 project. According to the phase 1 BRT design, configuration of Ubungo intersection will be significantly changed in order to maximize a benefit of BRT. Any right-turn traffics are forced to make left-turn first at the intersection, then make U-turns at the northern or southern signalized u-tern facilities as shown in Figure 3.2.1. Figure 3.2.2 shows the proposed signal timing of three intersections by phase 1 BRT design.



Source: BRT Phase 1 Design, Logit Consultants (2007)

Figure 3.2.1 New Ubungo Intersection Configuration by BRT Phase 1



Source: BRT Phase 1 Design, Logit Consultants (2007)

Figure 3.2.2 Signal Timing Plan by BRT Phase 1

(2) Estimation of Traffic Volume

In the future, traffic volume passing this important intersection will significantly increase. Especially, after completion of the construction work of Sam Nujoma Rd. the traffic to/from this road will suddenly and sharply increase. However, for the evaluation of BRT Phase 1 configuration as of this report production timing (December 2007), the existing traffic volume data is used temporarily for the simulation purpose except assumptions of dala dala and other buses.

Table 3.2.1 shows the existing dala dala volume at the Ubungo intersection in the morning peak 3 hours per direction based on the information of dala dala routes with the separately conducted headway and traffic count survey at the field.

In the BRT phase 1 case, the existing dala dala services along the Morogoro Rd. will be removed and replaced by the phase 1 BRT. In addition to the BRT, large buses will provide services as a secondary bus system between Nelson Mandela Rd. and Sam Nujoma Rd. The capacity of a secondary bus fleet is assumed to be twice of the existing dala dala, accordingly vehicular traffic volume of the secondary buses becomes a half of the existing dala dala between Nelson Mandela and Sam Nujoma Rd. in the simulation model.

Table 3.2.1 Estimated Dala dala OD Volume at Ubungo Intersection in 6:00 – 9:00

Existing	Sam Nujoma Rd. (Mwenge)	Morogoro Rd. (City Center)	Nelson Mandela Rd. (Tazara)	Morogoro Rd. (Kimara)	Ubungo Terminal	Total
Sam Nujoma Rd. (Mwenge)		123	191	22	74	410
Morogoro Rd. (City Center)	121		73	140	114	448
Nelson Mandela Rd. (Tazara)	215	291		9	289	804
Morogoro Rd. (Kimara)	17	275	8		0	300
Ubungo Terminal	55	223	300	0		578
Total	408	912	572	171	477	2540

In stead of dala dala, 108 secondary buses are included in other buses.

In stead of dala dala, 96 secondary buses are included in other buses.

BRT Phase 1	Sam Nujoma Rd. (Mwenge)	Morogoro Rd. (City Center)	Nelson Mandela Rd. (Tazara)	Morogoro Rd. (Kimara)	Ubungo Terminal	Total
Sam Nujoma Rd. (Mwenge)		123	0	22	74	219
Morogoro Rd. (City Center)	121		73	0	114	308
Nelson Mandela Rd. (Tazara)	0	291		9	289	589
Morogoro Rd. (Kimara)	17	0	8		0	25
Ubungo Terminal	55	223	300	0		578
Total	193	637	381	31	477	1719

Source: JICA Study Team

(3) Evaluation of BRT Phase 1 Configuration

As shown in Table 3.2.2, performance of the simulated network of the BRT Phase 1 configuration becomes worse than the existing one because BRT takes exclusive priority at this intersection. The travel time of through-traffic on the Morogoro Rd., which parallels to BRT, is reduced than the existing as shown in Figure 3.2.3. On the other hand, the delay of other traffic movements become worse, particularly that of the right turn traffic is considerable.

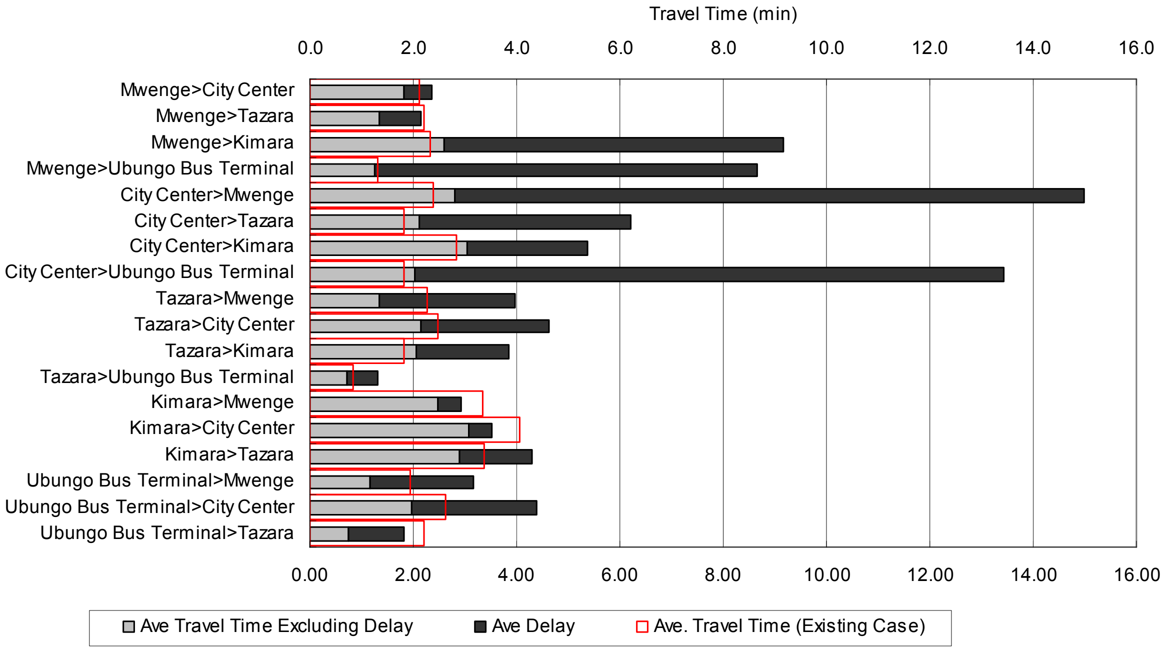
In addition, speed reduction facilities such as humps and safety facilities such as pedestrian crossings will lead to speed reductions of other motor vehicles on Morogoro Rd.

