CHAPTER 4 DAR ES SALAAM AND DODOMA STATE OF PRACTICE ON TRANSPORT AND ITS

4.1 Outlook of Dar es Salaam and Dodoma

The following table summarizes the major settings of the County of DSM and Dodoma.

Table 4.1.1 Outlook of DSM and Dodoma

Topic	Dar es Salaam (DSM)	Dodoma
Population	Approximately 5.8 million (2017)	Approximately 0.4 million (2012)
Feature of city	Transportation center, Commercial center	Capital
Major urban traffic issues	The population and traffic demand in Dar es Salaam increased at a speed much higher than the estimates of the Urban Transport Master Plan (M/P), which was formulated in 2008. On the other hand, since the project proposed in the previous M/P has not been fully implemented, chronic traffic congestion has occurred, which has become a bottleneck on the international logistics route starting from Dar es Salaam Port.	With the rapid increase in population due to the completion of the relocation of government agencies to Dodoma City up to 2020, traffic volume has increased rapidly, but various infrastructure plans and developments have not caught up. In addition, the country is located in the traffic center where the Central Corridor and the North-South corridor cross the country, and there is a concern that serious traffic congestion will occur on city roads due to the increased traffic volume.
The government's approach to traffic issues	Introduction of ITS, mainly for traffic lights, Introduction of BRT, etc.	Various infrastructure planning and development
Related recent surveys by your organization and other donors	The Project for revision of Dar es Salaam urban transport master plan in the United Republic of Tanzania, July 2018	Data collection survey on Dodoma city roads in the United Republic of Tanzania (2019.3)
National development policies (including ICT)	➢ Second Five Year Development Plan (FYD II) 2016: Tanzania Development Vision (TDV) 2025 – Consistent with UN SDGs. ➢ In response, the Ministry of Works, Transportation and Communications (MOWTC)* launched the National Information and Communications Technology (ICT) Policy in 2016. It consists of 4 major categories and 22 objectives. The 4 categories are 1) Access to key service, 2) Productivity and efficiency, 3) socioeconomic impact and 4) good governance. ➢ Digital Tanzania Program supported by the World Bank: The purpose is to aggregate the digital potential of the country.	
Trends in ICT utilization likely to be related to ITS	➢ Mobile Financial Services: Mobile money has become an important driver of Tanzania's financial inclusion. As of June 2018, the top six mobile operators in Tanzania are Airtel, Halotel, Tigo, TTCL, Vodacom and Zantel, with a total of 21 million subscribers. The Bank of Tanzania provides a payment platform using Mobile Money to ensure payment interoperability. Public utility payments such as taxes, water and sewage, and electricity can be corresponded. ➢ Vodacom and CUMii International provide vehicle tracking and fleet management services. ➢ Infrastructure-sharing initiative started in 2016. This includes mobile phone operators, equipment vendors and government. This includes supporting startups to create mobile content and services. ➢ Tech hubs that support technological innovation are supported by private investors and mobile operators. There are nine Tech Hubs (as of 2017). ➢ A Tier 3 level data center owned by MoWTC* is in Kijitonyama, a suburb of Dar es Salaam, and is operated and maintained by TTCL. As of January 2017, it was reported that there were few users.	

*) Ministry of Works, Transportation and Communications was split into Ministry of Works and Transportation and Ministry of Communications and Information Technology in Dec 2020.

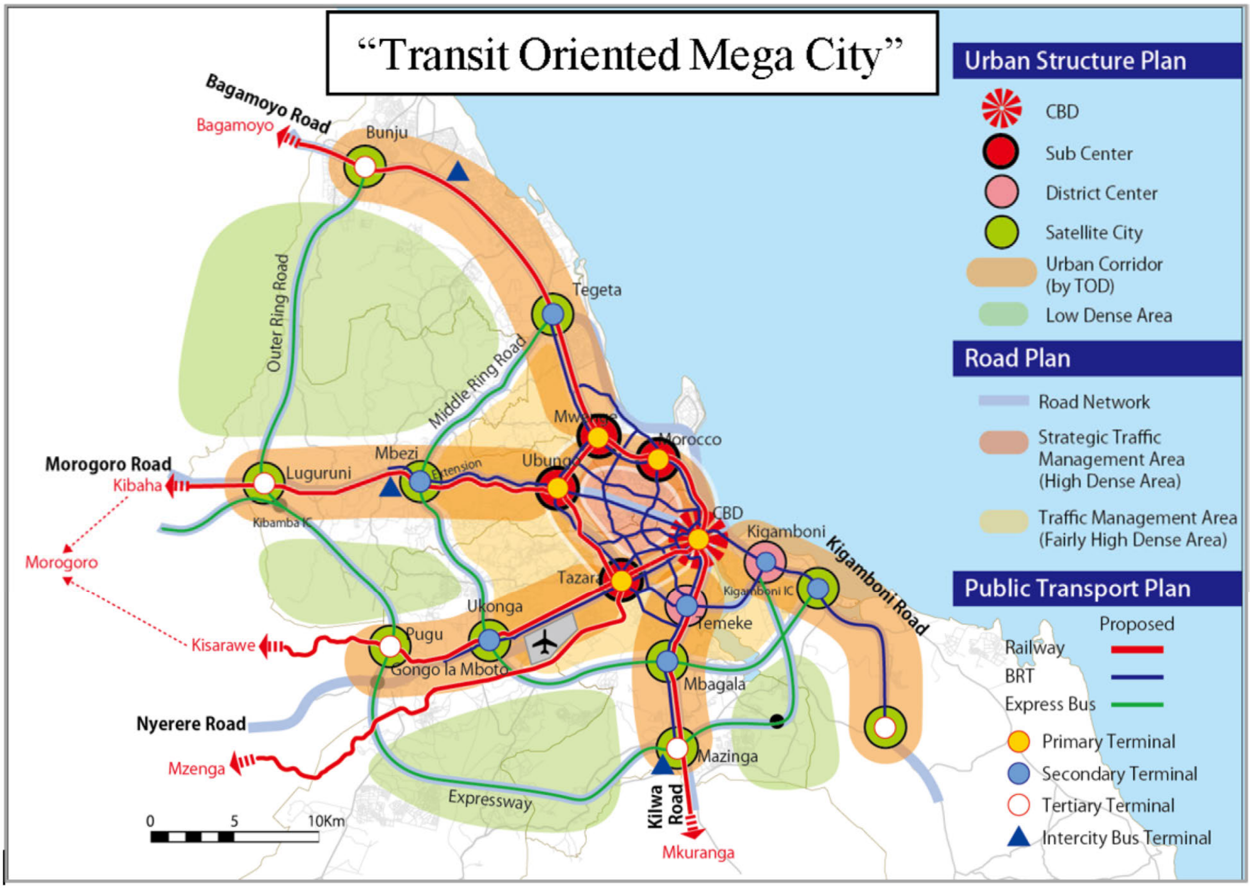
Source: JICA Study Team

4.2 Transport System Development in Dar es Salaam

4.2.1 Review on Superior Urban and Transport Planning

(1) JICA Revised M/P in 20118

The latest urban transport masterplan in DSM was prepared by the Project for Revision of Dar es Salaam Urban Transport Master Plan[1], finalized in 2018, funded by JICA (Hereafter, "Revised M/P"). It assumes the future population in DSM will be 12 million in 2040, though it was 5.8 million in 2017, requires it to be "Transit Oriented Mega City " materializing TOD development along the proposed BRT and railway corridors, proposes "Radial and Circular Trunk Road Network" formulation with several flyovers at major intersections which reduce the bottleneck and congestions, expecting "Traffic Management with Advanced Technology" including Dynamic Signal Control Optimization System, Real-Time Traffic Information System, and Public Transport Priority System until 2030. The masterplan envisions the "Palm and Fingers" urban structure, forming five radial urban corridors (fingers) and one loop corridor (palm), as shown in Figure 4.2.1.



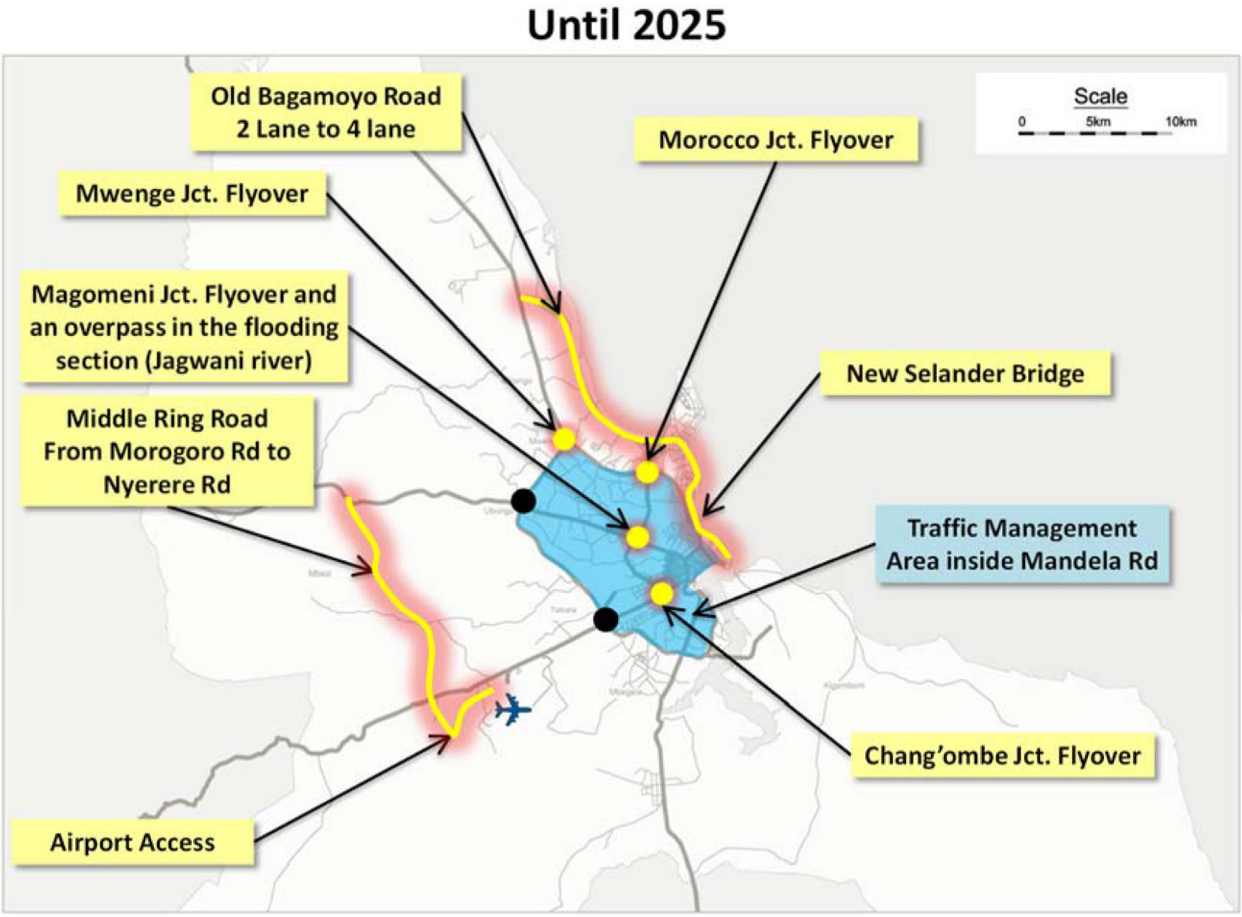
Source: Revised M/P

Figure 4.2.1 Conceptual Map of Urban Transport Master Plan (Long-Term Vision)

The Revised M/P stipulated the staged implementation plan for 2025, 2030, 2040 and after-2040, and proposed sectoral policies including urban structure, traffic management and public transport. For short term development until 2025, completion of BRT Phase 2 to 4, Fly-Over projects for Tazara and Ubungo

[1] JICA, the Project for Revision of Dar es Salaam Urban Transport Master Plan, Final Report, July 2018

intersections and introduction of Traffic Management system for the strategic traffic management area inside the Nelson Mandela road are suggested to improve road congestion in peak hours on Bagamoyo, Nyerere and Kilwa Roads. Figure 4.2.2 shows the strategic traffic management area and intersection improvement to be commenced by 2025.



Source: Revised M/P

Figure 4.2.2 Plan to Be Commenced until 2025

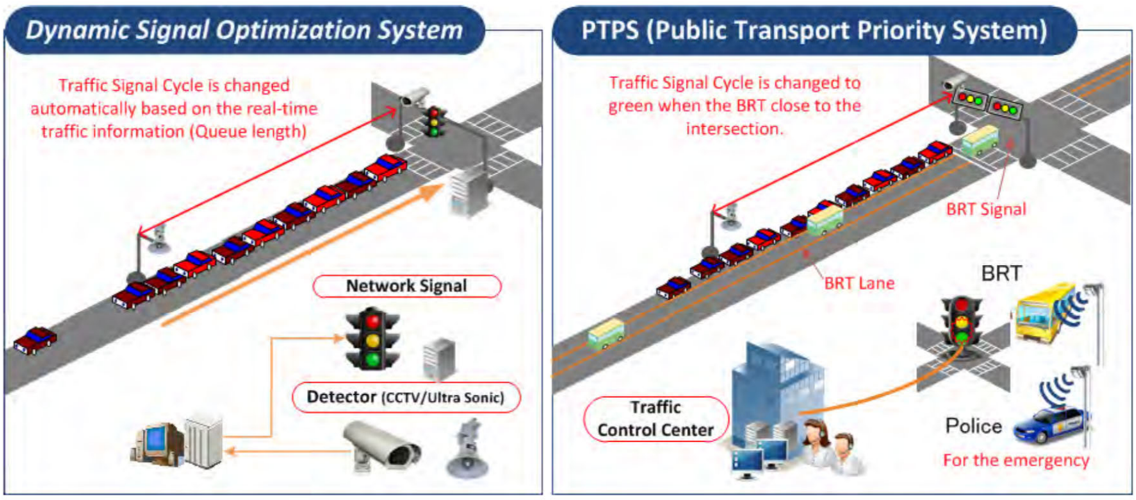
Regarding the traffic management and ITS, the Revised M/P summarized traffic management issues as follows:

- Traffic Concentration:
  - few detour routes for avoiding congestion
- Poor Infrastructure:
  - poor drainage facilities, no information provision about the disaster
- Parking Problem
  - Parked vehicles block smooth traffic flow, parked vehicles also block sidewalks
- Lack of Traffic Signals
  - Traffic signals are not adjusted based on the real-time traffic situation
- Lack of Public Transport
  - Service Operation area of public transportation is limited, connection between private vehicles and public transport or between both public transports (BRT & Daladala) is poor
- Traffic Accident:
  - occur along major roads, especially along the BRT route.

- Many stakeholders related to Traffic Management:
  - ➢ a demarcation of each organization should be clarified.:

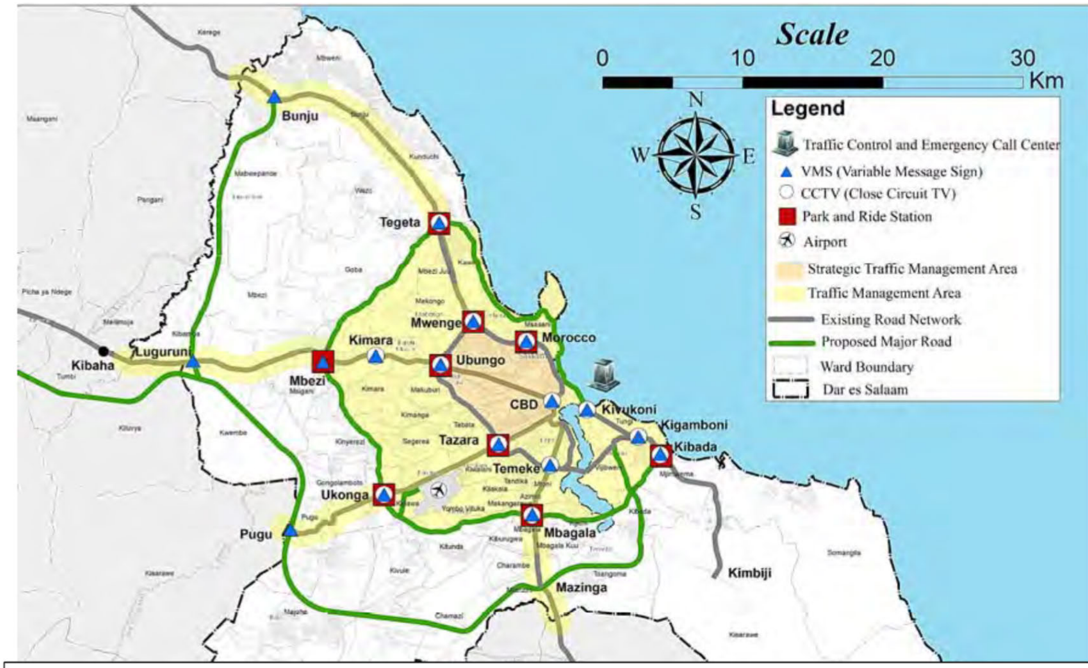
Based on the issues above, the Revised M/P summarized three components for traffic management, i.e., (1) Mobility Management Project, (2) Improvement of Traffic Circulation Project, and (3) Traffic Safety Project. The following shows the details of the three components:

- Component 1: Mobility Management:
  - ➢ 1. Promoting Modal Shift,
    - ✧ by improving the access to BRT/MRT stations, frequency increase of BRT operations
  - ➢ 2. Parking Management
    - ✧ Parking fee management to discourage the high demand in CBD, P&R promotion,
  - ➢ 3. Measures for Improvement Mobility
    - ✧ Priority lanes for NMT, fare promotion for BRT/MRT, car free policy
- Component 2: Improvement of Traffic Circulation
  - ➢ 4. Traffic Signal Optimization
    - ✧ Dynamic signal optimization and PTPS installation for target corridors, information collection and provision system, VMS development (see Figure 4.2.3)
    - ✧ It should be noted that DART had started ITS study to cover the traffic signal optimization and Revised M/P recommended to refer to for further analysis (see section 4.2.1(4))
  - ➢ 5. Intersection Improvement
    - ✧ Implementation of grade separation projects, and level crossing design improvements
  - ➢ 6. Area Restriction for Trucks and Cars
    - ✧ Staged implementation of area control for heavy vehicles and proper enforcement
  - ➢ 7. Real-time Traffic Information Provision
    - ✧ CCTV and VMS development, advanced system installation for ITS (see Figure 4.2.3)
- Component 3: Traffic Safety Program
  - ➢ 8. Traffic Safety Program
    - ✧ Black spots improvement (pedestrian bridges), promotions



Source: Revised M/P

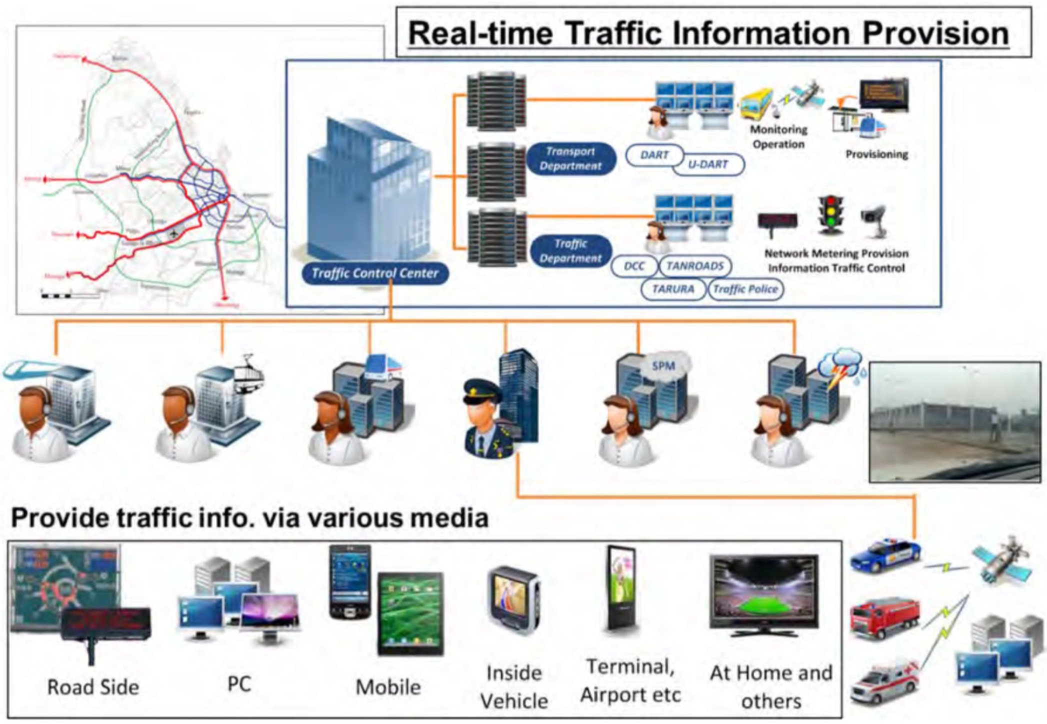
Figure 4.2.3 Dynamic Signal Optimization and Public Transport Priority System



Function
- **Dynamic Signal Optimization System & Additional Traffic Signal**
- **Public Transport Priority System**
- **Information Collection & Provision System** (Travel Time, Congestion info, Fleet Control info, Disaster Info)
- **Emergency Info from Emergency Call Centre** (For Police, Ambulance, evacuation for disaster, etc. ~2030)
- **Public announce for traffic rule and safety via VMS**
- **Enforcement**

Source: Revised M/P

Figure 4.2.4 Proposed Traffic Management Area by Traffic Optimization and ITS



Source: Revised M/P

Figure 4.2.5 Real-time Traffic Information Provision

(2) JICA Intersection Improvement and MRT follow-up study

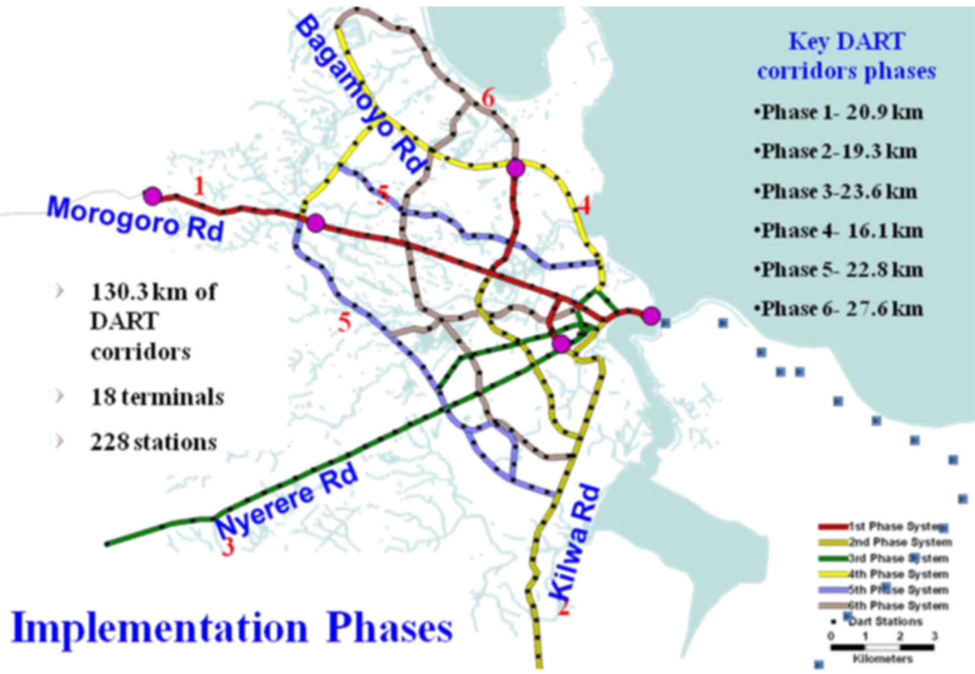
Another JICA data collection survey team for urban transport was dispatched during Jan – Mar 2020 to follow-up the proposed intersection improvement and MRT components by the Revised M/P. The study team analyzed the following points:

- Studied 11 intersections in DSM and prioritized Chang'ombe, Tazara, Morocco, Mwenge junctions for further implementation.
  - ➢ For Tazara junction, an additional underpass was proposed to the existing intersection with flyover.
- For MRT study, the study assessed the seven proposed rail corridors, which had been prepared by the TRC's F/S for Dar es Salaam Commuter Rail Project.
  - ➢ Route B1-B9, running on the SGR tracks along the Julius Nyerere road, and Route C2-C11, totally new elevated MRT development within the RoW of the on-going Bagamoyo Road widening section, along with two other sections require further F/S.

(3) AfDB BRT Planning

DART BRT Phase 1, in total 20.9km running along the Morogoro road corridor funded by the World Bank, was a successful project in DSM. AfDB prepared an expansion study and funds for Phase 2 and 3. The whole network structure of the BRT with a phased implementation program is shown in Figure 4.2.6, showing the following characteristics:

- The major 4 radial corridors would be served by phases 1 to 4
- The circular direction and supporting radial routes would be developed as Phase 5 and 6.
- The phases 1 to 4 have several branch routes for formulating the circular corridors



Source: Revised M/P

Figure 4.2.6 BRT Network and Phased Development Program

(4) DART ITS Masterplan

DART has drafted the ITS scoping study for BRT Phase 1 in Oct 2019, and circulate the draft among the stakeholders for further comment. The BRT Phase 1 operation is called as the interim stage, which means not in full operation, and the study covers necessary ITS elements for the BRT 1 full operation and listed ITS elements with priority as shown in Table 4.2.1. The table presented the priority of the items in three levels, i) Required, ii) potentially, iii) recommended, and iv) no mark. The items for "required" were shaded with orange color in the table.

Table 4.2.1 Proposed ITS Scope for BRT Phase 1 by DART

Technical Elements	Priority	Notes
Stations/Terminals		
1 CCTV Camera.	Required	Also, at Cashier Offices.
2 Turnstiles.	Required	
3 AFC Validators.	Required	Smartcard reader in turnstile and onboard validators for feeder busses. Propose to also have some additional handheld validators for backup.
4 Platform Doors (to allow boarding of bus)		Automated doors are preferred.
5 UPS	Required	Have to verify if current UPS's can handle the new load
6 Equipment (Sever) Room		Propose to install enclosed server rack, inclusive of air-conditioner.
7 Cashier Offices.	Required	
8 Ticket Office Machine		Should be able to issue commuters with smartcards.
9 VMS/AEDU	Required	VMS: Variable messaging signboards AEDU: Audible Electronic Display Unit
10 Access Point (AP).	Required	
11 Card Vending Machine (CVM)	Required at Terminals.	
12 VoIP Phone.	Required	
13 Safe (Intelligent)	Potentially.	
14 IP Loudspeaker (PA System)	Required.	
15 Building Management	Required.	
16 Signalized Pedestrian Crossings.	Recommended	
Depots		
17 CCTV Camera.	Required	
18 CCTV Backup Server (for incident download).	Required	
19 Bus Operations Centre Space		for Vehicle Operating Companies.
20 Equipment (Server) Room		Propose to install enclosed server rack, inclusive of air-conditioner.
21 Access Point (AP)	Required	Multiple AP's.
22 Building Management.	Required	
23 Workstation.	Required	Check to determine reusability of existing workstations.
24 Scheduling System	New system required.	Could be at TMC (Transport Management Center).
25 VoIP phone.	Required	
26 IP Loudspeaker (PA System).	Required	
Trunk Routes		
27 CCTV Camera		Where required to ensure full coverage of route.

Technical Elements	Priority	Notes
28 ANPR.	Potentially in future	Automatic Number Plate Recognition
29 UTC/TSC	Potentially in future.	
30 Outstations (OS's)		Propose to create subrings for network to improve resilience. Propose to accommodate in Terminals
Buses		
31 CCTV Camera.	Required	Footage to be stored on-board for a period of 7 days with footage older than 7 days being overwritten. In the event of an incident occurring, the footage can be downloaded.
32 On-board Computer.	Required	
33 Driver Console.	Required	
34 AFC Validators	Required for feeder busses.	
35 Infotainment.	Required	
36 VMS/AEDU.	Required	
37 Wi-Fi	Required	for bus to Station/Terminal/Depot communication
38 Passenger Counter	Potentially in future.	
39 AVL.	Required	To confirm reusability of current trackers.
Communication Network		
40 Network		The network infrastructure could be leased, obtained via a P3, or it could be owned by DART. The preferred option is for DART to own the network.
41 Bandwidth		The backbone communications network should have sufficient capacity to not only cater for the BRT, but also for other/future ITS deployments. Propose a redundant 10Gbps communications backbone over fibre.
TMC and Back-up Operations		(Transport Management Center)
42 TMC		DART to obtain a suitable site.
43 Video Wall.	Required	
44 Back-up Operations		DART to obtain a suitable site.
Data Centre and DR Site		
45 Data Centre		The eGovernment Agency provides Data Centre Facilities.
47 Disaster Recovery (DR) Site		The eGovernment provides DR Facilities.
Training and Capacity Building		
48 Training		Ensure sufficient AFC System and ITS training.
49 Capacity Building		Build local Tanzanian ITS capacity.

Note: Item #46 is missing in the source. Cited from the source as it is.
Source: Extracted from the DART ITS Scoping study for BRT Phase 1, edited by JICA Study Team.

The JST assesses the Scoping study as follows:

- The scoping study mainly propose to realize the two major system i) AFC (automatic fare collection) and ii) APTM (Advanced Public transport management); however, the detail specification, number/dimension of development, systematic relationship among the listed elements implementation schedule for the AFC and APTM materialization, etc, are not specified in the study.
  - ➢ APTM scope is mainly for bus operator (subcontractor) management, not mentioning bus priority at the intersection, little for safety operation, etc.
- The proposed scope is strongly dedicated for bus operation, but no consideration for traffic management including the general vehicles.

(5) DSM ITS Strategic Plan

The City of DSM publishes the ITS strategic plan with very comprehensive and updated vision for urban transportation traffic and travellers management. It specified 9 priority area for ITS development, from communication infrastructure to passenger services, and proposed 28 strategic approaches with detail description, as shown in Table 4.2.2.

Table 4.2.2 ITS Priority Area and Proposed Strategic Approaches

Area and Approaches	Descriptions
1. Transit Management	Continued investment in the citywide BRT system with emphasis on tools and systems that provide for connectivity and operations of this system. Emphasis is placed on improvement of the efficiency of the BRT operations, the ability to direct service changes in real-time to improve system performance, address safety of the system as well ensure performance-based management of these services.
TM1: Deliver Real-Time Transit Passenger Information	Users are provided with real-time location and arrival/departure information of the transit vehicle. Information is delivered via devices on board, electronic message boards at stations or smart phone transit apps.
TM2: Dynamic Transit Capacity Assignment	The ability to re-organise schedules and adjust supply based on real-time demand and patterns.
TM3: Transit Signal Priority	Transit Signal Priority allows transit vehicles to travel through a signalised intersection by first detecting a transit vehicle and extending or truncating green cycle times at traffic signals to allow the transit vehicle to travel more efficiently and better adhere to schedules.
2. Traveller Information	Providing a citywide traveller information service that will increase awareness and information on travel choices and reliability. This will assist in reducing congestion by being informed of network status and choices on how and when to travel.
TI1: Define Traveller Information Service	Develop functional requirements for a traveller information portal to demonstrate the benefits of the application.
TI2: Create an Open Data platform	Facilitate availability of static and real time operational data to trusted parties to develop innovative applications serving the purpose of providing traveller info to users.
TI3: Travel App	Project will create the ability access data and information regarding public transport schedules and status of vehicles. Consider partnership between authorities. Consider information such as: ➢ Real time traffic flow including speeds and volume ➢ Real time corridor drive times ➢ Real time weather advisories ➢ Congestion information and hot spots ➢ Incident alerts ➢ Construction and maintenance activity
TI4: Floating Car Data	Facilitate access to FCD to enhance operational management of transportation network. Identify other functionalities, also for road asset management e.g. Pothole detection technology can inform local authorities about the location and severity of potholes, and reduce the need to inspect roads.
TI5: Traffic Data Collection Programme	Requires baseline data to assess the current traffic conditions. Will use latest technologies, combined with the fibre optic network, to collect real time data and send it directly to the traffic management centre.
3. Transport Management and Data Centre	Development of a state-of-the-art data management centre to collect, manage and communicate extensive data generated by the transportation system and related areas. Utilise the centre for real-time operational management as well as on-going planning activities.
TMDC1: Functional program and Concept of Operations	Determine the various functions to be housed within the TMC, develop a Concept of Operations (ConOps) whereby ITS user services are converted into operational tasks; develop a floor plan that illustrates locations of operators, offices, video wall, data rooms etc.; determine operational polices, and prepare first order cost estimates for TMC.
TMDC2: TMC Site selection	Consider optimal site for TMC based on availability of communications backbone, cost and availability of property, accessibility for staff and public, scalability for future expansion.

Area and Approaches	Descriptions
TMDC3: TMS preliminary and detail design	Execute a preliminary design considering various site services such as structural, utilities, HVAC, transportation, mechanical, electrical, telecommunications, water/sewer, emergency services and the physical spaces. Detail design will commence on approval of the preliminary design. It will include tender-ready drawings and specifications for the TMC.
TMDC1: Big Data strategy (data management strategy)	Growth of new technologies and corresponding growth in data production. Ensure realization of value from new and large data sets by enabling effective analytical processing.
TMDC2: IoT Platform Strategy	Develop an IoT platform strategy that will consider inter alia the devices that will be integrated into the platform, functionality of device management and monitoring, the nature of the IoT hub, the extent of data processing services, how data will be stored on the IoT platform as well as the extent of data analytics and data visualisation.
TMDC3: Probe Vehicle data	Determine available data and gather information provided by vehicles. This information may include vehicle speed, vehicle location and vehicle identification.
4. Arterial Management	Development of arterial management systems, improve signal timing and coordination as well as improving competitiveness of transit as well as reducing travel times on the roadway network.
AM1: Adaptive Signal Control	Apply dynamic changing of signal timing to fit the traffic load. Improve the functioning of corridors by reducing travel time, delay and congestion. Consider initial pilot. Collaborate with signal control and manufacturers and software providers using innovative technology. Identify need for communications upgrade, system detection provision and system signal upgrade and expansion.
AM2: Arterial monitoring	Identify worst corridor. Investigate technology. Provide system detection, signal system upgrades. ITS infrastructure: Traffic detection, CCTV cameras, variable message signs, telecommunications network; develop functional requirements for IMS
AM3: Integrated Corridor Management	Develop an ICM plan along the alignment of Phase 1 of the DART implementation. ICM is the integrated management (ensure efficiency and maximise throughput) of all modes of transport (BRT, rail, vehicle, pedestrian, cyclist) within a corridor using ITS technologies and innovative practices.
AM4: Arterial/Rail intersection	The interface between rail equipment and roadside equipment need to be established to support the coordinated operation of the equipment.
5. Parking Management	Provide measures to improve information regarding available parking and have access to information to manage provision and pricing thereof.
PM1: Integrated DART parking	Travelers are provided the ability to utilise their DART e-payment media (smartcard) to park at park-and-ride facilities provided by DART at the trunk terminals.
PM2: Dynamic Parking Guidance and Reservation	Provides travellers the ability to utilise technology to reserve a parking space at a destination facility on demand to ensure availability. The parking availability is continuously monitored and system users can reserve parking space ahead of arriving at the parking location.
6. Multimodal Integration	Achieve effective management of the transportation network and improve the efficiency of the transportation system through integrated operations and management. This will result in reduced congestion and travel time during the daily commute.
MI1:Expand the regional communications network	Ensure connectivity on a wider network to enable communications with modes other than BRT.
MI2: Deploy advanced technology and connected vehicle systems	Expand connectivity to public transport modes other than BRT. Investigate use of smart phone apps for DalaDala to provide wider vehicle connectivity.
7. Electronic Payment Systems	Support initiatives to expand the use of automated payment systems for transit systems (such as BRT and ferries) and parking to provide for integrated multimodal fare systems.
EP1: Integrate Existing Electronic Payment Systems Across Modes and guide future systems towards common platform	Current city transportation services need to be reviewed and considered to be integrated into a single payment system. The DART fares (including park-and-ride) and the ferry system need to be integrated.

Area and Approaches	Descriptions
EP2: Identify and pursue partnerships that support and expand use of payment services	Review current transportation and City Services and identify potential partners to join a city-wide e-payment system. Develop a Concept for operations for such a system, as well as a guideline document related to specifications for readers, ID devices and network infrastructure.
8. Commercial Vehicle Operations	Provide electronic systems to commercial vehicles in moving freight to assist in regulating the operations and activities to improve knowledge regarding position of heavy vehicles, manage overload control and roadside operations in general.
CV1: Regional Commercial Vehicle Movement	Detect commercial vehicle movement & identify bottlenecks
CV2: Commercial Vehicle Enforcement Strategy	Identify corridors to be enforced. Provide extent of what is required i.e. infrastructure (e.g. fixed weigh scales), resources (enforcement staff), and technology (e.g. WIM and CCTV).
9. Communications Network	Ensuring that a robust telecommunications network is in place that supports the transmission of field data to a central-hub, as well as inter-agency data exchange.
CN1: Telecommunications Strategy	In order to support growing requirements, a citywide telecommunications strategy need to be established. Elements include: ➢ Develop network interconnection standards ➢ Prepare a bandwidth analysis of the current and future ITS ➢ infrastructure ➢ Prepare a detailed network architecture design ➢ Prepare a network deployment plan
CN2: Telecommunications Network Design	A Network design for City-wide communications needs should be established and linked or aligned with the DART network. Consideration should be given to required bandwidth and speeds, network availability, scalability, manageability as well as cyber security. The network typology should be defined and nodes, segments and links determined.

Note: The numbering of the TMDC has some overlappings, but this table were cited as it proposed.
Source: DSM ITS Strategic Plan, edited by JICA Study Team.

The JST assesses the Scoping study as follows:

- The study shows much comprehensive concept than the DART ITS scoping.
    - ➢ Data center, communication network, traffic data collection including floating vehicle data base development are infrastructure level for traffic management
    - ➢ The 6 approaches for TMDC are main actions for area wide traffic management. These approaches adopt very latest technical concepts, e.g., Big Data and Probe vehicle data utilization.
    - ➢ Verious application proposals and comprehensive coverage of transport users; including public transport and private vehicle passengers, e-payment users, commercial freight vehicles and BRT – daladala – Ferry.
- It is recommended the following items should be materialized for further traffic management approaches to achieve the traffic management are in 2025 compliance to the Masterplan.
    - ➢ All TMDC approaches, Arterial Management (AM) approaches and TM2 (Priority for BRT) has priority for public investment initiative.
        - ✧ The CN approaches will need public investment for traffic signal and DART operation
    - ➢ The other approaches require PPP coordination, as private stakeholders should be involved for implementations.

(6) CUPID technical transfer program (JICA)

The Capacity Building Project for Improvement of Dar es Salaam Urban Transport (called as Consensus for Urban Transport and Policy Improvement in Dar es Salaam (CUPID)) was implemented during 2011-

2014 for the Phase 1, and 2015-2018 for Phase 2, to follow up the first JICA transport masterplan (2008). The CUPID 2nd phase project covers a variety of transportation planning, including installation of one-way regulation, Daladala routes reorganization based on the one-way installation, improvement of taxi waiting spots, parking management improvement with POS devises, etc. Particularly those physical improvements focused on the CBD area of DSM.

The core activity of the CUPID institutional development was support for the DUTA (DSM Urban Transport Authority) establishment. The CUPID has supported the clarification of its function, organizational arrangement among the stakeholders, responsible Ministries, drafting the Act, and estimating the financial plan for the operation throughout the project activities. As a result of the series of discussions and efforts, the need for the "effective sector coordination" was mentioned in the draft National Transport Policy in 2016. At the end of October 2017, the exit strategy of DUTA was proposed at the final JCC meeting of JICA CUPID project. The discussion had been extended to the support from the development partners, since JICA CUPID has concluded its local activities by the end of October 2017. The World Bank is one of the supportive development partners to take over the JICA CUPID activities for further discussion and consultation among the stakeholders.

4.2.2 State of Practice on Road Development, Transport and Traffic Management[2]

(1) BRTs – Biggest impact to DSM transport environment

The BRT Phase 1 along Morogoro road, opened in May 2016, consists of 21km of trunk road, 57.9 km of feeder roads, 5 large terminals and 29 stations. At present, the system carries 200,000 passengers per day. The initial project cost was financed by the World Bank and the bank provided $180 million for the construction of the Phase 1. The following photo depicts the characteristics of the design and operations of DART with ITS aspects.

For expansion of the BRT, the World Bank has committed to the Dar es Salaam Transport Improvement Project (DUTP) with USD 425 Million equivalent loan amount[3] in 2017. The majority of project scope covers the BRT expansion for the third and fourth phase of BRT expansion and grade separation and flyover installation at the major intersection Ubungo along the BRT corridors, however, the scope also covers i) fare collection system and traffic management (as the subcomponent A4 with USD18M), ii) several ICT application and innovation for BRT operation for various stakeholders (as component C, USD 38M). The component A4 stipulate the ITS installation for BRT corridors, however, it mainly covers the fare collection and individual traffic signal installation and implemented by DART, and the Component C ICT innovation package (C5) are oriented to develop passenger information system for bus users and bicycle users[4]. DART CEO mentioned the DUTP Package A4 mentions necessity of traffic management for BRT corridors, however, the package realized installation of individual controlled traffic signals along the BRT Phase 1 corridor only.

2 See also Chapter 4.9 of the Final Report, Comprehensive Development Master Plan in the Mombasa Gate City, 2018
3 http://documents1.worldbank.org/curated/en/794251489201242940/pdf/TZ-PAD-02162017.pdf for the Project Appraisal Document
4 https://projects.worldbank.org/en/projects-operations/document-detail/P150937 for DUTP library, and Audit Report in Dec 2019, and Implementation Status and Results Report in Nov 2020.

Physically separated, median-aligned BRT lanes

Platform - boarding at stations

Real-time system monitoring with FMS

Off-board e-fare collection (non-working now)

Source: DART

Figure 4.2.7 Photos of BRT Phase 1 Operatoin in DSM

DART is a government entity to establish and operate the BRT system for Dar es Salaam, under the guidance of the President's Office, Regional Administration and Local Government (PO-RALG). The bus service operation is contracted out to UDART, as an interim operator. Fare collection services with a stored fare IC card system (e-fare collection) were also contracted out to the private company, Maxicom, and the stored fare IC cards had been distributed, however, the e-fare collection has been ceased since 2019 and it is operated by manual collection. DART has prepared the tender for AFC procurement specification document, and is going to announce the tender in April 2020. The revised AFC system are compatible for IC smart cards with NFC (ISO/IEC18092), tokens, and QR code.

The Interim operator U-DART has installed the FMS (Fleet management system) and monitoring BRT operation in real-time basis. U-DART adopt Mobi.Guider[5], a third-party software for operation optimization of bus fleet assignment with the real-time passenger demand, however, its operation is still temporary. DART considers to install a new FMS to monitor the operators' performance as DART pays the service fee to operators based on the occupied/on-business distance, not the whole distance.

The CEO of the DART mentioned the instability of electicity supply in DSM and his idea for a renewable energy installation concept, including EV-bus operation during the meeting with JST. The CEO also

[5] https://www.pressreleasepoint.com/kapsch-carriercom-it-trans-2016-public-transport-goes-smart

mentioned the need for capacity building in the ICT/IT team in DART for further ICT application of BRT operation in the DART network.

The BRT Phase 1 installation along the Morogoro Road succeeded to convert the slow Daladala (local paratransit service) to exclusive-lane-based rapid service with low price, well competing to of private vehicles accessibility. It has plan of several ITS application in various aspects, see further information in Section 4.2.1(4).

(2) Flyovers and Bridges

There are three junction improvement projects which are built or in the process of building along the Nelson Mandela Road, the port access corridor with a circular road function of DSM.

1) Kigamboni Bridge

Kigamboni Bridge is a 680-meter-long bridge that connects the Dar es Salaam ward of Kurasini from the east to the west of the Kigamboni District across the Kurasini Creek. Construction work began in February 2012 and it was completed in April 2016. The completion of the bridge has offered an alternative transport link to the new district of Kigamboni. It has a toll bridge. See the section 4.4.6(2) for ICT application in the toll collection.

2) Tazara junction flyover development

Tazara junction (Mfugale junction) was one the city's notably busy intersections, connecting Julius Nyerere Road and Nelson Mandela Road. It is the main junction connecting the city to the Julius Nyerere International Airport and serves as a connection to other city areas. Construction started in Oct 2015 and was completed in September 2018. It was funded by grant aid from Japan, approximately 45 million USD.

The overpass allows vehicles in one road (the Nyerere road) to pass over the intersection directly, thus reducing congestion by an estimated 80%. Dar es Salaam residents who use the Taraza intersection are now spending their time more productively instead of waiting in traffic jams.

As aforementioned, a concept to build an additional underpass along the Nelson Mandela Road was studied.

3) Ubungo Intersections

Ubungo junction is connecting the BRT Phase 1 Route, Morogoro Road and Nelson Mandela Road, situated 10km away from the CBD of DSM. The construction is funded by the World Bank, undertaken by the Chinese contractor CCECC, will cost approx. 86 million USD, and is originally scheduled to be completed in 2020.

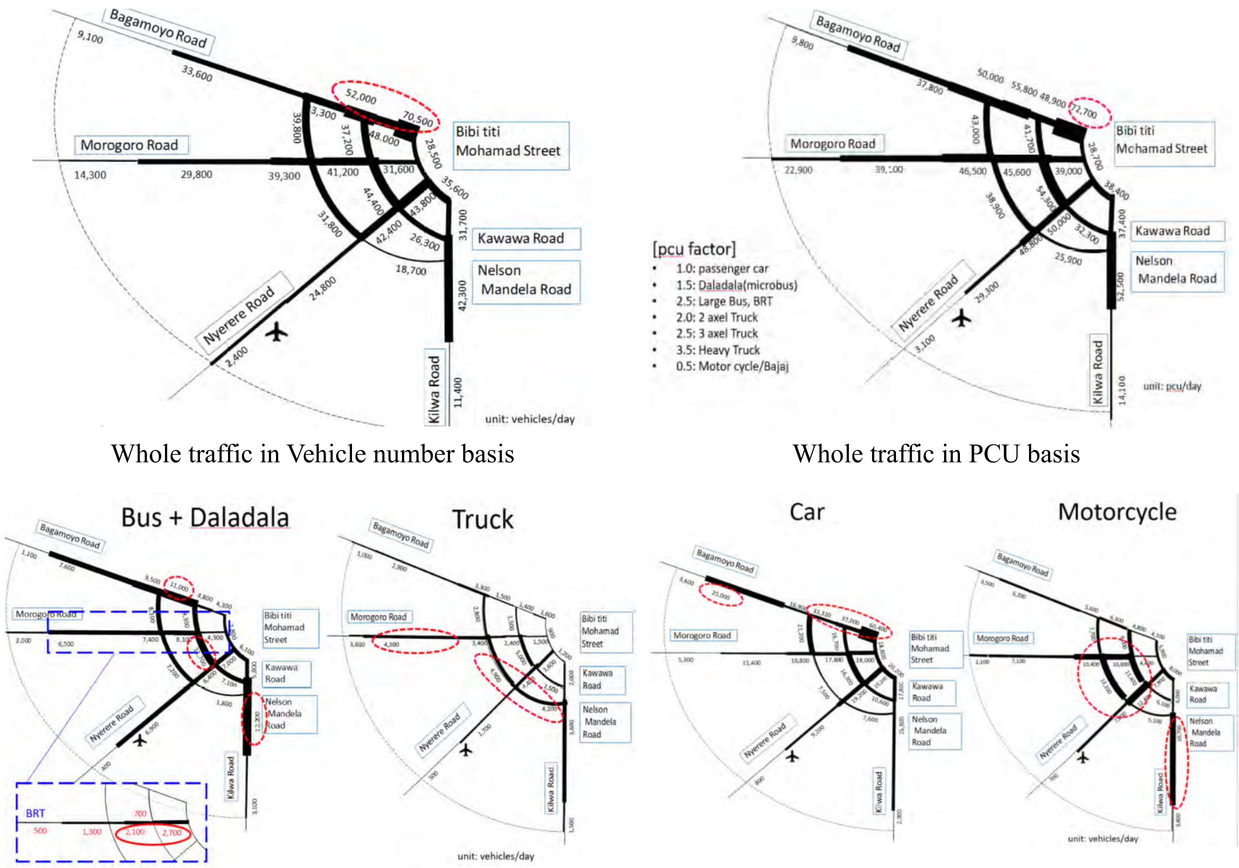
The project aims to build two layers of flyovers with BRT exclusive lanes, allowing straight movement without crossing traffic in both directions on the main corridors, and handles turning movement at the ground level. Close to the junction, a new BRT terminal is planned at the existing Ubungo intercity bus terminal, to accommodate the various BRT lines. The intercity bus terminal is also expected to move out to a suburb of DSM.

4.2.3 Reviews on Traffic Volume and Forecasts

There are two referable traffic volume and forecast summaries. The one is the Revised M/P, and the other is DART database.

(1) Traffic Volume and Forecast in the Revised M/P

The Revised M/P conducted a comprehensive traffic survey in Jan/Feb 2017, including vehicle counting, travel speed, person trip interview, parking[6], RP/SPs, etc. The following plates summarize the present traffic volume along the major corridors in DSM by vehicle categories.



Whole traffic in Vehicle number basis

Whole traffic in PCU basis

Source: Revised M/P

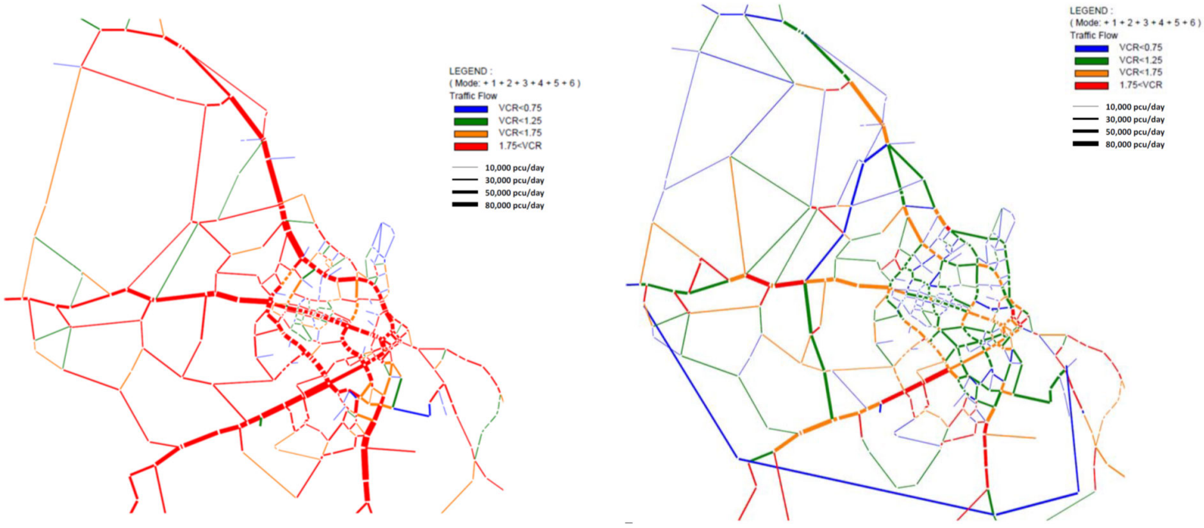
Figure 4.2.8 Vehicle Traffic Volume Summary

The figures above suggests the following:

- The section with the largest traffic volume exceeding 50,000 vehicles per day is along Bagamoyo Road, between Kawawa Road Junction to Selander Bridge.
- For the bus/Daladala, three sections are identified in red circles as having heavy concentration.
- As for the trucks, the link connecting the Port and Morogoro Road are major focus corridors.
- As for passenger cars, they are heavy in the northern part, along Bagamoyo Road. For Motorcycles, the southern part of the city shows a preference for motorcycles.

The future traffic volume forecast with scenario analysis for the target year 2030 was also conducted by the Revised M/P. The following plates shows the result of the scenario analysis for Do-nothing and Full-case development scenarios.

6 Such parking survey can be alternated by the scanning method. See the section 4.4.6(1) Mwanza parking management.



Traffic Volume in 2030 Case1, Do-nothing Case

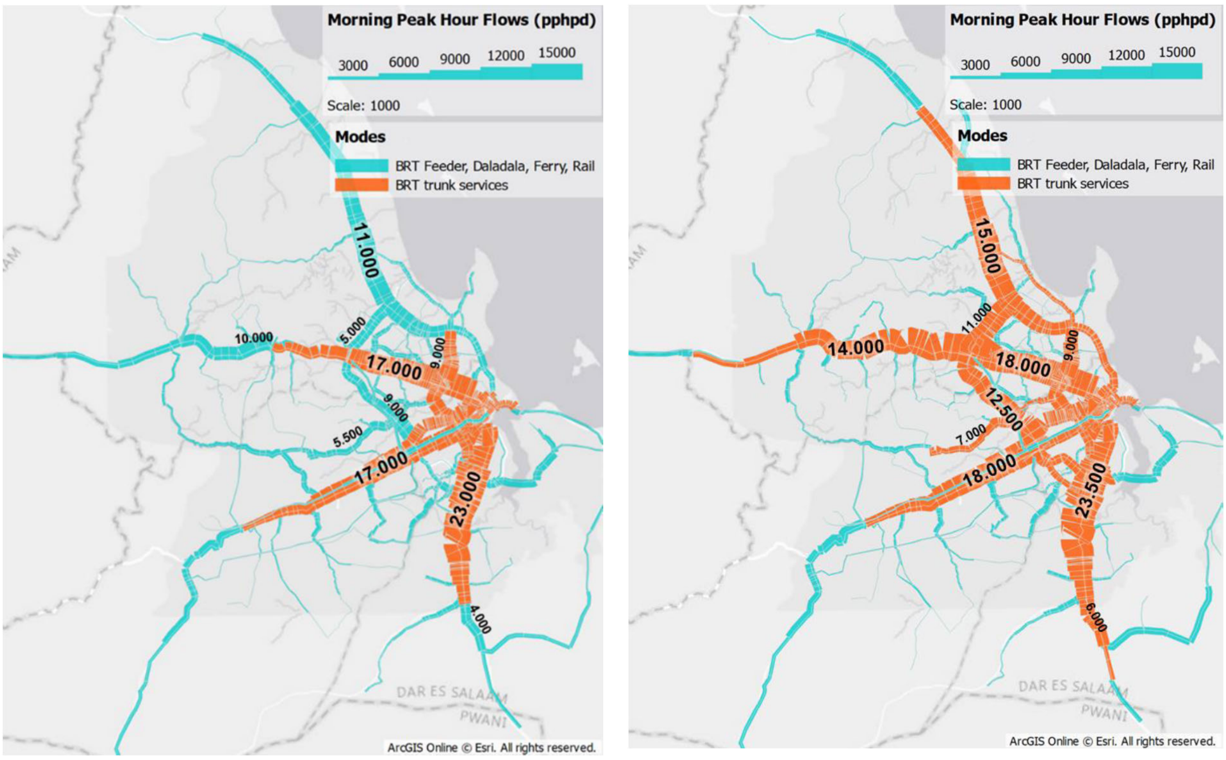
Traffic in 2030 Case 3, Masterplan Full scenario

Source: Revised M/P

Figure 4.2.9 Vehicle Traffic Volume Forecasts by Scenario in 2030

(2) Traffic Volume and Forecast in the DART Database

DART conducted passenger data collection in Sep/Oct 2018, and also shows its corridor based PPHPD forecast as follows.



Scenario 2025 morning peak hour demand

Scenario 2030 morning peak hour demand

Source: DART presentation in JICA Workshop on 26 Feb 2020

Figure 4.2.10 BRT Corridor PPHPD estimation

4.2.4 State of Practice on Project Development in Transport Sector

The following major transport projects are on-going in DSM:

- SGR development 1st phase
  - The 300km new railway development from DSM to Morogoro
  - Connecting the DSM central station in CBD, and building elevated structure for a 7km stretch in the DSM city
- The BRT Phase 2 development (funded by AfDB)
  - This is an alignment for Kilwa Road, on the southern directional radial route, including branch lone development connecting to the Morocco Branch line of the BRT Phase 1.
  - The project just covers the physical infrastructure development, and there is no ITS, traffic management system or fiber cable development portion.
- New Bagamoyo road widening project (Grant Aid by Japan) Phase 2
  - The Phase 2 project covers 4.3km widening Between Mwenge and Morocco Junctions.
- Dar es Salaam Metropolitan Development Project (DMDP)- funded by WB
  - The WB has financed the rehabilitation of more than 202km of urban local roads and 67km of major drainage, as flooding is the major traffic flow obstacle in DSM.
  - Includes capacity building of TARURA (PO-LARG) for DSM region.
- Coastal road and New Selander Bridge construction (funded by Korea, Economic Development Cooperation Fund (EDCF))
  - Connecting Msasani and CBD, a bypass of the Old Bagamoyo Road.
  - Total 6.23km road and bridge, the newly-built bridge will be 1.03km long with the main bridge built with the length of 670m with a maximum 125- meter-span extradosed bridge.
- Mbezi Luis Bus Terminal
  - Located 20km away from the CBD along the A7 Morogoro road. This will substitute the function of Ubungo long-haul bus terminal which will be changed into a BRT terminal. Construction of Phase 1 (bus terminal function) has opened on 20 of December 2020.
- The Project for Improvement of Transport Capacity in Dar es Salaam
  - Funded by Grant of the Government of Japan.
  - This project covers a bridge construction connecting Gerezani road and Bandari, south of CBD. This project will decrease travel time between Dar es Salaam Port and the city center, and contribute to operation of the BRT Phase 2. The bridge is under construction.

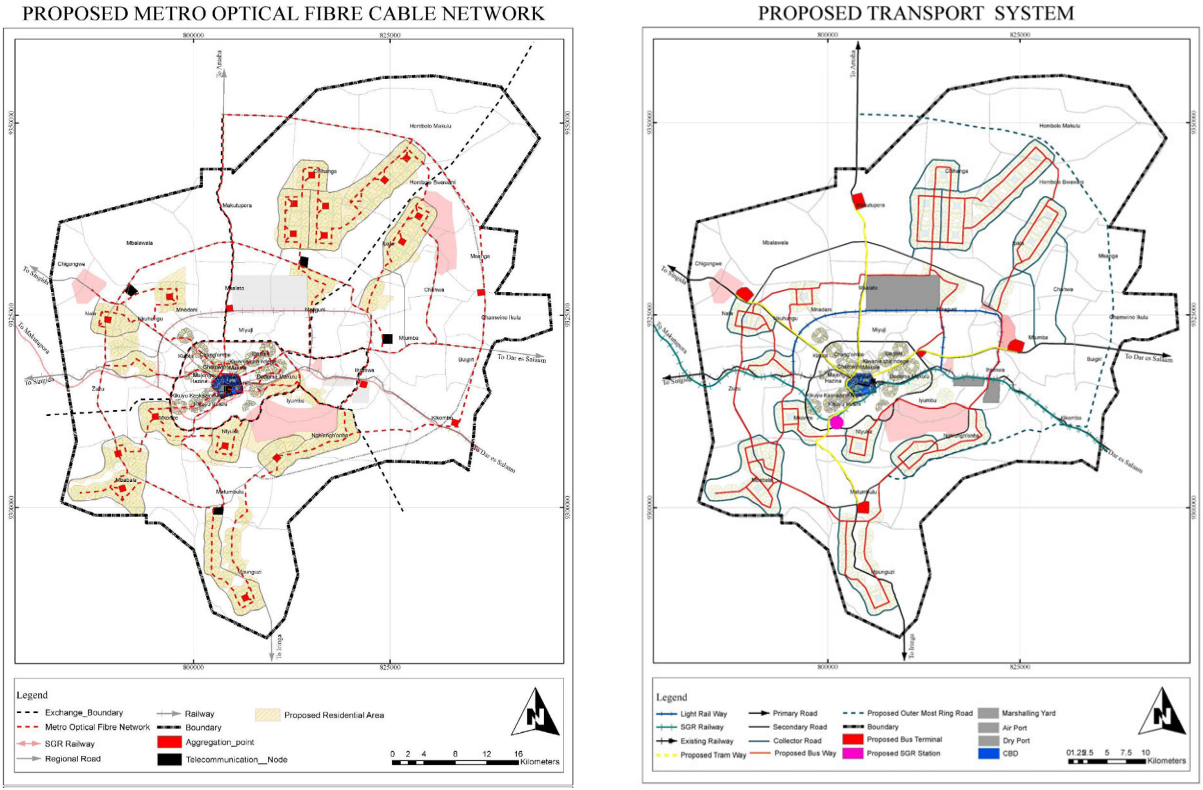
4.3 Transport System Development in Dodoma

4.3.1 Review on Superior Urban and Transport Planning

(1) Dodoma National Capital City Master Plan 2019-2039

The latest and superior plans for Dodoma is the Dodoma National Capital City Master Plan 2019-2039, prepared for Ministry of Lands, Housing and Human Settlements Development, published in April 2019. The masterplan consists of 10 sub categories of supplement studies including demographical and settlement analysis, seismic risk analysis, infrastructures and public utilities, transport setting, landscape setting, CBD redevelopment, environment impacts, and implementation planning. The supplement study for transport (Document #4) and CBD redevelopment (#6) proposes ITS services and ICT infrastructure policies in detail.

The main report of the masterplan envisions the city development concept, including regional economic hub, academic hubs, tourist destinations, sports and recreational functions, ecofriendliness, as well as smart city concept and transit-oriented city concept. The smart city concept requires ICT application in traffic safety and movement monitoring, and higher accessibility. The transit-oriented city concept expects to have the promotion of walkable city development integrated with public transport. The Main report proposes a development masterplan for various sectors, including land use, sanitation and waste management infrastructure, transport systems, CBD renovation and ICT infrastructure. The following figure illustrates the proposed masterplans.



Proposed Optical Fiber Cable Network | Proposed Transport Systems

Source: Dodoma National Capital City Master Plan 2019-2039

Figure 4.3.1 Dodoma Capital City Masterplan Proposals

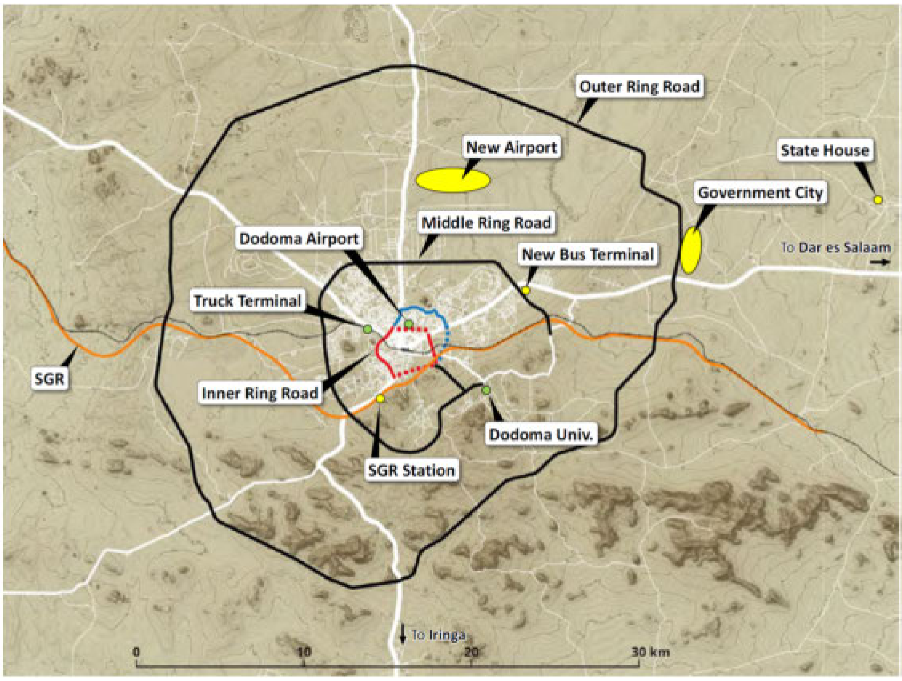
The supplement study #4 "Transport Infrastructure and Services" mainly refers to the findings of the JICA Final Report for the Data Collection Survey on Dodoma City Roads in 2019. The supplement study #6 "CBD redevelopment" shows the present situation of the TTCL fiber cable network and mobile phone coverage.

(2) Data Collection Survey on Dodoma City Roads

This survey was done in early 2019, funded by JICA, for assessing the inner ring road widening and construction project. As the Dodoma Capital City Masterplan proposed, the inner ring road was proposed together with the other outer ring and middle ring roads as shown in Figure 4.3.2. The figure also shows locations of the expected major projects including a new airport, government city, new bus terminals, SGR alignment and stations.

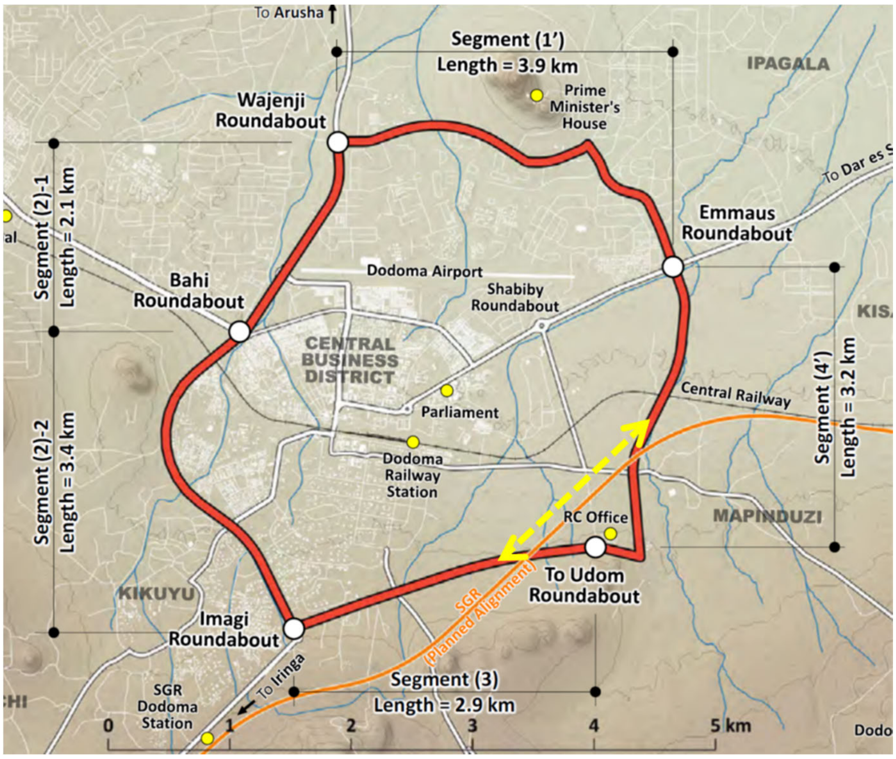
Figure 4.3.3 shows the proposed inner ring road alignment with project package information. It is expected and under negotiation that JICA will provide the grant fund for the segment (3) and segment (4'). The segment (3) is 2.9km in length, new construction, under TARURA ownership, and the segment (4') is 3.2km, with new construction, under TANROADS ownership. It should be noted that the alignment of both segments is under revision as the yellow dotted arrow shows in the figure to avoid crossing with the SGR alignment.

The study team confirmed that TANROADS is supervising the finalization of design, and the preliminary land acquisition assessment has already been done.



Source: Data Collection Survey on Dodoma City Roads (2019)

Figure 4.3.2 Three Ring Road Development Plans in Dododma with Major Development



Source: Data Collection Survey on Dodoma City Roads (2019) modified by JICA Study Team

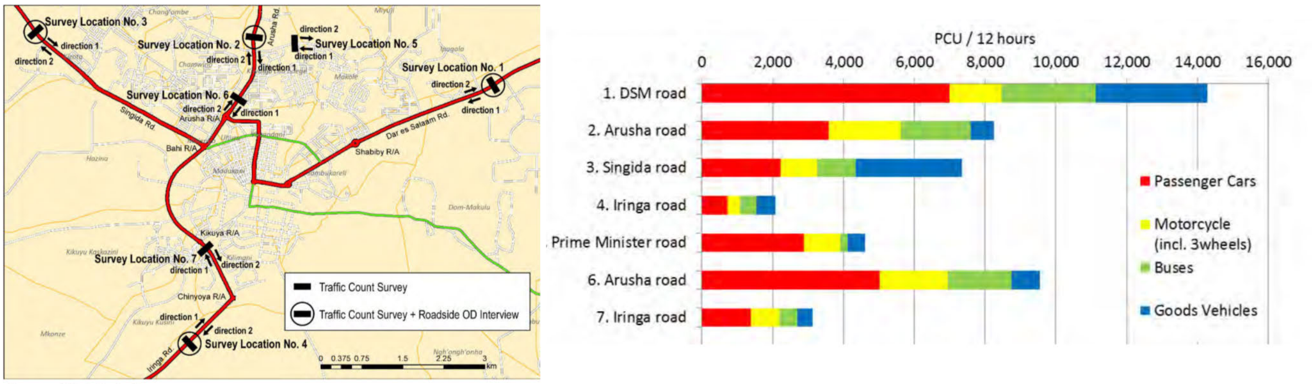
Figure 4.3.3 Inner Ring Road Development Concept and Its Revisions

(3) AfDB funding for Outer ring road and New Airport Development

The Outer ring road project, 110.2km of new construction, has already been connected to the AfDB loan funding (180 M USD) agreed upon in August 2019. Additionally, another concessional loan including the New Dodoma Airport development (Msalato International Airport) was engaged between AfDB and Government of Tanzania on 13 March 2020. The allocated amount to the Airport project was 271.63 M USD.

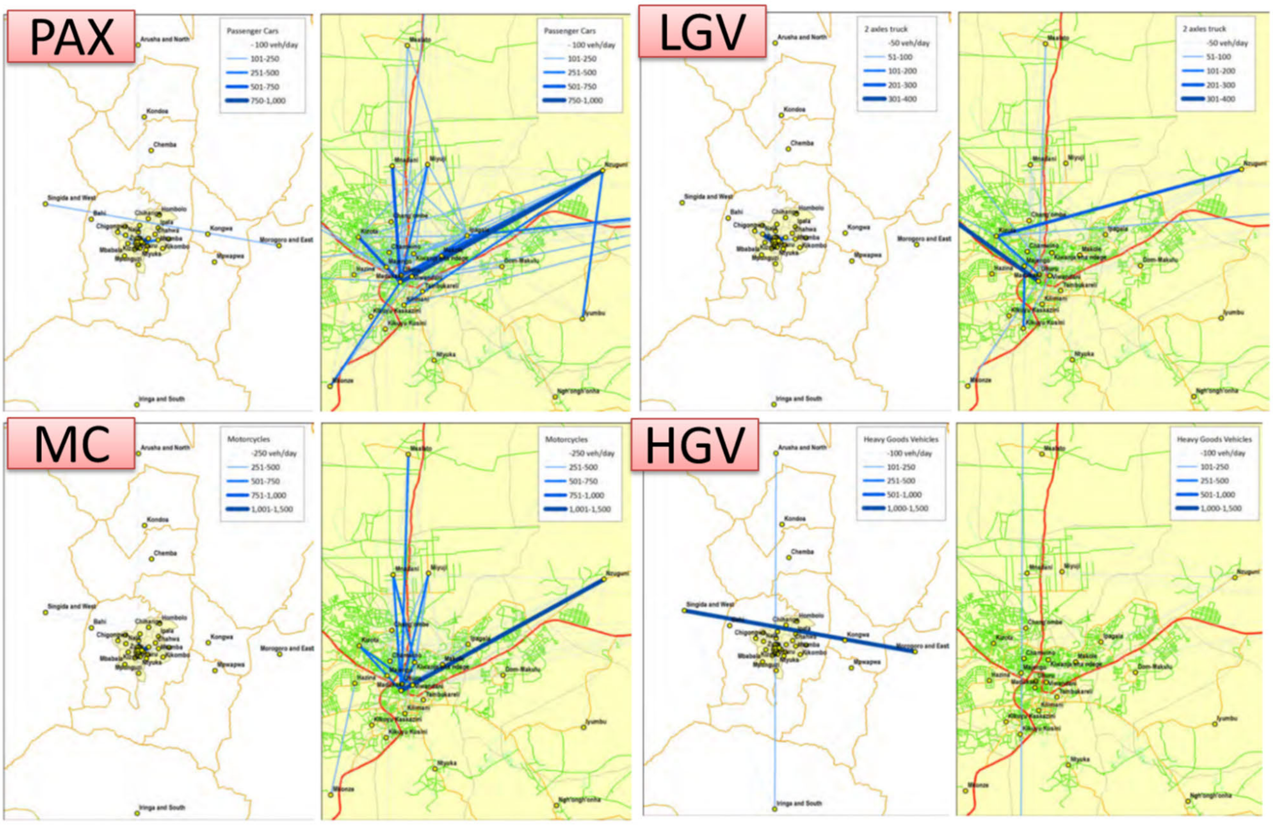
4.3.2 Reviews on Traffic Volume and Forecasts of Dodoma

The Survey for Data Collection Survey on Dodoma City Road conducted traffic counting in Dodoma in Jan 2019, which is the latest traffic volumes in Dodoma. The counting was done for 7 major influx locations with 4 vehicle categories, and summarized in PCU in 12 Hours, as shown in Figure 4.3.4. The survey also conducted OD surveys and clarified the major regional traverse and intra-city movements by vehicle categories as shown in Figure 4.3.5.



Source: Data Collection Survey on Dodoma City Roads (2019)

Figure 4.3.4 Traffic Volume in Major Sections in Dodoma in Jan 2019



Source: Data Collection Survey on Dodoma City Roads (2019)
Note: PAX; Passenger Cars, MC; motorcycles, HGV; Heavy Goods Vehicles, LGV; Light Goods Vehicles

Figure 4.3.5 OD in Dodoma for Major Vehicle Categories

The study team suggests the following further traffic trends in Dodoma.

- Outer Ring Road can diversify the Heavy Good Vehicle (HGV) movement between Morogoro – Shingida, which is coming into the city causing congestion in major corridors[7].
  - However, passenger car traffic will remain along the CBD-Nzugumi DSM road section and traffic along Arusha road will remain

7 Due to temporary road closure of the Morogoro – Dodoma section because of heavy rain land sliding happened in early March 2020, the traffic situation the ITS study team observed in March 2020 was abnormal (smaller).

- Inner ring road development is required to harmonize the growing passenger car and MCs demands with Pedestrians/NMVs, which is suggested by the Capital City Masterplan
  - Flyover cannot be developed for the junctions along the inner ring road, as its demand is lower than can be justified, and too close to secure the construction site.
  - Traffic signal installation will be the next option to achieve harmonization
- The traffic signal can be a symbol of smart city traffic management
  - Coordinated signal control methodology is a potential option for further development

4.3.3 State of Practice on Project Development in Transport Sector

The following projects are on-going:

- Bus terminal development (WB)
  - The new bus terminal development has been funded by the World Bank (WB), located 10km away from CBD along the DSM road. Ninety percent of the construction work has been completed and is waiting for inauguration. All intercity buses for the region will be destined to the new bus terminal.
- Stadium development
  - Close to the bus terminal, a new regional sport hub development is expected. There is no construction activities so far. It will impact traffic along the DSM corridor.
- Freight terminal
  - Dodoma city has an improvement idea, however, there is no apparent plans.
- Lena weighbridge station
  - TANROADS has developed a new weighbridge site in 2019.
- New Airport development
  - As aforementioned, the AfDB fund (equivalent to 271.63 M USD) has been directed to this project.

4.4 ITS and ICT Application in DSM and Dodoma

4.4.1 Traffic Signal Installation and Operations in DSM/Dodoma

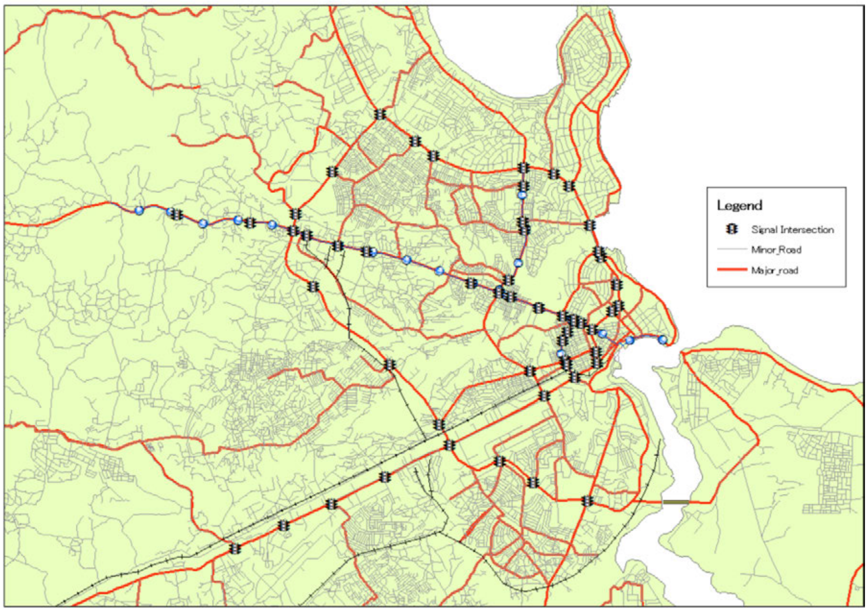
(1) DSM Signal Installation

1) Review on Revised M/P

There are 54 signal intersections in DSM. Traffic signals have been installed along only the national road so far. Actual construction and installation of traffic signals has been conducted by Tanzania Electrical Mechanical and Electronics Service Agency (TEMESA). TEMESA contracts with TANROADS regarding installation and maintenance of the traffic signal. There is no traffic control center in DSM.

The signal cycle of these traffic signals is fixed. Although they have the function of changing the cycle, the signal cycle is not to be changed according to traffic situation such as peak time, weekdays and holidays. One issue is that the traffic signals are old, and some traffic signal controllers cannot be fixed because there are no replacement parts.

Another issue is that the traffic police have controlled vehicle traffic at the congested intersections. Traffic movement should be harmonized for area traffic management, and individual control by manual traffic signal is difficult to do. Therefore, introducing adapted traffic signals and traffic control centers is very important for the improvement of traffic management.



Source: Revised M/P

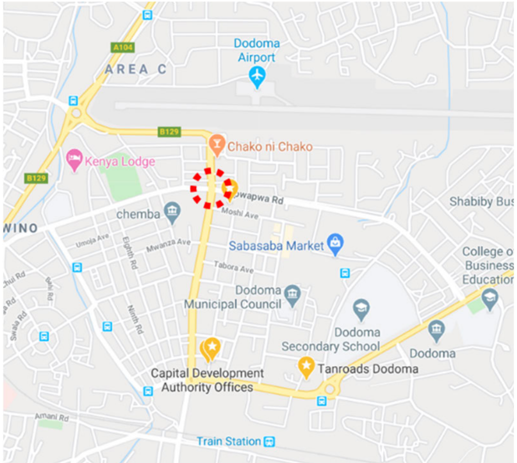
Figure 4.4.1 Location of Traffic Signal in DSM

(2) Dodoma Signal Installation

Dodoma has two signalized junctions, and only one junction is controlled with a signal.

Traffic light in Ndasha

Control box in Ndasha



Location (Ndasha)

Emmaus junction (restarted in May 2020)

Source: JICA Study Team

Figure 4.4.2 Traffic Signal in Ndasha and Emmaus Junction, Dodoma

- Ndasha Junction (under operation)
  - ➢ Located along the E-W School avenue and N-S Nyerere road. The school avenue is developed to accommodate the heavy vehicles, therefore, the heavy goods vechicles from DSM to Arusha and Singida/Mwanza pass through the Junction in an E-W direction.
  - ➢ The traffic signal was installed by TANROADS with its own budgets around 2007, and the present phasing was adjusted and set in 2018 according to traffic counting and analysis.
  - ➢ TANROADS requires external advisors for signals setting, and Dodoma office invited Arusha Tech (AIT).
  - ➢ TANROADS Dodoma office considers resetting is needed as traffic has increased since 2018.
- Emmaus (not in operation in March 2020, restarted in May 2020)
  - ➢ The signal itself was moved from the other intersection in Dodoma, which was considered unnecessary for signalization.
  - ➢ Located along the DSM road. The system was not connected to power due to the expected DSM road widening project when JST stayed in Dodoma. After the completion of widening in May, TANROADS Dodoma office restarted the signals with power.
- Other locations:
  - ➢ TANROADS Dodoma considers to signalize the Wajenzi junction. (see Chap 9.2.1)

(3) Signal Installation in Other cities in Tanzania

TANROADS involved Dar Es Salaam Institute of Technology, DIT, (and Arusha Institute of Technology, AIT) as technical advisor to its ITS projects in Tanzania. DIT has involved the following three ITS projects for traffic management in Tanzania recently.

- Mwanza: installed 9 signals for pedestrian crossing, and signals for reversible lane operation in three lanes road in Mwanza (Soma Road corridor),
- Manyala
- Gaesa

4.4.2 Traffic Surveillance System (Communication Infrastructures)

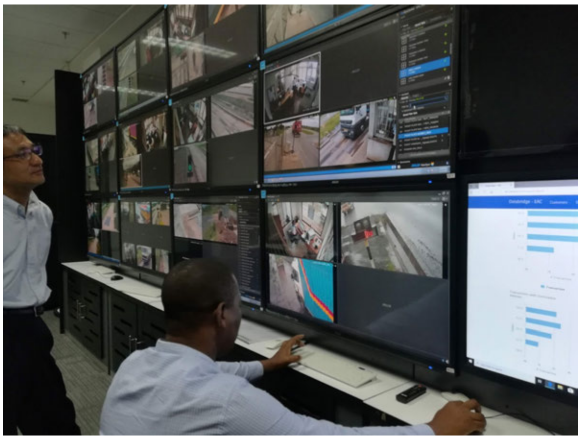
Generally, the penetration of CCTV in Tanzania is much lower than Mombasa, Nairobi and Accra. Kenyan cities have CCTV at every corner due to national security requirement for Al-shahab concerns, but, Tanzania has less security requirements compared to Kenya. However, the study team collected the following two practices in Tanzania for CCTV application in ITS.

(1) Weighbridge Operation Monitoring System of TANROADS

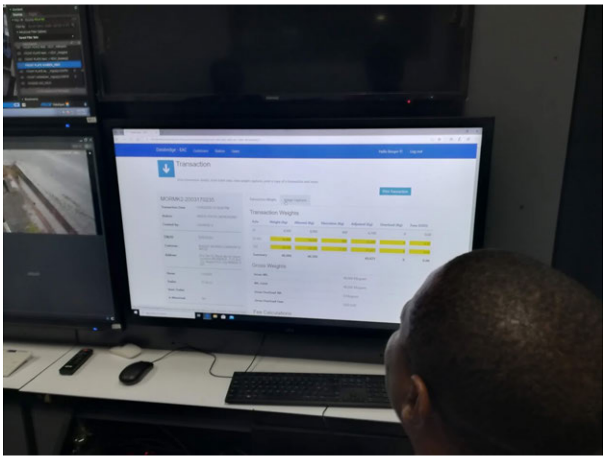
The TANROADS, the national intercity road agency, has developed CCTV based weighbridge control center monitoring system since 2015 and started its operation in 2018.

BEST PRACTICE

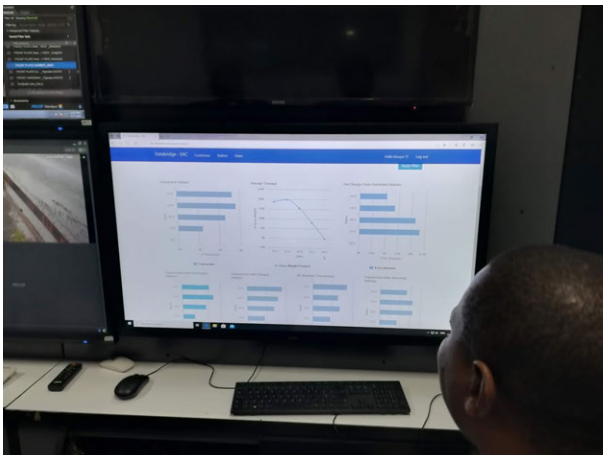
CCTV monitoring panels



Monitoring panels and operation panel



WeighBridge measurement records. Figures marked in yellow are the number of trucks with overloading, but if it is within 5%, so there is no fine levied.



Dashboard showing the last three days and today's passing traffic volume, average tonnage, and total surcharges

Source: JICA Study Team

Figure 4.4.3 Photos of CCTV Weighbridge Monitoring System of Tanzania

1) Background of the CCTV installation

The incentives for introducing this system are to be able to check the measurement results later and to monitor that the staff are doing their job properly (whether the staff has rewritten the measurement results can be checked later), so that TANROADS can operate with confidence.

- WeighBridge was a hotbed of injustice. Moreover, there were many inquiries about the measurement results that we were unable to respond to.
- The Weighbridge has three types of weighing systems:
  - a type that weighs one axis, a type that weighs up to three axis groups at a time, and a type that weighs the total weight of the vehicle.
  - Threshold to be determined by the number of heavy-duty trucks passing through the area: single-axle type for 250 or less trucks per day, three-axle group weighing type for 250 to 500 trucks per day, and total weighing type for more than 250 trucks per day.
- TANROADS has placed weighbridges in 42 locations throughout the country. Seven of these sites are being screened at WIM and measured at the weighbridge.
- Up to 5% of the specified axle weight is not subject to a fine (it is recorded as overloading in the record).
- The system is based on the Tripartite Transport and Transit Facilitation Programme (TTTFP) agreement between SADC (South African Development Community), EAC (East African Community) and COMESA (Common Market for Eastern and Southern Africa). The agreement provides for vehicle load control, common vehicle registration, driver registration, common border control, etc.

WIM[8] at Lena site in Dodoma

Weighbridge for three axle group measurement

Source: JICA Study Team

Figure 4.4.4 Operation of TANROADS Lena WeighBridge Station, Dodoma

2) Develpoment of the CCTV Monitoring system

The system began to be procured in 2015. The installation cost was 2.2mil USD (about 240million yen), and it was planned to use the World Bank's IDA fund at first, but it did not make it to the application period. The developer was a turn-key-based contract by a Tanzanian company (Inter-consult Ltd , Technoimage Ltd , DUKU Ltd).

- Designed for 2015-16, monitoring began at the first Mwanza Station in October 2018, with 13 CCTV locations in operation from April 2019.
- In the HQ of TANROADS, it is possible to monitor the image of the vehicle to be measured and the measurement results.

[8] See WIM operation in video https://photos.app.goo.gl/wyxPhruiZsG24ER19

- There are 12 monitoring screens, with 1 screen for each of the 11 main stations and 1 screen for the remaining 2.
- There are a total of 42 weighbridges, and the number of CCTV monitors is under consideration for expansion.

3) Develpoment of the CCTV Monitoring System

- The measurement results of each axle weight and four images of the vehicle (front, back, front, left and right) are saved as a single record in the database.
- The system does not recognize license plate characters in the weighbridge, but WIM does.
- One Weighbridge Station is equipped with a weighing instrument, 12 CCTV cameras, a measurement monitoring PC and a printer. There are 12 camera images transmitted to the center here, but the images displayed are images of the vehicle's entry to the weighing instrument, images of the operator's monitoring of the work situation, and images of the axial weight measurement results.
- The center uses CCTV camera images only for screen display and does not store video.
- The server uses two racks of servers at the government data center (eGA). However, the images of CCTV cameras are not being transmitted to this server, and the video images from the cameras are being saved at each weighbridge station. The storage capacity of each station is three months' worth of data, and it is designed to overwrite more than that.
- We are using TTCL's VPN service between Weighbridge and the data center. Although there are some wireless connections in remote areas, they are basically connected by optical fiber cables. VPN service between the data center and TANROADS HQs via fiber optics.
- In the case that data communication is not possible due to an obstacle, the data of the measurement result is saved at each station and transmitted when it becomes possible to communicate.
- The data center fee is 46mil Tsh/year per rack (2.25 million yen per rack per year, which means that TANROADS pays about 4.5 million yen for the annual data center fee). One rack user fee comes from the TANROADS budget and the other from the Road Fund.
- The data communication cost is 5 mil Tsh/Month per Weighbridge station. (250,000 yen per location per month: annual communication costs for the 13 locations are approximately 39 million yen per year). This cost is also an expenditure from the Road Fund.

4) E-payment on Penalty Collection

After July 2019, TANROADS stopped collecting fines in cash and switched to GePG. This allows the data to show how much in fines have been collected. In addition, leakage has also been avoided.

- The fines will be placed in the Road Fund, who allocates operational costs, including human resource development costs, to TANROADS.
- Under the EAC arrangement[9], the Road Agency coordinated to step into the collection of fines, which is under the jurisdiction of the Police, and is now a one-stop, fine collection.

(2) Traffic Police CCTV-based Enforcement

Traffic Police has started its speed violation enforcement since 2019 as a pilot project. It is called as an "Automated Camera Project." The CCTV based enforcement is deployed at intersections of Ubena Zomozi, Bwawani along Morogoro Road, 200 km away from Dar es Salaam. The CCTV and its background system

[9] Supported by the JICA's Axle Load Harmonization project for EAC, 2010-11

detect number plates of over-speeding vehicles, and report the number plates to cellphones of police officers for enforcement. The project was planned and implemented by Ministry of Works and Transport, TANROADS and Traffic Police. They have not disclose the number of the enforcement vehicles under this system as it is pilot basis.

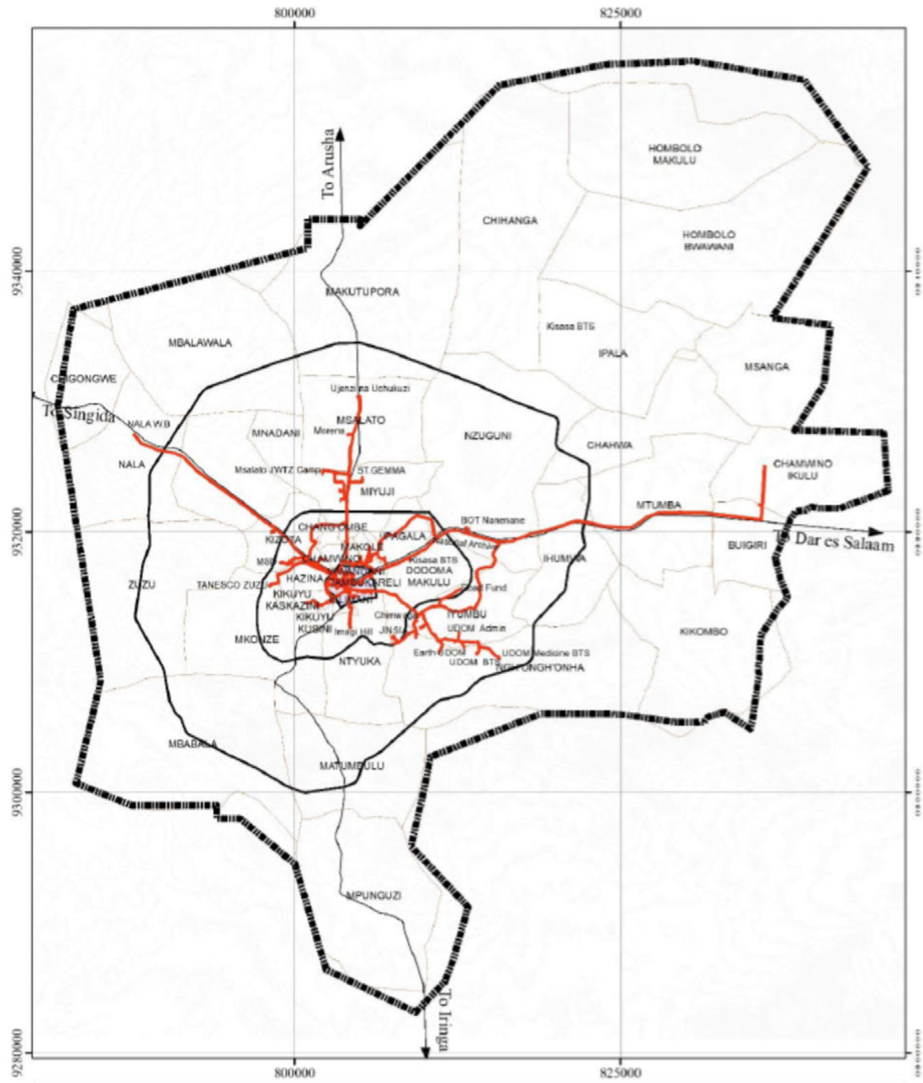
4.4.3 Communication Infrastructure

In Tanzania, government related agencies' ICT systems tends to utilize state owned TTCL's service. For example, the TANROADS weighbridge monitoring system utilizes TTCL's data communication service between weighbridge stations and the TANROADS monitoring center located at TANROADS headquarters. In addition, LATRA's vehicle tracking system for all long-haul buses is currently using TTCL's data communication service and another service, however they will integrate into TTCL's service in the near future.

As mentioned in the above section, the ICT system in the government agency also tends to utilize the government data center in Tanzania. The above TANROADS weighbridge monitoring system server is managed in the government data center. The study team also found that the vehicle registration system and driving license issuance and management system managed by Tanzania Revenue Authority (TRA) is using government data center as their back up and disaster recovery.

The ICT sector in Tanzania has been fully liberalized and the Tanzania Communication Regulatory Authority (TCRA) is the regulator to create fair market competition among Internet Service Providers (ISP), Voice and Data Licensed Operators. Currently, there are five telecommunication operators in Dodoma. These are the Tanzania Telecommunication Corporation (TTCL), Airtel Tanzania, Vodacom Tanzania, MIC (Tigo) and VIETEL (Halotel). While TTCL uses wired, wireless and optic fiber transmission systems, other service providers use the two systems of wireless and optic fiber. By using its own facilities, TTCL provides three levels of services ranging from fixed and mobile voice and data communication. Others provide the key services of mobile voice and data internet.

The TTCL's existing optical fiber cable route is shown in Figure 4.4.5.