Table 3.2.2 Network Performance in 6:00 – 9:00

	Existing Case	BRT Phase 1 Base Case
Number of Vehicles (arrived at destination)	11,071	10,629
Total Distance Traveled (km)	17,850	18,114
Ave. Travel Distance (km)	1.61	1.70
Total Travel Time (hour)	520	797
Ave. Travel Time (min)	2.82	4.50
Ave. Network Speed (km/h)	34.3	22.7
Total Network Delay (hour)	180.3	383.7
Ave. Delay (min)	0.98	2.17

Note: Above figures are taking into account only vehicles that reached their destinations.

Source: JICA Study Team



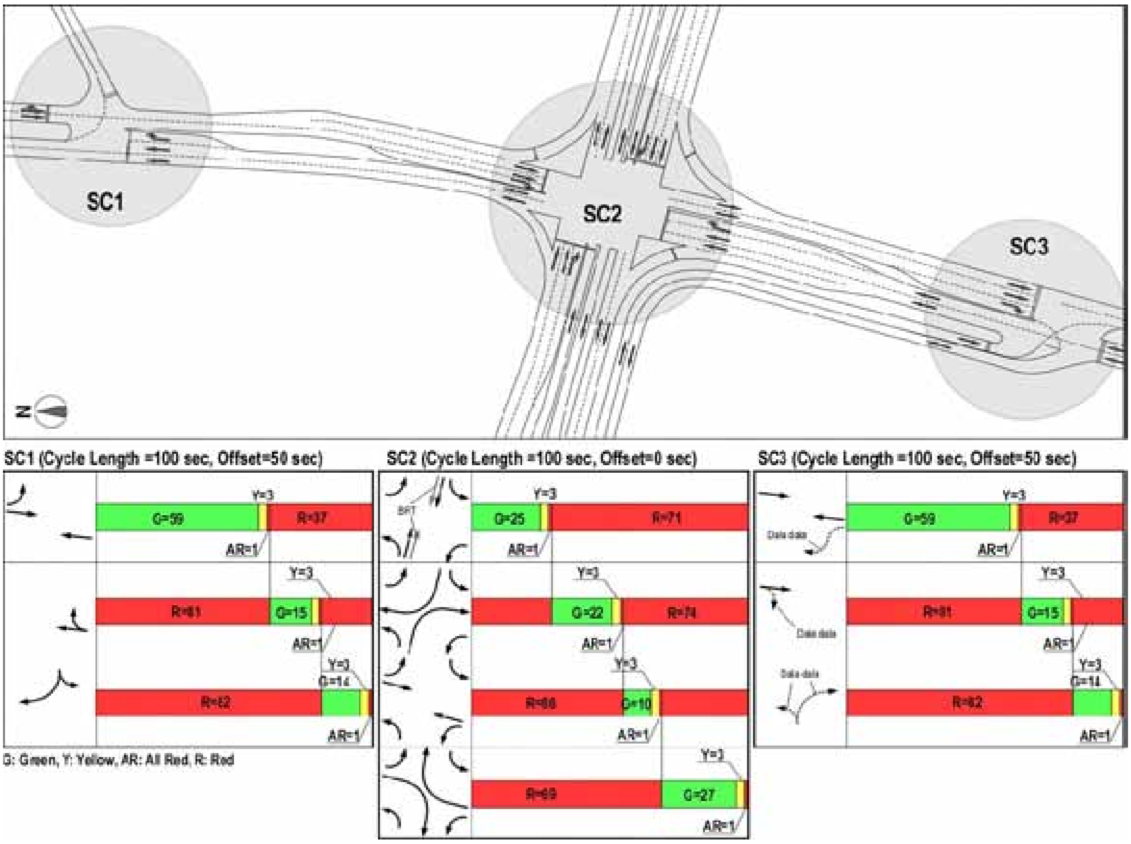
Source: JICA Study Team

Figure 3.2.3 Composition of Average Travel Time by Direction in 6:00 – 9:00

3.3 Possible Improvement: BRT Phase 1 with 4 phase signal

(1) Configuration of Intersections and signals

Figure 3.3.1 shows one of the alternative intersection configurations and signals. In this case, all right-turn movements at the Ubungo intersection are available in each signal phase. In adition, a signalized intersection at the south of Ubungo intersection is placed for dala dala to/from the Ubungo bus terminal.



Source: JICA Study Team

Figure 3.3.1 Alternative Configuration of Ubungo Intersection and Signal Timing Plan

(2) Traffic Volume

Assigned traffic volume (OD data) for evaluation of this case is same as that of BRT Phase 1 original plan.