Source: Dodoma City Master Plan

Figure 4.4.5 TTCL's Optical Fiber Cable Route in Dodoma

4.4.4 Traffic and Transport Information Provision Systems

Tanzania has little implementation achievements in a traffic and transport information provisions system, particularly for passengers and customers. The following are proposed for further implementation.

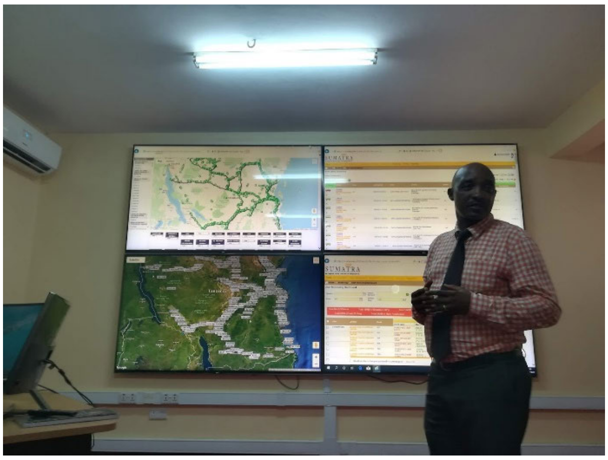
- DART has a plan to develop a real-time BRT service status information system and apps for passengers and customers in DSM.
- LATRA's intercity bus vehicle tracking system would be expanded for its service for information provision to passengers and customers. See detail in section 4.4.5(1) of LATRA VTS.
- TRA's vehicle registration databases are opened to various transport providers. See the details in section 4.4.6(2) of TRA vehicle registration database.

4.4.5 Public Transport Operation Management Systems

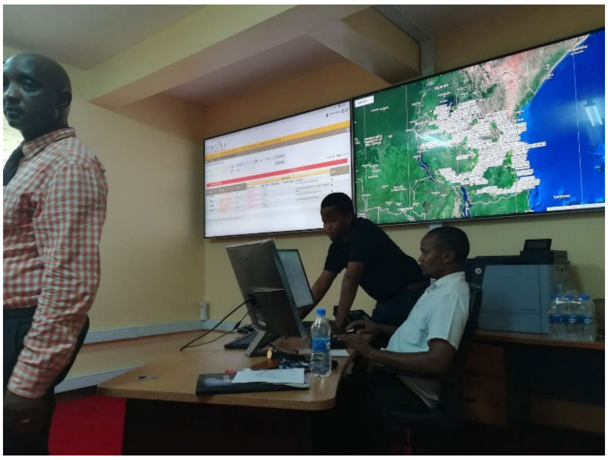
(1) LATRA's Vehicle Tracking System

BEST PRACTICE

LATRA, land transport regulatory agency, has recently developed the Intercity bus operation management system with its own budget, which has reduced the number of accidents and fatalities by more than 70% since installation, which is highly appreciated by private bus operators and the surrounding countries. It is called the Vehicle Tracking System (VTS) in LATRA. The detail of the background, achievement, system development, and expansion idea is summarized as follows.



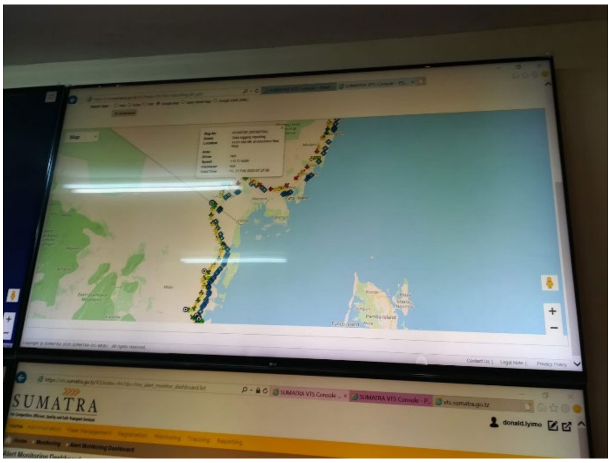
Main Front Panels (4 screens)



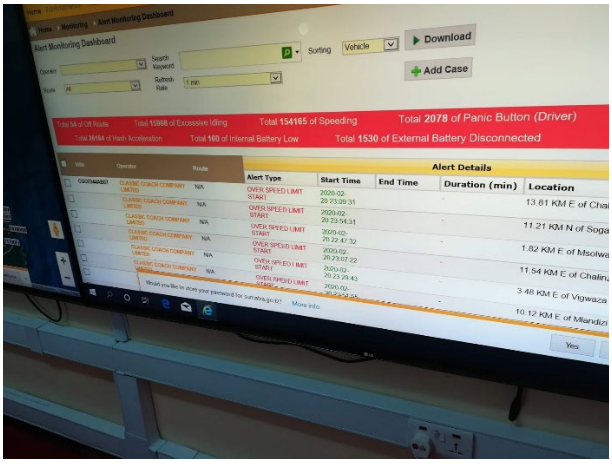
Sub Panels (2 screens)

Bus location and status of the operation speed with icons (under 85km, bus locations are shown in green)

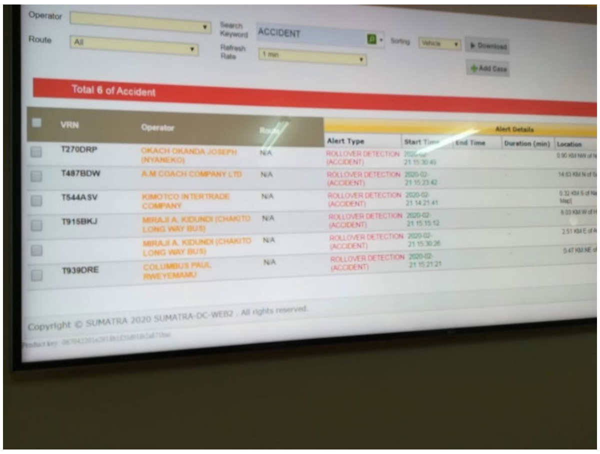
Registration number of buses, showing around 2000 buses in the two panels,



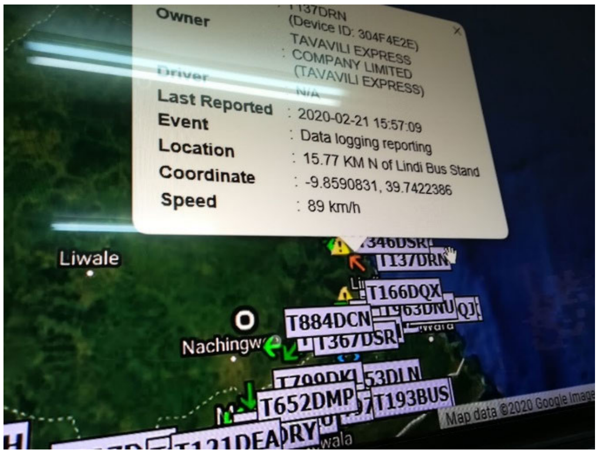
Records of international bus operation from DSM crossing over the Kenya border. Even across the border, bus monitoring is possible. As soon as it crossed the border, the icon turns red, indicates traveling more than 100 km/h. LATRA can't control the bus under the current circumstances.



Records of international bus operation: History of multiple over speeding records of DR Congo registered out of speed in 23:09 on 20 February 2020.



History of accidents



Overspeeding detail, showing 89 km/h

OBU, manufactured by Malaysian b'smart Ltd

The VTC building. The monitoring room stations are on the ground floor level. No-frill operation.

Source: JICA Study Team

Figure 4.4.6 Operation of TANROADS Lena WeighBridge Station, Dodoma[10]

[10] For more photos: https://photos.app.goo.gl/RHwVs9rPvUfATg9t8

1) Objectives and Outline of the Operation

- [Objectives] LATRA are currently monitoring the operation status of approximately 3,800 intercity buses in real time on a 24/7 basis and are operating with 4 people in 3 shifts (there are vacancies in the staff). The system itself has the capacity to monitor 60,000 units simultaneously.
  - In the operation room, there are 6 large monitors and 4 operator seats. There is a separate server room.
  - The targeted buses are intercity buses with 40+ passengers, including internationally operated buses from other countries. (See photos for buses of DR Congo and Kenya)
    - All buses operating within Tanzania are required by law to comply with the LATRA Service Regulations.
- [Motivation] Terrible situation of road accidents before 2015 was the biggest motivation. LATRA made a F/S with COWI (Denmark). Delivery of the physical speed governor (speed limiters) was enforced before 2010 but did not work as it could be tampered.
- [Speed Monitoring] The vehicle is equipped with a GPS on-board device that transmits information such as driving position, speed and acceleration to the center every three minutes via 4G or 3G, and displays the position, direction of travel (blue arrow) and vehicle number on the monitor.
  - The maximum speed set on the road is 80 km/h, and 86 km/h operation is indicated in orange (86 km/h or more), red (100 km/h or more) and dark red (110 km/h or more) according to the overrun conditions. In addition, the system also displays "Rollover Accident" and other information based on acceleration.
- [Enforcement] The center can directly contact the bus company and the police by phone. If an accident is suspected in the system, the LATRA office will respond immediately.
  - In the case of an accident event, data will be transmitted immediately regardless of the 3-minute transmission interval.
  - It has a function to output records (evidence) of excessive speed as a report, which is transmitted to the police, and the police take a fine from the driver according to the number of excessive speed incidents. If they are charged 3 times or more, LATRA will charge all of them instead of the police.
    - In the case of the police, 30,000 TSH (equivalent to USD15) per excess.
    - LATRA 100,000TZS (equivalent to USD50) for 3 or more times
  - The fine for over-speeding is borne by the driver. If there is more than one driver, it will be confirmed by logbook, etc. LATRA is considering whether to force the driver swipe his ID, or include fingerprint authentication for modernization.
  - The location of each bus vehicle is not only plotted on the map, but also judged from the locations of landmarks such as "9km west of the ABC intersection" and "2km east of the XYZ terminal".
- [Bus operation management] A fine is also imposed for willful deviation from the timetable. In this case, it would be a charge to the bus company.
- When the on-board Panic Button is pressed, the center will respond in an emergency.
  - According to survey team's actual ride on a bus company, there were no such function and on-board panic buttons.
- [Tamper-proof] If tampering with on-board equipment is discovered, bus operation will be suspended for 30 days (for that bus only).
  - In case of tampering with in-vehicle equipment, data is constantly monitored, and if data is not sent every 3 minutes when the vehicle is supposed to be in operation, the LATRA

branch staff will check it, and if tampering is found, the vehicle will be suspended for 30 days.

2) Achievement: Changes in drivers, accident reduction effects, and expansion to other countries

- When it was introduced in 2017, LATRA started by monitoring bus operations between Dar ~ Mwanza. In the beginning, most of the icons were bright red (running over 100 km/h). We started the fines, then immediately, every bus was kept under 85 km/h (green).
- **The number of accidental fatalities on long-distance buses in Tanzania continued to decline by 35% from the previous year from 2017 to 2019.** It is a visible effect.
  - ➢ Drivers strictly adhere to 80 km/h within Tanzania, however, when they cross the border, their attitude clearly changes and they start operating at or over 100 km/h (the icon changes from green to red).
  - ➢ Bus drivers are aware of this system as a Big Brother (always under surveillance).
- Neighboring countries' interests
  - ➢ Rwanda police are expected to agree on a speeding violation control agreement for international buses with LATRA by applying this system.
  - ➢ The Kenya NTSA (National Traffic Safety Authority) visited the LATRA in 2020 and showed interest in the system.

3) System Development and Operation detail

- It is a stand-alone self-budgeting project of LATRA.
  - ➢ The actual contractors are b'smart (https://www.bsmart-solutions.com/), a Malaysian company, and the Tanzania Computer Center (https://www.cctz.com/) JV.
- The vehicle tracking unit will be procured from three companies designated by LATRA from each bus company.
  - ➢ Terra Technology, Fleet Track (http://www.fleettrack.co.tz/) and Easy Track (https://easytrackafrica.com/) / Motor Chand JV, in accordance with LATRA standards.
- LATRA has its own server, but it's not possible to tell if it's being sent to the Cloud Server from each in-vehicle unit and then to our own server until an engineer who knows the details is asked.
  - ➢ The price of the device attached to the bus varies depending on the model, but the average price is about 700,000 TSH (about $350).
  - ➢ There are two types of bus-mounted devices: buy and rent. If bought out, the bus company will pay 30,000 TZS ($15) per vehicle per month. The cost for a rental is 60,000 TSH ($30). The three companies designated by LATRA will receive this money, from which the data communication costs will be paid.
  - ➢ In the case of rental, maintenance such as responding to the breakdown of the onboard equipment is included.
- The communication infrastructure is based on Vodafone at present.
  - ➢ In the future, the company plans to transition to a government-run TTCL.
  - ➢ The communication infrastructure for Internet access from the monitoring center already uses TTCL, as LATRA itself is government-affiliated and requires the use of TTCL.
  - ➢ The company also expects that the integration of all communication infrastructure, including mobile data communications, into TTCL will result in a discount on usage fees.
- The main server is operated by a local server, not using the cloud.
- The center was developed in an existing building, not by building a new housing for the system.

4) Expansion of Systems

- Expansion of Fleet Variety
  - Clearly effective in reducing traffic accidents, and the development of freight vehicles is an established route in the future. LATRA expects to extend this to government vehicles and BRTs who have complained of rough driving by bus drivers.
  - For railroads, LATRA has five GPS units that are being tested on locomotives.
- Bus service improvement
  - Each bus company will also be able to log in to the system to monitor and manage the operation of their vehicles.
  - LATRA is currently working on the introduction of E-ticketing (seat reservation and payment), and linking it with the passenger count data obtained through the introduction of E-ticketing.
  - The data can also be used for marketing purposes, such as planning the number of buses operated by bus operators.
- Expansion to a Passenger Information System (information provision for users).
  - Including on-site passenger information monitors at the intercity bus terminal in Dar es Ubungo bus terminal.
  - Not yet ready to provide apps, etc. due to budget constraints
- Not yet possible due to LATRA budget constraints, but the LATRA has interest in the following items:
  - GTFS data formatting
  - fuel consumption monitoring
  - vehicle inspection
  - monetization through data sharing with the private sector and providing platforms to other businesses

5) The JST's assessment

JST appreciates the project in the following aspects:

- Self-financed and self-managed project
  - Combined with Malaysian private technology company and local companies' involvement.
  - Presented the possibility of ICT technical capacity in the region
- No-frill development concept,
  - The center was developed in a residency in the DSM Suburb.
- Noteworthy achievement in traffic accident and fatality reduction
  - This project contributed to approach the SDG target of 3.6, half the number of global deaths and injuries from road traffic accidents.
- Accepted by stakeholders
  - The bus operators have accepted and approved the enforcement system, in its fairness and efficiency. The operators also cover the monthly payment.
- Regional oriented
  - The international bus service providers from the other countries

4.4.6 Other ICT Interventions

The following interventions are not developed for the DSM and Dodoma, however, JST appreciates the advanced ICT practices in the transport and traffic management sector.

(1) On-Street Parking Management System in Mwanza by TARURA and NPK

BEST PRACTICE

TARURA, the on-street parking manager for all cities in Tanzania, has implemented a pilot on-street parking management system with number-plate scanning ICT technology integrated with e-payment collection arrangement since 2019, in Mwanza, not our target city, but the second largest city in Tanzania. The new ICT system has been proposed and initiated by the local private company NPK, who was the authorized contractor of the Mwanza parking management. NPK invested the system development by itself, and TARURA supported the system integration with the governmental e-payment database. The details are explained as follows:

1) Background and System[11]

The NPK had a contract with TARURA to manage on-street parking in Mwanza, Tanzania. NPK used to manage parking payments through hired inspectors and POS devises, as other cities do, employed 150 inspectors, but it didn't make any operating profit at all. Therefore, they applied a system by SCANACAR in the Netherlands since April 2019 as a rationalization plan.

- There are 10 inspectors with 1 motorcycle (each person patrols for three hours, and they rotate in turn) and Enforcement team. There are 15 members in total.
- Most scans of parked vehicles can be done with a motorcycle. There are 4 cameras on the bike's cargo that can read the license plate of a parked vehicle within a range of up to 5m on both sides.
  - Even in parallel parking, if there is a 30cm gap between the vehicles, the system can read the license plate number while driving at 40km/h or more.
  - Two 4G SIMs (Vodacom and Airtel) are installed and data is siphoned off by one of the carriers. If both companies are down, they are stored in internal storage.
  - If it is difficult to access an area with a bike, inspectors can scan with their smartphone,
    - Inspector will not be directly involved in the fee collection at all.
- The motorcycle always moves following the routes the navigation system requested.
  - The system monitors the motorcycle movement, in case of an unexpected stop (as there is a risk of being threatened by the user.)
- Immediate database of vehicle registration numbers, latitude and longitude, photos, etc., are recorded.
  - The owner of the vehicle is charged a parking fee via GePG (detail information of charging shall be sent via SMS). See other details for billing
  - There is map data about the restricted area of on-street parking, and only vehicles within the restricted area are recognized as parked vehicles. Off-street parking can be excluded. Also, they have detailed specifications for on-street parking, such as the partial lifting of restrictions.
  - The system is possible to exclude charge claims with referring to the VIP database (e.g., not charge parking fees for emergency vehicles, police vehicles, etc).

[11] Better to see the video for proper understanding of the system https://www.youtube.com/watch?v=iaRLwsq2ZVI

- ➢ Parking fees must be paid by 24:00 on the day of the event. The next day there will be a delay penalty. If further claims pile up, the NPK Enforcement team will clamp the vehicle (clamping authority has been transferred from TARURA).

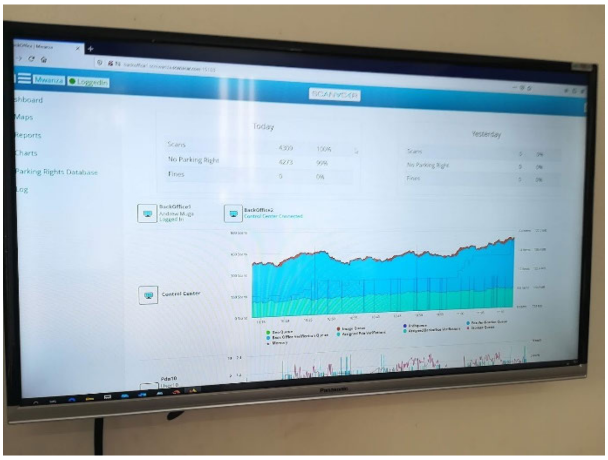
2) Achievement

- In the initial stages of its introduction, the system was used to collect 10% of the revenue. Due in part to the enforcement effects of clamping and other measures, 60% are now paid immediately and 40% are late in payment.
  - ➢ NPK charges 2,000 to 3,000 units per day. There is also a monthly pay-as-you-go contract for about 600 units.
  - ➢ The average monthly turnover is 120 Million TZS (approx. 60,000USD).
- The parking fee was 2,500 TSH per day before the introduction of the system, but it was lowered to 1,500 TSH on the introduction. There was also a monthly contract (36,000 TSH), and although the revenue cannot be simply compared before and after the implementation, sales increased by 50%.
  - ➢ The company's profits have also increased, and no POS paper rolls are needed.
  - ➢ As a result, **there were 3 positive outcomes: users (convenience, price reduction), the management company (increased profits), and TARURA (increased parking income).**

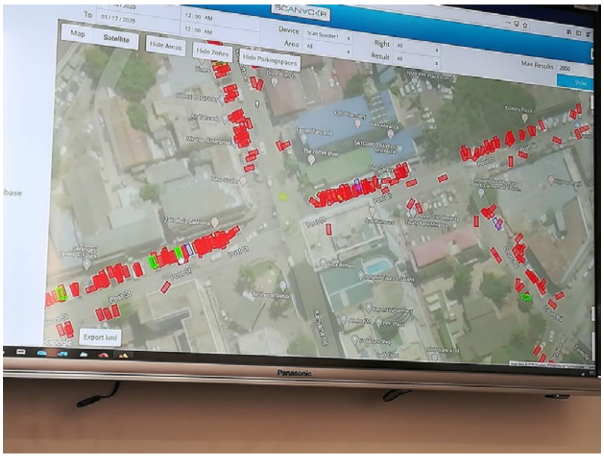
3) Billing: GePG database access

- Billing is done through GePG (*150*22# (phone number), Unstructured Supplementary Service Data - USSD[12] basis).
  - ➢ GePG is a government-run billing system led by the Ministry of Finance, and TARURA is available free of charge.
  - ➢ Not only USSD, but also apps-based communication are available.
  - ➢ NPK has full confidence in GePG and assures that "the success of this system is due to GePG's ease of billing".
  - ➢ The connection fee for M-Pesa etc. is 1%, so if 1500TSH is charged, the user will be charged 1515TSH. Bank accounts and credit cards can also be used.
- For GePG billing, the system automatically obtain the TRA vehicle registration data to ensure the billing data attached to the vehicle.
  - ➢ At the same time, a stolen vehicle and the discrepancy with a registered vehicle are confirmed. In the case of a stolen car, the police is contacted.
  - ➢ TARURA led the coordination with GePG and TRA, and although it took time, the connection went without a problem, as both TRA and GePG were profitable.
- In addition, NPK uses government servers (EGA, electric government agency).
  - ➢ The data communication between the bike and the server is 4G, but the data communication between the server and NPK is monitored by an Internet connection, and the user logs in with ID and PW, and the data communication is protected by encryption. Encryption is essential because some of the data we handle is sensitive, such as vehicle registration in TRA.

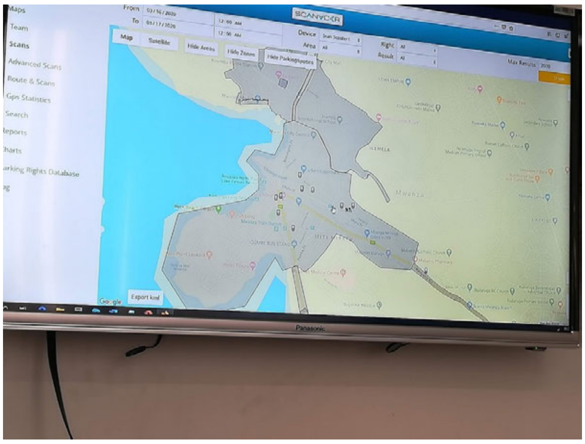
[12] Can be referred to as "quick codes" or "feature codes". It is a communications protocol used by GSM cellular telephones.



Dashboard: showing 4,300 scans achievement on the day with a graph showing the number of scans per hour



Location of the parked vehicles on the map. Red squares are unpaid (most are red because they are paid by 24:00 on the day of the event). Blue and green are, respectively, paid and paid in monthly contract.



Target parking control area in Mwanza, covering CBD and major corridors

Reference: The present manual parking fee collector in Dodoma, having the handheld POS devices with TARURA logo mark

Source: JICA Study Team

Figure 4.4.7 Operation of TARURA/NPK Parking Management System, Mwanza

4) Expansion Possibility

- For NPK, future plans include the following:
  - ➢ Hourly charging (bike can go on round-trips easily and the frequency can be expanded)
  - ➢ Parking fee hikes in urban areas (easing congestion through pricing policies)
  - ➢ Parking fees by vehicle (TRA data can be checked to determine the type of vehicle, large vehicles are more expensive and eco-friendly vehicles are cheaper)
  - ➢ Parking location information (users can be directed to available areas)
  - ➢ Expanding to other countries
    - ✧ This system can rationalize the inspectors. On the other hand, municipalities seeking to secure jobs are more likely to oppose it. Alternative positions are needed.
- TARURA would like to expand this system horizontally if it has enough budget within 2020
  - ➢ Applying to the DSM's present parking area, five scooters would be enough to scan the whole area. On the other hand, the capacity of the GePG doesn't seem large enough.

  - TARURA is the only on-street parking management organization in Tanzania, so business development is easy.

5) The JST's assessment

JST appreciates the project in the following aspects:

- Private initiative and local Private and Public Partnership project
  - Local private company initiated with fully profit seeking motivation
  - TARURA's positive attitude for GePG arrangement. Private company could not arrange the connection without TARURA's presence.
  - The Dutch company provided the main technology, however, most of the work is done by a local company.
- High efficiency
  - 90-95% manpower reduction in monitoring, which avoids cheating in fee collection.

(2) Open Policy of the Vehicle Registration Database

BEST PRACTICE

TRA, Tanzania Revenue Authority, manages the vehicle registration for vehicle tax levying purpose. TRA opens the database access for various public and private transport service operators to enhance the charging accuracy as well as TRA's enforcement of vehicle registration. Details of its development background with the open policy and its applications are reported as follows:

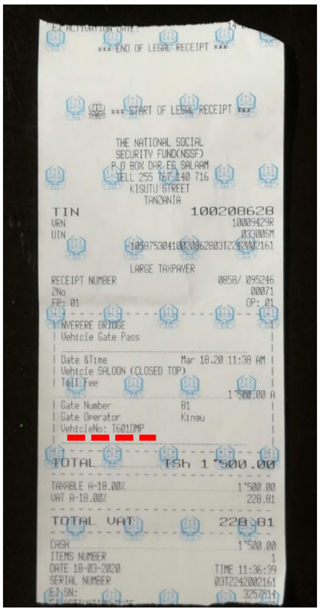
1) System Development

- This system was developed by an Indian company in 2015, by porting the database of a system developed by a company of Rep. of South Africa in 2003. The operation and maintenance of the system is managed by TRA. The source code for the software is also obtained from the developer, so any necessary modifications and maintenance can be done.
  - The system's servers are located in TRA, which uses the government data center for backup and disaster recovery.
- Currently, tax payments on vehicles are being made using the Revenue Gateway System (RGS), a cashless payment system unique to the TRA that started in 2008, but the government is moving toward unification with the GePG, the government's gateway. Under the current vehicle registration system, the vehicle owner's Tax Identification Number (TIN) is linked to the vehicle registration information, and the vehicle owner pays tax through the RGS, but from July 1, 2020, the system will be switched to GePG.
  - This system allows for tracking even if the owner of the vehicle changes.
  - The vehicle's license plate is issued by three companies approved by TRA. This license plate information is associated with the registered vehicle information.

2) Open Policy Application

- The vehicle registration database is open to the following stakeholders
  - Police can access the database from POS devises, to validate the double registration
    - For example, in some cases, if a vehicle is of almost the same model, it is possible to evade vehicle tax by registering one vehicle, obtaining a license plate, falsifying the plate, and attaching the plate to multiple vehicles.

- ➢ Tanzania Insurance Regulatory Authority (TIRA) is also able to refer to the database on their insurance contract preparation and assess the driving license status.
- ➢ TARURA's parking management for Mwanza and Tolling system of the Kigamboni's bridge
  - ✧ Both systems read the registration number, then inquires type of vehicles, and identify the amount of billing based on the type of vehicles
  - ✧ TRA also requires discrepancy of registered records with actual vehicle information on site to validate the registered data. If any discrepancies are found, the TRA will dispatch an enforcement team for further investigation.



Toll Gate receipt shows Plate number (underlined in red)

Tollgate at Kigamboni's bridge

Source: JICA Study Team

Figure 4.4.8 Example of TRA Vehicle Database Sharing: Toll Bridge Charging

(3) GePG, the payment platform for public services

GePG has positioned itself as the gateway for all cashless payment service providers in Tanzania. Options include payment by credit card, debit, transfer from a bank account, and payment by mobile money.

GePGs are available for the payment of fines at weighbridges, payment of tolls at Kigamboni Bridge, and payment of parking fees which are being implemented as a pilot project at Mwanza. In the case of the Kigamboni Bridge, some vehicles have only the option of paying in cash, so cash payment is also acceptable.

BRT's IC cards used to be linked to only one payment service provider. Therefore, BRT users were required to contract with this service provider for payment by IC card. However, BRT is also considering using GePG.

GePG increased its presence due to the president's promotion of ePayment as a policy three years ago. In the case of the parking payment system in Mwanza, for GePG billing, the system will automatically match the TRA vehicle registration data and pay with the billing data linked to the vehicle. At that time, any discrepancies with the registered vehicle will be verified with TRA database. In the case of a stolen car, the fact is notified to the police, which contributes to crime control.

In the case of the overload control at weighbridge, data on how much in fines were levied is now available for monitoring by the supervisor, avoiding fraud on the part of the collector compared to the case when fines were levied in cash.

(4) TARURA DROMAS / TANROADS RMMS

1) Road Asset Management System in TANROADS

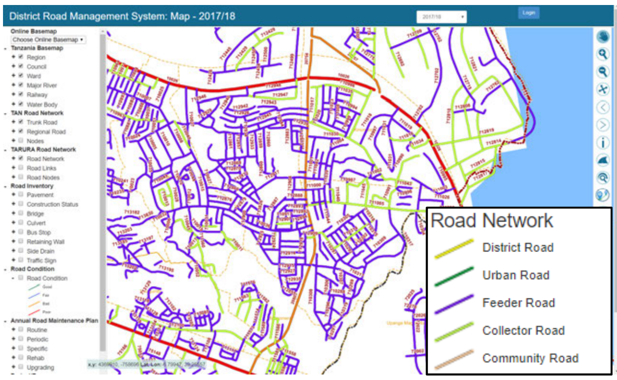
TANROADS has one laser-based road surface condition survey vehicle. There are 10,000 km of arterial roads managed by TANROADS, which are surveyed over a year by laser measurement and the results of these measurements are entered into the Road Maintenance Management System (RMMS). TANROADS formulates an annual maintenance plan based on the data entered into the RMMS.

Currently, IRI (International Roughness Index) and rutting are measured in laser measurements. TANROADS is considering whether to add an additional image recognition system or to procure just the image recognition system independently in the future.

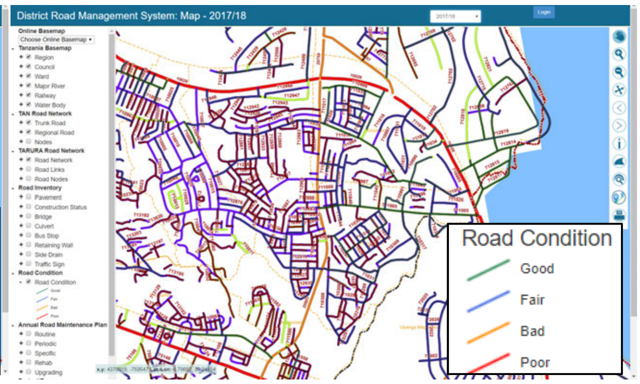
2) Road Asset Management System in TARURA

TARURA utilizes a GIS-based road maintenance and management system called DROMAS (District Road Management System). In addition to information on the road network, the system also records images of the road's surroundings, and cameras that equips GPS function are installed on the vehicles to acquire the location information and manage it on the GIS. The system also collects and manages road roughness data such as IRI using laser technology. The road network is very complex, however this system allows TARURA to check the road deterioration condition without visiting the site directly.

Since TARURA was a new organization and did not have a maintenance plan, it has been planning and implementing maintenance works by using DROMAS. This system is different from the TANROADS system called RMMS and is not interoperable.



Showing TARURA roads network



Showing road pavement conditions (2017-18 data)

Source: http://dromas.tarura.go.tz/dromas_map#

Figure 4.4.9 DROMAS Screen Shots Showing Morogoro Road Surrounding in DSM

3) Issues

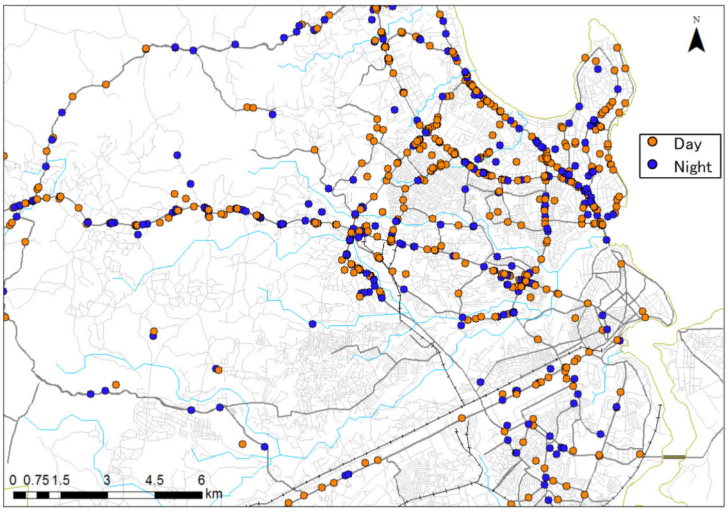
Both TANROADS and TARURA consider road maintenance and management to be an issue. They monitor the condition of the pavement and bridge facilities periodically, however such monitoring works take time and budget, and the data they collect is either once a year or nothing.

The consultant team informed each agency that there is a way to increase the frequency of road condition data collection through the usage of smartphones for IRI collection. If this data collection method could be used by each agency, the deterioration of roads could possibly be analyzed more.

Another issue is that TANROADS and TARURA introduced different road maintenance and management systems and the data in one system is not compatible with the other.

(5) Police RAIS services

RAIS (Road Accident Information system) is managed by Tanzania Ministry of Home Affairs (MOHAS) and Police, recording several traffic accident records as shown in Figure 4.4.10. The World Bank DUTP component C3 committed further improvement of existing RAIS, however, the details implementation are not clear according to the traffic police.



Source: JICA Revised M/P

Figure 4.4.10 A Sample of RAIS Output (2016 Accident Location Records in DSM)

4.4.7 Institutional Settings for ITS[13]

(1) Transport Organization in DSM/Dodoma

There are national level and local organizations for urban transport administration in Tanzania. The demarcation among the transport organization by the major transport administration tasks are summarized in Table 4.4.1.

[13] See for more basic institutional information in section 2.3, Main Text Volume I of the JICA revised M/P

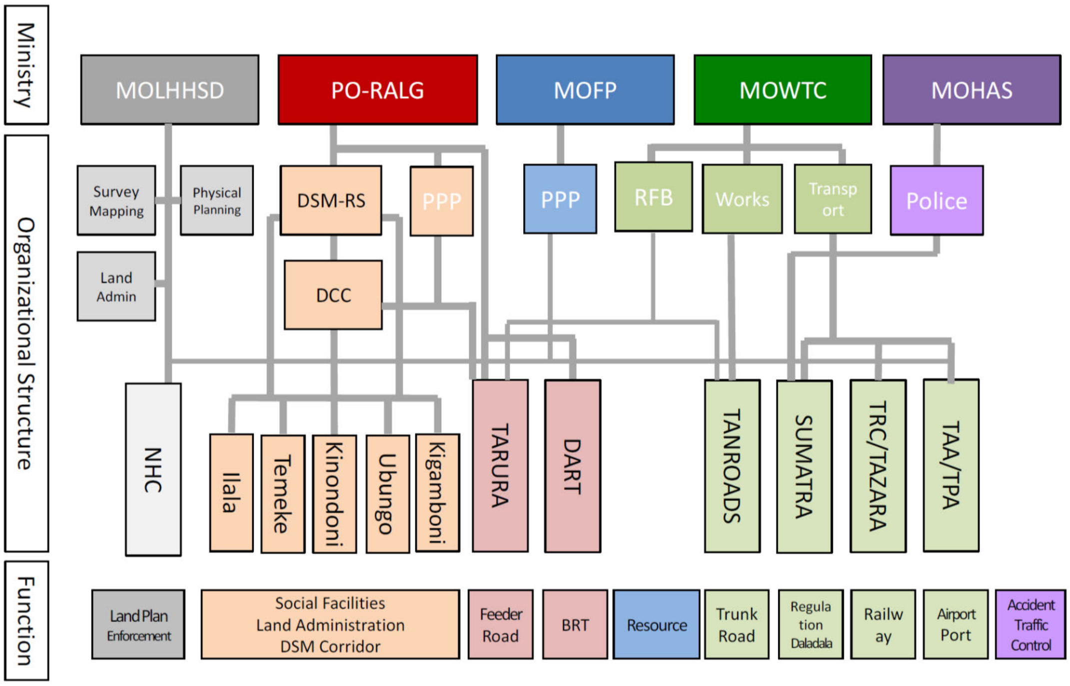
Table 4.4.1 Transport Administration Demarcation for DSM/Dodoma

Area/Task	National organization	Local Organization
Transport planning	Ministry of Works and Transport (MOWT)* PO-LARG DART (under PO-LARG)	(Municipality)
National road management	TANROADS, RFB	-
Urban road management	TARURA, RFB	TARURA local office (Municipality)
Urban Railway operation	TRC	-
Railway development	TRC	-
Road safety, Traffic safety	National Road Safety Committee (national level) / National Road Safety Council (NRSC) and Police under MoHAS	National Road Safety Committee (regional level)
Vehicle registration, road worthiness	LATRA	-
Driver licensing, Driver education	General: TRA, Commercial vehicles: LATRA	-
Public transport administration	LATRA	-
Public transport operation	DART/LATRA/TRA	-
Parking management	TARURA (with private)	-
Parking development	TARURA	-
On-street Advertisement	Collected by TRA	-
ICT planning	DART/Ministry of Communication and Information Technology*	-
Data center development	Electric Government Agency (EGA)	-
Licensing of telecommunication business	TCRA	-

Note: MOWTC has been split into two ministries; Ministry of Works and Transport, and Ministry of Communication and Information Technology in Dec 2020.

Source: JICA Study Team

The following chart from JICA revised M/P study shows relationship between the National Ministry, affiliate organizations and function. Note that SUMATRA has changed its name as LATRA.



Source: JICA Revised M/P Note: SUMATRA has changed its name as LATRA. MOWTC has been reorganized as Ministry of Works and Transport.

Figure 4.4.11 Organizational Structure and Relationship of the Stakeholders for DSM

(2) Ministries and Municipalities

1) Ministry of Works and Transport (MOWT)

MOWT has two deputies, works, transport and communication. Its HQ office is in Dodoma. Its main roles are policy making, regulation and supervision of affiliate agencies, and actual works are outsourced to implementing agencies including TANROADS, LATRA, etc. MOWTC has been split into two ministries; Ministry of Works and Transport, and Ministry of Communication and Information Technology in Dec 2020.

2) Ministry of Communication and Information Technology (MOCIT)

This ministry was newly organized in Dec 2020, and its policy making role in ICT and communication infrastructure development will also influence to ITS development.

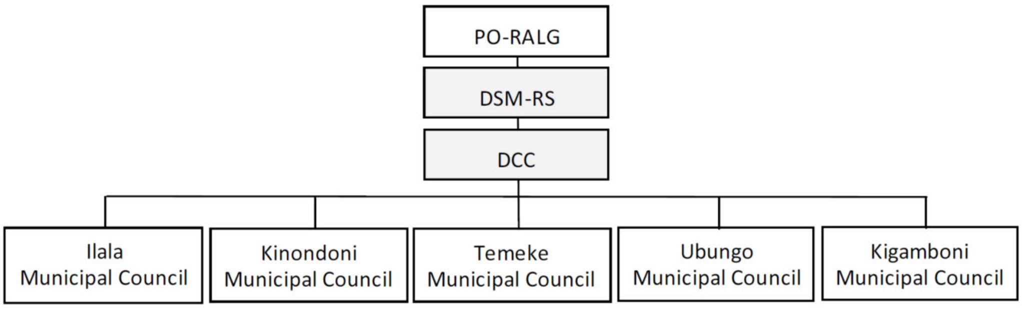
3) President Office of Regional Administration and Local Government (PO-RALG)

The function and responsibilities of PO-RALG are mentioned in the Local Government Act (1982). PO-RALG is mandated for formulating, monitoring and evaluating the decentralization, rural and urban development and their policy implementation. The infrastructure division of PO-RALG has three sections: urban infrastructure, rural infrastructure, and research centre.

4) DSM City Council and Municipalities

All the local government authorities are supervised by PO-RALG. Administratively, PO-RALG supervises DSM region,

DSM-region supervises DSM City Council (DCC), and DCC supervising 5 municipal councils.



Source: JICA Revised M/P

Figure 4.4.12 Administrative Structure of DSM

It seems the actual responsiibilty of each municipality for transport and ITS are limited. TARURA for DSM absorbed the road engineers from DCC and municipalities, and TARURA directly manages the road works and traffic management instead of DCC and municipalities.

5) Dodoma City Council

The Dodoma city council prepared the comprehensive masterplan for Dodoma (Dodoma National Cpaital City Masterplan 2019-2039) in 2019 for Ministry of Lands, Housing, and Human Settlement Development. It is mainly for land use plan, and its transport proposals mostly referred to the JICA's inner circular road study in 2019. The transport and road traffic officer for Dodoma concurrently serves for TARURA Dodoma office.

6) National Road Safety Committee (NRSC)

It is an interministral committee, headed by the Ministry of Home Affairs (MOHAS) for general traffic safety coordination. The committee has national and regional levels. For the Naitional level, the NRSC is headed by the MOHAS, with participation of MoWTC, Traffic Police, TANROADS and private sectors. For regional level, Traffic Police, TANROADS Regional Office, Private Operators of Bus/Truck, Representative of LATRA are involved.

It would be a stakeholder group for ITS application for traffic safety in national and regional level.

(3) Agencies and Authorities

1) The Tanzania National Roads Agency (TANROADS)

The core business of the agency is maintenance and development of the network to support the socio-economic development of the country. TANROADS is also responsible for the management of the Central Materials Laboratory and Regional Materials Laboratories that are responsible for materials testing and conducts research on new road technology. The Road Traffic Act stipulates that the Chief Engineer of TANROADS has responsibility to clarify the road traffic regulation including traffic signal setting.

TANROADS and its regional offices own, operate, and regularly revise its operation setting the traffic signals along the trunk roads. For technical details, TANROADS has an advisory service contract with DSM Institute of Technologies (DIT) and Arusha Institute of Technologies (AIT). TANROADS contracts out the actual maintenance of signal operation and setting to TEMESA (Tanzania Electrical, Mechanical and Electronics Services Agency).

TANROADS shows its interests in ITS application in road maintenance and axle load control. They developed its CCTV monitoring system, at present covering 11 weighbridges, and showed strong interests in the smartphone based IRR measurement services which is under implemente in Ghana and Kenya as technical cooperation by JICA (iDRIMS project)

2) Tanzania Rural Road Authority (TARURA)

As aforementioned, TARURA undertakes the feeder road development and management servces instead of municipalities and councils. However, the needs of traffic management with signalization is low, as its traffic is still low.

The parking fee annual revenue will be approximately 6 million USD, which is major a financial resource of TARURA. It is aggregated by the national treasury account, 60% of which is earmarked as TARURA budget. At present, TARURA manages the parking fee collection through the private service providers, and is going to rationalize with the e-parking methodologies as installed in Mwanza.

3) Dar Rapid Transit Agency (DART)

The Dar Rapid Transit Agency (DART) is an executive agency with the mandate to establish and operate a bus rapid transit system in Dar es Salaam, under the guidance of the PO-RALG. See section 4.2.2(1) for its recent achievement, and section 4.2.1(4) for the ITS investment plan in detail.

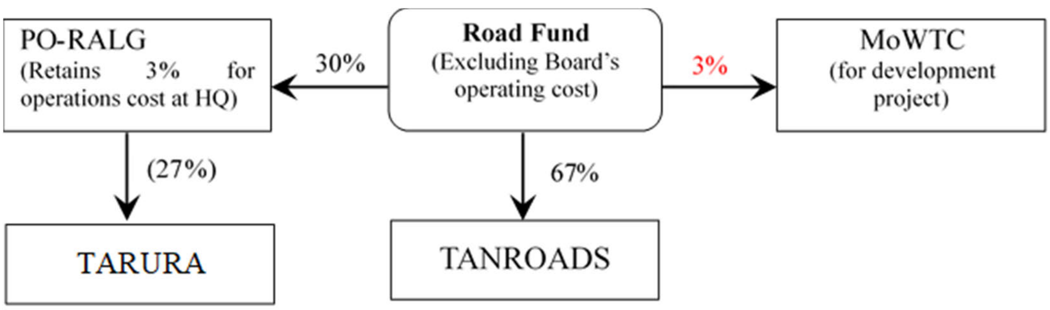
For signalization of DSM corridors, TANROADS mentioned they follow the plan of DART, as the traffic magement system on the TANROADS corridors should be harmonized with the BRT.

4) Tanzania Road Fund Board (RFB)

The primary role of the Road Fund is to provide a fund for the maintenance of roads, including road affliate structures and function including traffic signals. The payment of the traffic light electricity bill (TANESCO[14]) is also covered by the Road Fund. Routine maintenance is also 100% covered.

According to the interview, the RFB has no intention of reducing routine maintenance expenditures, which is why the signal introduced in 1994 by the Grant Aid from Japan is still working without any problems. On developing new road sections, the road agencies make proper estimation of the mainteiance cost to secure the maintenance budgeting to RFB.

The present fund allocation mechanism of RFB is shown as follows. The allocation rate is reviewed regularly.



Source: RFB and JICA Study Team

Figure 4.4.13 Administrative Structure of DSM

[14] Tanzania Electric Supply Company Limited

5) Land Transport Regulatory Authority (LATRA)

The Authority is set to regulate the land transport sectors, particularly: transportation of goods and passengers (commuter buses, inter city buses, goods carrying vehicles, taxi, motor cycles and try cycles), railways and cable transport. LATRA has its Head Office in Dar es Salaam, and has regional offices in all 26 regions of the rest of Tanzania.

As aforementioned, it is developer of the FMS for intercity buses for overspeed control. FMS in urban areas can be operated as probe vehicles for a traffic situation database.

6) Tanzania Revenue Authority (TRA)

The Tanzania Revenue Authority (TRA) is a government agency of Tanzania, charged with the responsibility of managing the assessment, collection and accounting of all central government revenue. It is a semi-autonomous body that operates in conjunction with the Ministry of Finance and Economic Affairs. The ICT department of TRA mainly take the coordination role for ITS/ICT application.

TRA is in charge of driver license issueing with the police, vehicle registration with LATRA, as those procedures are attached to taxation. As such, the inter-agencies procedures for transport sector may accelerate the application of the ICTs in Tanzania.

TRA has an experimental installation for the e-payment for the Daladala fare collection, however, the full implementation concept has been halted due to very little implementation and financial capacity of those operators.

The on-road advertisement revenue for TANROADS and TARURA is collected by TRA, however, it is earmarked to the road agencies and 100% of the revenue will be reimbursed to the road agencies.

7) Traffic Police (Tanzania Police Force)

Roles and tasks of Tanzania Police Force (TPF) in road sector is to take care of issues regarding traffic safety and control, regulation in accordance with Road Traffic Act, inspection of vehicles in the roadside and driver's test and so on. TPF is cooperating with other organizations such as LATRA and TANROADS in order to ensure that all issues related to the road transport sector.

For enforcement, the Road Traffic Act stipulate that the Traffic Police enforces the traffic operation.

8) e-Government Agency (e-GA)

The e-Government Authority (e-GA) is established in 2019 and it is a public institution mandated to coordinate, oversee and promote e-Government initiatives as well as enforce e-Government related policies, laws, regulations, standards and guidelines in public institutions. The e-GA provides a public data server functions to public entities. It is mandatory for public entities to use the e-GA data server for their ICT services.

9) Tanzania Communications Regulatory Authority (TCRA)

TCRA is a quasi independent Government body responsible for regulating the Communications and Broadcasting sectors. TCRA regulates the internet service and infrastructure development to enhance the services of the various sector, including ITS and traffic management.

(4) Concept of DUTA establishment

The concept of DUTA (DSM Urban Transport Authority) was proposed by JICA DSM Transport Policy and Systems Development Master Plan in 2008. The initial objective of the establishment of DUTA is to develop a coherent and independent platform with the legal power to coordinate the policy and planning for urban transport. Through the Feasibility study conducted by EU in 2009, it had been consulted under PO-RALG, stakeholders and development partners for more than 10 years.

In the revised M/P and its implementation program, DUTA establishment necessity was again proposed as the coordinator of the various transport stakeholders, particularly among the PO-RALG and MOWTC, and DUTA is the key element for implementation of data exchanging in ITS and TCC project for DSM. However, the establishment of DUTA is still under discussion.

4.4.8 Summary and Issues

(1) Summary of the ITS/ICT interventions

Table 4.4.2 Summary of Findings for DSM and Dodoma

Transport planning	DSM	Dodoma
Superior Urban and Transport Planning	The Revised M/P proposed the Area-wide traffic control necessity as the short-term development project by 2025 for inside of the Nelson Mandela road. DART ITS study specified details of ITS implementation schedule along its BRT corridors.	The inner ring road plan (2019) and Dodoma capital city masterplan (2019) shows interests in traffic management.
Road Development, Transport and Traffic Management	BRT Phase 2 construction is on-going, but not including ITS aspects. Several flyover and bridge projects realized smooth flow along the Nelson Mandela circulation road.	Outer ring road and new airport development by AfDB. Inner ring road basic design stage is on-going by TANROADS.
Traffic Volume and Forecasts	The revised M/P and DART studied on recent traffic volume and forecasts.	The studies show the passenger car management needs in future.
Project Development in Transport Sector	BRT project expansion with Phase 6. BRT Phase1 installed AFC and FMS, however, it is halted or not used fully.	New bus terminal, widening possibility of the DSM road
ITS interventions	**DSM**	**Dodoma**
Traffic Signal Installation	BRT (Phase 1) installed several traffic signals by WB DUTP A4 which are not coordinated.	One intersection are controlled by traffic signal.
Communication Infrastructure	Some government agencies applies to use the government owned TTCL services, instead, others use the private services.	Dodoma city M/P reported the fiber cable development status.
Traffic management	(On the national level, a CCTV monitoring system in weighbridge operations has been installed and operated by TANROADS.)	
Traffic and Transport Information Provision Systems	DART has developed its ITS study	-
Public Transport Operation Management	(On the national level, LATRA has developed the FMS for over-speeding enforcement)	
Utilization of Call Detail Record	Not applicable case in Tanzania	
Other ICT Interventions	Several good practices were found including Mwanza’s parking management and fee collection, GePG for cashless payment collection enhancement system, DROMAS, etc.	

Source: JICA Study Team

(2) Issues and Potential ITS Development for DSM

The following points are raised as issues for ITS project development in DSM:

- Strong and apparent needs for Area Traffic Management in DSM, with technical challenges
    - ➢ The revised M/P indicates the materialization of traffic management inside the Nelson Mandela Road (until 2025), which can be the biggest motivation for ITS and traffic management investment in DSM. DART's ITS study also proposed strong demand for traffic signals with PTPS (public transport priority system).
    - ➢ The existing traffic signals along the BRT Phase 1 are an independent control method without coordination each other. There are no potential contractors for the coordination signal control, however, the integrated interface development is required as several previous signal projects installed signals with various manufacturers. Note that the WB DUTP package A4 installed traffic signals however the coordinated control were not materialized. (see section 4.2.2.(1) for details)
    - ➢ DART has prepared the ITS development study (draft final report). After the receiving the study, JST will summarize the detail concept.
        - ✧ The installation plan should be scheduled in line with the progress of the BRT projects. The BRT implementation packages are clear from Phase 1 to Phase 6; however, the order of implementation will be revised based on market interests and needs.
- Relatively lower progress for AFC and passenger services.
    - ➢ DART also has recently developed its technical specification on AFC, which will be the new standard in DSM and Tanzania, however, the initial AFC has been halted and DART has applied manual fare collection so far. The passenger information system for BRT is also poor, as it is undertaken by the interim operator (U-DART). It seems that DART is working hard in daily operation and infrastructure development, and has not yet stepped into the stage of improvement in passenger satisfaction.
    - ➢ AFC and passenger service ICT application are the good tools for passenger satisfaction. AFC's cashless system will advance user experience, and a passenger information system through various media, including on-board and on-platform VMS and personal smartphones, will enhance the ridership. They are not yet implemented in DSM.
    - ➢ It should be noted that real-time data collection through the FMS (Fleet management system) is essential for the passenger information system. PPP approaches for data-collection are also required to realize the further penetration of the service.
        - ✧ On the other hands, the AFC needs for Daladala are unclear.

(3) Issues and Potential ITS Development for Dodoma

The following are raised as issues for ITS project development in Dodoma.

- Potential ITS development needs along the DSM corridors
    - ➢ The DSM corridor in Dodoma will attract various developments in the small capital city, including government offices, stadiums, intercity bus terminals, shopping centers and residential development, which generate several merging points along the corridors.
    - ➢ Its widening project will also accelerate motorization. The outer ring road development may exclude long-haul freight traffic from the DSM corridors and city center; however, the passenger car demand acceleration is unavoidable as the other cities has experienced.

- Traffic safety problem in suburban area
  - TANROADS Dodoma office agreed on the signalization needs for individual accident-prone intersections in suburb areas. ITS project aims to traffic efficiency enhancement; however, Dodoma still has basic safety needs.
- Needs for smart city development
  - The Capital city masterplan envisions the smartcity development concept of Dodoma. The ITS project development can be the part of the smart city branding.
  - Other than traffic signal installation, several ITS/ICT project can be considered including;
    - Autonomous bus services installation along the DSM corridor, between the city center to government city, where regular business commuters can be expected. Every government agency in the Government city has operate commuter buses for its staff.
    - On-road VMS system for enhancing the detouring to circular roads, particular for inner ring roads and outer ring roads.
- Consider as "Too early" or "should be ready for motorization"
  - Dodoma is still small city with 300,000 people, and most people considers the ITS project development in Dodoma as too early.
  - The transport planners always felt its powerlessness in such discussions. Most cities experience traffic congestion.

(4) Issues and Potential ITS Development for Tanzania

Other than city oriented ITS, the following explains the potential needs for national and regional level ITS potential in Tanzania.

- EAC region-wide development possibility of FMS
  - The Achievement of LATRA's FMS for intercity bus is quite noteworthy. It also attracts official visits from surrounding countries and realizes international agreement for system integration. The system has already covered the international bus operators from other countries who operates in Tanzania market.
  - The regional EAC office can accelerate the expansion the FMS system in EAC countries. EAC's regional integration policy has expanded passenger exchanges
  - JICA is assisting the EAC's cross border traffic facilitation issues on i) harmonization in axle load standard during 2010-12, and ii) One-stop border post operation (manual development, planning and training) after 2012.
- Parking fee collection for transport demand analysis
  - TARURA expects the expansion of the innovative parking collection system to other cities in Tanzania. Not only for fee collection, the system can collect and summarize the real-time information of the daily vehicle traffic needs, staying hours and OD. By the ordinary traffic survey method, such information was collected by costly traffic surveys just for a few days with lower data reliability.
  - The traffic control and management also need innovative approaches in using that data. The system can automatically calculate the number of parked vehicles which can be used for signal control policy similar to the probe vehicle data utilization. A technical assistance project for enhancing the ITS data integration and utilization in transport sector can be proposed for Tanzania.

- Data transaction infrastructure needs
  - ➢ The use of government data server seems popular among the ICT application in the transport sector, for video data storage, transaction data storage, analysis application server functions, etc. It is expected that as the variety of transport services and ICT application increases, more loads on servers can be expected.
  - ➢ The possibility of technical assistance for government server development or grant aid can be considered to enhance the ITS project in Tanzania. The government agency tends to utilize the government server system for their operation, therefore, such assistance may decrease the operation cost of the ITS systems.

CHAPTER 5 THE PROJECT FORMULATION ON TRAFFIC CONTROL SYSTEM

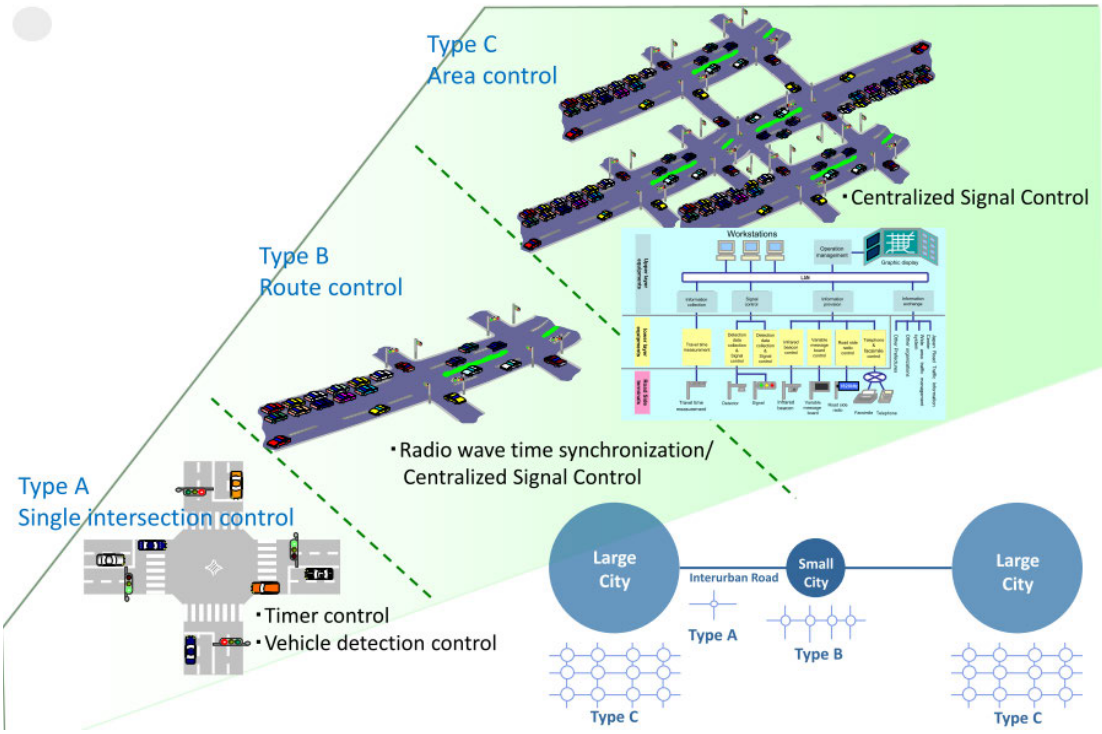
This chapter reviews the general idea of project formulation of a traffic control system for urban transport improvement. The first section will give the outline of the technology of traffic control system, and the second section will present past projects experiences and extract some issues for implementation. The third section will introduce the latest technical approaches for traffic control systems which may improve the issues above, then the fourth section will suggest applicable approaches for the four target cities, applying the latest technical approaches. The last section will present the several latest approaches on ITS which can be applicable to the four cities, not for the traffic control system.

5.1 Traffic Control System

5.1.1 Coordinated Signal Control

(1) Type of Control

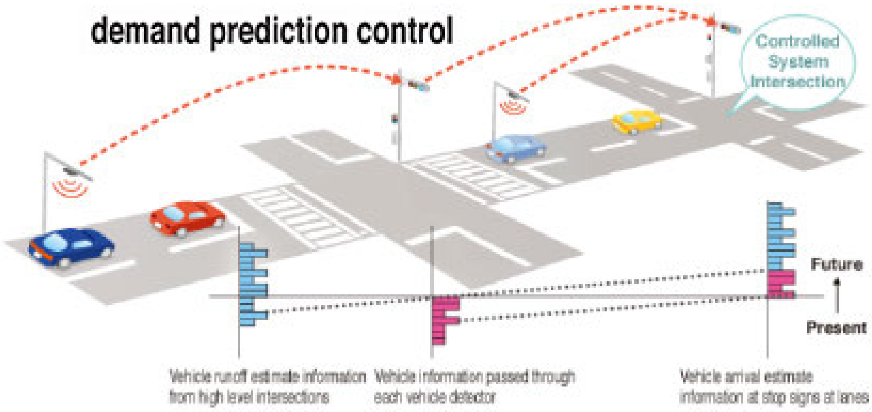
The types of signal control can be classified by the stages of controlling, i.e., A) individual control (Single Intersection Control / Isolated Signal Control), B) Coordinated control of signals at intersections on arterial roads (Route Control / systematic Control), and C) area control of multiple roads (Area Control), as shown in Figure 5.1.1. Generally, it is common for coordinated control to be considered for installation in traffic control even in emerging countries, particularly for cities facing motorization and rapid urbanization. The coordinated control can be expanded to the area control as it is an optimization of the several coordinated routes.



Source: OMRON Social Solutions https://socialsolution.omron.com/

Figure 5.1.1 Types of Signal Control

The mechanism of the coordinated control is depicted in Figure 5.1.2. The key items are the traffic counting sensors between the intersections. The counted real-time traffic volumes and speed are sent to the control center which makes a prediction on the coming traffic volumes at the intersections located further down. If the control center predicts that exceeding traffic can be expected further down, and the control center mechanically orders extending the green period of the traffic signal at the next intersection, which will facilitate smooth, efficient traffic flow, called a "Green Wave". Usually the prediction is to be adjusted with the local vehicle speed regulation; over-speeding vehicles would be stopped at the red phase at the next traffic signal.



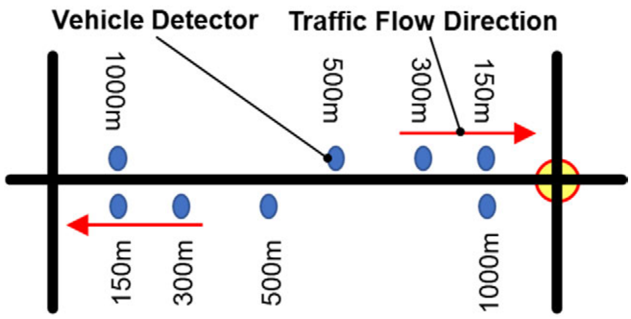
Source: Sumitomo Electric System Solution https://www.seiss.co.jp/en/products/its/traffic_control/

Figure 5.1.2 Coordinated Signal Control

(2) Types of Coordinated Signal Control

There are three major signaling systems in the world, i.e., i) SCATS (Sydney Coordinated Adaptive Traffic System) developed in Australia, ii) SCOOT (Split Cycle Offset Optimization Technique) developed in the UK, and iii) MODERATO (Management by Origin-Destination Related Adaptation for Traffic Optimization) developed in Japan. These systems are technically different, particularly in the location of the sensors/vehicle detectors.

SCATS sets vehicle detectors near the intersection stop line to measure traffic parameters and SCATS controllers do not predict demand from upstream intersections. SCOOT places vehicle detectors near the exit of the intersection to measure traffic parameters and SCOOT estimates the flow distribution of vehicles arriving at the intersection. MODERATO, on the other hands, installs multiple vehicle detectors at 150m, 300m, 500m and 1,000m upstream from the target intersection stop line to estimate the flow distribution of vehicles entering the intersection as well as the retention length. This mechanism of MODERATO can estimate a more accurate prediction with detail traffic flow, however, the number of vehicle detector is larger compared to other systems.



Source: JICA Study Team

Figure 5.1.3 MODERATO's Characteristics: Vehicles Detector Requirment

Table 5.1.1 Comparison of Major Traffic Signal Control System

Item	MODERATO	SCOOT	SCAT
Developed Organization/Country	Japan	UK	Australia Roads & Traffic Authority
Applied City	All Japanese prefectures	More than 200 cities in the UK and other countries	More than 80 cities in 27 countries
Outline of the system	Traffic signal control is made on a real time basis by generating traffic signal's control parameters (split, cycle and offset) automatically based on the measured traffic data of the cycle unit of 1 min. 2.5min. and 5 min. At a bottleneck intersection, the retention length is measured for the individual inflow roads, and it is effective for over-saturated capacities of traffic for the intersection	Green time is obtained based on the delayed time calculated on the basis of vehicle cluster wave. The cycle length can be updated every 2.5 or 5 minutes and update can be completed within some seconds.	Traffic information is generated based on sensors installed closely before the stop line of the intersection. Traffic signal's parameters are obtained every cycle referring to the traffic information, thus the reflection of real time condition is high.
Good/Bad points	Suitable parameters are selected from non-saturated condition to over-saturated conditions. It is possible to combine the adaptive signal controls and it is possible to control so as to suit individual intersections. The number of sensors tend to be more than other systems as it tries to measure the retention length.	Suitable parameters are possible to select in the non-saturated stage. However, in the over-saturated stage, waiting time tends to be too long as the system selects the maximum cycle length.	In the non-saturated stage, the real time control is ensured as the control method is adaptive to the gap between the traffic counter and the signal parameter. In the over-saturated stage, the cycle length tends to be longer than the necessary length.

Source: JICA Study Team

Since the MODERATO needs relatively higher number of sensors, the installation cost and maintenance cost tends higher than the other control systems.

5.1.2 Actual Operation of Traffic Control System in Japan

Traffic signal implementation and management in Japan is undertaken by the Police, who are the traffic administrators. The National Police Agency, the headquarters of the Police, supervise and clarify the technical specification, and Prefectural Police Departments supervise the implementation for its prefecture. Road agencies[1] are responsible for the maintenance and management of roads and undertake the collection of traffic information and provide information only, but do not work for signal control directly.

Traffic signals and its equipment are delivered by signal manufacturers to the prefectural police departments, while the main system of the control center is provided to the prefectural police with a lease contract, and prefectural police departments pay lease fees to leasing companies. In addition, communication between the signal controllers and the control center is not done by its own network, but by the leased line from a telecommunications carrier such as NTT[2], so that communication costs are paid to the carriers. Redundancy has been ensured by leasing lines from two different carriers. The motivation for applying the lease contract is to minimize the replacement expenditures. Generally, it is recommended to procure an ICT system, including ITS, through the lease contract.

Of course, running costs are an increasing factor, but the number of signals in Japan is about 200,000 nationwide and about 15,000 in Tokyo, while the number in the United Kingdom is about 25,000 nationwide, which is one-eighth of Japan's. Since it is unlikely that developing countries will implement signals at the same level (density) as Japan, running costs are not expected to be as much of a problem as in Japan.

5.1.3 Improvement of Traffic Signal Control by Japanese Technology to Utilize Probe Car Data

In traffic signal control, it is necessary to grasp the traffic situation on the road in real time and control the signals based on the data. This is applicable for MODERATO in Japan as well as for SCAT and SCOOT. Therefore, it is essential to set up vehicle detectors as an infrastructure to monitor traffic conditions.

As the number of traffic signal implementation sites increases, the maintenance of vehicle detectors increases and the initial cost of setting up, wiring, and operating cost increases, resulting in "Infrastructure heavy”.

In the case of MODERATO, it is possible to understand the traffic flow in detail and make more accurate predictions by implementation many vehicle detectors, which makes it possible to optimize signal control for the traffic conditions compared to other systems.

Under such circumstances, Japan has been promoting the dissemination of ETC2.0 and VICS on the government's initiative from an earlier stage than other countries. Therefore, about 5 million ETC2.0 on-board units (Cumulative total: April 2020) and 66 million VICS-capable on-board units (Cumulative total: December 2019) are now in use to collect probe data. In addition, a great deal of probe data is collected from car navigation systems with communication functions and smartphone applications, and the technological development and practical application of probe data utilization is at an advanced level.

Japanese signal manufacturers have been developing technologies to improve the control of traffic signals by using probe data[3] collected from each vehicle since early on, and some of these technologies have already been put to practical use.

Therefore, by utilizing Japan's superior technology, the system will enable advanced traffic signal control while reducing the number of vehicle detectors needed for traffic signal implementation, rather than the overabundant infrastructure that has been used to date.

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1 Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Local government and Expressway Companies
2 Nippon Telegraph and Telephone Corporation, is incorporated pursuant to the NTT Law and the fourth largest telecommunications company in the world in terms of revenue
3 Improvement of Traffic Signal Control Using Probe Data < https://global-sei.com/technology/tr/bn78/pdf/78-09.pdf >

However, the effectiveness of using probe data to grasp traffic conditions and control traffic signals depends on the quantity and quality of probe data that can be collected in the target city. In addition, the transfer of technology for the operation and maintenance of MODERATO is also essential for sustainable operation. Therefore, in the initial stage of traffic signal implementation, it is important to introduce a traffic signal system using common vehicle detectors, and then implement a technical cooperation project to transfer technology for the operation and maintenance of the system, and conduct demonstration tests of traffic signal control using probe data to verify the effectiveness of the system.

5.1.4 Operational Issues of Traffic Control System

The traffic control system is broadly divided into 1) traffic control center information for data collection, sharing, analytical processing & control systems, information provision related equipment , 2) communication network related equipment between the center and the controller on roadside, 3) traffic light controller on site, 4) communication network related equipment between the controller and the other equipment such as traffic light, traffic counters on roadside, and 5) traffic lights, traffic counters at each intersection, as classified in the Table 5.1.2. The table also explains the institutional responsibility for the installing, operating and maintenance phases of the system.

Table 5.1.2 The Each Component of the Traffic Signal System and Individual Responsible Party on O&M

Location	Equipment component	Responsible Party		
		Installation	Operation	Maintenance
1) Traffic Control Center (TCC)	Server, Multi Screen Display, Operation PC, Backup Power supply, etc.	Traffic Signal Manufacturer and its supplier	Executing agency of the Project and related Operator	Support of traffic signal manufacturer
		Software: Traffic signal manufacturer Hardware: provided by the executing agency		*Software: Traffic signal manufacturer Hardware: provided by the executing agency or outsourcing from the executing agency*
2) Communication Network between 1) and 3)	Optical Fiber Cable, switch, transmission module, network monitoring/ management system (NMS)	Subcontractor to be hired by the signal manufacturer	Monitoring of NMS: Executing agency/ outsourced operator	Maintained by own technicians Outsourcing to the communication service provider
		Utilizing communication service provider's data communication service	Operation under the contract condition with the communication service provider	*Maintenance under the contract condition with the communication service provider*
3) Signalized intersection	Traffic signal controller	Traffic Signal Manufacturer and its supplier	Executing agency of the Project and related Operator	Normal Maintenance: Executing Agency/ Subcontractor of the project Technical Support: Traffic Signal Manufacturer
4) Communication Network between 3) and 5)	Copper Communication Cable or wireless communication	Subcontractor to be hired by the signal manufacturer	Executing agency of the Project and related Operator	Maintained by the own technician
5) Signalized intersection and its surrounding area	Traffic signal light, traffic counter, etc.	Traffic Signal Manufacturer and its supplier	Executing agency of the Project and related Operator	Normal Maintenance: Executing Agency/ Subcontractor of the project Technical Support: Traffic Signal Manufacturer

Source: JICA Study Team

In the past projects under the grant aid from Japan, all the equipment was procured by a Japanese manufacturer and the operation and maintenance of the equipment basically belongs to the executing agency of the project or is partially outsourced to a local operator as shown in Table 5.1.2, except for the italic character portion.

When implementing a signal improvement project in each target city, it is necessary to adopt an appropriate project scope of work, with an operation and maintenance organizational structure which refers to the original in Japan. It should consider the further details of the owner's intentions, organization, technology, budget, etc., so that the operation, maintenance, and renewal of equipment in the future can be carried out and sustainability can be ensured. For example, the sustainability of operation and maintenance can be improved by installing software on the hardware procured by the contractor and storing in the center server in a data center owned by the county government or the city and delivering it as shown in the italic characters of No. 1) in Table 5.1.2.

It is also necessary to have a mechanism for relevant organizations to check whether the contract stipulates that the communication equipment & cables and other utilities will be repaired properly by the party who damages it in case of damage in other projects, such as those involving road excavation if the executing agency of the traffic signal system will own the communication cable as its asset.

If the executing agency of the traffic signal system will utilize data communication service provided by the communication service provider as shown in the italic characters of No.2) in Table 5.1.2, it is necessary to have engineers within the executing agency who can check and verify the conditions of the contract between the executing agency and the data communication service provider. In addition, it is essential to check whether or not the necessary budget for it can be secured sufficiently. Those are important points to check for the sustainability of the traffic signal system project.

5.1.5 Additional Measures with Traffic Control Systems

Traffic signal installation is not an almighty measure for traffic control at intersections and for area traffic management. The following approaches are usually implemented in the world.

(1) Geometric Design Improvements

Intersection geometric design improvement, including proper lane marking and islands, are essential before the signalization. Moreover, recently major cities have applied more advanced and strategic approaches.

The Tokyo Metropolitan Government, the Metropolitan Police Department, the Ministry of Land, Infrastructure, Transport and Tourism (Tokyo National Highway Office), and related organizations collaborated to implement "Smooth Tokyo 21" as a project to tackle congestion in Tokyo, which was renamed "Hyper-Smooth Tokyo" in 2016 with the aim of easing congestion by implementing intensive measures at major congestion points in Tokyo.

The Smooth Tokyo 21 major target was “Corridor” control. Both the police and road agencies agreed on the target routes in the city, and input improvement measures along the target routes, and assessed the effects of the measures along the target routes. The main approach of the measurement was combination of 1) coordinated signal installation and 2) the consecutive physical and geometrical improvement of road design, particularly at the intersections along the corridor.

Regarding the physical measures implemented around signalized intersections, the following three are major ones, i.e., A) development of cargo parking zones (installation of parking zones that allow vehicles to stop for 15 minutes or less for business use only), B) clarification of areas where parking and stopping are prohibited by color pavement (discouraging parking and stopping by clarifying areas near intersections where parking and stopping are prohibited), and C) enforcement of illegal parking control and awareness-raising activities by traffic instructors (especially strict control of parking and stopping in the areas specified in B).

Pre-Treatment Post-Treatment

A: Development of Cargo Parking Zones

B: Clarification of Areas where Parking and Stopping are Prohibited by Color Pavement

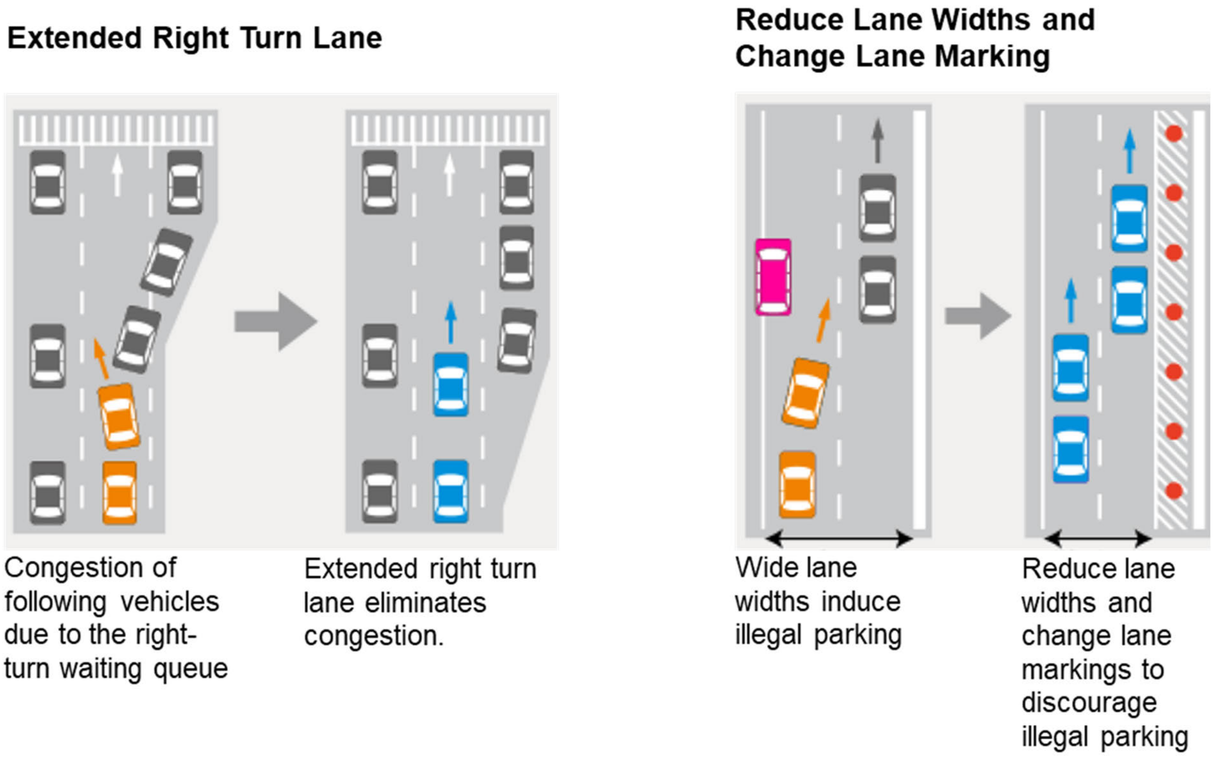
C: Enforcement of illegal Parking Control and Awareness-raising Activities by Traffic Instructors

Source: Ministry of Land, Infrastructure, Transport and Tourism http://www.mlit.go.jp/road/road/traffic/sesaku/10.html

Figure 5.1.4 Efforts to Reduce Traffic Congestion

The large number of right-turning vehicles at the intersection and the overflowing of right-turning waiting vehicles from the right-turning lane can impede the progress of straight ahead vehicles and cause congestion. In addition, the wide width of the road often leads to on-street parking.

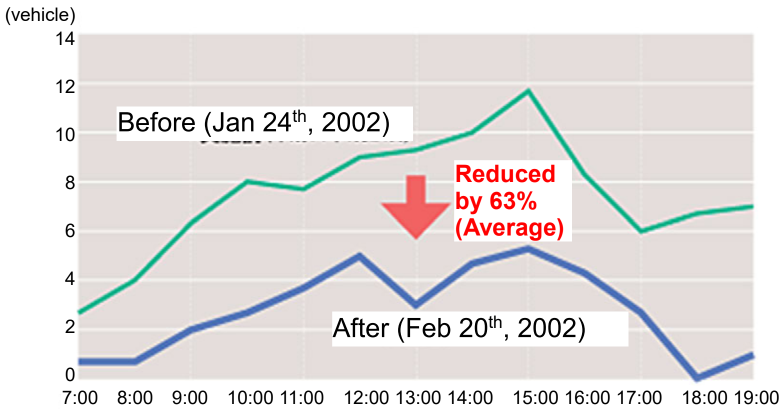
In such cases, where improvements to the road structure could be made without site acquisition, intersection improvements such as the installation and extension of right-turn lanes, as well as reviews of lane widths and the number of lanes were made.



Source: Hyper-Smooth Report (March, 2017 : Tokyo Metropolitan Government)

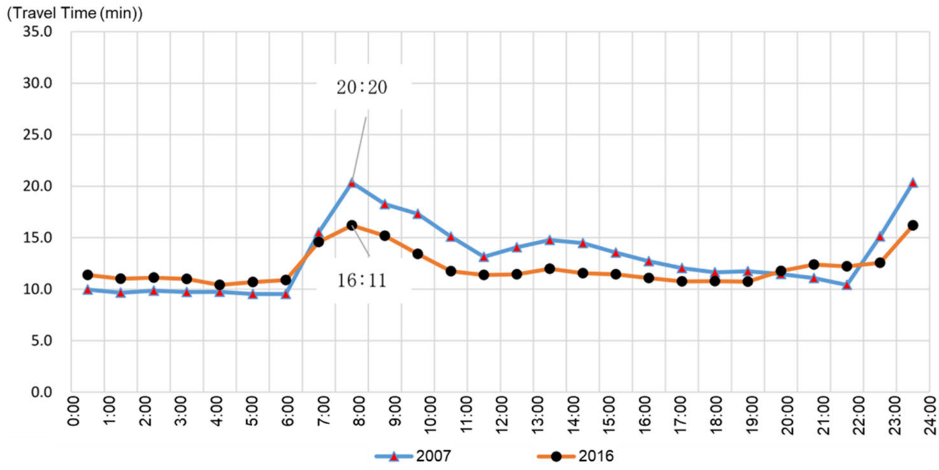
Figure 5.1.5 Improving the Road Structure

As a result, the number of on-street parking was reduced by 63% before and after the implementation of the measures, contributing to the increase in traffic capacity and the draining of traffic. A combination of traffic signal enhancements (real-time dynamic control) and various Geometric Design Improvements resulted in a reduction in travel time at the corridor level.



Source: Ministry of Land, Infrastructure, Transport and Tourism
http://www.mlit.go.jp/road/road/traffic/sesaku/10.html

Figure 5.1.6 Reduction in the Number of On-street Parking (Before/After Comparison)

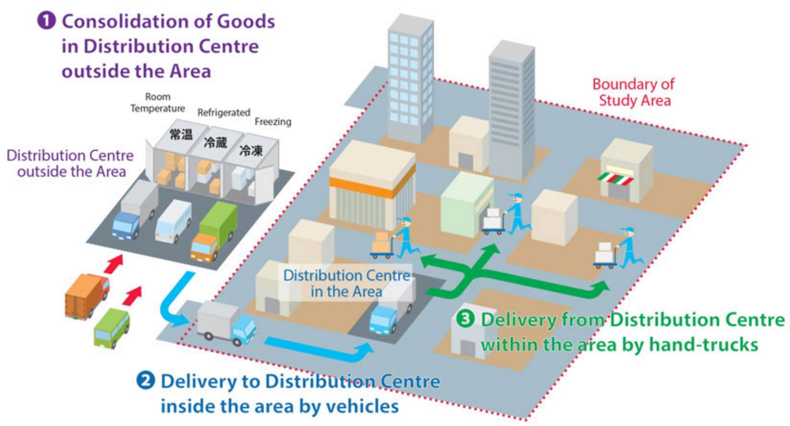


Source: Hyper-Smooth Report (March, 2017 : Tokyo Metropolitan Government)

Figure 5.1.7 Reducing of Travel Time on Mejiro Avenue (Before/After Comparison)

(2) TDM approaches, including Area Freight Consignment

In urban areas where many commercial facilities are located, there is a large distribution of vehicles that start and end at each store, and each store has a separate distribution route. This has led to an increase in the number of cargo handling vehicles and parked vehicles in the area, causing a disruption to walking space and causing congestion. Under such circumstances, in Shinjuku, Tokyo, in order to control traffic congestion due to the influx of cargo sorting logistics vehicles into narrow streets and parking and stopping of vehicles, a demonstration experiment is being conducted with the cooperation of each store and logistics company in the area, where logistics that start and end in the area are collected at a nearby logistics consolidation facility, and delivery within the area is made possible by moving and parking only the vehicles that consolidate delivery to each store in the area, and delivery from the said vehicles to each store is made on foot using a cart. This is a kind of TDM (Transportation Demand Management) approaches to reduce the whole traffic demand in the city.



Source: JICA Study Team
https://www.tric.jp/en/projects/typical_project_h28_01.html

Figure 5.1.8 Reduction of Local Cargo Parking through Joint Cargo Sorting (Demonstration Experiment in Shinjuku, Tokyo)

(3) Traffic Calming / Placemaking / Parklet

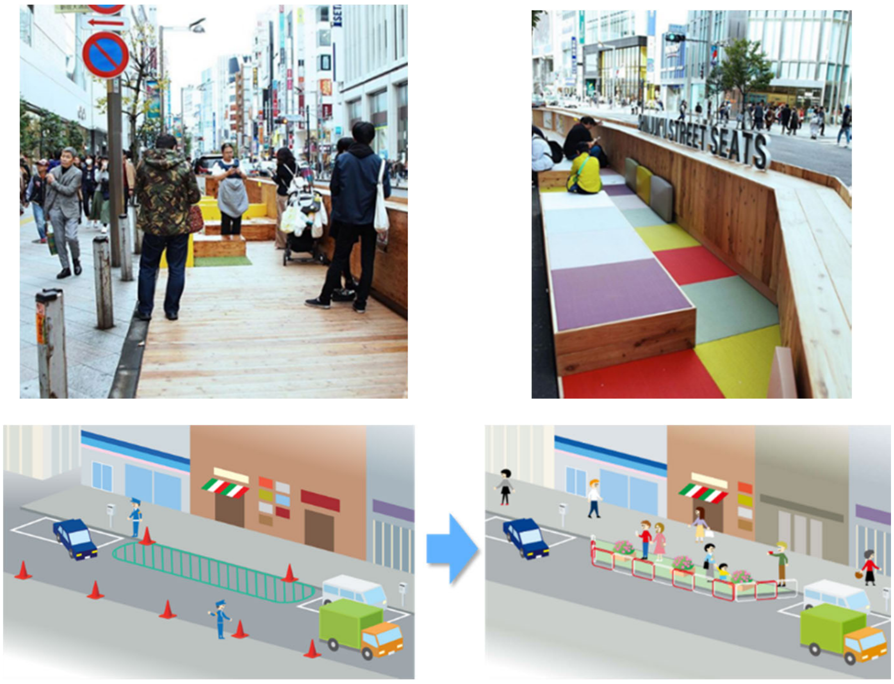
For Midosuji, the main North-south street in Osaka, Japan, the government of Osaka City proposed to convert the present 44-meter-width vehicle-oriented road into streets exclusive for pedestrians until 2037. Osaka City mentions it is the latest approach of urban street planning, sharing the urban space with a variety of stakeholders in the city, and it would be the symbol of city branding and city competitiveness in the global market.

Source: https://www.city.osaka.lg.jp/kensetsu/page/0000442376.html

Figure 5.1.9 Image of Traffic Calming Proposal (Case of Osaka City Midosuji)

Not only Osaka, but other major cities are proposing traffic calming methodologies incorporated with traffic management. The high volume of pedestrian flow due to the daytime high-concentration of business areas should be harmonized with traffic management, and lane-closing, shrinking the width of the lanes are commonly implemented for converting the vehicle space for street space.

As the first step of such conversion, micro step approaches (placemaking) can be proposed. For example, in Shinjuku, Tokyo, a placemaking experiment is being conducted on Shinjuku Street at the east exit of Shinjuku Station to open up a part of the road space and allow pedestrians to take a break. These measures were implemented in conjunction with measures to reduce the number of vehicles used for cargo handling and distribution, and were designed to evaluate the impact on traffic flow on Shinjuku-Street and to improve the convenience of pedestrians visiting Shinjuku.



Source: Shinjuku Mall & Passage, http://shinjuku-east.tokyo/ and
https://www.tric.jp/en/projects/typical_project_h28_01.html

Figure 5.1.10 Case Study of Placemaking in Shinjuku, Tokyo

5.2 Traffic Control Projects Reviews

5.2.1 Past Traffic Control Projects

(1) Issue/Findings on Traffic Control project implemented around year 2000

The signal projects implemented around the year 2000 were not focusing on signal control, but on the introduction of signals in conjunction with the development and improvement of road infrastructure and intersection improvements.

In Dar es Salaam, Tanzania, a basic design study for the Project on Road Network Development Plan in Dar es Salaam Metropolitan Area was implanted in 1991, and as part of the scope of works, a total of 10 signals were planned: 2 on Upanga Road, 5 on New Bagamoyo Road, and 3 on Morogoro Road. Those signals were actually introduced in the late 1990s.

The target intersections were selected based on an average daily traffic volume of 15,000 vehicles or more and the introduction of signals was intended to minimize hindrances to traffic flow. As for the signaling control system, the systematic control with the same signal cycle time, which is effective when the intersections are close to each other, was adopted.

The signal control system introduced at that time was not the control system that measured the traffic volume and speed with sensors, and dynamically switched the signal parameters to reflect the situation.

In the city of Kampala, Uganda, JICA implemented development study on arterial road network improvement in 1996-1997. In the study, formulation of a road development master plan and feasibility study to the prioritized project were implemented. During the study, it was concluded that the cause of traffic congestion in the city was "due to intersections/roundabouts with insufficient traffic capacity, flooded roads, and damaged pavement. Based on the priorities of this study, traffic signal installation with geometric improvements and removals of roundabouts were implemented. Then in the Project for Improvement of Traffic Flow in Kampala City, traffic signals are introduced at four intersections including intersection improvement aiming to achieve smooth traffic flow and road safety. The control method of the signals in the Project was systematic control with the same signal cycle time.

The main purpose of this project was not to control the dynamic signal control according to the measured traffic data at the signalized intersections, but to achieve smooth traffic flow and road safety.

(2) Issue/Findings on Traffic Control Project implemented around 2010

The Project for Development of Traffic Management System in Phnom Penh, which was completed in December 2018 in Phnom Penh Capital, Cambodia, was a project to introduce traffic signals that control signal parameters according to traffic conditions, and although the intersection improvements were also implemented, the main focus of the project was the introduction of traffic signals including a center control system. In addition to the introduction of traffic signals at 115 intersections, the system consisted of a traffic counter to measure traffic volume and vehicle speed, a communication network between a traffic signal controller at signaling intersections which are connected to the signal light and traffic counters (for 109 intersections), and a central control system to analyze traffic conditions at the control center and switch parameters of signal controller at each intersection.

One of the issues and lessons learned in this case was the communication cable between the signal controllers at each intersection and central control system. In the initial plan, the plan was to utilize the existing optical fiber cable owned by the Ministry of Post and Telecommunications (MPTC), however after the contractor's contract, it was revealed that these spare fiber optic cores could not be used. Thus, the optical fiber cable was additionally installed as the client's own asset by the design modification of the original scope of work of the project. In accordance with this design modification, the implementation period was extended to 35 months from the original 22 months.

In the past, electronic government promotion projects were implemented in many countries, and optical fiber cable was installed for connecting government agencies. In the traffic signal project, spare cores of such optical fiber cables was considered for use in data transmission between the signal controller at each intersection and the center controlling system; however a careful check is required for the existing fiber cores especially considering the maintenance condition. On the other hand, if the optical fiber cable is installed under the Project as the government agency's asset, the necessary manpower, organization, and budget should be secured to maintain the data communication. If the responsible government agency finds it difficult to maintain the traffic signal control, the securing of an outsourcing budget for it should be required to check if a similar project will be planned.

(3) Issue/Findings on the traffic control project after 2015

In Kampala, Uganda, after the mentioned project, a technical cooperation project was implemented for introducing coordinated traffic signal control for 4 intersections aiming to improve the traffic flow, which also tried to evaluate the effectiveness of the coordinated control from 2015. Thereafter, a coordinated traffic signal control would be planned to introduce for 28 intersections including the establishment of traffic control center under the grant aid basis.

The technical cooperation project included a pilot project to verify the effectiveness of coordinated traffic signal control. It contributed to deepening of the stakeholders' understanding on necessity of traffic control center which will be installed in the grant aid project to be implemented later. It also contributed to improve the stakeholders' human resources.

In fact, the implementation period of those projects is expected to last around 8 years in total. If the grant aid project was planned to commence from the beginning, it might be completed already. Therefore, the client's intention on the implementation schedule should be clarified before commencement of the project.

5.2.2 Other Issues

(1) Integration of multiple signal control protocols

In Nairobi, Kenya, KURA intended to adopt the UK's SCOOT as a standard for signal control system. This selection is considered to be the 2nd best method instead of the lack of a Kenyan own control method. The reason for this is that KURA wants to ensure interoperability and avoid a situation where incompatible signal control systems are mixed up in the city.

In Accra, Ghana, the signal system along the Quality Bus corridor requires the disclosure of interface information for traffic signal control as a condition of the contract, so that even if other control systems are introduced in the future, the other systems can be integrated and controlled under the current controller. This condition serves as a stepping-stone to future integrated control.

However, as a recent trend, there is a system[4] that can control different control methods in an integrated manner, and by utilizing this system, it is becoming possible to realize integrated control even in cities where different control methods are mixed currently.

(2) Preparedness of the sudden communication failure like cable cutting

In Nairobi, there was a cable cutting incident after the signal system was installed by SIEMENS, a German company, around 2007. Siemens was reluctant to respond, and when they did, they were charged for the repairs, which was apparently unexpected for the city of Nairobi.

This is likely due to the fact that the relationship between the warranty for the defect period and the normal maintenance and operation support contract was unclear after the installation work was completed. It is basically unacceptable for a contractor to accept repairs for causes other than defects in the equipment he has installed without compensation. It is important for both the executing agency of the project and the party responsible for operation of the installed system to understand this point.

On the other hand, in the city of Mombasa, after a Chinese contractor for a KeNHA-controlled road development project cut the fiber-optic cable which had been installed and been connecting the County Government offices. This contractor has been barred from entering the cable cutting site and neither the city of Mombasa nor KeNHA can intervene in any way. The cable is connected to cameras that monitor the traffic condition at various intersections and roundabouts in the city of Mombasa, and some of the image transmissions at the monitoring center cannot be seen. The city of Mombasa has considered laying a cable on the detour route, but as of the end of March 2020, the failure due to the cable cutting has not been recovered for about 3.5 months.

For the Kenyan public works including international assistance, there is a need to clearly stipulate the responsibility for repairing existing facilities when they are damaged by works carried out in the country,

[4] As an example, the Israel based Axilion appeals its capacity to develop the integrated coordinated system with dedicated protocols of traffic signal suppliers such as SWRCO, Siemens, PEEK.

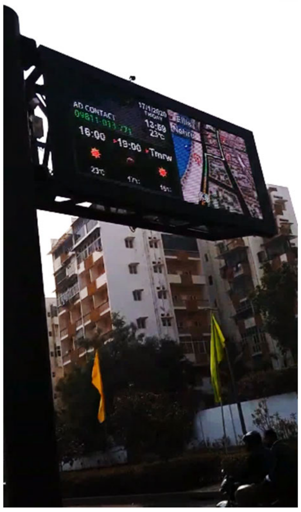
including other country's contractors. It should also be confirmed that such provisions apply to assistance provided by the donors.

(3) Measures to improve sustainability

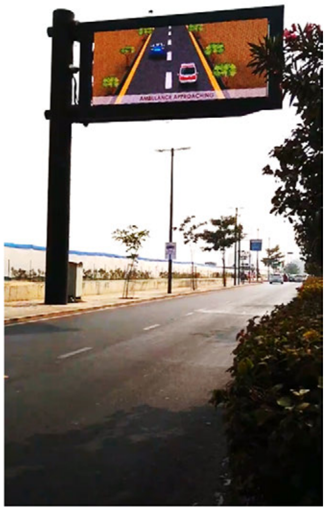
In Ahmedabad, India, a traffic management system was introduced by a Japanese company, Zero-Sum, through JICA's public private partnership project categorized as Verification Survey with the Private Sector for Disseminating Japanese Technologies. In the project, in order to ensure the sustainability of the introduced system, a unique trial was made to display advertisements on variable message sign (VMS) together with road traffic information, and the revenue from these advertisements considered allocating to the maintenance and management costs.

Advertising (left half) / Traffic information (right half)
Source: Zero-Sum Ltd. https://www.zero-sum.co.jp

Advertising (left half) / Traffic information (right half)
Source: Nagoya ElectricWorks Co.,Ltd. https://www.nagoya-denki.co.jp/news/115688.html



Weather forecast info. (left half) / Traffic info. (right half)
Source: JICA Study Team



Emergency Vehicle Approach Information
Source: JICA Study Team

Figure 5.2.1 VMS Displaying Road Traffic Information and Advertizement

The provision of road traffic information is not a for-profit project, and the organization responsible for traffic management implements and provides the service by basically using public funds. The sustainability of that equipment would be improved by having the beneficiaries also share the operation and maintenance costs and renewal investment costs.