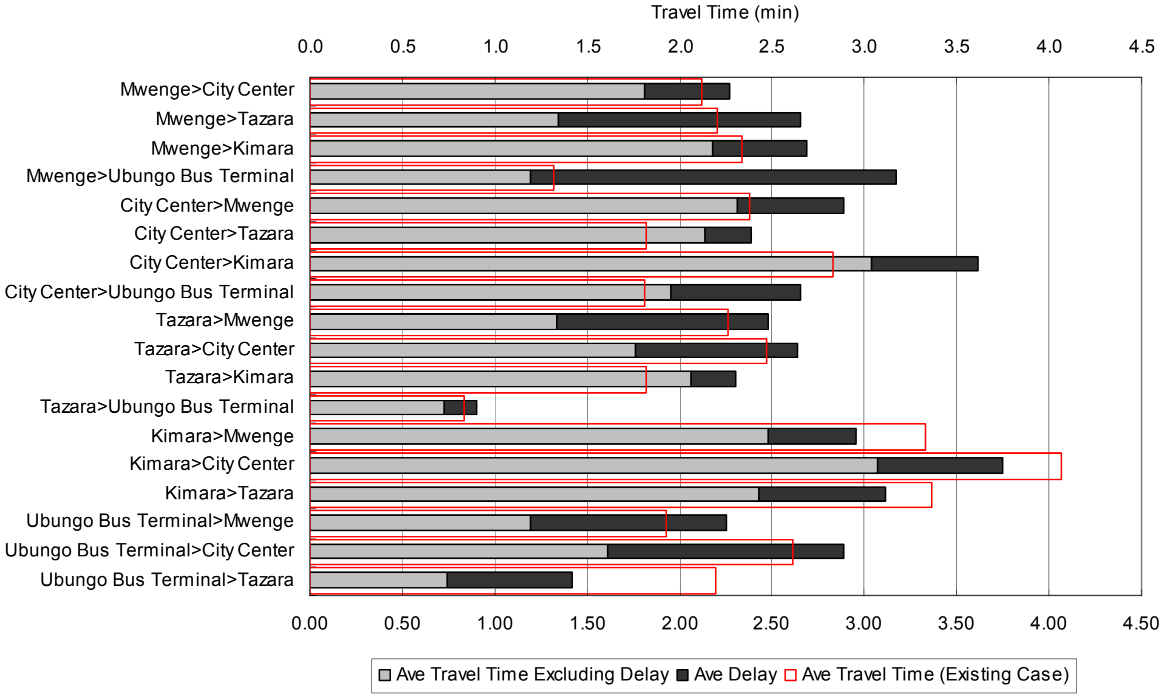
(3) Evaluation

Table 3.3.1 shows the results of simulation. Average delay of "BRT with 4 signal phase case" is shorter than other cases. However, as shown in Figure 3.3.2, a delay time will increase in some movements such as dala dala to/from the Ubungo bus terminal.

Table 3.3.1 Network Performance in 6:00 – 9:00

	Existing Case	BRT Phase 1 Base Case	BRT with 4 phase signal
Number of Vehicles (arrived at destination)	11,071	10,629	10,707
Total Distance Traveled (km)	17,850	18,114	17,319
Ave. Travel Distance (km)	1.61	1.70	1.62
Total Travel Time (hour)	520	797	524
Ave. Travel Time (min)	2.82	4.50	2.94
Ave. Network Speed (km/h)	34.3	22.7	33.0
Total Network Delay (hour)	180.3	383.7	126.6
Ave. Delay (min)	0.98	2.17	0.71

Note: Above figures are taking into account only vehicles that reached their destinations.
Source: JICA Study Team



Source: JICA Study Team

Figure 3.3.2 Composition of Average Travel Time by Direction in 6:00 – 9:00

As shown in Table 3.3.2, the performance of BRT proper in the original case is better than that of 4 phase signal case because priority is given to BRT. The speed of BRT will be reduced from 16.6km in the original case to 16.0km in the 4 phases case and the travel time running the simulated network will increase from 5.7 minutes to 5.9 minutes respectively. Since the difference in the BRT operation performance between the original case and the 4 phases might be small as suggested by the simulation, it can be recommended to apply a simple 4 phases operation with some intersection configuration first. However, this analysis here is made based on the existing traffic volume, further investigation will be necessary by considering future traffic demand passing this intersection.

Table 3.3.2 Performance of BRT in 6:00 – 9:00

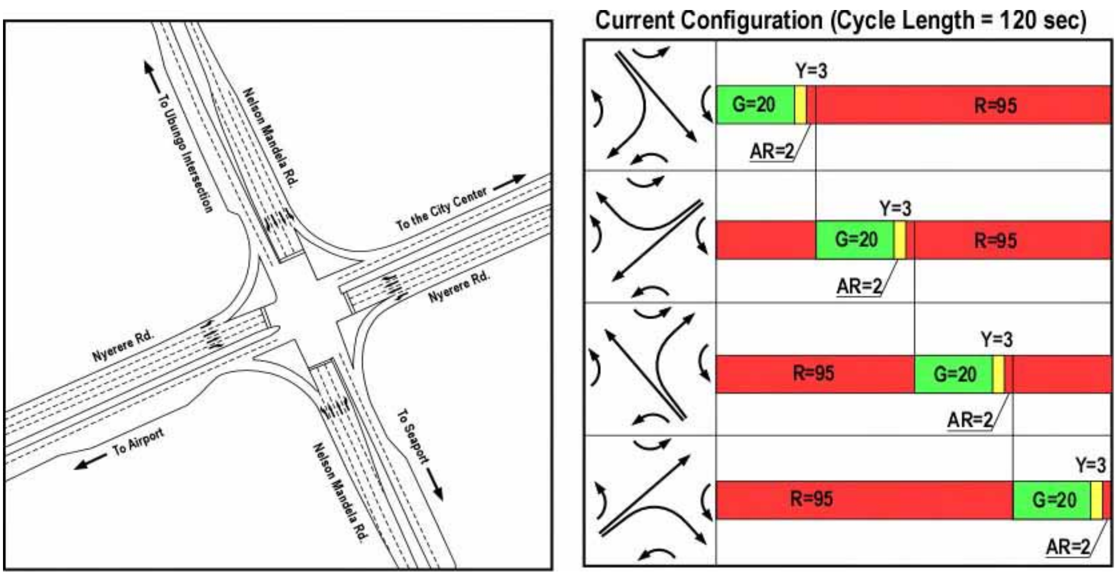
	BRT Phase 1 Base Case	BRT with 4 phase signal
Ave. Travel Time (min)	5.7	5.9
Ave. Travel Speed (km/h)	16.6	16.0
Ave. Delay (min) including stopping at stations	1.26	1.47