5.3 New Movements in Traffic Control System

5.3.1 Alternatives for Vehicle Detectors

(1) Ordinary Vehicle Detectors

In general signal control systems, vehicle detectors are installed on the roadside of the intersection, and the signal phase pattern is switched by grasping the traffic situation from the traffic volume obtained from the vehicle detectors. Basically, vehicle detectors will be installed in all directions at signalized intersections, and more vehicle detectors are needed to grasp the traffic situation in more detail.

There are various types of vehicle detectors including [Loop-Coil Type], [Image Sensor Type], [Supersonic Sensor Type], and [Infrared Beacon Type]. The infrared beacon is an original Japanese method.

In Japan, [Supersonic Sensor Type] is the mainstream and about 140,000 units are installed, followed by [Infrared Beacon Type] about 50,000 units and [Image Sensor Type] about 0.6 million units, while [Loop-Coil Type] is the mainstream in developing countries and other foreign countries because of its low maintenance cost.

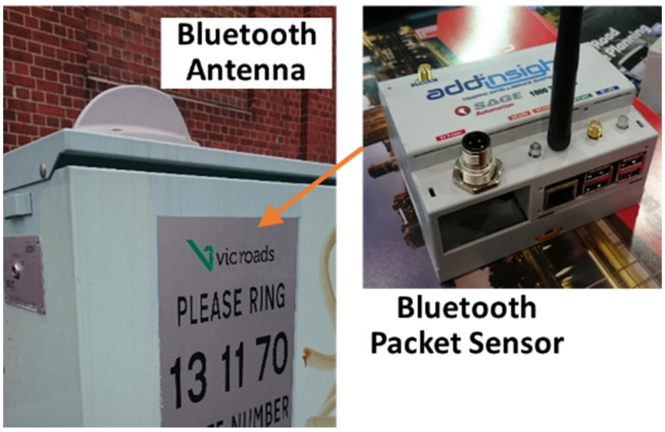
The problem with the [Loop-Coil Type] system is that the sensor is destroyed when the road is excavated due to road maintenance, etc., and it cannot be re-used.

On the other hand, both the [Image Sensor Type] and [Supersonic Sensor Type] are hardly affected by the road maintenance work, but the cost of civil engineering work, such as gantry installation, is high, and the maintenance cost is also high compared to the [Loop-Coil Type].

Under these circumstances, a new method of understanding the traffic situation is described below.

(2) New Detector Technology 1: Bluetooth application

- The system collects travel times and travel speeds for each vehicle by matching the MacIDs of smartphones and other devices that pass near the Bluetooth beacons installed on the side of the road at each intersection.
- It has also been introduced in Adelaide, Melbourne, Australia, and Hong Kong.
- In most cases, travel time and speed are collected to provide information to users, but future use in signal control systems is also being considered.

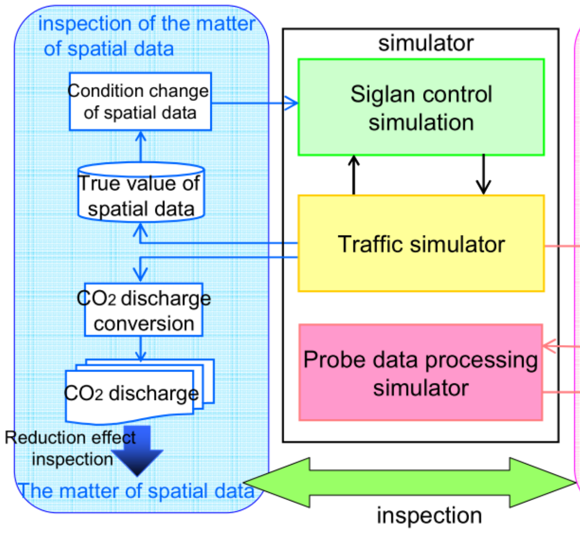


Source: Final Report of Implementation Support and Follow-up for Knowledge Co-Creation Program "Practical Technology on Intelligent Transport Systems (ITS)"

Figure 5.3.1 Bluetooth Signal Detection Antenna (Left) and Bluetooth Signal Receiver (Right)

(3) New Detector Technology 2: Probe Data (Floating Car Data)

- The system uses probe data, such as location information collected by smartphones and the Fleet Management System (FMS), to understand traffic conditions such as travel time and travel speed.
- The collected probe data will be accumulated over a long period of time and used for statistical processing and simulation to understand the changes in traffic conditions due to changes in the Signal Phase Pattern.
- Compare before and after changing the Signal Phase Pattern, understand the effects of changing the Signal Phase Pattern, and optimize the Signal Phase Pattern.



Source: The constitution of the simulation experiment http://www.utms.or.jp/
(Universal Traffic Management Society of Japan)

Figure 5.3.2 The Constitution of the Simulation Experiment

(4) Collection of Traffic Information using Smartphones and other devices

Overseas, there are a several car navigation systems that use smartphones, such as Google Navigation[5], INRIX[6], TomTom[7], and HERE[8]. One of the features is Waze. Waze is an application that combines a smart phone navigation system from Israel with a social network service (SNS), enabling users to share probe information based on GPS information, as well as real-time sharing of traffic jams and traffic accidents between users.

[5] Car navigation application provided by Google https://play.google.com/store/apps/details?id=com.google.android.apps.maps
[6] The company provides location-based data and analytics, such as traffic and parking, to car manufacturers, cities and road authorities around the world and to turn-by-turn navigation applications, also develops mobile and in-vehicle applications and provides traffic and parking information for major cities. https://inrix.com/
[7] The company sells GNSS satellite-based car navigation devices and car navigation applications based on location information technology and map generation technology. https://www.tomtom.com/
[8] The company provides mapping and location data and related services to individuals and businesses, and provides navigation and location-based services to a variety of companies worldwide. https://www.here.com/

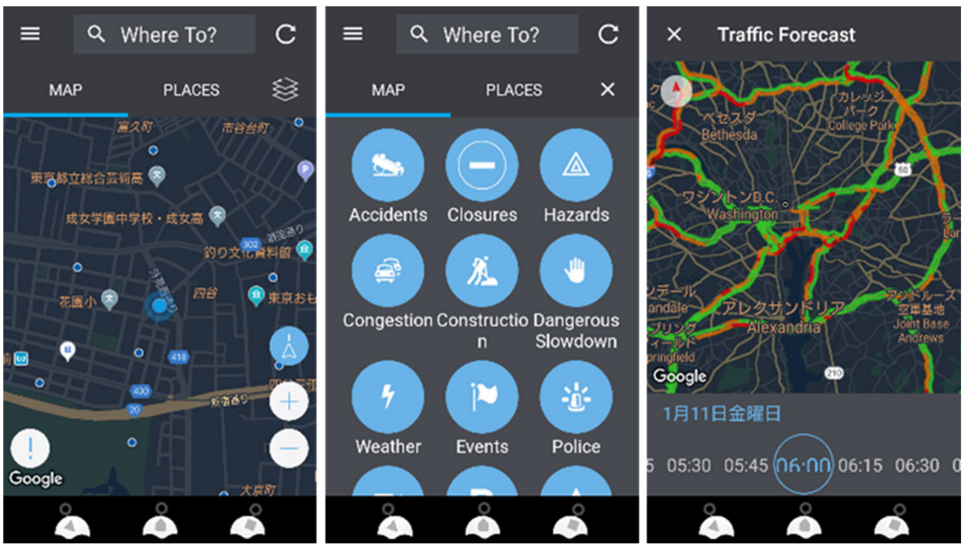
Navigation　　Report Posting　　Point Ranking

Source: Waze Website http://www.waze.com/

Figure 5.3.3　Screen Image of Waze

It also has the ability to edit road information such as town names, street numbers, road names, and road maps. For example, if the paving function of Waze is used to drive on a road that is not shown on the existing road map multiple times, a new road is generated based on the probe information and reflected on the road map of Waze. Waze is said to have more than 10 million users worldwide, and in June 2013, Google acquired Waze to enhance the maps, road information and traffic information provided by Google.

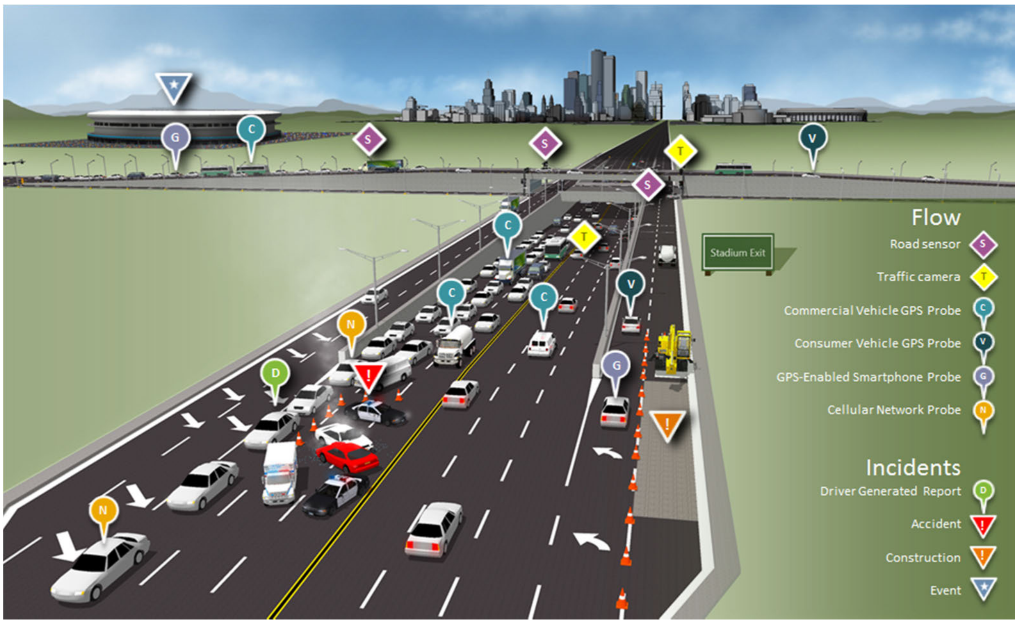
In addition to providing the same information as Waze, INRIX also has a navigation function and predictive traffic information in cooperation with road administrators.



Source: INRIX http://www.inrix.com/

Figure 5.3.4　Road and Traffic Information Provision Application by INRIX

Although INRIX is an application provided by a private company, the company not only collaborates with automobile manufacturers for the purpose of collecting probe data, but also collaborates with road administrators such as local governments to understand and forecast traffic conditions by analyzing vehicle sensor data as well.

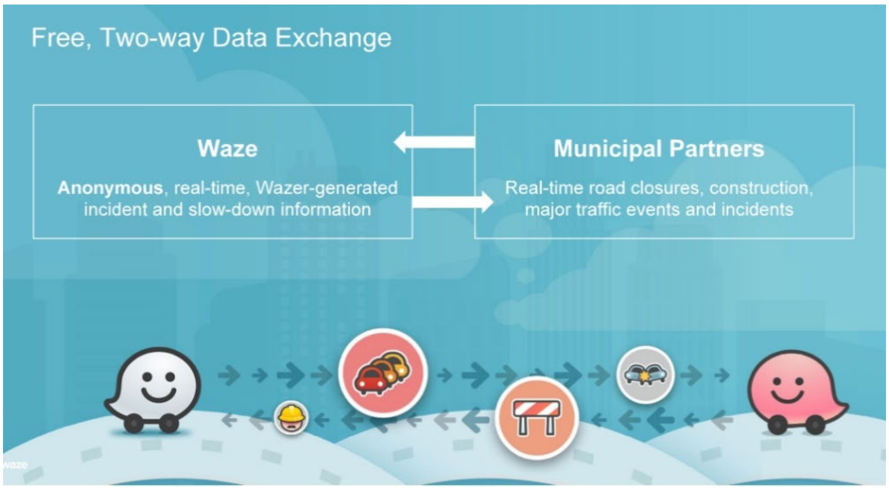


Source: INRIX http://www.inrix.com/

Figure 5.3.5 Image of Traffic Information Collection and Integration by INRIX

(5) Public-Private Partnerships through Waze (Waze for Cities Data)

Waze has a program called the Connected Citizens Program (renamed Waze for Cities Data in October 2019), which allows the reciprocal use of free traffic information with road managers and municipalities, and nearly 100 municipalities and organizations in the U.S., Europe and elsewhere have already partnered. In terms of data provision, instead of providing traffic control information, construction information, and information on major traffic events and accidents to Waze from road managers and local governments, Waze provides anonymized real-time traffic information and Wazer provides traffic events and congestion information in XML or JSON format through the Waze API, with real-time data updated every two minutes.



Source: Waze Website http://www.waze.com/

Figure 5.3.6 The Concept of Waze for Cities Data

Table 5.3.1 Data Items Provided by Waze
(Left: Posted Event Information / Right: Congestion Information)

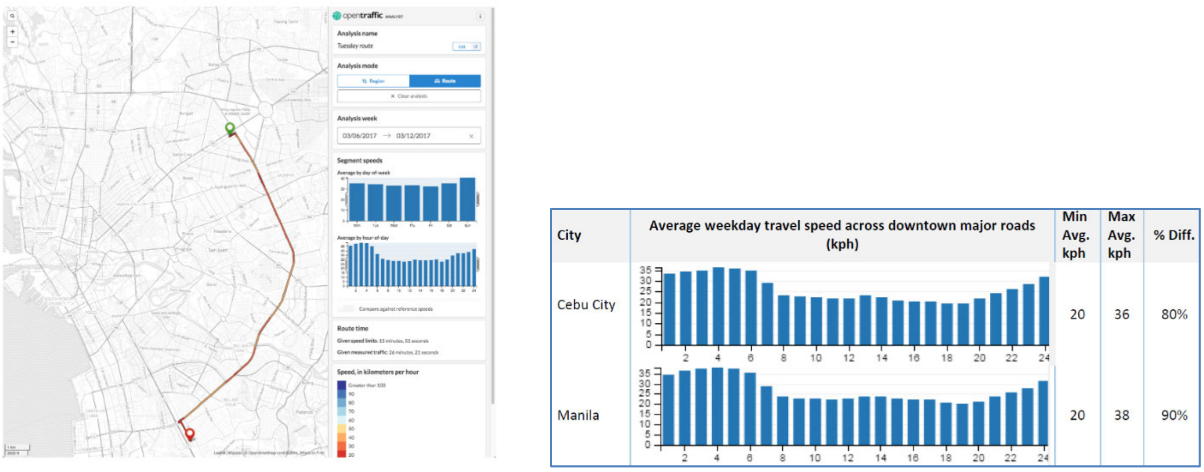
Element	Value	Description
pubMillis	Timestamp	Publication date (Unix time – milliseconds since epoch)
location	Coordinates	Location per report (X Y - Long-lat)
uuid	String	Unique system ID
magvar	Integer (0-359)	Event direction (Driver heading at report time. 0 degrees at North, according to the driver's device)
type	See alert type table	Event type
subtype	See alert sub types table	Event sub type - depends on atof parameter
reportDescription	String	Report description (supplied when available)
street	String	Street name (as is written in database, no canonical form, may be null)
city	String	City and state name [City, State] in case both are available, [State] if not associated with a city. (supplied when available)
country	String	(see two letters codes in http://en.wikipedia.org/wiki/ISO_3166-1)
roadType	Integer	Road type (see road types table in the appendix)
reportRating	Integer	User rank between 1-6 (6 = high ranked user)
jamUuid	string	If the alert is connected to a jam - jam ID
Reliability (new)	0-10	How reliable is the report…..
reportByMunicipalityUser	Boolean	Alert reported by municipality user (partner) Optional.

Element	Value	Description
pubMillis	Timestamp	Publication date (Unix time – milliseconds since epoch)
type	String	TRAFFIC_JAM
line	List of Longitude and Latitude coordinates	Traffic jam line string (supplied when available)
speed	Float	Current average speed on jammed segments in Km/h
length	Integer	Jam length in meters
delay	Integer	Delay of jam compared to free flow speed, in seconds (in case of block, -1)
street	String	Street name (as is written in database, no canonical form. (supplied when available)
city	String	City and state name [City, State] in case both are available, [State] if not associated with a city. (supplied when available)
country	String	available on EU (world) server (see two letters codes in http://en.wikipedia.org/wiki/ISO_3166-1)
roadType	Integer	Road type (see road types table in the appendix)
startNode	String	Nearest Junction/steet/city to jam start (supplied when available)
endNode	String	Nearest Junction/steet/city to jam end (supplied when available)
level	0 - 5	Traffic congestion level (0 = free flow 5 = blocked).
uuid	Long integer	Unique jam ID
turnLine	Coordinates	A set of coordinates of a turn - only when the jam is in a turn (supplied when available)
turnType	String	What kind of turn is it - left, right, exit R or L, continue straight or NONE (no info) (supplied when available)
blockingAlertUuid	string	if the jam is connected to a block (see alerts)

Source: Waze http://www.waze.com/

(6) Public-Private Partnership between the World Bank and Grab

The World Bank's Washington headquarters led Open Traffic, a pilot project in the Philippines to analyze traffic conditions based on Probe Data collected by Grab, and following the demonstration of this project, the World Bank entered into a business partnership with Grab Taxi, a taxi dispatch and reservation service in Southeast Asian countries, in April 2015 to collaborate on research on traffic congestion mitigation and road improvement. In the World Bank's Open Traffic effort, the Open Traffic Partnership (OTP) was launched to develop a global architecture for combining anonymized traffic data in collaboration with various Probe Data holding agencies. In addition to Grab, Easy Taxi, the National Association of Urban Transportation Organizations (NACTO), the World Resources Institute (OHS), and others are also working with the OTP to develop partnerships with government partners to help transportation agencies use Probe Data to improve traffic management and planning.



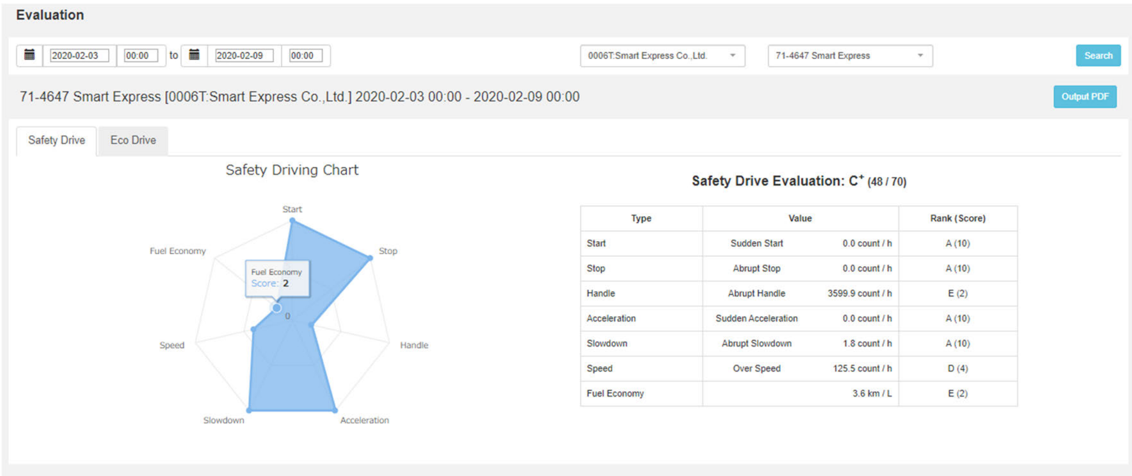
Source: Open Traffic Report (World Bank)

Figure 5.3.7 Example of Analysis Results in Open Traffic

5.3.2 FMS for Traffic Control Improvement

The Fleet Management System (FMS) has been introduced for the purpose of improving the efficiency in the allocation of vehicles and providing information to customers by grasping the position of the vehicles, and reducing the risk of traffic accidents and fuel consumption by grasping the driving behavior of the vehicles.

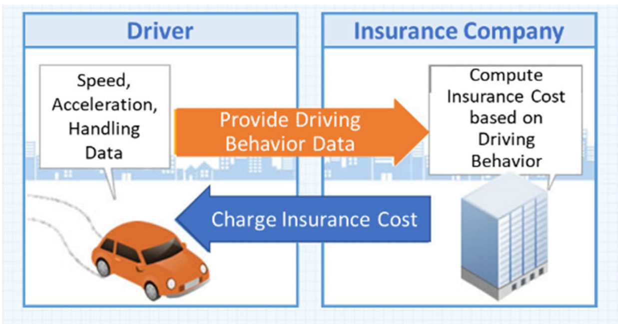
GPS-based location information gathering devices used for FMS have been manufactured all over the world, and as a result, inexpensive in-vehicle devices have come to be supplied, and FMS has been used all over the world.



Source: JICA Study Team

Figure 5.3.8 Example of Operating Behavior Diagnosis by FMS

Pay How Your Drive (PHYD) insurance, in which premiums fluctuate depending on how you drive, has the advantage that policyholders (drivers) will pay lower premiums, and as a result, they will try to drive safely, and insurance companies will be able to reduce their claims payments as a result.



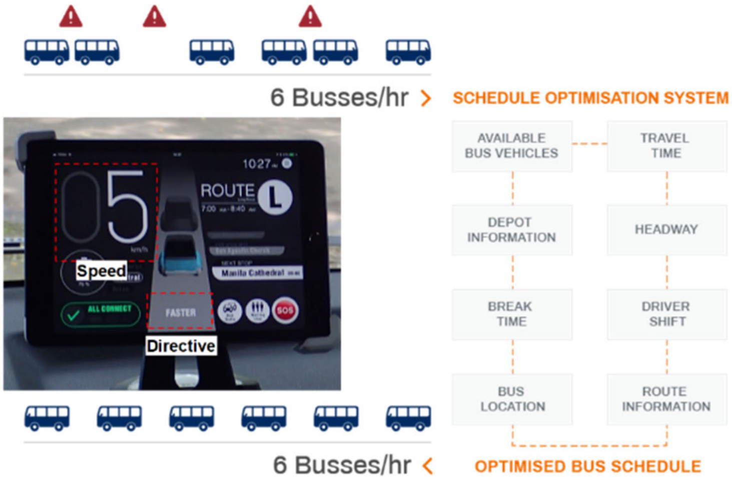
Source: Car Insurance News https://www.bang.co.jp/cont/column-20150212/

Figure 5.3.9 Pay How Your Car Insurance

In bus transportation, the frequency of bus operation and the planning of bus routes can be done by simultaneously knowing the location of the vehicles and the number of passengers.

In addition, while Japanese bus services operate on a schedule with a timetable for each bus stop, many bus services in many countries operate on a schedule with only a general interval.

For the convenience of users, it is desirable to have the buses run at intervals as even as possible, so a system has emerged that provides guidance to the drivers of each bus to make the intervals even by understanding the position of each bus.



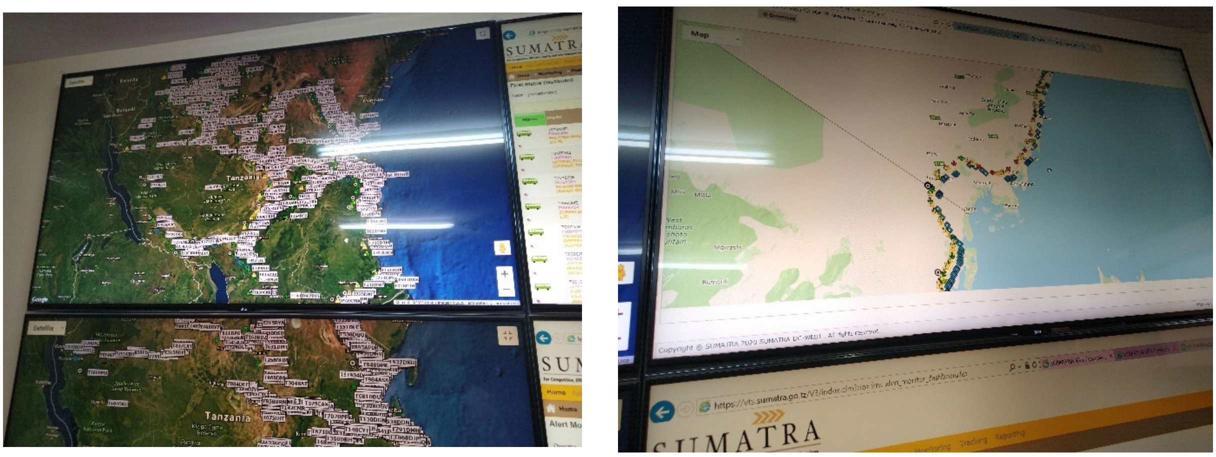
Source: JICA Study Team based on NEC materials (https://www.nec.co.nz/)

Figure 5.3.10 Image of an Interval Management System for Public Transportation

In this way, services that utilize data obtained by FMS, including GPS on-board equipment, are being used in many countries around the world.

Some countries, such as Thailand, Vietnam, the Philippines, and Sri Lanka, have mandated the installation of GPS on-board equipment in commercial vehicles, such as trucks and buses, and have mandated the provision of location information to government agencies.

In Tanzania, the Land Transport Regulatory Authority (LATRA) has implemented similar measures for intercity buses, and by enforcing speed violations, the system has been effective in reducing traffic accidents by 30% after the introduction of the system.



Source: JICA Study Team

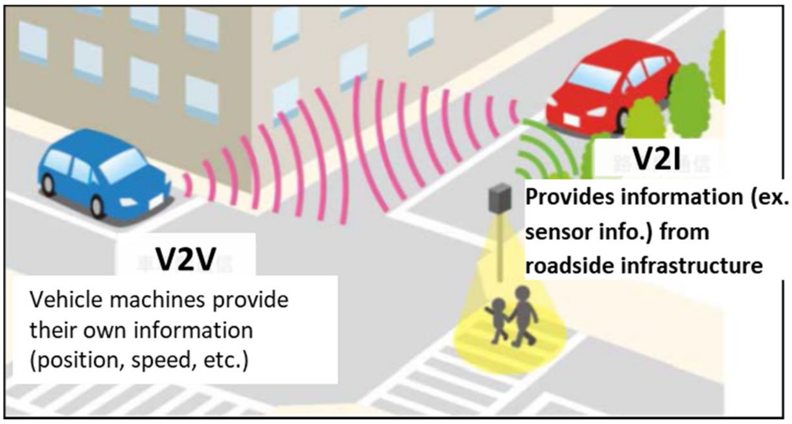
Figure 5.3.11 Control Centre of the Land Transport Regulatory Authority (LATRA)

5.3.3 V2X

(1) Overview of V2X

V2X stands for Vehicle to Everything and is a communication technology that includes V2V (vehicle-to-vehicle), V2M (vehicle-to-motor cycle), V2P (vehicle-to-pedestrian), V2N (vehicle-to-network), and V2I (vehicle-to-infrastructure), and is a fundamental technology for recently connected vehicles.

In Japan, V2I has been put to practical use as one of the Driving Safety Support Systems (DSSS) in order to improve the safety environment of road traffic. In addition to the fact that roadside devices for distributing traffic safety information have already been installed in prefectures throughout Japan, Toyota Motor Corporation has also launched vehicles equipped with V2X communication devices, and at present (April 2020) the number of vehicles equipped with V2X communication devices has reached approximately 200,000.



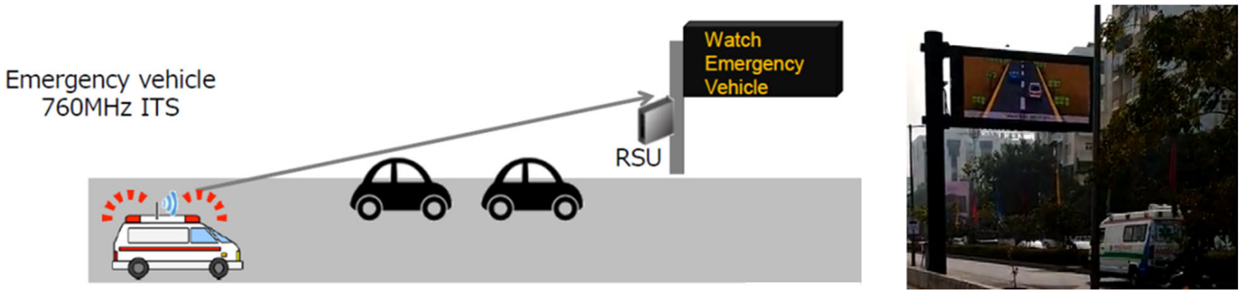
Source: Ministry of Internal Affairs and Communications
http://www.soumu.go.jp/main_content/000492421.pdf

Figure 5.3.12 Image of the Application with V2X

(2) Applications using V2X

1) Public Transportation Priority System (PTPS)

It is widely known that smooth ambulance transport of injured people at the time of a traffic accident is essential to improve the prognosis of injured people, and it is necessary to transport injured people to medical facilities by ambulance or other means quickly and smoothly. However, in addition to the fact that traffic congestion caused by traffic accidents impedes the smooth running of emergency vehicles, there are also cases where emergency vehicles cannot arrive at the scene quickly because they do not evacuate when an ambulance approaches, and where transport from the scene to a medical facility is impeded. This V2X technology signals the approach of an emergency vehicle with a Variable Message Sign (VMS) in front of the vehicle. At the same time, the traffic signal in front of the vehicle is switched to green to realize smooth and quick passage of the emergency vehicle, which is being tested in Ahmedabad, India.

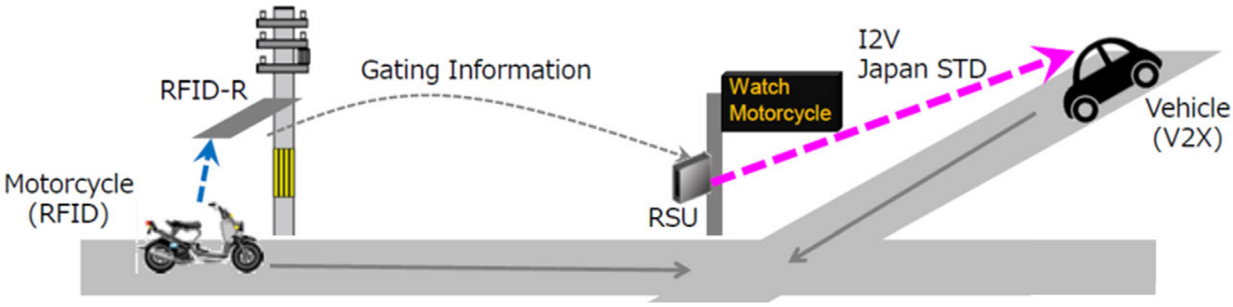


Source: IT Strategy Office, Cabinet Secretariat
https://www.kantei.go.jp/jp/singi/it2/dourokoutsu_wg/dai3/siryou1-2.pdf

Figure 5.3.13 Public Transportation Priority System (PTPS) by V2X Technology

2) Prevention for Collision Accident at Non-Signalized Intersection

The reduction of injuries, illnesses and fatalities caused by road accidents has become a major social issue in many countries around the world, and Target 3.6 of Goal 3 in the SDGs calls for halving the number. There are various factors that contribute to traffic accidents, but one of them is a traffic accident at an unsignalized intersection, and another is a traffic accident at the intersection of ordinary vehicles and ambulances. Therefore, by using V2X technology, a system has been developed to indicate to other vehicles that a vehicle is approaching an intersection with a Variable Message Sign (VMS) or On-Boad-Unit (OBU) mounted on the vehicle, which is being tested in Quezon City, Philippines.



Source: IT Strategy Office, Cabinet Secretariat https://www.kantei.go.jp/jp/singi/it2/dourokoutsu_wg/dai3/siryou1-2.pdf

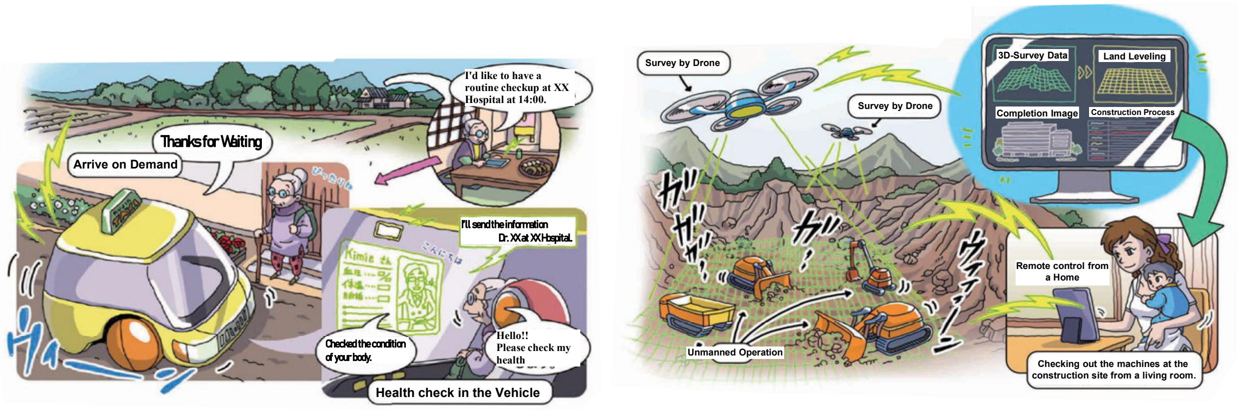
Figure 5.3.14 Prevention for Collision Accident at Intersection by V2X Technology

5.3.4 5G Application for Traffic Control

(1) Features and Challenges of 5G

The development of 4th-generation (4G) as LTE in many countries around the world has increased the speed and capacity of mobile communication systems and has responded to the increase in traffic caused by the spread of smartphones.

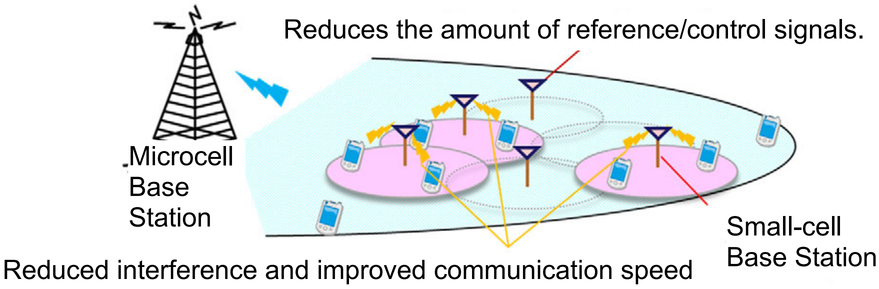
Furthermore, as we enter the era of automated driving, smart cities, and the IoT, it is said that the development and use of 5th generation (5G) communications, which is characterized by (1) high speed and high capacity, (2) super-majority connectivity, (3) ultra-low latency, and ultra-reliability, is indispensable for the communication infrastructure for vehicles, people, and all other things in the world, instead of the current 4G.



Source: Towards a Wireless Society by 2020 - KIAI General Meeting Presentation Materials
(May 29, 2018, Ministry of Internal Affairs and Communications)

Figure 5.3.15 Image of Remote Operation Using 5G

5G is a technology that uses a high frequency band (millimeter wave), which is currently underutilized, to achieve ultra-high-speed communication. However, conventional methods based on large base stations (microcells) make it difficult to reach radio waves indoors or underground, and congestion occurs in downtown areas. 5G requires the development of small cells (small base stations) that cover a range of 200 to 300 meters as infrastructure to supplement microcells.



Source: Nikkei XTECH https://xtech.nikkei.com/

Figure 5.3.16 The Relationship between Macrocells and Small Cells

Some of the characteristics of small cells include the following

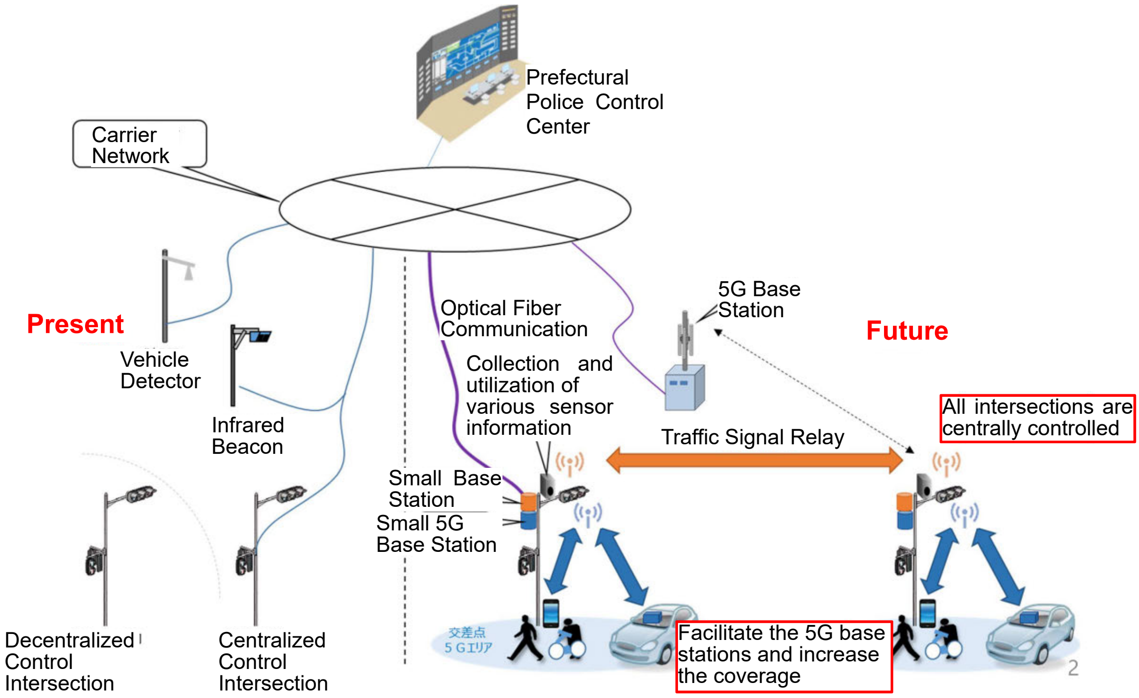
1) A communication area smaller than a radius of several hundred meters
2) Because the area is small, the number of terminals to be connected is relatively small.
3) It is easy to reach the wave directly and the reception quality is relatively high.

For (1), it is a major challenge to secure a small cell base station every 200 to 300 m. If it is to be installed on private land, it is necessary to negotiate with each private landowner individually, which requires a considerable amount of time and labor. With this situation as a backdrop, the installation of base stations on utility poles and other social infrastructure is being considered. However, the use of electric poles is expected to become more difficult in urban areas, as the undergrounding of electric cables is expected to increase in the future.

In order to install them in public areas such as streetlights and road sites, it is necessary to discuss their occupancy with the road administrator and bear the occupancy fee.

(2) Efforts to link 5G with traffic signals

In July 2019, the Cabinet Office set up a liaison council of relevant ministries and agencies for the nationwide deployment of Trusted by linking 5G with traffic signals, with the aim of promoting the development of 5G base stations (small cells) at signal poles in conjunction with the upgrading of traffic signal and control systems. This initiative is expected to solve the problem of 5G base station installation sites and accelerate the development of 5G base stations, especially in urban areas.



Source: Development of Technologies Necessary for Smooth Coordination between 5G and Traffic Signals

Figure 5.3.17 Image of 5G Utilization in Traffic Signal and Control Systems

5.3.5 CCTV for Traffic Control

The Public Works Research Institute, Japan (PWRI), a national research and development agency for civil engineering and transport technology, announced a study project offer titled "innovative and challenging technology development", in November 2019, aiming for the following three aspects.

i) Nondestructive inspection technology for the inside of a structure using radiation
ii) New safety management using 4D models, and
iii) A comprehensive system using ITS technology suitable for developing countries

The third one is related to the ITS in developing countries. The study description is presented as follows;

In developing countries (especially in Asia), traffic congestion in urban areas has become more severe due to the rapid progress of motorization. At the same time, road infrastructures developed through yen loans and other means are facing a period of full-scale renewal, requiring appropriate repair and maintenance management. On the other hand, the explosive spread of smartphones and Wi-Fi in developing countries has led to a decline in the prices of on-street CCTV cameras and surveillance cameras, making it possible to develop inexpensive, simple, and comprehensive systems that contribute to solving problems by utilizing these devices and AI technology. This study aims to develop a comprehensive system that utilizes ITS *technology, based on the premise of information collection and provision, etc., suitable for developing countries. This is expected to contribute to the appropriate repair and maintenance of roads in developing countries and to reduce congestion by providing road traffic information. In addition, it is expected that the improved and highly accurate system, which utilizes the actual data collected in developing countries, will be used in Japan as well, thereby improving the level of road management.*

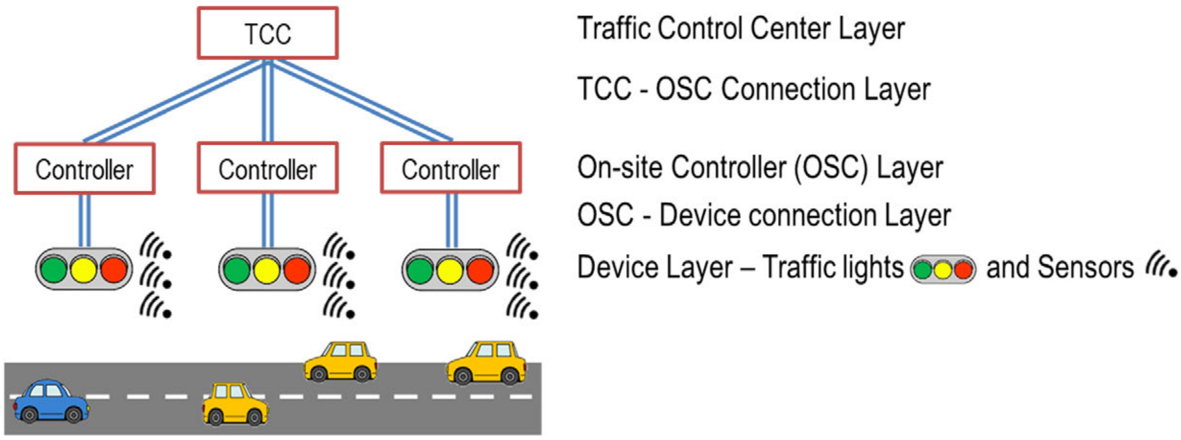
The announced offer is still in procurement procedure, but it is expected to be undertaken by a private group with ICT background.

As mentioned above, the outcomes of the study is to realize utilization of the CCTV based real time traffic information, which can be expanded to the signal control instead of on-site sensors or probe car data collection. For example, Mombasa has 90 on-street CCTVs at the major intersections, and this analysis can contribute to develop the traffic flow information and minimize the traffic congestion.

5.4 Comparison of State of Practice of ITS/Traffic Signal System in Japan and Target 5 Cities, and Development Strategy

The state of practice of the ITS system (traffic management system with coordinated signals) development in the five cities is clarified in comparison with the general signal development in Japan, and the direction of the ITS system development in the five cities are identified. It should be noted that descriptions of the system are simplified for comparison in this section.

5.4.1 Outline of Traffic Signal Development in Japan



Source: JICA Study Team

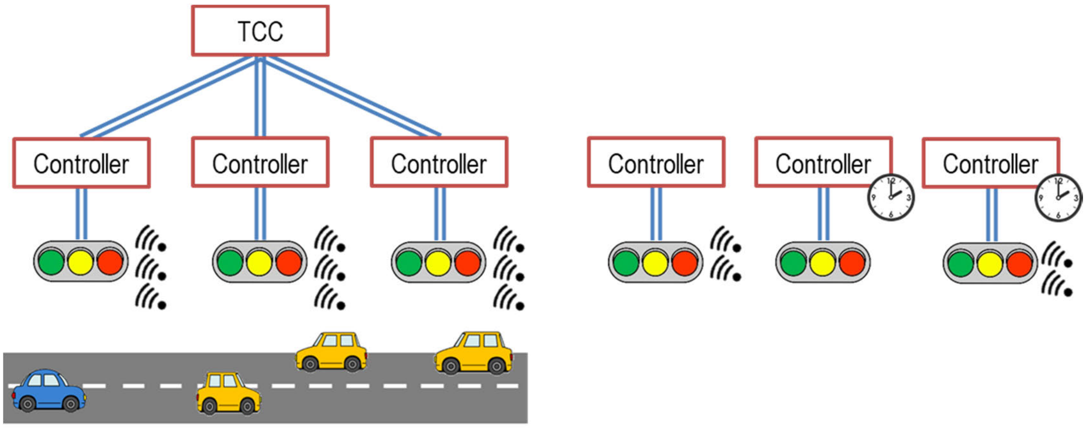
Figure 5.4.1 A Model for the ITS/Traffic Management System in Japan

A general ITS system in Japan consists of five layers (three layers of equipment and two layers of connections), as shown in Figure 5.4.1. In Japan, each prefecture has developed the system with a single contractor, therefore, basically, there is no mix of signal contractors.

The device layer consists of signals and road-side sensors, and at present, more sensors are delivered to realize more accurate traffic observation for control. One controller is delivered at each intersection. The controller and signal are duplexed with power lines, and the roadside sensors are also connected by cable.

The TCC and the controllers are connected by a dual wired network (using a leased telecommunication optic fiber service) with a highly redundant «star» connection.

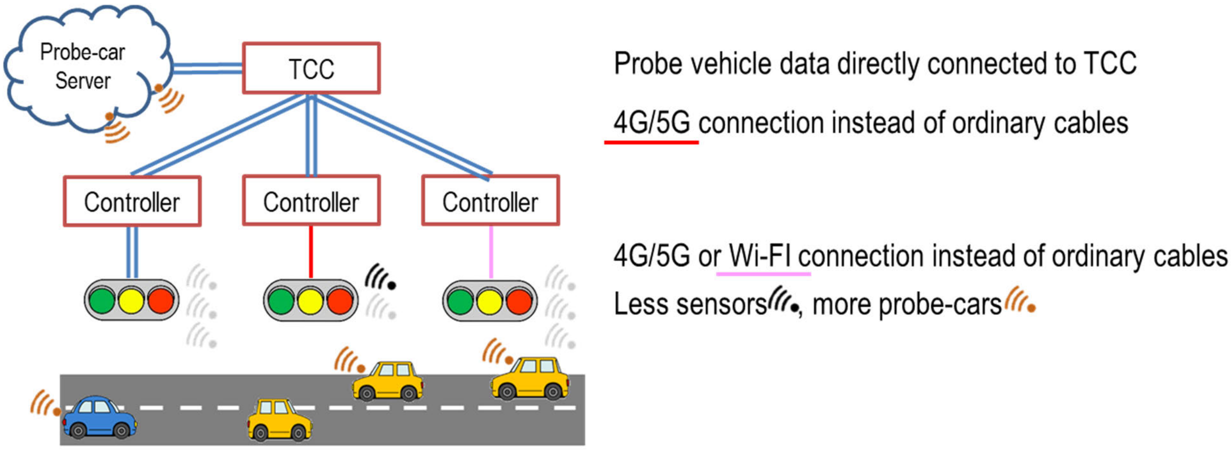
Traffic control center (TCC) was originally developed and owned by the prefectural police, however, now it is generally procured on a lease basis because of the rapidness of the IT system revolution. The technical standards are set forth in the National Police Agency specifications.



Source: JICA Study Team

Figure 5.4.2 A Model for the ITS/Traffic Management System in Japan -with Individual Signals

As shown in Figure 5.4.2, not all signals are incorporated into a coordinated control system, and some signals remain independent. In this case, there are two types of systems: adaptable control systems that use sensors to adjust the signal phasing periods according to the surrounding traffic conditions, and systems that change the specified and scheduled pattern according to the time of day.



Source: JICA Study Team

Figure 5.4.3 Future Potential Model for the ITS/Traffic Management System in Japan

As a recent trend, as aforementioned, traffic information of road congestion and travel speed from the probe vehicles directly enters the TCC, in addition to using the existing roadside sensors and controllers. If this is expanded, it is expected to reduce roadside sensors and, in turn, improve "high dependency on physical infrastructure" conditions. Those physical infrastructures require civil work for installation and cabling, periodic maintenance, operation cost for communication and electricity, etc.

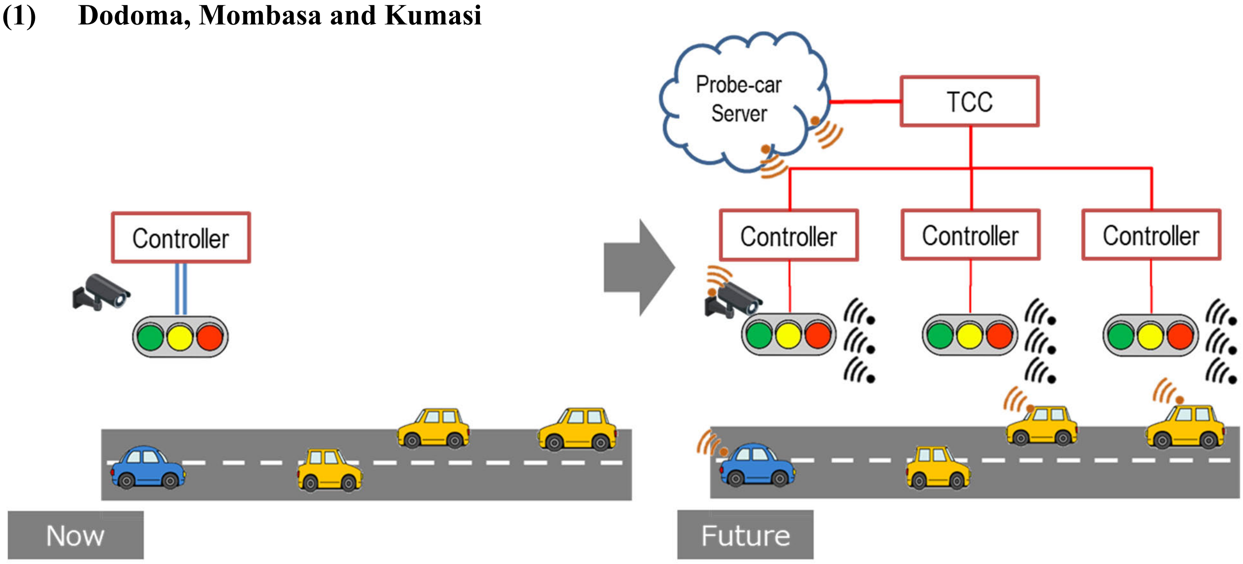
It can be considered that future 4G/5G/other wireless communication system development may replace OSC-device connections and TCC-OSC connections.

Regarding the OSC-device connections via wireless communication including 4G are technically possible, and the connection to the road sensors in Accra in 2019 has adopted wireless connections in the OSC-device layer. However, the 5G application are still negative according to its small area of communication and the recent experiments in field[9].

5.4.2 Consideration for the Target 5 Cities for ITS Development

Here, ITS technical application and approaches are summarized for the target 5 cities, based on its present status[10].

(1) Dodoma, Mombasa and Kumasi



Source: JICA Study Team

Figure 5.4.4 A Model for the ITS/Traffic Management System Development for Dodoma, Mombasa and Kumasi Case

In the case of Mombasa, there are currently only a few individual signals. CCTV cameras are in place. For Dodoma, there is one individual signal, so its situation is similar to Mombasa. In Kumasi, there are several individual signals, its situation is also similar to Mombasa.

Regarding the installation of the ITS system, TCC functions and TCC-OSC connection should be delivered. Technical possibility of utilization of 4G/wireless communication should be considered for communication layers, and possibility of application of prove vehicle database to reduce the necessary number of roadside sensors should be considered. For Mombasa, the possibility of utilization of CCTV camera video information will be checked as traffic flow sensor in the system.

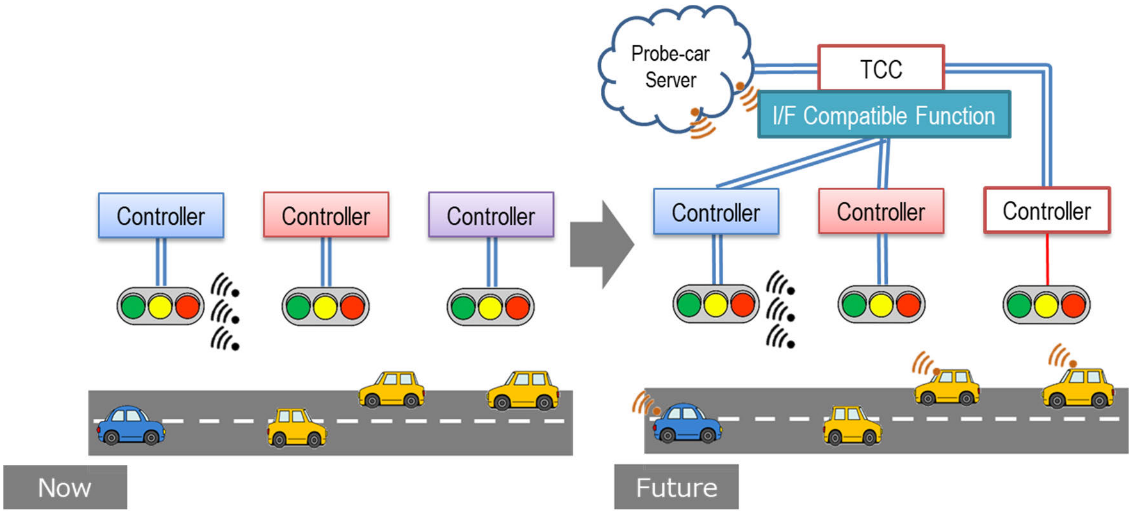
Regarding Mombasa, the necessity of geometric improvement for the existing roundabouts will make the initial cost higher.

9 Regarding the OSC - Device connection Layer, there is a possibility of replacement by 5G, but it is said that the 5G base station Although cost is high, 4G (Private) or Wi-Fi connections are applicable in reality. As aforementioned, the Prime Minister's Office and Ministries in Japan prefers the applicability of 5G to signal control in Japan, however, it is negative as the small coverage of communication of 5G is approximately 100-300 meter radius, which is not enough for inter-junction communication. It is reported the technical congestion and conflicts in the 5G communication (5.9GHz band) with the existing ETC (5.8GHz) and WiFi (5GHz) in the experiment in this year in Japan.

10 Based on this discussion, the chapter 10.1 discusses on the ITS approach by type of cities and development stage.

Considering the further expansion in future, it is necessary to introduce a mechanism to realize I/F compatibility with various on-site controllers at the time of the initial TCC development. (see next section for I/F)

(2) Dar es Salaam



Source: JICA Study Team

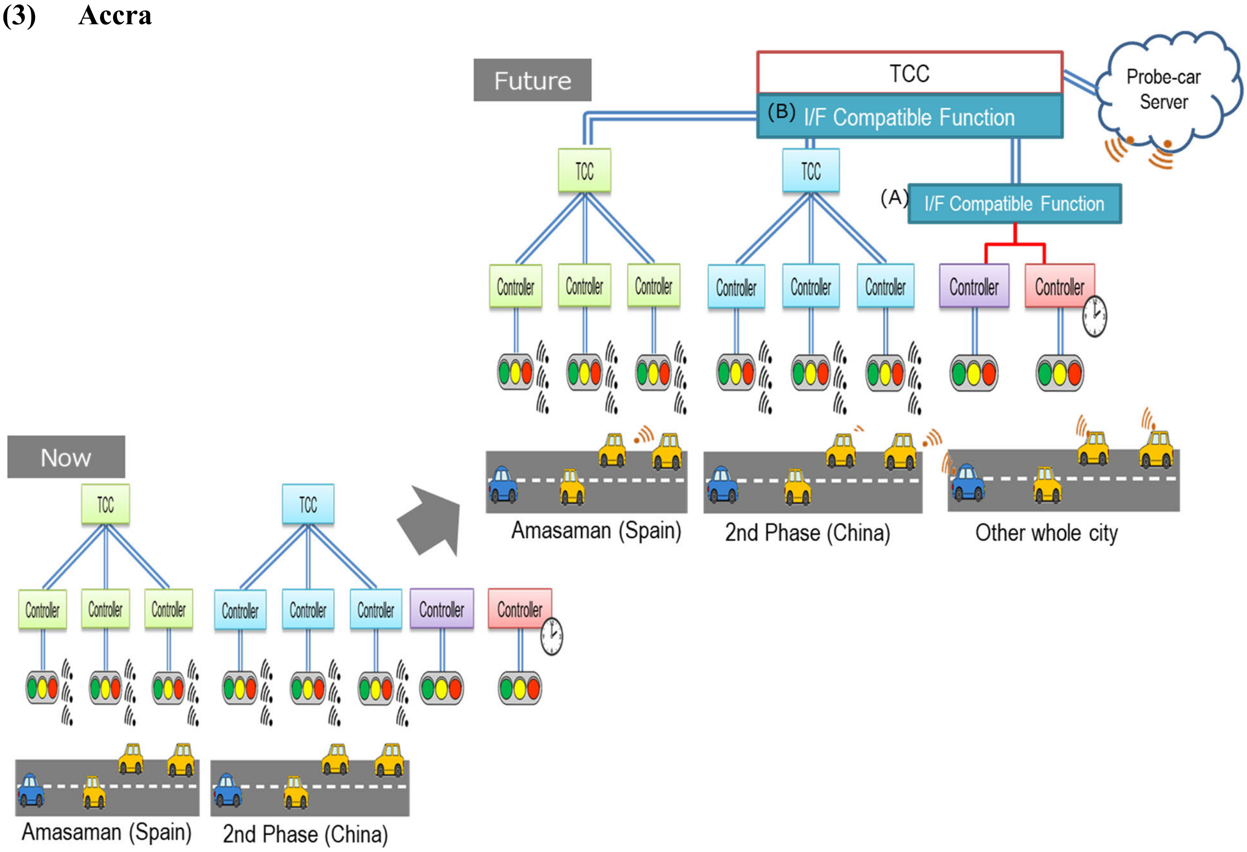
Figure 5.4.5 A Model for the ITS/Traffic Management System Development for DSM Case

In the case of the Dal es Salaam, there are multiple signals contractors who have developed individual signals, which are from different manufacturers. It is quite a different situation from the Japanese market, with non-uniformity of manufacturers and standards in the system. According to the present situation, the TCC has not been developed.

For further development, TCC should be developed with the proper I/F function to secure communication in multiple protocols of various controllers. Replacement of the existing controller can be considered as an alternative, however, it may increase the initial cost. The I/F function development in TCC can be realized as software development.

The application of probe vehicle data also should be considered to improve the operation.

(3) Accra



Source: JICA Study Team

Figure 5.4.6 A Model for the ITS/Traffic Management System Development for Accra Case

In the case of Accra, the 1st phase ITS system for the Amasaman corridor has already been installed. It seems that China may support the introduction of the 2nd phase. The manufacturers of the existing independent type signals are unknown. The system development in the future can be depicted as Figure 5.4.6.

In order to realize integrated TCC control for whole city network, it is necessary to develop I/F compatibility functions, shown as (A), for existing signal control and develop higher-level I/F compatibility functions, shown as (B), for integration with other TCCs. Accra DUR itself seems to have no resistance to the release of the controller and TCC I/F for the function (B)

It should be noted whether introducing the I/F function (B), which means the overall city control or "gilding the lily", is essential for traffic control. Perhaps, multiple optimization in corridor-based may be simple in the Accra situation.

5.4.3 Other Suggestions on Procurement and Ownership

As aforementioned, in Japan, the TCC functions, cables are not owned by the Police, but it is procured by a leasing contract for a specific period. Generally, a lease contract is applied for procurement of ICT devices and equipment, which has shorter deterioration period. For public sector, the fixed and leveling lease expenditure has advantage in its budgeting.

The latest signal control function is provided as Software as a Service (SaaS), a kind of API[11]-based data transaction on internet, which offers fixed price per fixed period per intersection. For example, an Israeli-based TCC function provider offers such function in New York since 2019. Additionally, the prove-car server and traffic data analysis can be provided by SaaS, therefore, expected TCC functions can be organized with SaaS, with a fixed price, with less infrastructure than today. Based on above, the TCC function and some part of prove-car data functions can be procured without initial investment in future.

For the targeted countries, most of existing procurement have not been applied any lease contract, however, government-owned servers can be utilized for installation of the TCC function. The function of the signal coordination control is a software which can be installed to those government-owned servers. This may influence to initial costs and O&M cost.

5.5 Other ITS Technologies

This section explains ITS technologies, but not directly used for traffic control, but applicable for public transport operation improvement, over-loading and road asset management.

5.5.1 Standardization of Public Transportation Information with GTFS

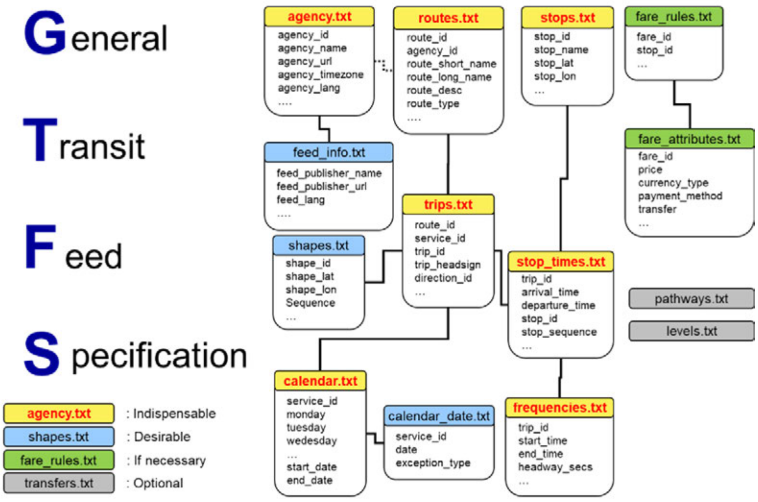
(1) General Explanation of GTFS

Regarding transfer information for buses and trains, Japan has an overwhelmingly advanced transfer information service provided by the private sector, due in part to the fact that the timetables are more accurate than those of other countries. However, although the timetable data was provided by each public transport operator, the format of the data was different for each company, and the results of the timetable changes were not digitized, so the frequency of updating the data was slow. In addition, with the increasing popularity of inbound tourism, which has brought many foreign tourists to Japan, it was not possible for small and medium-sized local public transport operators to introduce a system to digitize timetable data.

Under such circumstances, Google established the General Transit Feed Specification (GTFS) as a standard format to provide transfer information for all types of public transportation on Google Maps, and as long as the data is provided in a GTFS-compliant format, it can be distributed worldwide on Google Maps. This will allow visitors from overseas to use the transfer information service by using their smartphones.

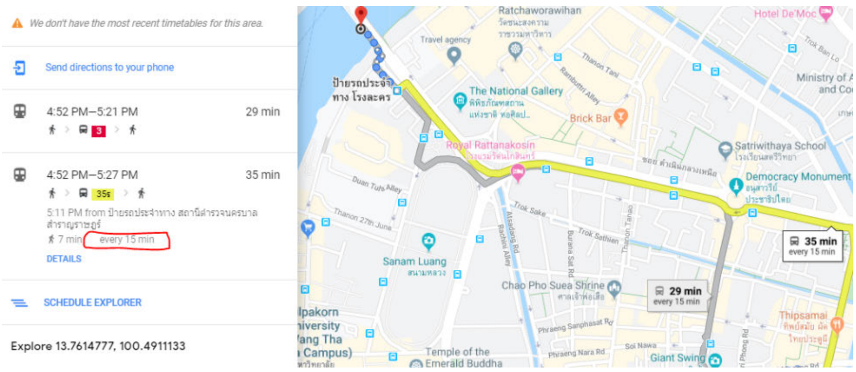
In Japan, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has adopted GTFS as a standard format for bus information, and GTFS-JP, which is based on GTFS and takes into account the unique circumstances of Japan, has been separately established and is being adopted by bus operators throughout Japan.

[11] Application Programming Interface



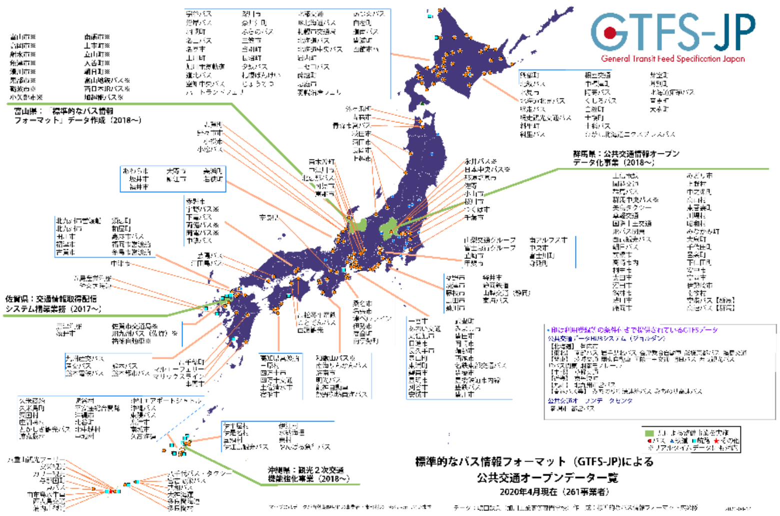
Source: JICA Study Team

Figure 5.5.1 GTFS File Structure



Source: Google Map https://www.google.co.jp/maps/

Figure 5.5.2 An Example of Public Transportation Transfer Guidance Using GTFS



Source: Standard bus information format https://www.gtfs.jp/

Figure 5.5.3 Bus Companies That Adopt the Standard Bus Information Format in Japan

(2) GTFS Application possibility

For Dar es Salaam and Accra, there is the possibility of GTFS installation. For DSM, the BRT operator's management system can extract the GTFS information and is ready to publish and share with third parties. For Accra, the static GTFS data for Trotro routes had already collected in 2015, but not yet updated. The GTFS standard requires every two years updates for static route information and Accra (AMA) does not have the budget for an update.

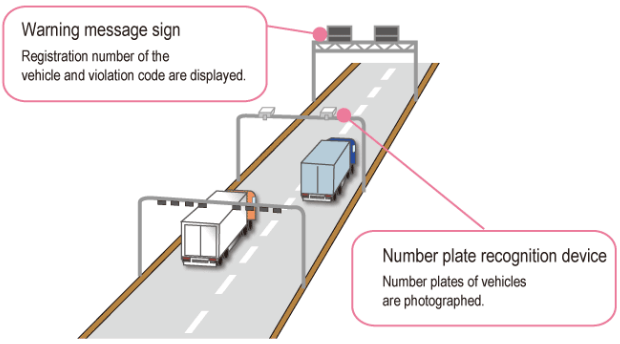
5.5.2 Management

(1) On-Board Weighing Possibility

The problem of overloading of truck vehicles has become a major problem in Japan too, where overloaded vehicles cause significant damage to road infrastructure and the cost of repair is enormous. Each road administrator cooperates with local traffic administrators to enforce overloaded vehicles, but comprehensive control is difficult, and many overloaded vehicles are still driving on the roads.

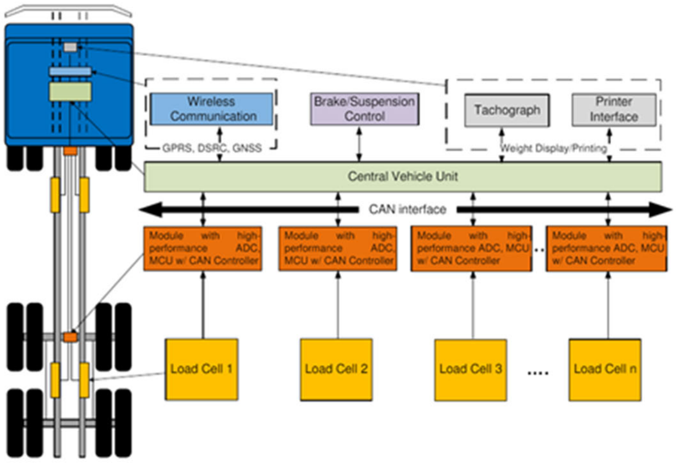
Weigh-In-Motion (WIM) systems that automatically determine the overload status of trucking are being implemented, but as of April 2020, there are only about 36 WIM systems in Japan, so comprehensive monitoring and enforcement has not been achieved.

In this circumstance, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is considering monitoring the payloads by making it mandatory to install On-Board Weighing (OBW), which has been partially introduced in Europe, and is considering comprehensive monitoring and enforcement of overloaded vehicles by making it mandatory to install OBW.



Source: Ministry of Land, Infrastructure, Transport and Tourism
https://www.mlit.go.jp/road/road_e/p7_vehicle.html

Figure 5.5.4 Weigh-In-Motion (WIM) in Japan



Source: Texas Instruments
https://www.researchgate.net/publication/338802530_Designing_High-Performance_On-Board_Weighing_OBW_Systems_in_Commercial_Vehicles

Figure 5.5.5 An Example of On-Board Weighing (OBW)

(2) OBW Application possibility

This study's main interest is urban transport, and overloading is usually issue for intercity and interregional transport, particularly in African countries with major port and economic corridors connecting to landlocked countries, which always face overloading control issues, as the overloaded vehicles to/from inland countries always destroy the pavement structure. The regional economic communities, EAC, SADC, ECOWAS, etc., put continuous efforts for regional harmonization of the loading control.

OBW is a destructive approach in overloading control, which may minimize the expensive static weighbridge development, and simplify the measurement anywhere.

5.5.3 LPWA for Road Asset Management

In recent years, there has been a lot of progress in the development of IoT technology that allows everything to be connected to the Internet. In order to connect to the Internet, an information and communication infrastructure is necessary, but the cost of Mobile Data Communication is generally high, so the cost of maintaining communication devices for each item and communication costs are an issue when so many things need to be connected.

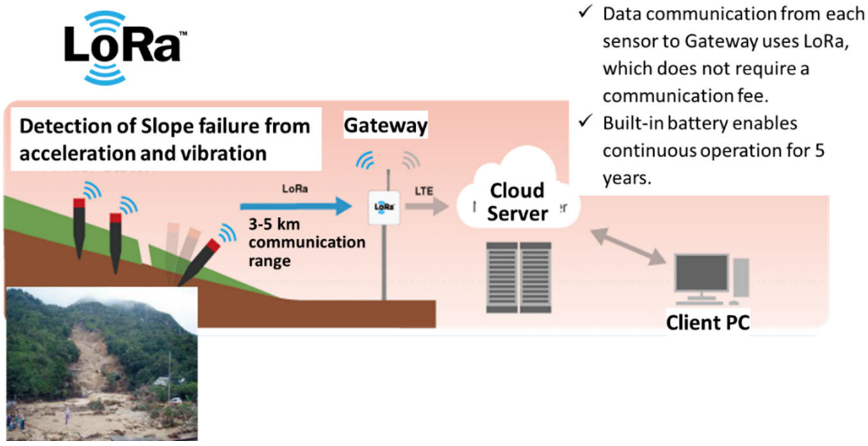
In the case were the amount of data and the frequency of communication are very small, a communication technology called Low-Power Wide-Area Network (LPWA) has been put to practical use as an information and communication technology that can be transmitted over long distances, consumes less power, and can be used inexpensively. As an example, LoRa and ELTRES are described below.

(1) LoRa

LoRa is one of the LPWA technologies developed by Semtech in the U.S. and is a communication technology that enables long-distance transmission with low power consumption. The transmission range is generally 3 to 5 km, but it uses sub-gigahertz radio frequency bands that do not require a license for frequency use.

In one example, this technology has been used to install a number of acceleration sensors and LoRa transmitters on slopes where there is a risk of landslides, etc. When the acceleration sensors detect the slightest movement, the information is transmitted via the LoRa transmitters to a gateway connected to a 4G-LTE network several kilometers away, giving early warning of a landslide.

If a large number of sensors are equipped with 4G-LTE, maintenance and communication costs will be high. However, by using LoRa, the cost can be reduced because 4G-LTE is used only by the Gateway. Also, since the power consumption is very low, there is no need to replace the battery for several years, depending on the frequency of communication.



Source: Prepared by the JICA Study Team based on ABIT materials (https://www.abit.co.jp/)

Figure 5.5.6 Image of Slope Monitoring Using LoRa

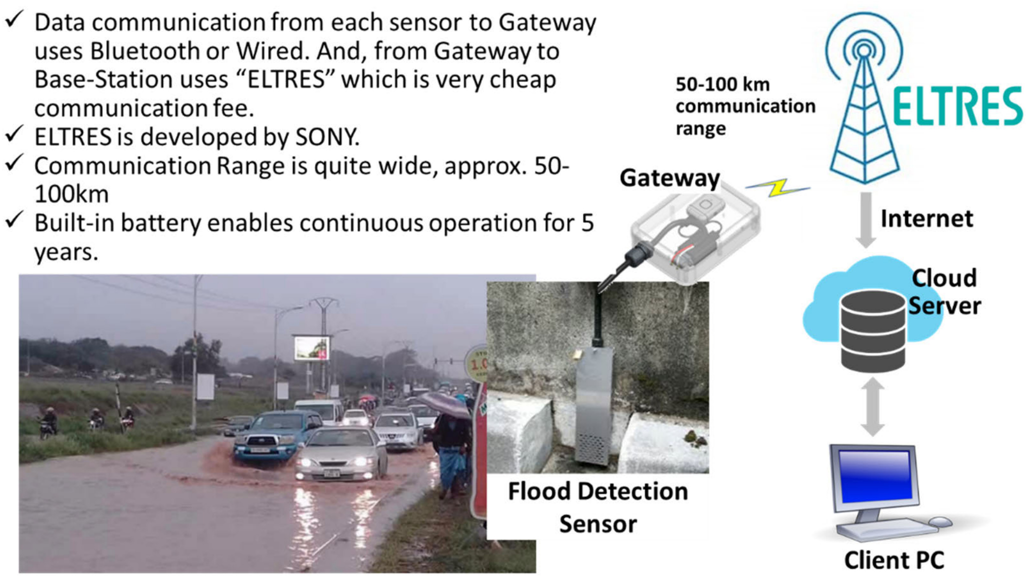
(2) ELTRES

ELTRES is one of the LPWA technologies developed by Sony in Japan, which enables long-distance transmission with low power consumption. The transmission range is generally 50 to 100 km, but it uses sub-gigahertz radio frequency bands that do not require a license for frequency use.

What makes this technology different from other LPWA technologies is that it has a very wide transmission range, so a single base station in one city can cover almost the entire area.

Also, since the power consumption is very low, there is no need to replace the battery for several years, depending on the frequency of communication.

By using this technology built into the ELTRES communicator, for example, a single base station can be set up in a city, and sensors and ELTERS communicators can be installed at various flooded areas within the city. If flooding occurs, the system will be able to quickly determine the status of the flooding and provide early guidance to road users on detours.



Source: Prepared by the JICA Study Team based on SONY materials
(https://www.sony-semicon.co.jp/products_en/eltres/index.html)

Figure 5.5.7 Image of Flood Monitoring Using ELTRES

(3) LPWA Application possibility

For DSM, TARURA's network in DSM always faces flood control and the World Bank supports TARURA through the Metropolitan Urban Transport Project for drainage management improvement. As shown above, the ELTRES flood monitoring approach is useful for DSM environment. For road asset management, all city road agencies needs to monitor the slopes along the hilly roads, and the applicatini of LoRa will be useful for those road agencies.

5.5.4 IRI Monitoring by Smartphone Application

(1) Ordinary Monitoring Technologies

It is essential for the efficient use of the limited road maintenance budget to assess the extent of damage to roads and plan for road repairs according to the extent of such damage.

Before the use of ICT, visual observations and profilometer measurements (Figure 5.5.8) were used to assess the damage of roads.

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

Figure 5.5.8 Measurement by Using Profile Meter

Currently, various other methods are being used, such as the use of a dedicated vehicle for high-precision measurements using laser, etc., or the use of the same technology to mount measurement equipment on an existing vehicle afterwards.

Source: TONOX http://tonox.jp/ (LEFT) / TOA Road Corporation https://www.toadoro.co.jp/en/ (RIGHT)

Figure 5.5.9 Road Surface Texture Measurement Vehicle

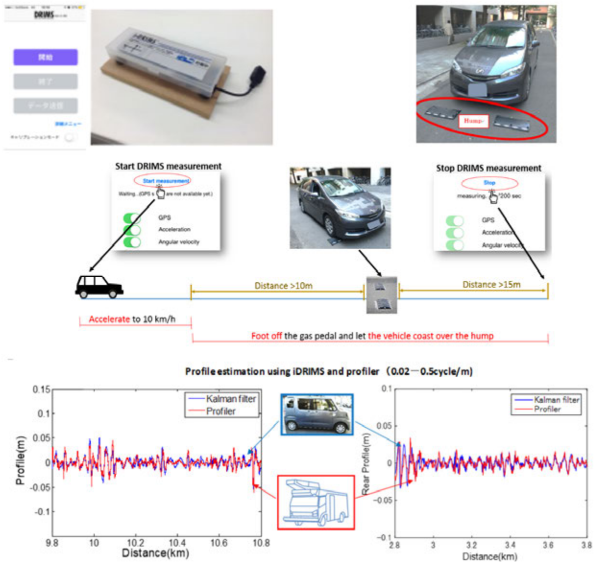
However, although these road surface condition devices have become cheaper than before, they cost about $300,000 to $500,000 per unit, and it is not easy to provide a sufficient number of them to measure all roads. In addition, it often takes several weeks to deliver the measurement results.

In order to plan the maintenance of roads, it is necessary to measure the road damage continuously and periodically, but for comprehensive measurement, a cheaper and simpler method of measuring road surface condition is needed.

(2) New trends: Smartphone based measurements

In this situation, with the recent development of ICT, a system to measure the IRI (International Roughness Index) simply by measuring the unevenness of the road surface from GNSS position information and acceleration sensor information that can be collected by a smartphone has appeared.

For example, in the iDRIMS (Dynamic Response Intelligent Monitoring System), a smartphone (compatible with iPhone only) is installed on the dashboard of a car, etc., and by driving on a small hump, calibration is performed based on the results of driving on the hump, and thereafter, IRI can be measured by collecting data with the smartphone while driving on the road.



Source: JP Techno – DRIMS https://www.drims.online/

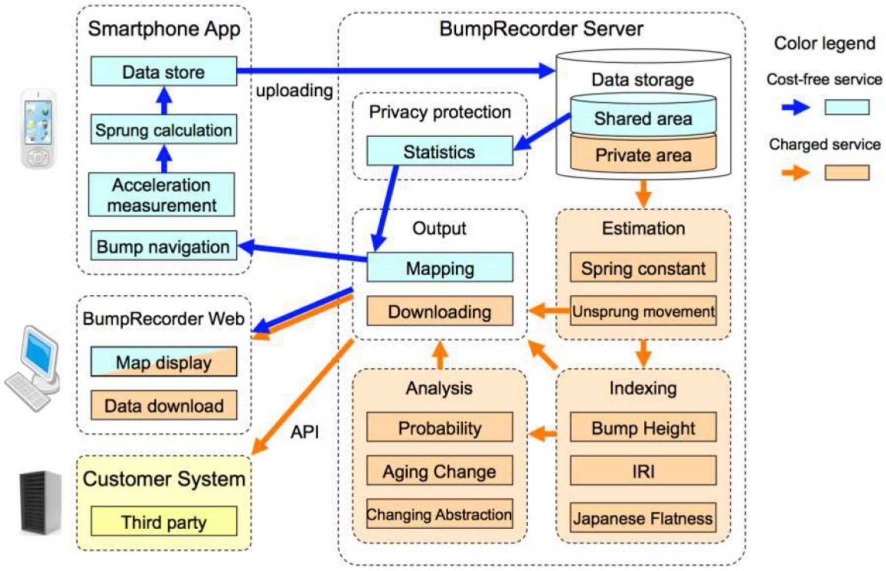
Figure 5.5.10 IRI Mesurement by DRIMS

Bump Recorder, like iDRIMS, installs a smartphone (compatible with Android OS smartphones) on the dashboard of the car, etc., but calibration is done automatically during the measurement and no special procedures are required. Therefore, it is easy to change or add vehicles. The data collected by the dedicated application is sent to a dedicated server to automatically provide measurement results such as IRI, step height, and the ride comfort (LT value developed by Railway Research Institute-Japan, a coefficient-adjusted version of ISO 2631-4) on the Web. The measurement results are available about 10 minutes after they are sent to the server, which is highly convenient and quick.

For Ghana and Kenya, the iDRIMS based TA for road maintenance improvement are working. For Tanzania, TANROADS and TARURA has shown strong interest on installation of the smartphone based measurement. TARURA owns the DROMAS pavement condition database (see chapter 4) which can accomodate the data collected by the smartphones.

Source: Bump Recorder http://www.bumprecorder.com/en/english

Figure 5.5.11 3 Types of Installation Images of Smartphones



Source: Bump Recorder http://www.bumprecorder.com/en/english

Figure 5.5.12 System Architecture of Bump Recorder

(3) Issues and Further Application

The ordinary measurement system is owned and operated by the road agency only. According to TARURA, Tanzania, its measurement is done at maximum once per year due to the limit of budget of the road agency and limit of equipment, and they are difficult to implement the measurement for its whole network.

The advantages of the smartphone-based measurement are its flexibility and frequency. It can organize a measurement system with assistance of various road users. The road agency can distribute a smartphone with measurement application and ask those road users to measure during their regular delivery frequently, instead of the road agency. The frequent measurement can measure trends of pavement deterioration, which can be used for proper forecasts of deterioration progress. It may cover the disadvantage of the smartphone-based measurement, less accuracy in measurement.

The more the road network developed, the more monitoring activities are required. Road users like milk collectors, retail distributors, etc, wth regular collection routes in broad region are suitable for the application of smartphone-based measurement, and potential to alternate the road agencies measurement.

For the on-going iDRIMS project in Ghana, it just provide the service only for the road agency, and there is no idea to involve road users for measurement so far.

In Kenya, the study team inquired individually KeNHA and Bollore (the largest private freight forwarder) about the idea for such measurement with various road users. Basically the both agreed to the idea, but both showed their doubt on willingnes of cooperation of the other party. It can be guessed there are little application in the target region for road users and road agencies to cooperate on road management together, therefore, it is important to cultivate the cooperative attitude among those parties for road management if we would develop the technical cooperation with this idea.

CHAPTER 6 DEVELOPMENT NEEDS AND PROJECT FORMULATION FOR MOMBASA

6.1 Summary of Project Proposals

In Mombasa, JICA Study Team (JST) recommends introducing coordinated signal control to the corridor in line with traffic demand with the aim of alleviating traffic congestion during peak hours and ensuring smooth traffic flow in response to future traffic demand. There will be two bridge construction projects in the near future. Those are Mombasa Gate Bridge and second Nyali Bridge respectively. By those bridge construction projects, the traffic concentration to the Mombasa Island will be estimated to worsen. Therefore the mentioned signal control project will be essentially required. The recommended project also includes improving the intersection from the existing roundabout, which is a current bottleneck of traffic flow. JST recommends the following projects for short-, medium-, and long-term implementation.

(1) Short Term Project (Approx. within 3 years)

Table 6.1.1 Proposed Short Term Project

Name of the Project	Outline of the Scope of Work	Executing Agency
The Project for Improvement of Traffic Management in Mombasa	• Introduction of Coordinated Signal control system for four (4) or six (6) Major corridor including necessary traffic sensors. • Establishment of Traffic Management/Control Center • Communication system between roadside controller and the center equipment. • Necessary intersection geometrical improvement for traffic signal improvement	County Government of Mombasa (CGM) Department of Transport, Infrastructure & Public Works

Source: JICA Study Team

(2) Middle to Long Term Project (more than 3 years to 10 years)

JST also recommends implementing the technical cooperation project for ensuring operation and maintenance of coordinated traffic signal control, collected data utilization for further improvement, and enhancement of capacity of future expansion of the traffic control area by CGM itself.

Table 6.1.2 Proposed Middle to Long Term Project

Name of the Project	Outline of the Scope of Work	Executing Agency
Technical Cooperation Project for Traffic Management/Control in Mombasa	• Utilization of probe data collected from the probe car • Cooperation on operation and maintenance of traffic signal control • Support for CGM to expand the traffic signal control area	CGM Department of Transport, Infrastructure & Public Works

Source: JICA Study Team

The details of each are described in the following sections.

6.2 Project Implementation Scheme

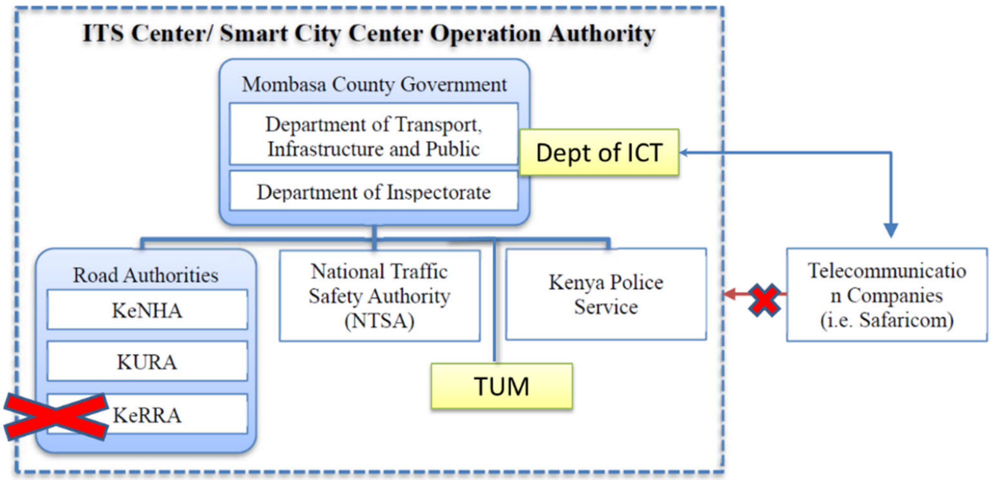
On formulating the ITS and traffic signal development project in Mombasa, the following technical and institutional issues should be specified with several options.

- Implementing Organization Setting
- Signal Coordination Technical Standard
- System Communication Method
- Data Center Function
- Control Center/System Operator Power supply concerns
- Phased Programs
- Project Implementation Road Map
- Civil work components
- 2-phased operation
- TA for Traffic Management

(1) Implementing Organization

The CGM shall lead implementation, organize the Committee for Traffic Management and Safety, which shall be act as PIU in the project implementation phase, as all stakeholders in Mombasa for traffic and transport appreciate the proactive leadership of the CGM. The committee has been already organized by the CGM and acted for policy coordination. It should be noted that NTSA has a will to share the PIU secretariat function with CGM. The PIU organization structure can be depicted as Figure 6.2.1, and the tasks of each organization are summarized as follows;

- **CGM DTIPW: C/P for overall management and implementation setting,** including traffic management and engineering aspect
- **CGM Dept. of Inspectorate: C/P for O&M arrangement,** actual operation
- CGM Dept. of ICT: O&M for ICT infrastructure and DATA
- KURA/KeNHA: Technical support
- NTSA: regulation support
- Police: traffic enforcement by law
- TUM: data analysis, HR contribution



Source: JICA Study Team (revised from the Preliminary Study Proposal)

Figure 6.2.1 PIU Setting

(2) Signal Coordination Technical Standard

It is necessary to decide which technical standard of the signal control technology will be adopted for the Mombasa ITS project. Though Nairobi is going to adopt SCOOT (British) in pilot stage and KURA suggests the importance of interoperability in Kenya, the traffic management is under responsibility of each county government; therefore, CGM's decisions should be respected.

JICA team recommends adopting MODERATO for the following reasons:

- High utility in various traffic situation in Mombasa
  - In light traffic, it forms a safe traffic flow by not only reducing delays and stops, but also controlling speed.
  - When close to saturation, increase the green-signal time efficiency of the major junctions to maximize the processing of traffic volumes and thus reduce the occurrence of traffic congestion.
  - In super saturation, it directly determines the split and cycle length by taking into consideration of the traffic congestion length calculated from the detector information.
    - In addition, from the viewpoint of traffic management at major junctions, priority control is performed on conflicting traffic flow.
    - For SCOOT/SCAT, in the over-saturated condition, waiting time tends to be too long as the system selects the maximum cycle length (see Table 5.1.1 in the section 5.1.1(2) also).
- The green-split-optimization in the cycle
  - To minimize the occurrence traffic congestion, appropriate green-signal time allocation is extended in coordination basis

There is a potential to rationalize number of road-side sensors along the corridor by adopting prove cars and CCTV for traffic flow data collection, as mentioned in Chapter 5. However, the idea is quite new, and this study would not apply the idea for the project formulation.

(3) Communication System

As for the communication network sections between roadside signal controllers and traffic lights, and between roadside controllers and vehicle detection sensors, the high quality communication network is required within the acceptable delay of the data in order to avoid the Green – Green displaying condition different directions. Thus it is common to apply the wired communication network for those sections.

However, there seems to be several options of communication systems, with institutional options for the network section between roadside controllers and the traffic control center. Due to the optical fiber cable cutting incident which is used by the County Government of Mombasa, and delay in recovery, the study team compared major options between roadside controllers at each signalized intersection and the traffic control center shown below:

JST considered those options that it would be difficult to utilize the existing cables, considering the fact that the existing optical fibers have not been restored for four months after the mentioned cable cut incident.

Table 6.2.1 Options of Communication Systems between Roadside Controller and Traffic Control Center

Communication System	Pros	Cons
Optical Fiber Cable (OFC) owned by CGM	It will be CGM's own facility. Thus there will be no running cost to the communication service operator. OFC is widely used for signal control, thus there will be no concern of interface with the equipment components.	Installation cost is relatively expensive. The cable cut incident may happened due to road construction work. Thus the immediate cable repair work will be required Required data traffic volume is very small compared to the OFC's transmittable capacity
Wireless Communication (4G) provided by communication service provider	Installation costs are very low. There will be no concern of communication failure due to cable cut during the road construction work in Mombasa county area.	Running cost is required to pay to the data communication service provider There is no Japanese manufacturer to deliver the traffic signaling system with wireless communication between traffic control center and roadside controller (No actual deployment). Since delay of data communication is critical, dedicated service will be required (The cost will be high).

Source: JICA Study Team

As for the institutional task demarcation among the related parties of traffic signal control, the prospective conditions are shown in the following table.

Table 6.2.2 Prospective Institutional Task Demarcation (Tentative Draft)

Communication System	Owner of the communication facility/equipment	Operator/ User	Maintenance Responsibility
Optical Fiber Cable (OFC) owned by CGM	CGM (Department of Transport, Infrastructure & Public Works: DTIPW)	Traffic Inspectorate	OFC network: Outsourcing from ICT Office of CGM
Wireless Communication (4G) provided by communication service provider	Data communication service provider (Terminal Equipment will be CGM or leased by the operator)	Traffic Inspectorate	Data communication service provider

Source: JICA Study Team

Table 6.2.3 Technical Issues by Implementation Stage

Communication System	Major cost during operation	Technical preparedness	Necessary technical knowledge for the CGM personnel
Optical Fiber Cable (OFC) owned by CGM	• Maintenance cost • Repair cost for cable cut	• Network Monitoring System/ Network Management System • Testing machine, repair material, and its stock management	Operation and Maintenance on Wired Communication Network (relatively high)
Wireless Communication (4G) provided by communication service provider	Subscription cost for communication service provider	Technical personnel should manage the subscription contract condition between CGM and communication service provider	Contractual condition check on wireless data communication (not so high)

Source: JICA Study Team

There will be pros and cons for both communication systems to be applied between roadside controllers and the traffic control center. If the CGM hopes to obtain its own optical fiber cable network, the necessary budget for operation & maintenance, and immediate repair work should be secured and the required technical skill for the CGM personnel should be transferred from the contractor to be installed for such a network system. If CGM considers outsourcing a part of O&M operation or incident response, the necessary budget should be secured.

If the CGM selects the wireless communication service provided by the communication service provider, the CGM should secure the budget for subscription of the service and require managing the service level agreement between CGM and the service provider.

(4) Data Center Function

The county's data center will be applied for center control server, data storage, and backup. CGM ICT office will maintain for it. The server will not be in the traffic control room. Control monitors, workstations, operator's PCs will be delivered to the traffic control room.

(5) Control Center/System Operator

The study team shall recommend to develop the control center in the existing Inspectorate Office for the following reasons:

- Recommended as 24-hr operation can be secured already in the DTI office
- The DTI Control center can accommodate the additional LCD panels.

(6) Power supply concerns

The Gatecity M/P[1] clarified that the total capacity of the Kipevu power plants in Mombasa is 359 MW against the peak demand of Mombasa County which is 166 MW in 2015. The M/P pointed out a concern for limited redundancy and aging of the existing distribution cable in the island, however, the expected corridors for signaling are located along the major distribution line and such concerns can be controlled.

(7) Phased Programs

The implementation will follow the phased program as shown below. The program must show the priority by corridors and by intersections.

- Phase 1: Target junctions by 2023-2024
- Phase 2: before 2nd Nyali bridge and Gate bridge
- Phase 3: by 2030
- Phase 4: by 2035

(8) Project Implementation Road Map

The study team proposes a project implementation road map as follows.

- Preparatory Study (F/S & B/D): 2021-22
- Grant Agreement in 2022
- Procurement/Const. in 2023 –
- TA for transport management should be added

[1] Chapter 5, PP26-33

(9) Civil work components and classification

The traffic signal improvement requires proper geometric improvement and lane marking arrangement to secure the traffic signal effects[2]. The following proposals should be considered.

- Roundabouts at the target corridors shall be removed and geometric improvement for proper 4-legs intersection with lane marking and traffic islands should be applied.
  - The intersection size should be minimized to realize solid traffic flows and avoid unnecessary parking.
  - The surplus space will be used for pedestrian spaces
- Right turning lanes should be added for two-way flow in a phase.
  - Lane width should be adjusted between 3.0m-3.5m, not fixed to 3.5m, minimize the shoulder, and secure the right turn lanes.
- In the pedestrian oriented areas, optimize the cross-sectional profile to maximize the footpath capacity, instead, jaywalk-control facilities should be installed.