Chapter 4 Tazara Intersection Analysis

4.1 Current Traffic Condition

(1) Current Configuration of Intersection and Traffic Signal

Tazara intersection is located on the crossing of Nyerere Rd. and Nelson Mandela Rd. as shown in Figure 4.1.1. An independent traffic signal system has been installed at this intersection, but without fine-tuning, accordingly it is necessary for traffic polices to control the traffic in peak periods at present.



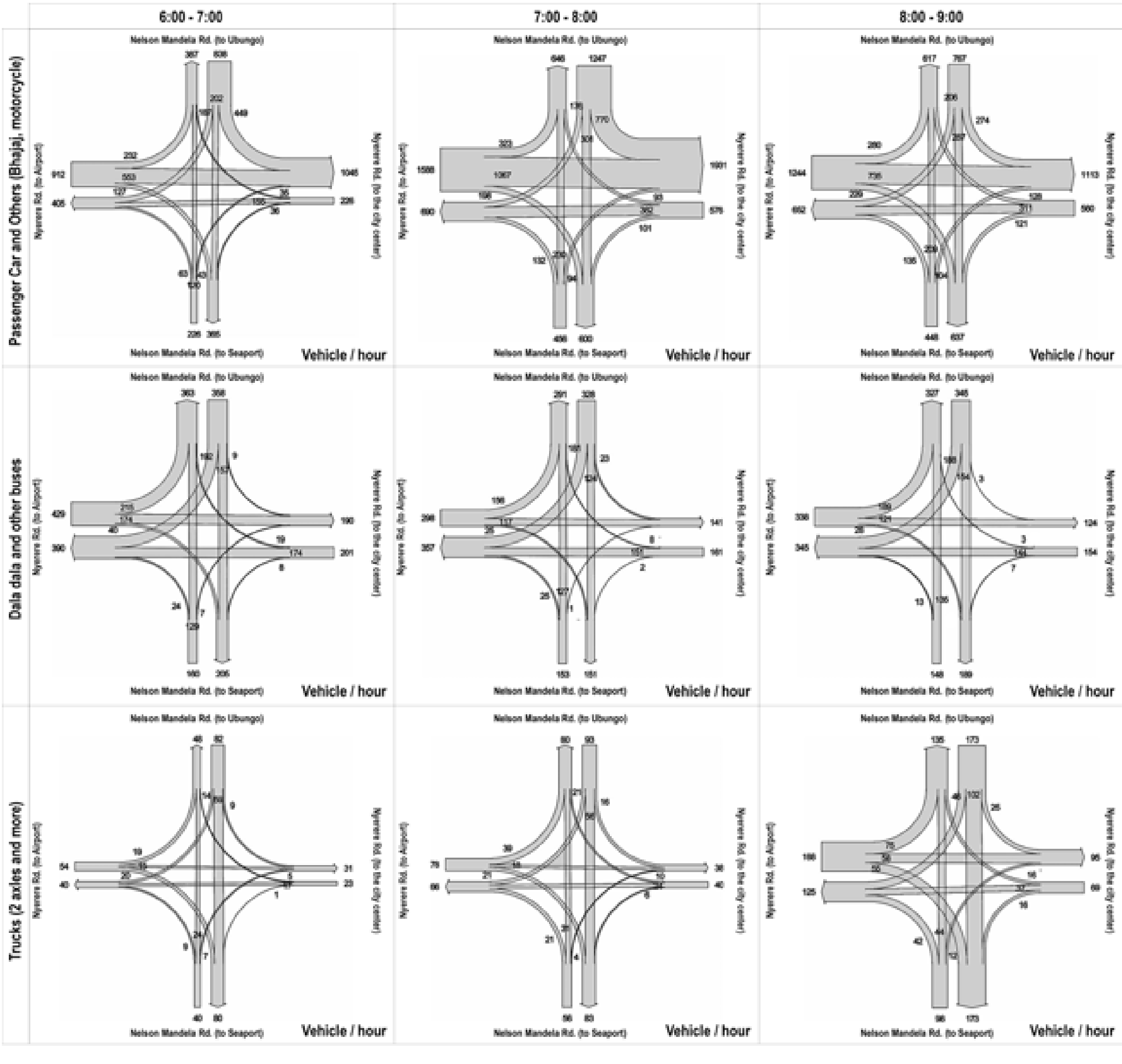
Source: JICA Study Team

Figure 4.1.1 Current Configuration of Intersection and Traffic Signal

(2) Current Traffic Volume

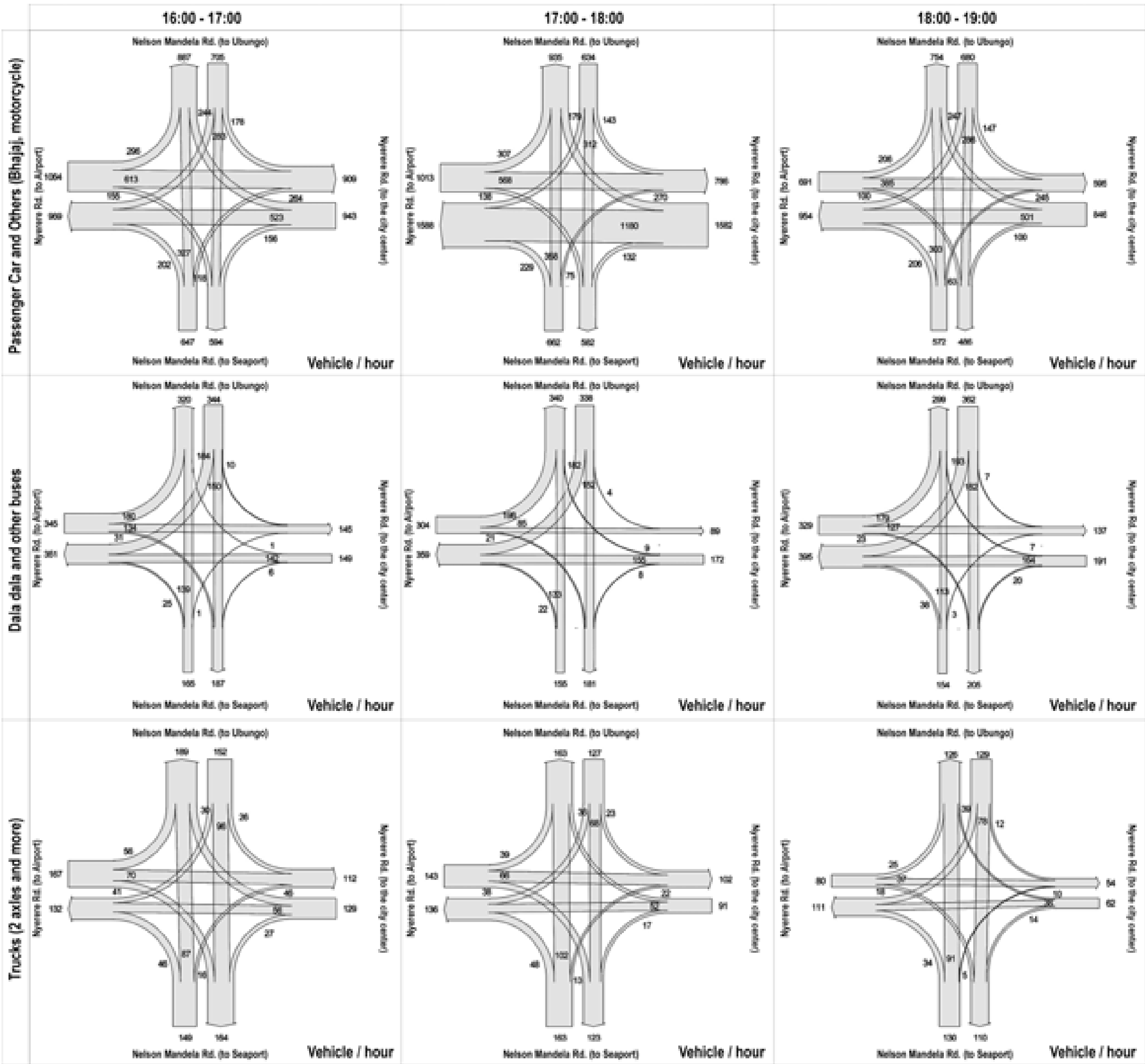
Figure 4.1.2 and 4.1.3 show the results of turning traffic count survey conducted in July 2007. Passenger cars of direction from the Nyerere international airport to the city center are dominant in morning peak hours, of which the highest peak is observed during 7:00 – 8:00. The hourly fluctuation of dala dala and other buses is not remarkable but the peak is observed in early morning. The traffic flow of trucks is different from dala dala, traffic volume becomes larger in late morning.

In the evening peak period, the peak of passenger car flow is observed in the opposite direction of the morning peak, that is, traffic from the city center to the airport direction is remarkable. There are no major differences between traffic flow of dala dala in morning peak and evening peak. The traffic volume of trucks decrease as it gets later in the evening.



Source: JICA Study Team

Figure 4.1.2 Current Traffic Volume in Morning Peak Period



Source: JICA Study Team

Figure 4.1.3 Current Traffic Volume in Evening Peak Period

(3) Traffic Signal

Table 4.1.1 and 4.1.2 show the performance of Tazara intersection based on the intersection traffic count in the morning peak and evening peak hour in 2007. A flow ratio of intersection in the morning peak is 0.809, and 0.941 in the evening peak. If the traffic signal phasing is improved, that is, combination of straight and right-turn traffic by each approach in applied to the intersection, the flow ratio of intersection in morning peak can be improved to 0.778 in the morning, but it in the evening peak becomes 0.950 as shown in Phase Pattern 2 in the tables.

For the micro simulation purpose, the traffic signal phase shown in Figure 4.4 is applied, which is commonly used signal phasing pattern with this type of intersection.