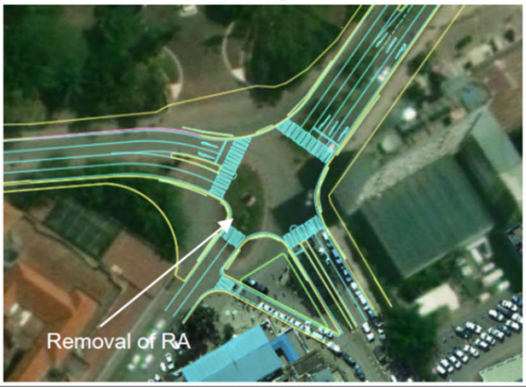
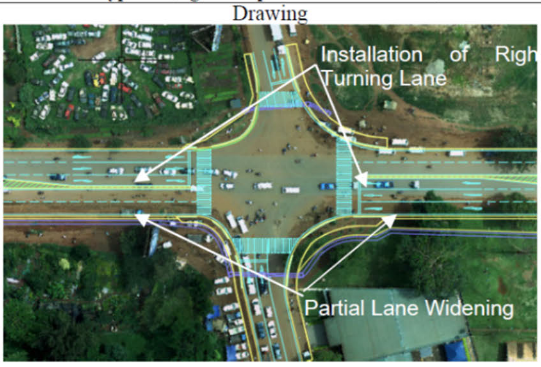
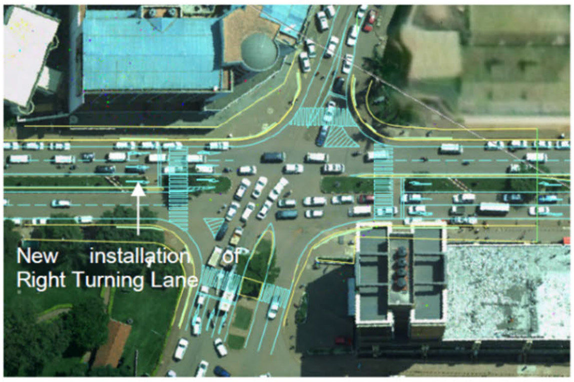
Referring to Kampala project, the necessary civil workload can be classified into 4 options, as shown in Table 6.2.4.

- Class A: Convert a roundabout into a Cross or T-junction.
- Class B: Utilize the existing median strip to make a right-turn lane. Widen a section of the current narrow roads. (add approx. 3-5m)
- Class C: Setup a right turn lane using the existing median strip
- Class D: Install a traffic signals without doing any road improvement (Overlaying the pavement and marking of the road are done)

[2] Basically, roundabout intersections has a limit of capacity. Round-shaped flows in the junction will decrease the traffic capacity of the junction. The round island should be removed, straight lane marking and traffic islands should be added to rectify the traffic flow.

Table 6.2.4 Classification of Intersection Civil Work Load

Table 2.8 Images of Types of Junction Improvement

<table>
<tr><th>Type A (e.g. No.15 Rwenzori Roundabout)</th><th>Type B (e.g.No.1 Spear Motors Junction)</th></tr>
<tr><td>Drawing

</td><td>Drawing

</td></tr>
<tr><td>Work Outline
<u>Removal of Existing Roundabouts.</u>
- Removal of plants, drainage, curs, clock towers and commercial billboards.
- Removal of the existing underground.
- Relocation of the existing underground structures and overhead lines (Covered by Uganda Government)
<u>New Construction Work</u>
- Pavement, drainage, and road markings.
- Installations of traffic signals and road lighting.</td><td>Work Outline
<u>New Construction</u>
- Construction and pavement of new right-turn lanes, road marking work.
- Installation of median strips.
- Overlay work of the existing paved section.
- Installation of traffic signals and road lighting.</td></tr>
<tr><th>Type C (e.g. No.5 Station Junction)</th><th>Type D (e.g. No.18 Kyaggwe Rd/Lumumba Ave Junction)</th></tr>
<tr><td>Drawing

</td><td>Drawing

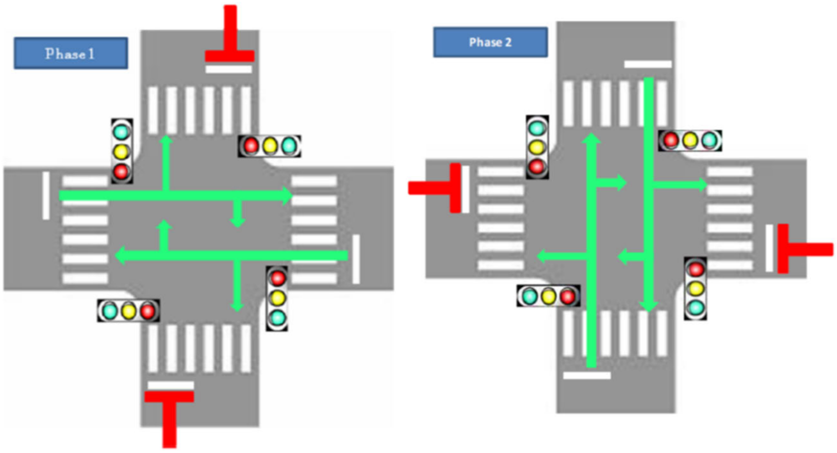
</td></tr>
<tr><td>Work Outline
<u>Removal of the existing median strips.</u>
- Removal of plants and curbs.
<u>New Construction</u>
- Construction and pavement of new right-turn lanes, road markings.
- Installation of median strips.
- Overlay work of the existing pavement section.
- Installation of traffic signals and road lighting</td><td>Work Outline
<u>New Construction</u>
- Installation of traffic signals and road lighting.</td></tr>
</table>

Source: Preparatory Survey for Project for Improvement of Traffic Control in Kampala City (2019)

(10) 2-phased signal operation

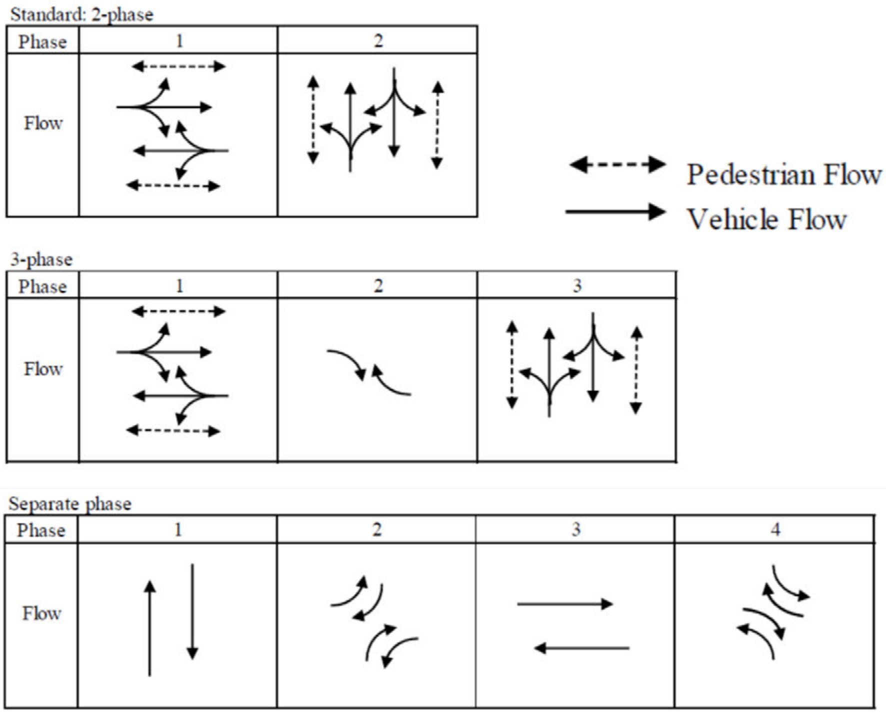
The traffic signal operation is expected to be designed as a 2-phased operation, enhancing the traffic flow efficiency. Figure 6.2.2 shows the acceptable options for the 2-phased operation.

Giving traffic phase to each entry flow will not be accepted because it will reduce the efficiency of the corridor based coordination. It is note that the recently signalized junction in Nairobi (Yaya Center junction) adopts such signal control.



Source: JICA Study Team

Figure 6.2.2 Concept of the 2-phased Operation



Source: JICA Study Team

Figure 6.2.3 Acceptable Options for the 2-phased Operation

(11) TA for Traffic Management

The JST proposes that a Technical Assistance Program (TA) for traffic management should be implemented in parallel to enhance the project effectiveness. The scope of the TA will cover the technology transfer for traffic management with the coordinated traffic signals and geometric improvement, moreover, it may include the following:

- Enforcement transport service efficiency improvement
  - Three Wheelers/Matatu enforcement seems same as before. Numerical limit regulation should be considered, particularly in town
  - Uber (human request) based -> AI based vehicle distribution (CCTV, density, daily travel pattern)
- Off-street bus sites should be developed otherwise we cannot build signals at Mwembe Tayari.
  - Pilot project for transferring the on-street bus parking to the KRC station, less used CFSs
- TUM capacity expansion program for data processing and analysis

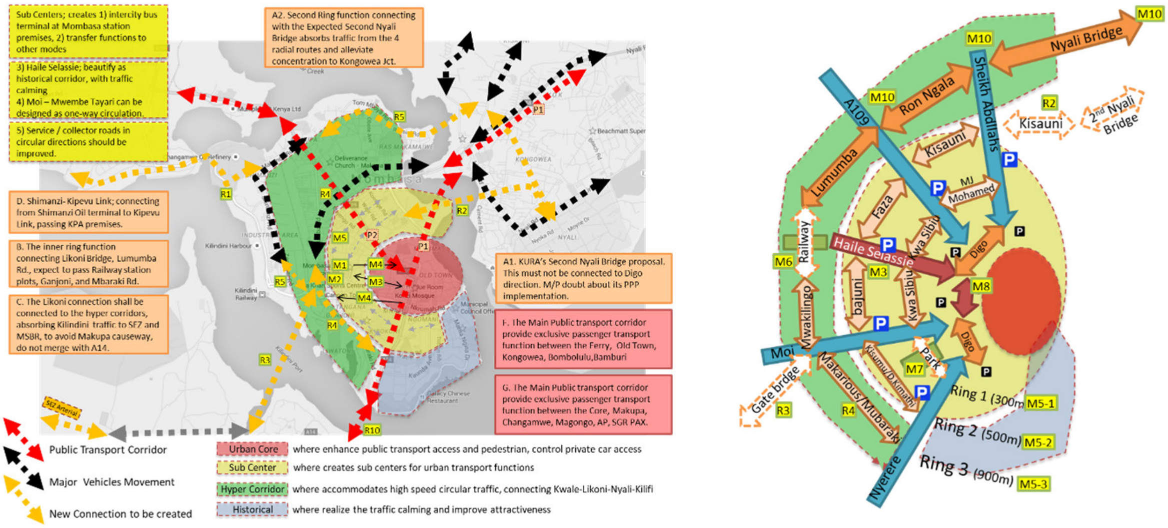
6.3 Selection of the Corridors and Intersections

6.3.1 Strategy on Selection of Intersections

The JST proposes the following policy for selection of the target intersections:

- Corridor-based or Area wide selection:
  - A group of intersections with 300 – 700m intervals should be selected to secure the coordinated signal outcome.
  - Not based on individual intersection improvement need.
  - Combination of corridors
- Respect superior planning and expected traffic generators
  - Proposals for Masterplan and Vision 2035
  - MGB and 2nd Nyali bridge: correspond to New traffic generators
- Respect area/route characteristics
  - Pedestrian oriented area: Additional infrastructures for pedestrian safety and jay-walk control should be considered (widening and adequate barriers)
  - BRT routes: consider PTPS
- Procrastination and advise for Chaos section
  - Make chaotic route/intersections where the ITS cannot work properly lower prioritization and advise "What to do"
- RA removals and Phase operation
  - Roundabouts should be removed, Two-phase operation with r-turn movement should be installed.

Figure 6.3.1 summarizes the superior planning and area characteristics of the island, which can be referred to the selection.



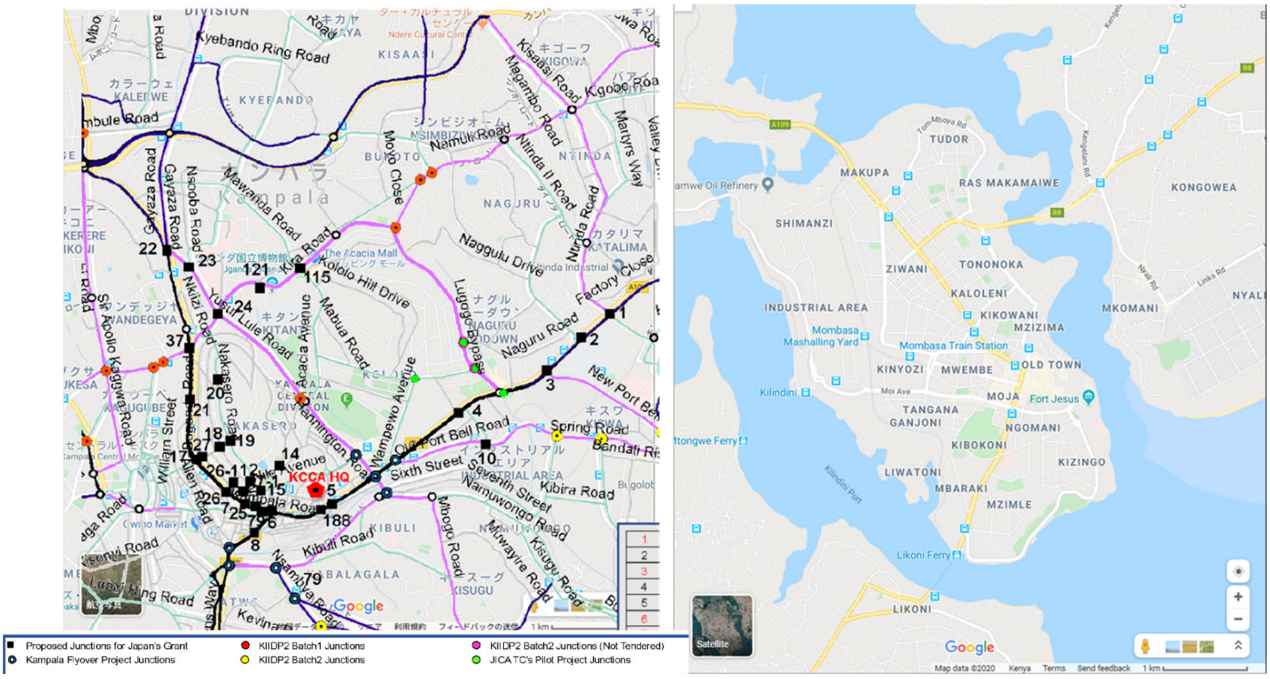
Source: JICA Comprehensive Masterplan

Figure 6.3.1 Area Characteristics and Future Road Network Development

(1) Reference Case in Other Cities -Kampala-

The Kampala traffic management project is going to install the coordination signals along the major corridor and peripheral intersections connected to the corridor. Figure 6.3.2 shows the selected locations of the coordinated signal installation, comparing the CBD of Mombasa in approximately the same scale.

The Kampala project map presents the intersections along the Northern Corridor (shown as ■ and black direct line), the historical urban axis, which are chosen for the coordinated signal installation. The intervals of the target intersections are 1.5km, between the junction 4 and 5, where flyovers will be developed. It is in a similar condition along the Nyali bridge section in Mombasa. Several intersections not located along the Northern corridor were chosen (junction 14, 18, 19, etc.), which can be referable for the collector parallel street signalization in Mombasa.



Source: JICA Comprehensive Masterplan

Figure 6.3.2 Area Characteristics and Future Road Network Development

6.3.2 Corridor Based Selection

This section summarizes the JST's selection results for the following corridors, including some corridors running along the following.

- Kengelani ~ Nyali ~ Buxton ~ 77 ~ Lumunba Route
- 2nd Nyali bridge – ring road directional routes
- A8（Barkley ~ Mwembe Tayari ~ 77 ~ Makupa ~）
- Nyerere ~ Digo, Moi（Nkuruma ~ Moi), Haile Selassie
- Nyali/Kisauni (Links Road/New Malindi Road)
- Chamgamwe / Likoni

(1) Kengelani ~ Nyali~Buxton ~ 77~Lumunba (Nyali Corridor)

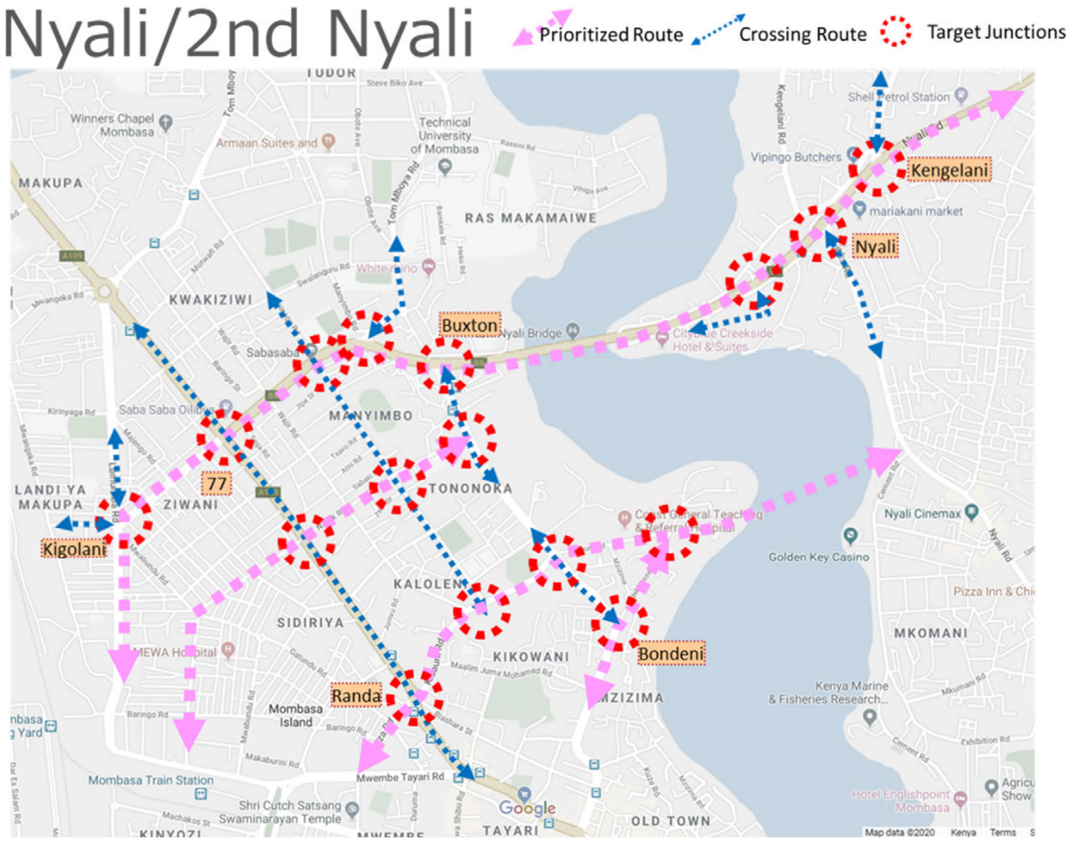
Table 6.3.1 shows the series of target intersections, interval length of the intersections, number of legs of the intersections, expected civil work needs (see Table 6.2.4 for classification A/B/C/D), lanes of the road and connected roads, and several notes for peripheral circumstances. Figure 6.3.3 shows the alignment of the corridor and location of the intersections. On implementation of this corridor, the Pros and Cons can be summarized as follows;

- Advantage
  - ➢ Little need for large scale civil work as most intersections are already square 3 or 4 legs junction. Only adjustment of lane width should be considered.
- Disadvantage:
  - ➢ Quite high traffic volume, mixture of undisciplined matatu traffic, high security concern for VIP may damage proper control of coordinated signals.
  - ➢ The 2nd Nyali bridge installation may alleviate the situation in the near future.

Table 6.3.1 Nyali Corridor

Location/interval	Legs	Civil W	Routes, # of Lanes	Notes
100m		(A7)		A7 widening work is expected
Kengelani	3	C	A7 – 6 x Old Malindi 1	
200m				Short link
Nyali	3	C	A7 – 6 x Links 3	Links: reversible lanes
300m				Matatu stages
Merging	3	C	A7 – 6 x Merge (Kengelani)	
800m				
Buxton	3	C	A7 – 6 x Sheikh Abdllahs 6	
200m				
Tomboya	3	C	A7 – 6 x Tomboya 2	
200m				
Koinage	4	B	A7 – 6 x Koinage 2	
300m				
77 (sava-sava)	4	C	A7 – 6 x A8 – 6	
300m				
Kigolani	4	C	A7~Lummba SB 6 x Lumumba NB 6 and Sharif Abdhul 2	

From north to south, east to west
A7: New Malindi Road, SB: Southbound NB: Northbound. see Table 6.2.4 for Civil Work classification
Source: JICA Study Team



Source: JICA Study Team

Figure 6.3.3 Corridor-Based Intersection Selection (Nyali – 2nd Nyali)

(2) 2nd Nyali Bridge – ring road directional routes (2nd Nyali Corridor)

Figure 6.3.3 shows the alignment of the corridor and location of the intersections. It is expected that the 2nd Nyali bridge may bring a lot of traffic directly to Digo road and the downtown area. Proper diversion should be prepared before the bridge installation. The following items should be considered;

- Tononoka internal ringroad connection should be designed to attract another diversion.
- The present Kisauni/Tononoka road applies Happy Hour operation.
- Difficulties:
  - Nyali 2nd bridge plans are not yet finalized, and it will be designed as PFI basis, therefore, the connection would be denied by the private concessionaires.

Additional to the Nyali and 2nd Nyali corridors, the following sub-corridors implementation can be proposed,

- Kisauni Road
  - Proper diversion for the 2nd Nyali bridge should be prepared before the bridge installation.
  - The present Kisauni road applies Happy Hour operation. (Evening/outbound)
- Narok Road
  - Tononoka internal circular connection should be designed to attract another diversion.
- Difficulties:
  - Nyali 2nd bridge plans are not yet finalized, and it will be designed as PFI basis, therefore, the connection would be denied by the private concessionaires.

(3) A8 Corridor（Barkley ~ Mwembe Tayari ~ 77 ~ Makupa）

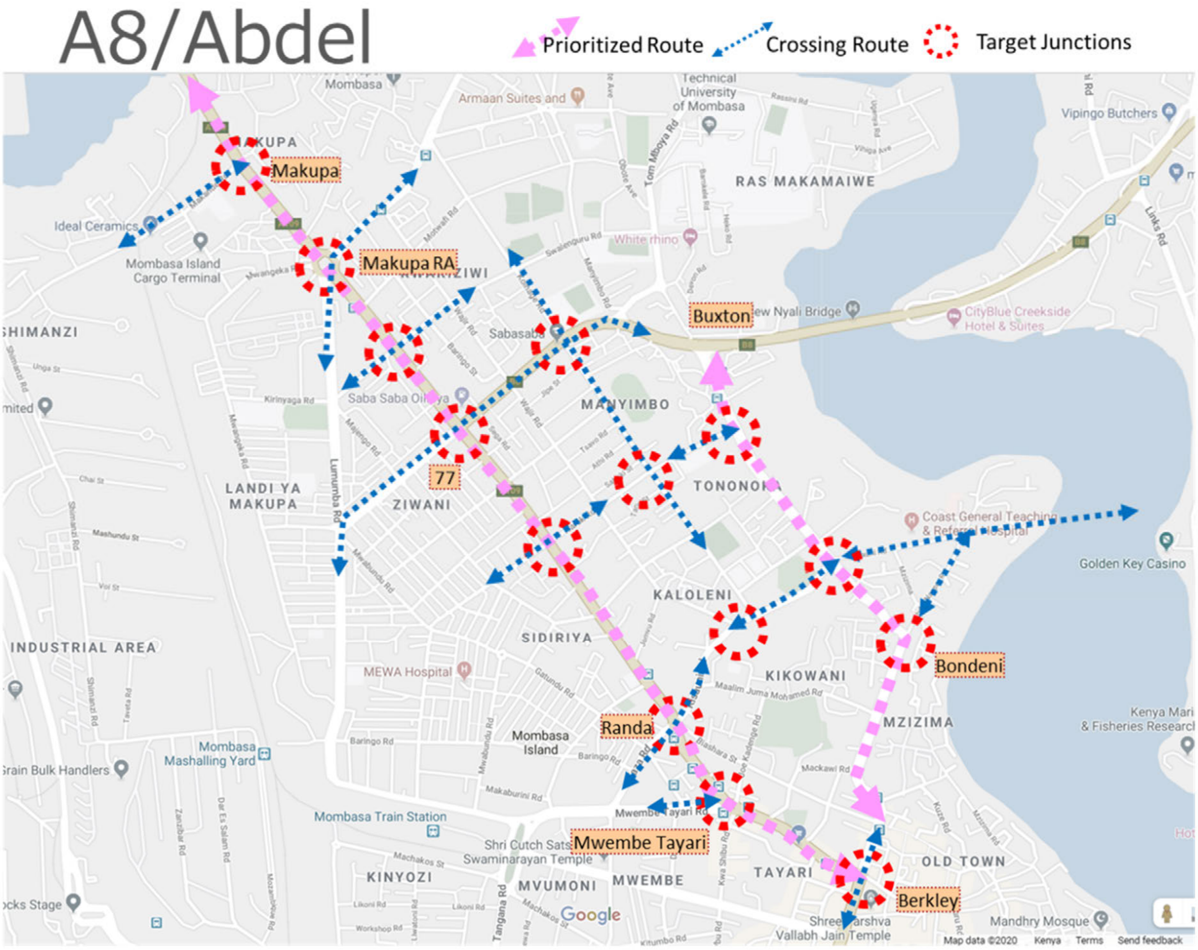
Table 6.3.2 shows the series of target intersections, and other data in the same manner. Figure 6.3.4 shows the alignment of the corridor and location of the intersections. On implementation of this corridor, the characteristics can be summarized as follows;

- Requires RA removals.
- Disadvantage:
  - A8 (Changamwe-77) is currently on a widening process, and 77-Barkley is pipelined for repaving, however, its work schedule is not yet fixed, so the signal installation timing cannot be fixed.
  - Mwembe Tayari and Lebanon intersections are full of long-haul bus services stopping on the street. Removing of RA are also needed for those two, as well as Berkley.
  - Makupa RA is quite big, and KeNHA’s work is on-going (no plan for removing the RA?)

Table 6.3.2 A8 Corridor

Location/interval	Legs	Civil W	Routes	Notes
Makupa	3	B	A8 6 – Makande 2	Heavy freight on Makande
300m				Short link
Makupa RA	5	A	A8 – Tomboya2 Lumumba4 Mwangeka2	Removal of RA, A8 widening work is on-going
500m				Matatu stages
77 (sava-sava)	4	C	A8 – 6 x A7 – 6	
300m				
Narok	4	B	A8 – 6 x Narok – 2	
400m				
Randa	4	A	A8 – 6 x Kisauni-Faza – 2	Long-haul bus stages
300m				Long-haul bus stages
Mwenbe Tayari	5	A	A7~Lummba SB 6 x Lumumba NB 6 and Sharif Abdhul 2	Long-haul bus stages
				SME wholesale parking
Berkley	3	A		

Source: JICA Study Team, see Table 6.2.4 for Civil Work classification



Source: JICA Study Team

Figure 6.3.4 Corridor-Based Intersection Selection (A8 and Sheik Abdullah)

Additional to the A8 corridors, the following sub-corridors implementation can be proposed,

- Sheik Abdulah
  - ➢ Proper lane width. Little civil work.
- Koinage Rd.
  - ➢ Divert the local traffic on A8 to Koinage.
  - ➢ Remove center divider on Ronald Ngara and realize crossing from Tononoka to Tudor along Koinage.

(4) Nyerere~Digo, Moi (Nkuruma~Moi), Haile Selassie

Figure 6.3.5 shows the alignment of the corridor and location of the intersections. On implementation of this corridor, the characteristics can be summarized as follows:

- Need to remove center dividers and historical RAs.
  - ➢ Alternative off-street parking development required
- Need pedestrian barriers for jaywalking and exclusive pedestrian crossing signals with traffic stop.
  - ➢ Particularly need at: Mackinnon Market, Nkuruma,Tayari
- Matatu/3W control

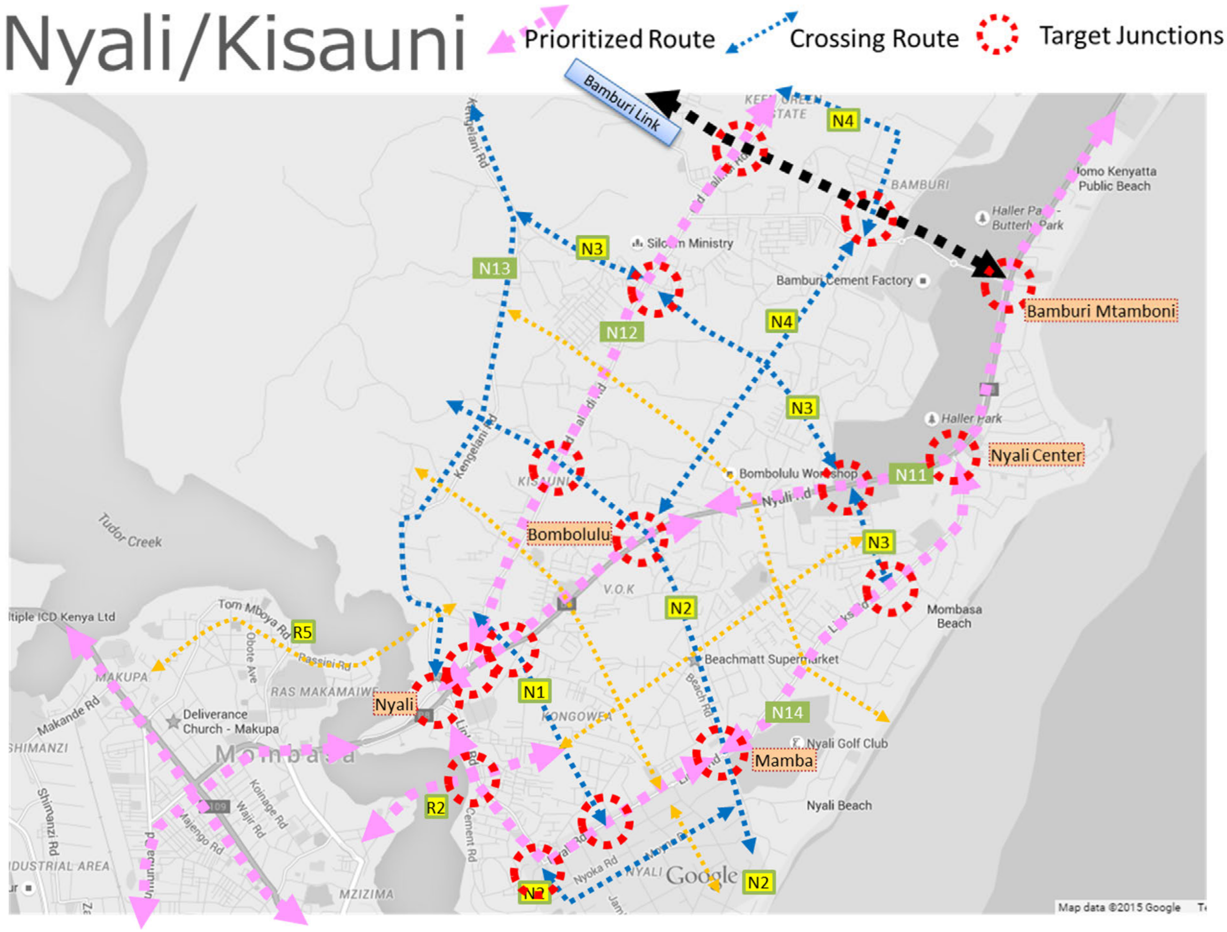
Source: JICA Study Team

Figure 6.3.5 Corridor-Based Intersection Selection (Central District)

(5) Nyali/Kisauni (Links Road/New Malindi)

Figure 6.3.6 shows the alignment of the corridor and location of the intersections. On implementation of this corridor, the characteristics can be summarized as follows;

- Priorities on
  - New Malindi Rd., Links Rd, and Old Malindi Rd.
  - Intervals between the intersections come longer than other corridors in the Island
- The 2nd Nyali access arrangement with signal installation is quite essential however its implementation and alignment are not clear at present
- Traffic control devises for the Links reversible lane (Happy Hour) arrangement should be considered as priority components
- Variable message signboard (VMS) components can be considered for traffic information provision before the entering Nyali bridge crossings.
- Some intersections in the suburb requires individual signal installation due to safety control, not coordination control.



Source: JICA Study Team

Figure 6.3.6 Corridor-Based Intersection Selection (Nyali/Kisauni)

Source: JICA Study Team

Figure 6.3.7 A Sample of Revesible Lane Control Equipments

(6) Changamwe / Likoni

For Changamwe, the traffic situation has improved due to the SGR shift and the several flyovers which will increase the capacity of intersections, therefore, the need for traffic signals is low.

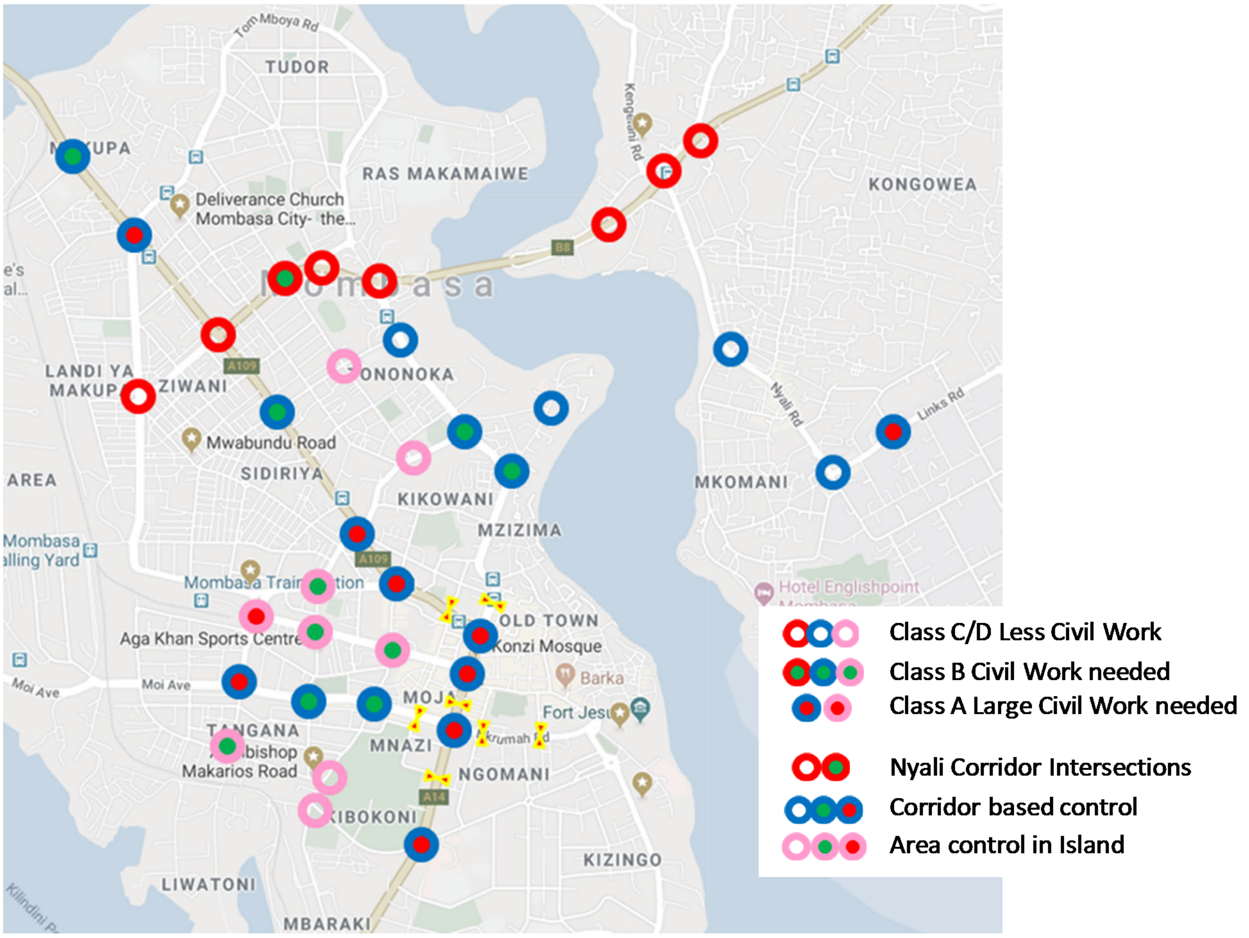
For Likoni, the traffic volume is still low in the region, and the expected MGB and southern bypass are designed and developed as full access control, therefore, the need for traffic signals is low.

6.4 Prioritization for the Selected Corridors and Intersections

6.4.1 Summary of Selected Intersections

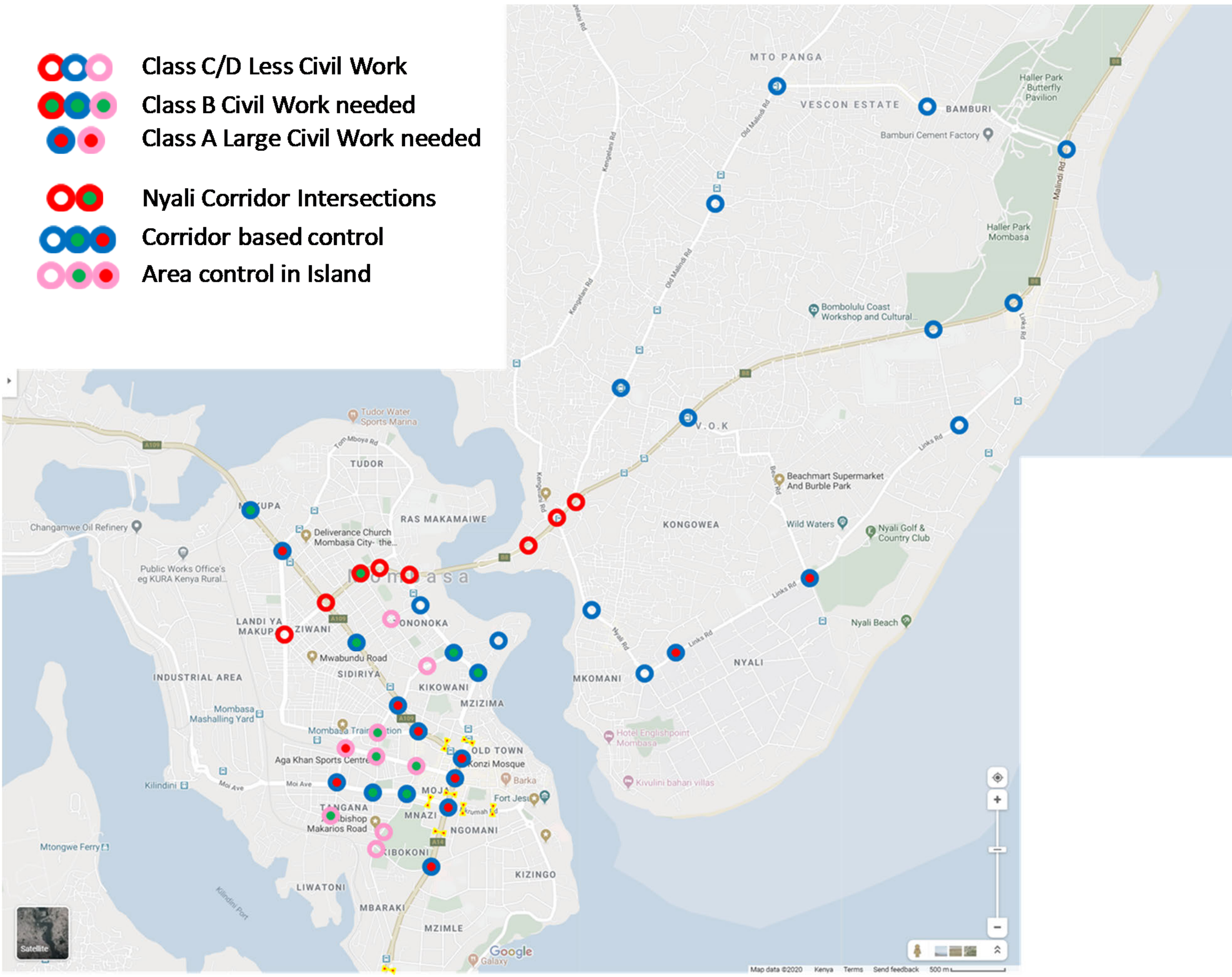
Figure 6.4.1 and Figure 6.4.2 shows the all proposed intersections in a map, with the classification of required civil work-loads (Class A-D). The junctions for Nyali corridors are shown in red, as it can be prioritized due to its less civil work-loads and high traffic control requirement as "Hyper-corridor", and connection to the expected MGB. The other corridor based intersections are shown in blue, as the coordinated signals shall be applied to realize the linear movements. The pink icons are other locations in the island, expected area optimization function.

Figure 6.4.3 summarizes the number of intersection with the classification. In total, 46 locations are proposed.



Source: JICA Study Team

Figure 6.4.1 Selected Intersections with Cvil Work Load (CBD and Nyali)



Source: JICA Study Team

Figure 6.4.2 Selected Intersections with Cvil Work Load (Whole Region)

Priority	Civil C/D	Civil B	Civil A
Nyali Corridor	7	1	0
Corridors in Island	2	6	8
Circulars	4	4	1
Corridors in Nayli	11	0	2

Source: JICA Study Team

Figure 6.4.3 Summary of Selected Intersections with Cvil Work Load (Whole Region)

6.4.2 Initial Prioritization and Road Map

As discussed in Chapter 2.1 (6) and (7), the prioritization and roadmap for implementation are proposed as follows:

- 4-level Prioritization
  - Urgent: Nyali Corridor 8 intersections as shown in
    - As minimum civil work requirement
    - Already reaches saturated situation but the corridor is controlled with the number of traffic inspectorate allocations. It will minimize the assignment of inspectorates along the corridor and the DTI can allocate their resources to other sections
    - Needs to be delivered before the MGB completion properly
    - Closest to the DTI facility in Tudor, minimum length of cabling if necessary
  - By MGB/2nd Nyali implementation: + + in the island (16)
    - As those new traffic generators require modernized traffic control along the corridor
    - MGB's implementation schedule will be announced after the completion of DD. The timing of signal development should be adjusted to the completion
    - The implementation of Nyali 2nd bridge is still unclear.
  - By 2030: All intersections in the Island
  - By 2035: All intersections in Nyali

6.4.3 Preliminary Cost Estimation

The following assumptions were applied for civil cost estimation.

- Civil cost per sqm by Type of works:
  - Type A: 300 USD, Type B: 250 USD, Type C: 120 USD, Type D: 80USD
  - This cost includes removal of roundabout, re-pavement and proper widening, lane marking and geometric improvement, etc, not including cabling work
  - The improvement work will be applied in the area of intersection, and same length of road width for each legs.
  - The size of intersection is calculated by widths of the existing roads.
    - For 6-lanes road: 30m, for 4-lanes road: 22m, for 2-lanes road: 12m
  - For pedestrian crossing improvement, it includes 100m of handrailing along the corridor.
- Signal installation per location, including on-site controllers
  - Traffic light, 22000 USD per location, Pedestrian lights; 8000 USD per location
  - For 6 lanes 4-legs intersection; 8 traffic lights, for others 4 traffic lights
  - For T-shaped junction, the number of the traffic lights were reduced proportionally
  - 8 pedestrian signals for 4-leg junctions, 6 pedestrian signals for T-shaped junctions.
- Sensors
  - Assuming 4 sensors per flow, i.e., 16 sensors at 4 legs intersections.
  - 5000 USD per location.
  - This number of sensors seems to be over estimation for the adjacent intersections in a corridor.
- Connection at intersection controller and equipment
  - Included above
- Assumed Cost per one (1) intersection
  - For 6x6 lane 4-leg junction, the cost is estimated US$320,000 per junction.
  - For 2x2 lane 4-leg junction, the cost is estimated US$232,000 per junction

- Other conditions
  - As for the reinstatement cost of the pavement, it is included in the civil work portion
  - The power supply cable and communication cable installation cost is included in each unit cost and assumed cost per one (1) junction mentioned above
  - Optical Fiber Cable installation cost including cable splicing work, cost for spare material and testing tools are included.
  - Cable installation cost and traffic signal installation cost does not include relocation cost for the existing other utilities and removal cost of the unused existing facility of other utilities. It will be considered in the next step
  - As it is rough cost estimation referring to the past similar projects, detailed cost estimation work will be required to finalize during F/S and B/D for the project.

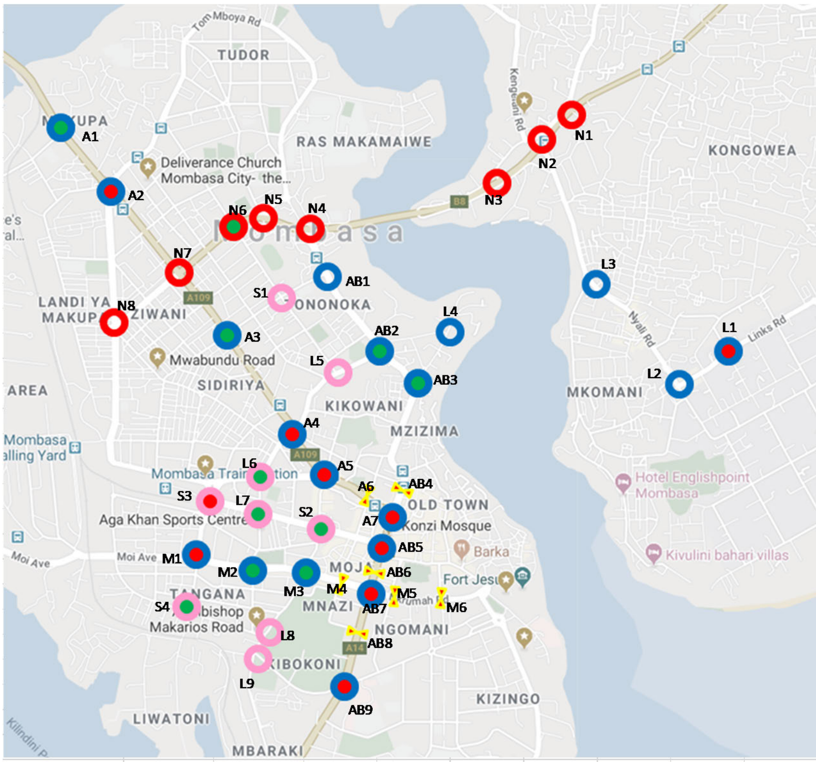
The initial cost estimation can be summarized as follows:

Table 6.4.1 Cost Estimation for Coordinated Traffic Signal and Intersection Improvements (Summary), USD

Routes		Civil Cost	Signal Cost	Total
Nyali	○	2,347,200	1,852,000	4,199,200
A8	○	4,446,000	1,556,000	6,002,000
Abdel Nassr	○	3,412,800	1,552,000	4,964,800
Moi	○	1,639,440	876,000	2,515,440
Sub total		11,845,440	5,836,000	**17,681,440**
Links-2nd Nyali	○	1,308,000	1,908,000	3,216,000
Supplement	○	1,406,400	892,000	2,298,400
Sub total		2,714,400	2,800,000	5,514,400
Total		**14,559,840**	**8,636,000**	**23,195,840**

Source: JICA Study Team

The detail locations and code, cost estimation per location are shown below.