Table 4.1.1 Traffic Signal Saturation in Morning Peak Hour

Period: AM Peak (7:15 - 8:15)

Approach	1			2			3			4				
	Nelson Mandera			Nyerere Rd.			Nelson Mandela Rd.			Nyerere Rd.				
	From Ubungo Intersection			From City Center			From Uhasibu			From Airport				
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT		
Basic value of saturation flow rate	1800	2000	1800	1800	2000	1800	1800	2000	1800	1800	2000	1800		
Number of lane	1	2	1	1	2	1	1	2	1	1	2	1		
Lane width (m)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0		
and adjustment factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
Share of bus (%)	2.6%	28.2%	45.6%	1.6%	27.8%	2.5%	12.5%	41.8%	1.0%	37.9%	12.1%	8.8%		
and adjustment factor	0.99	0.95	0.92	1.00	0.95	1.00	0.98	0.92	1.00	0.93	0.98	0.98		
Share of truck (%)	2.4%	12.3%	7.1%	9.8%	5.2%	10.0%	20.8%	9.2%	6.2%	11.9%	2.5%	11.0%		
and adjustment factor	0.98	0.89	0.93	0.91	0.95	0.91	0.83	0.92	0.94	0.89	0.98	0.90		
Share of left turn (%)														
and adjustment factor														
Share of right turn (%)														
and adjustment factor														
Saturation flow ratio	1749	3372	1541	1633	3602	1628	1453	3381	1692	1495	3811	1593		
Total traffic volume (vehicle/hour)	756	496	425	122	594	120	144	316	97	420	929	227		
- Passenger Cars	682	295	201	108	398	105	96	155	90	211	794	182		
- Dala dala and buses	20	140	194	2	165	3	18	132	1	159	112	20		
- 2 axles Trucks	11	24	22	8	27	10	25	19	5	44	22	16		
- 3 and more axles	7	37	8	4	4	2	5	10	1	6	1	9		
- Others	48	24	11	4	26	7	31	94	6	73	228	27		
Flow ratio	0.432	0.147	0.276	0.075	0.165	0.074	0.099	0.093	0.057	0.281	0.244	0.142	λi	Σλ
Phase ratio phase1		0.147						0.093					0.147	0.809
phase2			0.276						0.057				0.276	
phase3					0.165						0.244		0.244	
phase4						0.074						0.142	0.142	
Required Green phase1		19						19						
phase2			35						35					
phase3					31						31			
phase4						18						18		
Cycle Length	120													
Capacity	1,749	534	449	1,633	931	244	1,453	535	494	1,495	985	239		
V/C	0.447	1.164	1.126	0.085	0.730	0.569	0.140	0.835	0.219	0.374	1.164	1.175		
Phase Pattern 2														
Flow ratio	0.432	0.147	0.276	0.075	0.165	0.074	0.099	0.093	0.057	0.281	0.244	0.142	λi	Σλ
Phase ratio phase1		0.147	0.276										0.276	0.778
phase2											0.244	0.142	0.244	
phase3								0.093	0.057				0.093	
phase4					0.165	0.074							0.165	
Required Green phase1		35	35											
phase2											31	31		
phase3								12	12					
phase4					21	21								
Cycle Length	120													
Capacity	1,749	534	449	1,633	931	244	1,453	535	494	1,495	985	239		
V/C	0.447	1.164	1.126	0.085	0.730	0.569	0.140	0.835	0.219	0.374	1.164	1.175		

Table 4.1.2 Traffic Signal Saturation in Evening Peak Hour

Period: PM Peak (16:45 - 17:45)

Approach	1			2			3			4				
	Nelson Mandera			Nyerere Rd.			Nelson Mandela Rd.			Nyerere Rd.				
	From Ubungo Intersection			From City Center			From Uhasibu			From Airport				
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT		
Basic value of saturation flow rate	1800	2000	1800	1800	2000	1800	1800	2000	1800	1800	2000	1800		
Number of lane	1	2	1	1	2	1	1	2	1	1	2	1		
Lane width (m)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0		
and adjustment factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
Share of bus (%)	3.4%	33.8%	43.7%	3.9%	10.5%	3.0%	8.4%	24.7%	0.0%	39.0%	14.2%	11.4%		
and adjustment factor	0.99	0.94	0.92	0.99	0.98	0.99	0.98	0.95	1.00	0.93	0.97	0.98		
Share of truck (%)	12.1%	17.7%	8.2%	13.0%	3.7%	7.0%	17.5%	15.9%	12.2%	8.3%	10.3%	15.8%		
and adjustment factor	0.89	0.85	0.92	0.89	0.96	0.93	0.85	0.86	0.89	0.92	0.91	0.86		
Share of left turn (%)														
and adjustment factor														
Share of right turn (%)														
and adjustment factor														
Saturation flow ratio	1595	3184	1529	1581	3777	1672	1507	3289	1604	1541	3527	1520		
Total traffic volume (vehicle/hour)	174	464	389	154	1282	299	263	554	98	503	662	184		
- Passenger Cars	130	225	187	128	1100	269	195	329	86	265	500	134		
- Dala dala and buses	6	157	170	6	134	9	22	137	0	196	94	21		
- 2 axles Trucks	20	52	27	17	47	14	26	40	12	33	65	26		
- 3 and more axles	1	30	5	3	1	7	20	48	0	9	3	3		
- Others	23	85	16	12	56	3	31	30	6	74	46	12		
Flow ratio	0.109	0.146	0.254	0.097	0.339	0.179	0.175	0.168	0.061	0.326	0.188	0.121	λi	Σλ
Phase ratio phase1		0.146						0.168					0.168	0.941
phase2			0.254						0.061				0.254	
phase3					0.339						0.188		0.339	
phase4						0.179						0.121	0.179	
Required Green phase1		19						19						
phase2			28						28					
phase3					38						38			
phase4						20						20		
Cycle Length	120													
Capacity	1,595	504	357	1,581	1,196	279	1,507	521	374	1,541	1,117	253		
V/C	0.123	1.302	1.316	0.117	1.170	1.175	0.230	1.375	0.306	0.418	0.703	0.899		
Phase Pattern 2														
Flow ratio	0.109	0.146	0.254	0.097	0.339	0.179	0.175	0.168	0.061	0.326	0.188	0.121	λi	Σλ
Phase ratio phase1		0.146	0.254										0.254	0.950
phase2											0.188	0.121	0.188	
phase3								0.168	0.061				0.168	
phase4					0.339	0.179							0.339	
Required Green phase1		28	28											
phase2											21	21		
phase3								19	19					
phase4					38	38								
Cycle Length	120													
Capacity	1,595	504	357	1,581	1,196	279	1,507	521	374	1,541	1,117	253		
V/C	0.123	1.302	1.316	0.117	1.170	1.175	0.230	1.375	0.306	0.418	0.703	0.899		

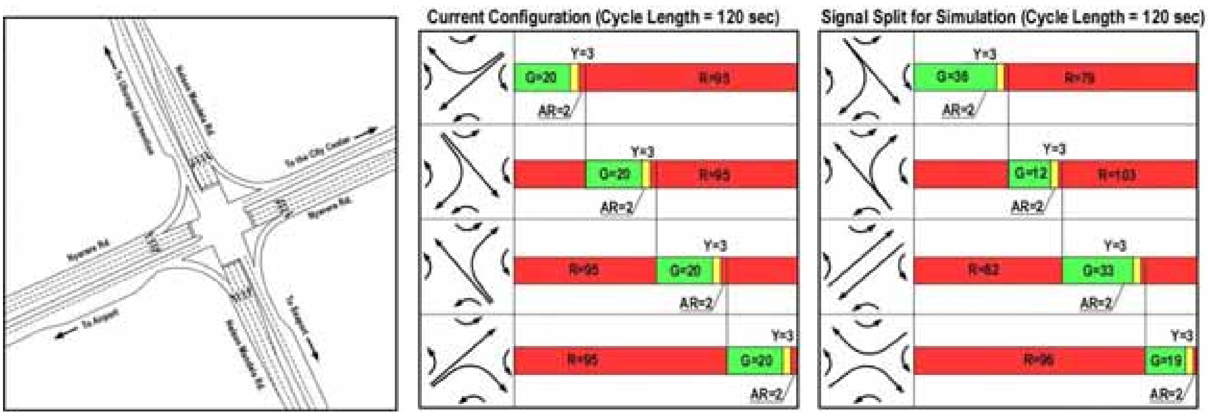


Figure 4.1.4 Signal Configuration for the Simulation

4.2 Evaluation of Current Condition

Figure 4.2.1 shows the results of microscopic simulation at Tazara intersection by 2007 turning traffic volume. By optimizing traffic signal, average travel speed will be able to increase to 42.4 km/h from 33.0 km/h. In 2007, a effectiveness of fly-over is not remarkable.

Table 4.2.1 Results of Microscopic Simulation

	Current Signal Configuration	Optimized Signal Case (Base Case)	with Fly-Over Case
Number of vehicles assigned	12,872	12,895	12,879
Total Distance Traveled (km)	30,020	29,988	30,008
Total Travel Time (h)	908	708	700
Average Network Speed (km/h)	33.04	42.37	42.86
Total Network Delay (h)	339	136	131
Average Travel Distance (km)	2.33	2.33	2.33
Ave. Travel Time (min)	4.23	3.29	3.26
Ave. Delay (min)	1.58	0.63	0.61

4.3 Fly-over case

(1) Configuration of Intersections

Figure 4.3.1 shows the configuration of Tazara intersection with Fly-over. In future, BRT occupy two lanes of Nyerere Rd. therefore, traffic signal pattern is considered as shown in Figure 4.3.1.

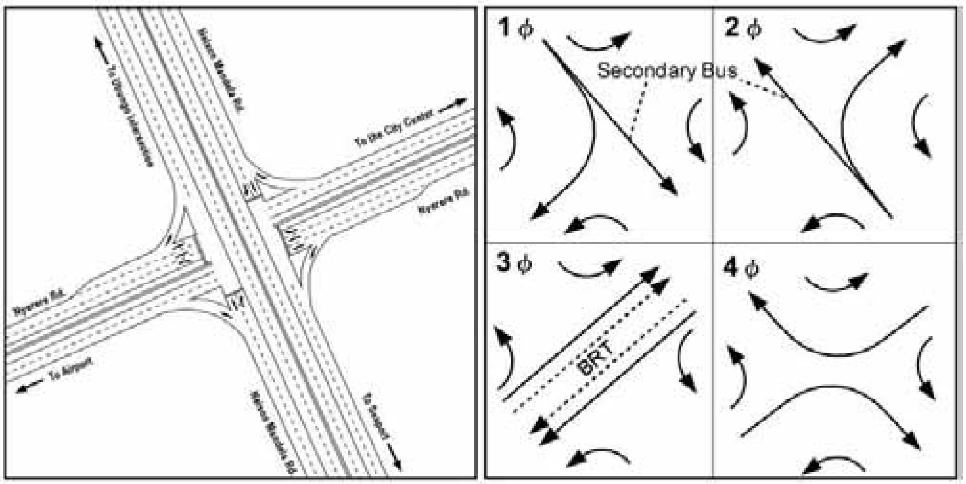
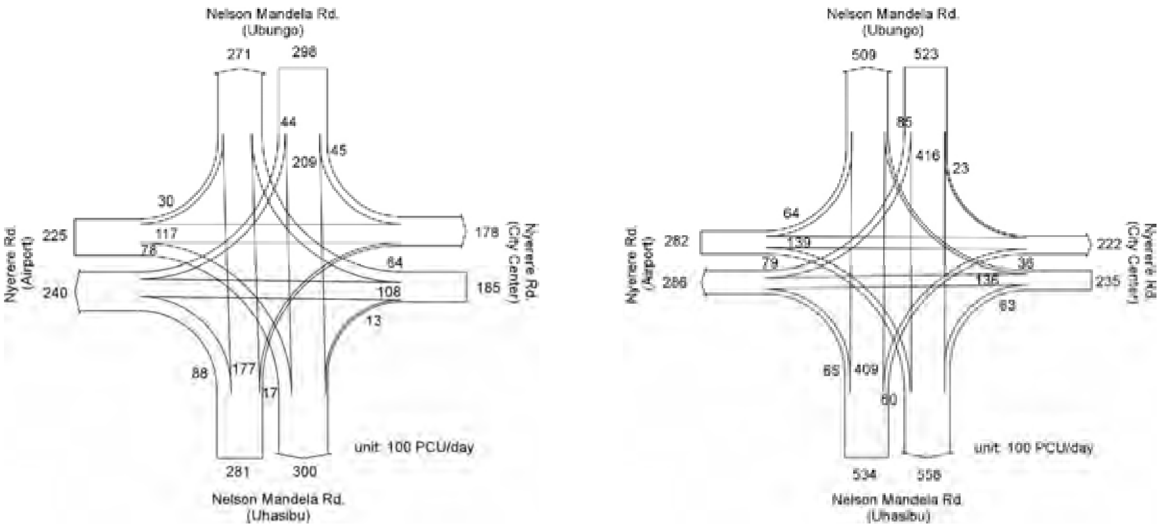


Figure 4.3.1 Configuration of Tazara Intersection with Fly-over

(2) Estimation of Future Traffic Volume

Based on the strategic model, daily directional traffic volume at Tazara intersection is forecasted as shown in Figure 4.3.2. For the purpose of evaluation of fly-over, traffic demand in peak hour should be required. Future traffic demand in morning peak hour is assumed based on the passenger car O-D consists of home-to-work place and home-to school trip only. Figure 4.3.3 shows the estimated directional passenger car demand in morning peak hour.



Note: excluding BRT

Figure 4.3.2 Future Daily Directional Traffic Demand in 2015 (left) and 2030 (right)

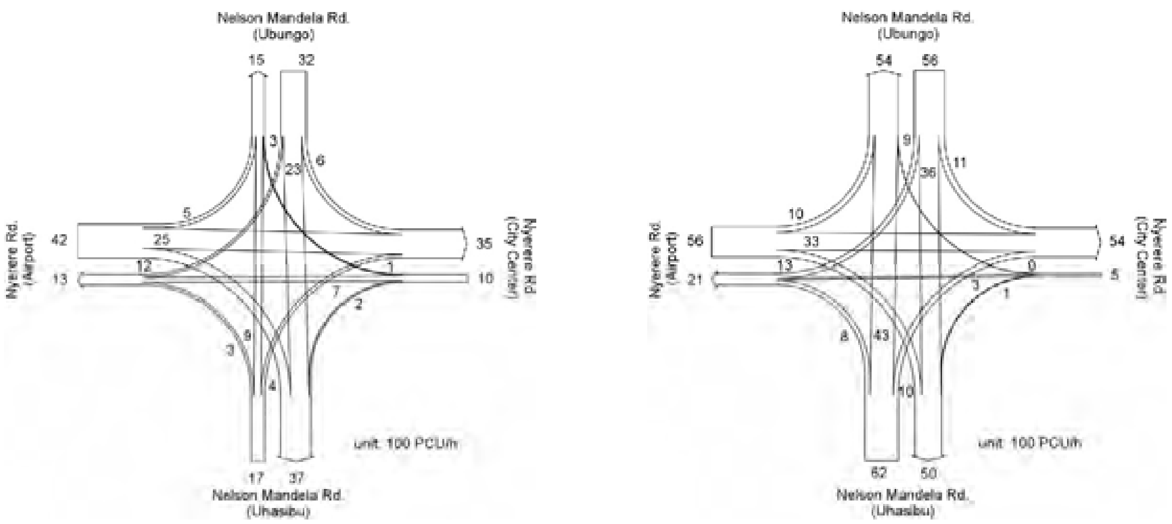


Figure 4.3.2 Traffic Demand in Morning Peak Hour in 2015 (left) and 2030 (right)

(3) Evaluation of Fly-over

Table 4.3.1 shows the results of microscopic simulation at Tazara intersection in morning peak 3 hours. With fly-over case is able to reduce average delay to 4.45 minutes from 7.44 minutes in 2015, and effectiveness by fly-over is confirmed remarkably.

Table 4.3.1 Results of Microscopic Simulation

	2015 without F/O	2015 with F/O	2030 without F/O	2030 with F/O
Number of vehicles assigned	15,752	19,961	15,952	21,190
Total Distance Traveled (km)	37,585	47,745	38,026	50,845
Total Travel Time (h)	2,670	2,385	2,604	2,252
Average Network Speed (km/h)	14.08	20.02	14.60	22.58
Total Network Delay (h)	1,954	1,480	1,880	1,288
Average Travel Distance (km)	2.39	2.39	2.38	2.40
Ave. Travel Time (min)	10.17	7.17	9.80	6.38
Ave. Delay (min)	7.44	4.45	7.07	3.65
Number of vehicles (not assigned)	14824	10723	40137	35059