Source: JICA Study Team

Figure 6.4.4 Target Intersections/Corridors for Cost Estimation

Table 6.4.2 Cost Estimation Settings for Intersection Improvements (Detail), M USD

ID	Group name	Code	Imp. Class	Main RL	Sub RL	Crossing
1	Nyali	N1	C	6	2	T
2	Nyali	N2	C	6	3	T
3	Nyali	N3	C	6	2	T
4	Nyali	N4	C	6	6	T
5	Nyali	N5	C	6	2	T
6	Nyali	N6	D	6	2	X
7	Nyali	N7	C	6	6	X
8	Nyali	N8	C	6	4	X
9	A8	A1	B	6	2	T
10	A8	A2	A	6	4	X
11	A8	A3	B	6	2	X
12	A8	A4	A	6	4	X
13	A8	A5	A	6	2	X
14	A8	A6	PED	6	2	P
15	A8	A7	A	6	6	T
16	Abdel Nassr	AB1	C	6	2	T
17	Abdel Nassr	AB2	B	6	2	X
18	Abdel Nassr	AB3	B	6	2	T
19	Abdel Nassr	AB4	PED	6	2	P
20	Abdel Nassr	AB5	A	6	4	T
21	Abdel Nassr	AB6	PED	6	2	P
22	Abdel Nassr	AB7	A	6	4	X
23	Abdel Nassr	AB8	PED	6	2	P
24	Abdel Nassr	AB9	A	6	2	X
25	Moi	M1	A	4	4	X
26	Moi	M2	B	4	2	X
27	Moi	M3	B	4	2	X
28	Moi	M4	PED	4	2	P
29	Moi	M5	PED	4	2	P
30	Moi	M6	PED	4	2	P
31	Links-2nd Nyali	L1	A	2	2	X
32	Links-2nd Nyali	L2	C	2	2	T
33	Links-2nd Nyali	L3	C	2	2	X
34	Links-2nd Nyali	L4	C	2	2	T
35	Links-2nd Nyali	L5	C	2	2	T
36	Links-2nd Nyali	L6	B	2	4	X
37	Links-2nd Nyali	L7	B	2	4	X
38	Links-2nd Nyali	L8	C	2	2	T
39	Links-2nd Nyali	L9	C	2	2	T
40	Supplement	S1	C	2	2	X
41	Supplement	S2	B	4	2	X
42	Supplement	S3	A	4	4	X
43	Supplement	S4	B	4	2	T

Note: Imp. Class – Improvement class see the table for Civil work load (Table 6.2.4)
RL: Road lane numbers, Crossing: X – 4 legs, T- 3legs, P/PED- Pedestrian crossing development

Source: JICA Study Team

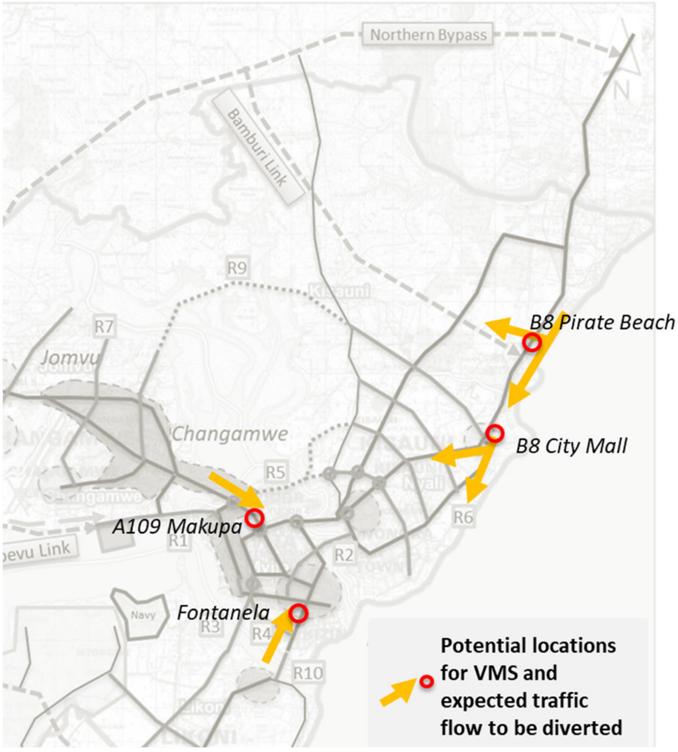
6.5 Comprehensive Project Formulation

6.5.1 Project Package

The previous section explained selection of the target corridors and cost estimation of civil engineering cost for the traffic signal installation. Other than the traffic signal improvement, the following items for traffic management improvement are proposed to enhance the comprehensive approach.

(1) Variable message signboards (VMS) development

- On-road VMSs to inform the traffic information including congestion information, traffic management and diversion direction, disaster evacuation directions would be broadcasted. See examples of VMS in the Chapter 5.2.2.
- On developing the 2nd Nyali bridge, the Gatebridge and the Northern Bypass and Bamburi Link, a regional area-wide road network will be formulated and proper traffic information should be disseminated to induce the proper route choice and minimize the traffic congestion in the city center.
- The project proposes to deliver 4 sets of the VMS. Details of VMS functions should be designed in the subsequent studies. The candidate locations are following.
    - From Nyali to Island (North to South)
        - At the A7 Pirate Beach: for diversion of Northern BP, Nyali (A7) / 2nd Nyali (Links), MGB region-wide traffic information
        - At the City Mall: for Nyali (A7) /2nd Nyali (Links) choice, MGB traffic condition
    - From Island to Nyali (South to North)
        - At the south of Fontanela: for diversion from Digo to Moi Avenue, choice of Nyali/2nd Nyali,
        - At the north of Makupa RA: for diversion from A8 to Lumumba, choice of Nyali/2nd Nyali



Source: JICA Study Team

Figure 6.5.1 VMS Location and Expected Traffic Diversion

(2) Links road reversible lane "Happy-hour" traffic management improvement

- This proposes to facilitate the proper electric signboards development for the reversible lane and one-way regulation along the Links road and connected roads. The Links road will be also connected to the expected the 2nd Nyali bridge which requires proper network development.
- The proposal expects to develop a gantry structure and electric signboards at 6 locations, showing the regulation during the designated hours. Details of reversible lane signboards functions should be designed in the subsequent studies. The candidate locations are following.
  - 2 locations along the 3 lanes section of the Links Road
  - 2 locations along the 2 lanes section of the Links Road
  - 2 location along the Moin Drive

Image of the reversible lane operation and signal installation in Links Rd three-lanes section

Source: JICA Study Team, Google Map

Figure 6.5.2 Image of the Reversible Lane Installation

(3) Comprehensive Moderate-based Control Center

As aforementioned, a control center function should be developed at the existing DTI traffic inspection building, 1st floor (2nd floor in Japanese counting style). The necessary servers, monitoring panels, connections would be delivered. The traffic control system will be designed with MODERATE area traffic optimization algorithm and modified for Mombasa traffic situation. This item covers expenditures for cabling work connecting individual traffic controllers on site.

(4) Initial Cost Estimation

Table 6.5.1 organizes the comprehensive project formulation, including system development cost, reversible lane traffic management system, and VMSs for traffic information provision. It does not include, however, the cost for the TA for bus parking management in Mwembe Tayari, or other traffic management.

Table 6.5.1 Cost Estimation for Whole Package (All corridors)

Category	Items			Unit rate	Cost
Traffic Signal Installation		unit	Nos	USD	USD
	Civil engineering portion	Nos	1	14,560,000	14,560,000
	Traffic signal and sensors	Nos	1	8,636,000	8,636,000
	sub-total				23,196,000
Variable Message Signboards (VMS)					
	VMS	Nos	4	300,000	1,200,000
	Software development	Nos	1	200,000	200,000
	sub-total				1,400,000
Links Road Reversible Lanes					
	Reversible Arrow Signals (6 locations)	Nos	6	100,000	600,000
	Software development	Nos	1	30,000	30,000
	sub-total				630,000
Comprehensive Moderate-based Control Center					
	Center System	Nos	1	3,000,000	3,000,000
	Cabling including Conduit Installation	Nos	1	1,800,000	1,800,000
	sub-total				4,800,000
Whole Package					**30,026,000**

Source: JICA Study Team, note: the figures are rounded in thousands.

As for A8 corridor, current on-street long distance bus terminal around Mwenbe-Tayarior area are recommended shifting to another appropriate area of Mombasa since it is the major cause of traffic congestion on this corridor. Even though introducing traffic signal, it will be considered not effective under the current situation.

Thus if the remaining prioritized two (Nyali and Abdel Naser) or three (Nyali, Abdel Naser and Moi) corridors are considered to be the Project scope of work, the estimated cost of the Project is summarized below;

Table 6.5.2 Cost Estimation for Prioritized Corridors (Prioritized 2 Corridors)

Category	Items			Unit rate	Cost
Traffic Signal Installation		unit	Nos	USD	USD
	Civil engineering portion	Nos	1	5,760,000	5,760,000
	Traffic signal and sensors	Nos	1	3,404,000	3,404,000
	sub-total				9,164,000
Variable Message Signboards (VMS)					
	VMS	Nos	4	300,000	1,200,000
	Software development	Nos	1	200,000	200,000
	sub-total				1,400,000
Links Road Reversible Lanes					
	Reversible Arrow Signals (6 locations)	Nos	6	100,000	600,000
	Software development	Nos	1	30,000	30,000
	sub-total				630,000
Comprehensive Moderate-based Control Center					
	Center System	Nos	1	2,750,000	2,750,000
	Cabling including Conduit Installation	Nos	1	1,700,000	1,700,000
	sub-total				4,450,000
Whole Package					**15,644,000**

Source: JICA Study Team, note: the figures are rounded in thousands.

Table 6.5.3 Cost Estimation for Prioritized Corridors (Prioritized 3 Corridors)

Category	Items			Unit rate	Cost
Traffic Signal Installation		unit	Nos	USD	USD
	Civil engineering portion	Nos	1	7,400,000	7,400,000
	Traffic signal and sensors	Nos	1	4,280,000	4,280,000
	sub-total				11,680,000
Variable Message Signboards (VMS)					
	VMS	Nos	4	300,000	1,200,000
	Software development	Nos	1	200,000	200,000
	sub-total				1,400,000
Links Road Reversible Lanes					
	Reversible Arrow Signals (6 locations)	Nos	6	100,000	600,000
	Software development	Nos	1	30,000	30,000
	sub-total				630,000
Comprehensive Moderate-based Control Center					
	Center System	Nos	1	2,750,000	2,750,000
	Cabling including Conduit Installation	Nos	1	1,700,000	1,700,000
	sub-total				4,450,000
Whole Package					**18,160,000**

Source: JICA Study Team, note: the figures are rounded in thousands.

6.5.2 Expenditure Item of Operation and Maintenance Cost

If the mentioned project is implemented, the following expenditure items will be required as operation and maintenance of the introduced system and equipment.

Table 6.5.4 Prospected Operation and Maintenance Cost of the System to Be Introduced

No.	Expenditure Items on Operation & Maintenance	Remarks
1	Personnel cost	If CGM need to hire the personnel additionally
2	Electricity cost for roadside equipment and center equipment	
3	Periodic Inspection costs for the roadside equipment and center system	It is required at least once a half year. CGM has option to implement it by their own resources or outsourcing under a maintenance contract with the local service provider.
4	Periodic Inspection costs by the traffic signal system manufacturer	It is recommended once a year. It depends on the maintenance contract between CGM and traffic signal system manufacturer
5	Procurement and management cost of spare parts	Procurement, in-stock management, and budget estimation based on the actual maintenance condition of the spare parts such as signal light, controller, parts of variable message sign, communication equipment, and lightning surge protection devices and so on.
6	Parts replacement cost	Necessary cost for replacement of the parts, including fuel, safety measure, and vehicle usage/rental cost for work at structure installed high, or outsourcing cost for it.
7	Painting including anti-corrosion type for pole, gantry, cabinet or other structures related to the traffic signal.	Conducted after regular inspections as needed.
8	Emergency repair costs in the event of a communication failure	Emergency repair of cable cuts (emergency replacement with spare cable and cable jointing work, and necessary spare parts and measurement tool for it). If this work is outsourcing, necessary budget will be required.
9	Repair work for conduit and cable chamber	If the duct for communication cable or electric power supply cable is damaged due to other owner's work, the repair cost for it is required

No.	Expenditure Items on Operation & Maintenance	Remarks
10	Consumables	Fuel of the vehicle for inspection work or parts replacement, ink or paper for the printer, etc.
Following items are required if the project include those items.		
A	Software license fees	When software is introduced that requires to pay a license fee every year (database software or others)
B	Communication costs	When the data communication service of a communications carrier is used
C	Radio frequency charge	If CGM wants to build CGM's own network using the licensed frequencies
D	Data center usage fee	If CGM uses the services of a data center service provider other than CGM

Source: JICA Study Team

The estimated operation cost and maintenance cost for the prioritized two corridor is shown below;

It is the case for prioritized two corridors (Nyali and Abdel Naser) and 17 signalized intersections are included. It also includes center system, 4 variable message sign, and 6 reversible lane indicator. The data communication system is assumed to applying fiber optic transmission system using optical fiber cable between center system and intersection controller.

Table 6.5.5 Estimated Operation Cost for the Prioritized 2 Corridors

No.	Category	Unit	Annual Cost (US$)	Corresponding Item in Table 6.5.4
1	Cost for Electric Power Supply	Lot	22,000	No.2
2	Spare Parts of the equipment	Lot	38,200	No.5
3	Consumables	Lot	1,100	No.10
	Estimated Annual Operation Cost		US$ 61,300	

Source: JICA Study Team

In the operation cost, it is assumed that additional personnel will be not required. Hence the additional personnel cost is not included in the above calculation.

As for the maintenance cost, it is estimated in the following table;

Table 6.5.6 Estimated Maintenance Cost for the Prioritized 2 Corridors

No.	Category	Frequency	Annual Cost (US$)	Corresponding Item in Table 6.5.4
1	Traffic Light Maintenance Cost	Once a month	84,600	No.3, No, 6 and No.7
2	VMS Maintenance Cost	4 times per year	6,650	
3	Reversible Lane Indicator Maintenance Cost	4 times per year	7,750	
4	Emergency Repair for cable cut	upon cable cut	7,100	No.8 (It is assumed that 3 times per year)
5	Traffic Control System Maintenance	Once a year	11,300	No.4 (remotely checked by the manufacturer)
6	Conduit Repair Work	6 times per year	2,100	No.9 (It is assumed that 6 times per year)
7	Maintenance of pavement	5 locations per intersection per year	2,400	Not included in the Table 6.5.4
			US$121,900	

Source: JICA Study Team

The total annual operation and maintenance cost is estimated US$183,200 for the prioritized two corridors. It will be approx. 0.55% of the projected expenditure for the Operation, Maintenance and Repair in the CGM budget for FY 2019/2020 (i.e. KES3,623,153,147 = Approx. US$33,393,000).

If we apply 4G data communication between center controller and intersection controller which will be installed at each signalized intersection, data communication cost is required as operation cost. However, the emergency repair work for cable cut and conduit repair will be reduced since the cable is installed only around the signalized intersection. If we consider such case, the annual operation cost is estimated US$63,500 and the annual maintenance cost is estimated US$115,800 for the 2 prioritized 2 corridor. In total it is estimated US$179,300 annually.

After introducing the system, around 10 years later, CGM will require to replace the hardware such as servers, PCs and so on. In addition, installed software will be required to modify due to necessity of migration of software to the new OS. The items are shown in the following table.

Table 6.5.7 Necessary Items on Replacement Cost (Depreciation Cost) and Modification Cost in the Future for Sustainable Operation

No.	Expenditure item for replacement or depreciation	Remarks
1	Replacement cost of hardware in the center system	Server, PC, backup power supply equipment, communication equipment such as switch, media converter, etc
2	Software modification cost including porting cost to the new OS (including data migration)	Since the OS of the introduced system will no longer be supported in about 10 years, it will be necessary to port to a new OS.
3	System modification cost in the case of traffic signal control area expansion or new function introduction such as PTPS	It may be necessary to partially modify the center system in order to connect new control equipment to the existing system. If the new function is required, it will be necessary to inform the manufacturer to install the existing system.
4	Communication equipment and cables	When the prescribed transmission quality is no longer ensured due to age-related deterioration, it is necessary to replace switches, media converters, cables, etc. In this case, the network management system must be reconfigured.

Source: JICA Study Team

6.5.3 Notes for Implementation

(1) Overlapping Concerns with Other Project Scopes

The Nyali corridor signalization package (N1-N8) does not overlap with the scope of the Mombasa Gatebridge (MGB) construction project. The northern approach road section of the MGB will land along the Lumumba road around Jela Baridi (King'orani Prison). On the other hand, KeNHA had an option to extend the northern approach road over the 77 Junction (N7). Regarding this overlapping, the study team confirmed with KeNHA Mombasa Office in Oct 2020 that the MGB project will be implemented as the original scope without the extension idea, and KeNHA will also implement the A7 and A8 widening project for further traffic increase. It should be noted that the road section of N2 - N7 along the Nyali corridor already have proper road width and alignment, therefore, additional widening between N2-N7 are not needed, and proposed geometric improvement at intersections including N4 can realize the expected traffic flow improvement.

The JICA Study team recommends that JICA shall monitor the latest information of the MGB final design.

(2) Socio-Environment Impact

This project package can be managed to implement within the right of way of existing road. This proposal will not expect any land acquisition and relocations of formal entities on sites, however, congestions and local environmental impact can be expected due to the civil work along streets in CBD. It can be classified as Category "**B**" as initial evaluation[3].

The following should be noted as socio-economic impact of the proposed project;

- It should be required that civil work for geometric improvement at intersections minimizes the influence on traffic flow and local environment.
- The proposed idea for pedestrian traffic management including installation of traffic signals, handrails, etc, will make influence the local residences and businesses, particularly in the downtown district. It will require proper stakeholder meeting for further acquaintances of the project.
- The long-haul bus terminal operation at the Mwembe Tayari junction should be revised if the A8 corridor will be included in the project package. A proper business sustainability plan should be formulated by the CGM together with the bus operators. A technical cooperation packages could be proposed to assist the social arrangements.
- The traffic signal control will influence not only private vehicle users but also pedestrians and public transport users. The modal share in Mombasa (2015) shows 45% for walk, 37% for public transport (Matatu/3W), and 3% for private vehicles.
- The old town / downtown district where the pedestrian signal installation were proposed has some vulnerable groups, including elders, female-headed households, Islamic or Somali background, etc. Those groups require walkability in old town district and the project will influence them positively.

(3) Impact and Performance Indicators of the Project

The proposal covers the following corridors with high traffic volumes and high passenger volumes. The proposed development will influence to more than 150 thousand vehicles and 400 thousand passengers per day.

Table 6.5.8 Present Traffic & Passenger Volume along the Target Corridors

Corridors	PCU Traffic per day in 2015	Passenger Volume per day in 2015	Note (location)
Nyali Corridor	73,656	202,000	At Nyali bridge
A8	28,146	N.A.	At Makupa RA south
Abdel Nasser	44,568	122,000	At Kisauni Rd.
Moi Avenue	26,953	58,000	At Tuskis

Note: Passenger volume is estimated passengers moving along the corridor for 24 hours, includes pedestrian and NMV/MV
Source: JICA Gate City Masterplan (2018)

The following performance indicators would be proposed. It should be noted that the traffic signal installation can realize the smooth traffic, but cannot decrease the travel time, therefore, the average travel time in the present situation should be kept as a target. The actual average time should be measured by the follow-up studies.

[3] See JICA Guidelines for Environmental and Social Considerations (2010), https://www.jica.go.jp/english/our_work/social_environmental/guideline/pdf/guideline100326.pdf

Table 6.5.9 Expected Target Performance Index

Performance Index	Target section	Methodology	Notes / Target
Average and Maximum Vehicle Travel time between region-wide destinations in Peak hours	1) A7 Kengelani Jct to Lumumba Rd Kigorani Jct (3.0km) 2) A8 Fontanela junction to A8 Changamwe RA (6.6km)	By sedan vehicle, average of 5-times trials in both directions or use Google Map API equivalent services, in weekday peak hours.	Target: 1) 20-30 minutes in 2020 ->16 minutes after two years operation (20% decrease) 2) 20-30 minutes in 2020 -> 16 minutes after two years operation (see the observed actual average and maximum travel time in 2020 for reference)
Average travel speed between region-wide destinations in Peak hours	Ditto	Ditto	Target: 1) 9km/h in 2020 -> 12km/h after two years operation 2) 13.2km/h in 2020-> 16.5km/h
Vehicle Queue length at the peak hours	At major junctions, including 77, Fontanela, Buxton, Nyali	Actual measurement in both directions, in weekday peak hours	The length should be kept in the present conditions. (reference: see the present maximum queue length in Sep 2020 peak hours in Figure 6.5.3.)
Accident in the island and target corridors	Whole island, or target major junctions.	Statistic information by Police. This should be monitored in longer period.	The traffic accident will be decreased.
Operation period of the system (Mean time between failure: MTBF)	Should be calculated in the design phase	A counting system should be designed to monitor by itself for whole period	Except for external reasons, e.g., electric failure[4], wire-cutting, flooding, etc
Recovery time (Mean time to recover: MTTR)	Less than 1 hour	ditto	ditto
Interfere by DTI/Police	Zero	Owner (DTIPW) monitoring	The system should not be replaced by manual operation, Except for VIP visiting at the site.
Operation cost	--	Owner (DTIPW)	a proper amount should be expended.
Maintenance cost	--	Owner (DTIPW)	a proper amount should be expended.

Source: JICA Study Team

Table 6.5.10 Reference: Actual Vehicle Travel Time in Peak Hours (Oct 2020)

Average	A7		A8	
Minutes	**Downflow**	**Upflow**	**Downflow**	**Upflow**
Morning	Kigorani-Kengelani	Kengelani-Kigorani	Fontanela-Changamwe	Changamwe-Fontanela
Tue	24.9	17.9	26.5	26.0
Wed	21.2	18.5	20.2	21.1
Thur	27.0	18.9	26.7	26.2

Maximum	A7		A8	
Minutes	**Downflow**	**Upflow**	**Downflow**	**Upflow**
Morning	Kigorani-Kengelani	Kengelani-Kigorani	Fontanela-Changamwe	Changamwe-Fontanela
Tue	31.5	21.9	29.4	28.9
Wed	25.4	21.6	22.2	23.7
Thur	31.1	24.6	28.7	30.1

Note: During 6-8 Oct 2020, 7-9am and 4-7pm, extracted vehicle running time from Google Map API every 10 minutes. This table shows Morning period only as morning performance is severe and worth to use as Performance Index.

Source: Google Map API measured by JICA Study Team

4 Basically, the electric supply in Mombasa is sufficient, but weakness in distribution system was identified as the electric failure. See the Gatecity Masterplan (2018), chapter 5.4.

Source: JICA Study Team

Figure 6.5.3 Reference: Maximum Queue Length in Peak Hours (Sep 2020)

(4) Technical Cooperation Package

The following technical cooperation package would be proposed to enhance the operational capacity of the CGM DTI and DTIPW. A technical assistance team (TA team) will be dispatched and work together with the counterpart organization.

- Counterpart and executive agency:
  - ➢ DTI (Inspection and operation) and DTIPW (system design and management)
  - ➢ Stakeholder groups (PIU, shown in Figure 6.2.1)
- Period:
  - ➢ This package will be implemented during the design stage and implementation stage of the signal installation project, expected to be 4 years in total.
    - ✧ At least one year after inauguration of the traffic control operation.
- Activity Components and Objectives
  - ➢ Phase 1) Arrange the necessary social coordination for traffic management (particularly in Mwembe Tayari and A8//Digo Corridors): The TA team will assist the necessary coordination for implementation of the project implementation. The following issues are to be arranged;
    - ✧ The DTIPW shall materialize a plan for on-street long-haul bus terminal relocation arrangement from Mwembe Tayari intersection.
    - ✧ The DTIPW shall organize a plan for pedestrian safety education, particularly vulnerable groups in the Old town area, including female-headed family, small-scale wholesale business labors, hand-cart operators, Matatu/3W passengers, matatu/3W drivers.
    - ✧ The DTIPW will advise to the designing team of the intersection improvement regarding usability of the vulnerable groups.
  - ➢ Phase 2) Technical arrangement for smooth traffic flow in geometric improvement design and control setting: The TA team will plan the OJT program in geometric improvement of the intersection design, and supervise implementation of the program. The OJT program will include the following
    - ✧ The DTI and DTIPW understand the objectives and technical approaches for the signal installation and civil work

  - ✧ The DTI and DTIPW should be understand how lane marking, traffic island, roundabout removals, signal phasing and timing, etc are designed and optimized in the design stage.
  - ✧ The DTI and DTIPW should understand how the coordinated signal operation are designed and implemented in other cities (training in Japan or Uganda)
  - ✧ The DTI should understand the rationalized traffic inspection methodology with coordinated traffic management system and VMSs.
- ➢ Phase 3) Operational arrangement for traffic control system for institutional and financial setting: The TA team will assist the CGM to secure the operational budget for the coordinated traffic control systems.
  - ✧ The DTI and DTIPW will calculate the necessary budget for the system operation for 10 years after the installation, particularly for necessary technical expenditures including electricity, server, communication cost, regular inspection, and future replacement, and expenditures for human resources.
  - ✧ DTI should materialize a rationalization plan of inspectors' mobilization along the target corridors
  - ✧ The DTI and DTIPW can organize the revenue improvement to cover the expenditure of the system operation, including advertisement development at the signal poles, advertisement in VMSs, parking fee, etc.
  - ✧ The CGM can secure the operational budget for the system.
- ➢ 4) OJT for traffic control system operation: the TA team will assist the DTI and DTIPW for the traffic management with the system.
  - ✧ The DTI can organize the human resources for the system operation, and implement OJT for the operation. The DTI can coordinate the OJT with the signal installation contractors.
  - ✧ The DTIPW can assess the system appropriateness and implementation.

(5) Project Design Matrix for Traffic Control System installation

The project design matrix were presented as Table 6.5.11.

The input can be classified into physical and institutional package, which are explained in the previous sections (1) and (2). The CGM are required to secure the O&M capacity and budget to operate the system properly.

The output is to develop and operate the coordinated signal system itself. The system will work properly if proper O&M budget are secured, however, traffic enforcement should be properly implemented, and the users should be familiar to the system.

The project objective can be expected to realize the smooth traffic along the target corridors, which can be measured by the proposed performance indices. Generally, the traffic inspectors tend to interfere the system operation manually, and Matatu and aggressive drivers ignore the traffic codes.

The super goal of the project is specified as "Realize smooth and low energy regional road traffic in the Mombasa region" as a proposal. This will not be achieved without other transport network development and demand management measures, including the Gatebridge, 2nd Nyali, BRT/LRT development.

Table 6.5.11 PDM for Traffic Control System Installation in Mombasa

Target	Indicators		Conditions/Assumptions
Super Goal: Realize smooth and low energy regional road traffic in the Mombasa region	GHG emission reduction, average travel speed reduction, in region-wide scale	By actual counting and estimation	
Objectives: realize the smooth traffic along the target corridors	i) Average vehicle travel time ii) Queue length iii) Accident	By actual counting and statistical info.	Physical development for traffic diversion including MGB, 2nd Nyali Bridge, BRT/LRTs development
Output: Develop and operate the coordinated signal system along the target corridors.	i) operation index (MTBF/MTTR) ii) O&M expenditure	By actual counting and statistical info.	Proper traffic enforcement based on traffic signal will be implemented. The passengers must obey and be familiar to the signal-based operation principle.
Input: Area traffic management for major 4 corridors coordinated control system installation in Mombasa	*Physical Package)* 30-35 signal installation with proper civil work, VMS/reversible lane function and cabling, control center function *Soft component)* TA for operational capacity development		CGM can arrange the implementation procedure and can secure the O&M budget.

Source: JICA Study Team

6.5.4 Stakeholders' Interests

The study team conducted the on-line stakeholder meeting on 16 September 2020, with 19 participants including the study team, CGM, KeNHA, KURA, Kenya Police, TUM and NTSA. The study team presented technical and institutional proposals above, and collected opinions from stakeholders, and confirmed further implementation of the ITS project formulation procedures in Mombasa. The following are major finding and interests from the stakeholders. Details of the Stakeholder Meeting are attached as appendix.

Table 6.5.12 Stakeholder Inetrests and Further Actions

Comment/Interests	Further action to be considered
Traffic simulation should be done to confirm the direct effect of the project beforehand. (TUM) The impact of the roundabout removal should be assessed by the traffic simulation. (KeNHA)	The study team will recommend conducting traffic simulation and assessment of the ITS measures in the further F/S stage, as this study scope covers project formulation only.
The traffic monitoring/control function should be branched and movable because the CGM DTIPW expect to monitor the situation by themselves, and may expand the management function to outside of island in future. (CGM DTIPW)	Such idea should be included and noted in the Final report.
JICA's Kampala experience for ITS implementation should be shared. (TUM)	The technical assistance package should include such on-site training in Kampala.

Source: JICA Study Team

6.5.5 Further Measures to Ensure the Sustainability

In order to make full use of the signal equipment to be installed, and ensure the sustainability, the following points are recommended considering

(1) Utilization of probe data collected from the probe car

The technical cooperation project on the probe data including collection of probe data, introduction of traffic signal control using it, and development of human resources for data analysis is recommended. If possible, establishment of a system for continuous use of probe data is also considered. (With the possibility of the BRT being introduced by the World Bank in the direction of Changamwe and the second Nyali Bridge being considered, it is expected that traffic demand will continue to change even after the traffic signal control system is introduced. Therefore, the program aims for CGM to enhance the capacity of traffic signal control by utilizing prove car data.)

(2) Cooperation on operation and maintenance of traffic signal control

Technology transfer that aims to improve maintenance capabilities, including preparedness for sudden events such as cable disconnection, points to check during periodic inspections, and visualization of the process of securing a budget for spare parts.

In Mombasa, the maintenance of the fiber optic cables is currently outsourced to a private company, and normal maintenance capacity is not particularly problematic, including the use of tools and the availability of the necessary maintenance personnel. However, the preparedness to the serious incident is required to improve since the optical fiber cable was not recovered after cable cut incident in December 2019 for more than four (4) months. Therefore how to recover with the alternative options should be transferred to the staff of CGM. It includes basic maintenance knowledge including the strengthening of the management skill for the outsourcing maintenance work. It also includes improvement of maintenance budget estimation skill both for normal maintenance and emergency cases.

As for the server maintenance work, considering CGM tried to establish small data center for their own and the staff of DICT will maintain it, JST considers that DICT staff will be able to maintain the servers to be installed in future project provided that the necessary technical transfer is made. The CGM data center is not established yet as of October 2020, however, it is planned to establish around January 2021. In the next study for the traffic signal control project, it is recommend studying the possibility to utilize the CGM data center for installing and maintaining the servers of traffic signal control.

(3) Support for CGM to expand the traffic signal control area by itself

After the traffic signal control system is introduced, the coverage area of the signal control will be expanded in the future. For such cases, it will be required the capacity development for signal control area expansion planning. The program may include the trial study on cost efficient system including wireless communication between traffic control center and on-site controller. The prospective location will be Likoni area where the traffic demand will be increased after construction of the Gate Bridge.

(4) Stakeholder's coordination mechanism

After introduction of signal control system, it is recommended holding periodical stakeholder's coordination meeting and continue to discuss the topics to improve the traffic situation in CGM. It will be good mechanism as the most of issues are related to two or more organization's functions or jurisdictions. For example, traffic accident data analysis and improving the road safety, how to ensure the emergency vehicle's passage during peak hours, analysis of traffic congestion and share it among the stakeholders, analysis of parking regulation and how to contribute to the traffic flow in CGM and/or other topics.

CHAPTER 7 DEVELOPMENT NEEDS AND PROJECT FORMULATION FOR ACCRA AND KUMASI

7.1 Summary of Project Proposals for Accra

As mentioned in the Chapter 3, 1) Expansion to area traffic control from corridor-based control, 2) safety improvement and 3) shift to other cities, were proposed as potential direction for ITS project formulation in Accra, GAMA and Ghana. The following project were proposed as potential projects.

(1) Short Term Project (Approx. within 3 years)

The JST shows two (2) projects in the following table. The one is related to the traffic signal and the other is related to V2X technology.

Table 7.1.1 Proposed Short Term Project

Name of the Project	Outline of the Scope of Work	Executing Agency
The Project for development of Area wide Traffic Signal Control System by using existing Control System.	• In addition to the existing area wide traffic signal control system, additional area wide signal control system will be introduced (For example, Japanese MODERATO) for other corridor(s) after implementation of 2nd phase signalization project • The control system should be interoperable to the existing control system	Department of Urban Roads
Technical Cooperation Project on Road Safety applying V2X and VMS	• Pilot project for introducing V2X technology to the black spot of traffic accident to improve the road safety • It is assumed the case between vehicle and motorcycle • Collected data will be utilized for effectiveness evaluation and further expansion	NRSA or MTTD It is required to clarify prior to the project implementation.

Source: JICA Study Team

(2) Middle to Long Term Project (more than 3 years to 10 years)

JST also recommends implementing the technical cooperation project for cooperation among the different government agencies through the data collection, utilization and sharing process.

Table 7.1.2 Proposed Middle to Long Term Project

Name of the Project	Outline of the Scope of Work	Executing Agency
Vehicle Management by using FMS and related Technical Cooperation Project on Road Safety	• Introduction of Fleet Management System (FMS) to long distance buses to monitor the speed and accident • Introduction of FMS to public transportation to collect prove car data and utilization of it for traffic management and other purposes.	NRSA or MTTD It is required to clarify prior to the project implementation.

Source: JICA Study Team

The details of each are described in the following sections.

7.2 Project Implementation Scheme for Accra

7.2.1 Possibility on Area Wide Traffic Signal Control System Introduction

(1) Background

In Greater Accra/Metropolitan Accra, Quality Bus System (QBS) was introduced through the World Bank financed Urban Transport Project (UTP) in the past. It aimed alleviating traffic congestion in the Greater Accra/Metropolitan Accra, and enhancing traffic management by introducing area wide traffic signal control then tried to enhancing commuting people's mobility basically.

What has become clear in the experience of UTP is that the traffic situation that needs to be improved extends beyond the unit of assembly, while the absence of an agency with the appropriate political leadership to address it makes the traffic problem more difficult to address. Therefore, the JICA Study Team recommends strengthening cooperation among relevant agencies and practically improve addressing transportation problems through the following projects. The key concept is the collection and utilization of data, and the aim is to build substantive cooperation by having the relevant responsible agencies consult and agree on data sharing.

(2) Technical Approaches for Area Traffic Control

It should be clarified whether it is possible to introduce MODERATO to the area controlled by another existing signaling control system like in Accra and integrate them into MODERATO or to be integrated by another signaling control system in a city. The clarification was made to the following traffic signal manufacturers and related authorities.

- The JST collected the information from traffic signal manufacturers such as Nippon Signal Co., Ltd. and Sumitomo Electric Industries, Ltd. In addition, the team collected opinions from the Toyota Tsusho Corporation that collaborates with Axilion. The Axilion is an Israel based manufacturer that declares being capable of integrating any type of traffic signal system.
- The JST collected information from Japan Traffic Management Technology Association, to see if they can respond to the requests from other countries' implementing organizations to disclose the technical standards of Japanese signals. Basically, it is possible to disclose the standard if the further detail about disclosure should be discussed and decided when it becomes necessary according to the Association.

Although a further detailed study will be necessary, the Japanese traffic signal control system can be integrated with the existing system technically, or it's also possible to coexist. However, JST would like to point out that it is still not fully confirmed whether Japanese manufacturers will intend to do so when it becomes necessary. The concept of the integration or co-existence is shown in the Figure 7.2.1. The Figure shows the concept for Accra after completion of Phase 2 signalization project. The counterpart agency assumes DUR.

The characteristics of major coordinated traffic signal control system is shown the following table;

Table 7.2.1 A Comparison of Major Traffic Signal Control System

Item	MODERATO	SCOOT	SCAT
Developed Organization/Country	Japan	UK	Australia Roads & Traffic Authority
Applied City	All Japanese prefectures	More than 200 cities in the UK and other countries	More than 80 cities in 27 countries
Outline of the system	Traffic signal control is made on a real time basis by generating traffic signal's control parameters (split, cycle and offset) automatically based on the measured traffic data of the cycle unit of 1 min. 2.5min. and 5 min. At a bottleneck intersection, the retention length is measured for the individual inflow roads, and it is effective for over-saturated capacities of traffic for the intersection	Green time is obtained based on the delayed time calculated on the basis of vehicle cluster wave. The cycle length can be updated every 2.5 or 5 minutes and update can be completed within some seconds.	Traffic information is generated based on sensors installed closely before the stop line of the intersection. Traffic signal's parameters are obtained every cycle referring to the traffic information, thus the reflection of real time condition is high.
Good/Bad points	Suitable parameters are selected from non-saturated condition to over-saturated conditions. It is possible to combine the adaptive signal controls and it is possible to control so as to suit individual intersections. The number of sensors tend to be more than other systems as it tries to measure the retention length.	Suitable parameters are possible to select in the non-saturated stage. However, in the over-saturated stage, waiting time tends to be too long as the system selects the maximum cycle length.	In the non-saturated stage, the real time control is ensured as the control method is adaptive to the gap between the traffic counter and the signal parameter. In the over-saturated stage, the cycle length tends to be longer than the necessary length.

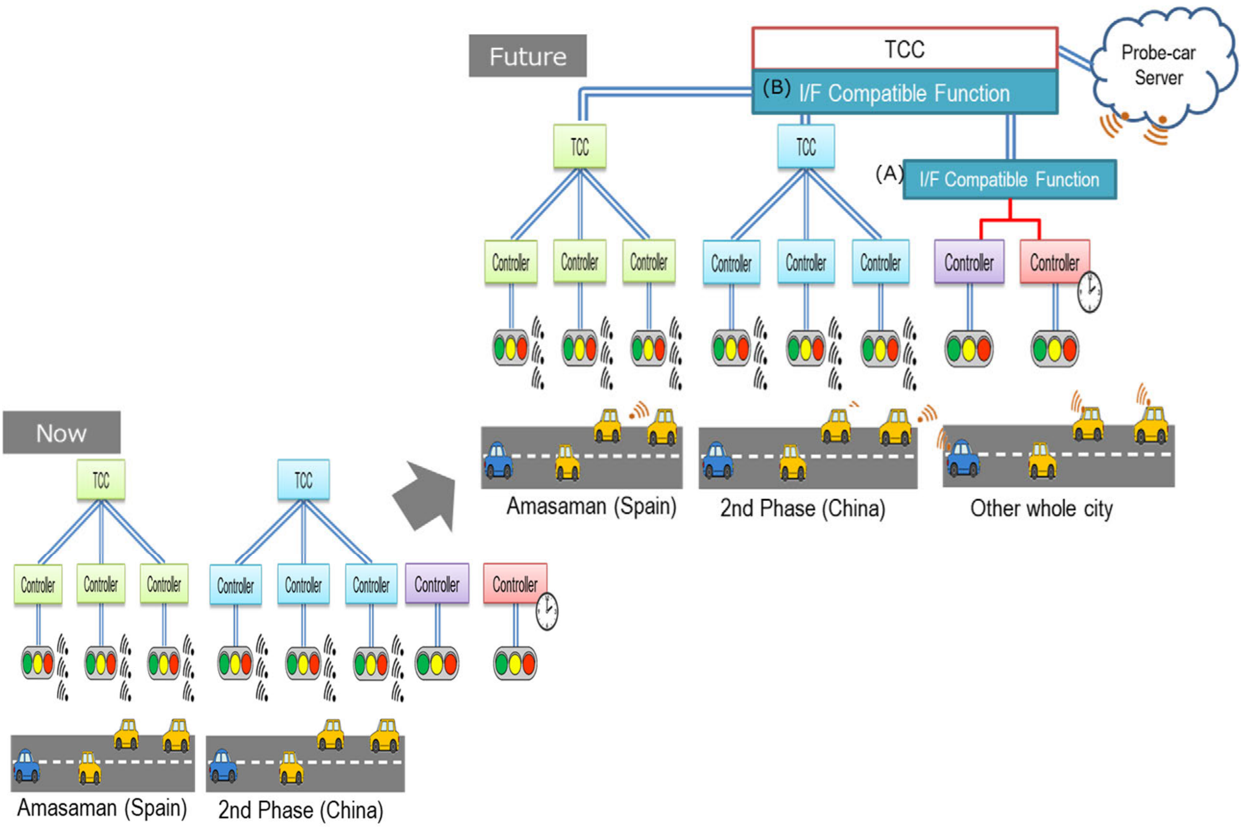
Source: JICA Study Team

The merit of MODERATO is summarized below;

- <u>Wide range coverage of the traffic condition</u>: MODERATO is able to select the suitable signal control parameters from non-saturated condition to over-saturated condition. This feature is effective in urban areas where the traffic volume varies widely with the hours of the day.
- <u>Possible to combine with the adaptive signal control</u>: MODERATO is possible to combine with the adaptive signal control and it is possible to control to be adjusted to the individual intersections. Adaptive signal control is applicable to the intersection where the drivers/pedestrians feel unsafe although the crossing road's traffic volume is not so high and it can be installed along the same corridor where centralized controlled MODERATO based signals are installed.

Further detailed information on traffic signals and measures to improve the traffic flow is available in Chapter 5 of this report.

In addition, co-existing concept for the several different coordinated traffic signal systems is also shown in the followings;



Source: JICA Study Team

Figure 7.2.1 A Model for the ITS/Traffic Management System Development for Accra Case

In the case of Accra, the 1st phase ITS system for the Amasaman corridor has already been installed. It seems that China may support the introduction of the 2nd phase. The manufacturers of the existing independent type signals are unknown. The system development in the future can be depicted as Figure 7.2.1.

In order to realize integrated Traffic Control Center (TCC) controls for whole city network, it is necessary to develop I/F compatibility functions, shown as (A), for existing signal control and develop higher-level I/F compatibility functions, shown as (B), for integration with other TCCs. Accra DUR itself seems to have no resistance to the release of the controller and TCC I/F for the function (B)

It should be noted whether introducing the I/F function (B), which means the overall city control or "gilding the lily", is essential for traffic control. Perhaps, multiple optimization in corridor-based may be simple in the Accra situation.

It is also noted that since Ghana has a few roundabout intersections and has already made progress in introducing signals or elevated intersection, there will be few civil works involving the removal of roundabouts and intersection improvements, and the introduction of the signaling system will focus on the systematic signal control and area wide signal control.

7.2.2 Technical Cooperation for Road Safety

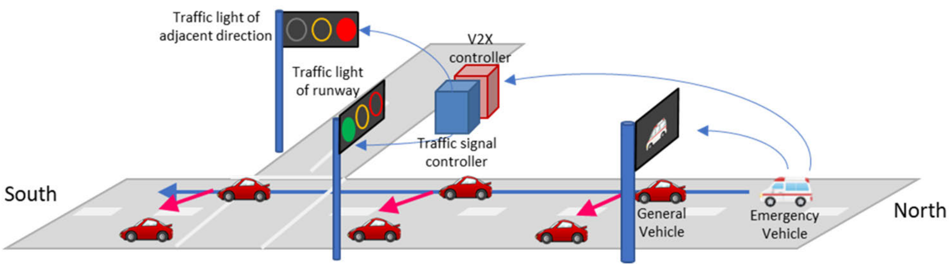
The institutes related to transport and traffic management in the target region are too fragmented to coordinate with other assemblies, however; the JST identified that technical cooperation projects for traffic safety improvement will be considered as fields where the relevant agencies are able to collaborate more easily. The advanced ITS application can be implemented in the target regions as its road infrastructure were developed relatively in higher quality to accommodate the ITS application.

(1) Technical Cooperation Project on Priority Signal Control for Public Transportation and Road Safety applying V2X and VMS

V2X technology, which allows information to be exchanged between a vehicle and other vehicles, infrastructure, people, and everything in between, has already begun to be installed in vehicles manufactured by vehicle manufacturers. For example, Toyota Motor Corporation has sold about 200,000 vehicles equipped with V2X communicators as of 2019, and the infrastructure for V2X communicators is being developed in each prefecture in Japan as Driving Safety Support Systems (DSSS). Volkswagen also equips V2X communication devices as standard equipment on some of its vehicles. In the U.S., 50% of new cars will be equipped with V2X communication devices by 2023, and this is expected to spread rapidly in the future.

Under these circumstances it is expected that the number of vehicles equipped with V2X technology will increase in the developing countries, where used vehicles are imported from developed countries, in the next 10 years.

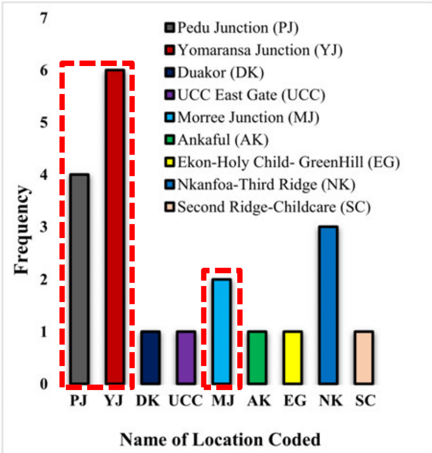
In the other hand, Japan's V2X technology has been demonstrated in India, the Philippines, and Taiwan since FY2018. The demonstration in India has demonstrated the use of V2X to control priority signals for emergency vehicles. In the Philippines, it has been demonstrated that V2X can be used to prevent head-on accidents at unsignalized intersections.



Source: Material from Zero-Sum < https://www.zero-sum.co.jp/en/ >

Figure 7.2.2 Japan's V2X Demonstration in India

In Accra, Ghana, BRTs are operated, but because they do not have dedicated lanes, they are affected by traffic lights and traffic congestion, and there is an issue of ensuring regular travel time. As shown in Figure 7.2.2, road accidents in urban areas such as Accra are occurring more frequently at intersections, especially among vulnerable road users such as pedestrians and motorcyclists.



Source: Identification of Road Traffic Accident Hotspots in the Cape Coast Metropolis, Southern Ghana Using Geographic Information System (GIS)
< https://www.researchgate.net/publication/329029966 >

Figure 7.2.3 Fatalities Involved Road Traffic Accidents in the Cape Coast Metropolitan Area

Therefore, the introduction of a priority signal system for BRT vehicles (as well as emergency and ambulance vehicles) using the V2X technology at traffic signal intersections will be significant in promoting the use of public transport by Accra residents to shorten travel time and ensure punctuality. At the same time, it would be meaningful to raise awareness of road safety in Ghana by conducting a V2X pilot project at intersections where collision traffic accidents may happen with sudden entering vehicle are aimed at reducing.

It is technically possible for BRT vehicles and emergency vehicles to be equipped with the V2X function to provide priority signal control. However, in order to recognize the approach of BRT vehicles and emergency vehicles in sections other than intersections, and to encourage other vehicles without V2X functions to avoid them, it would be effective to provide information by using a combination of Variable Message Signs (VMS) to alert surrounding vehicles. Also, in order to reduce collision traffic accidents at intersections, it would be effective to provide information to other vehicles and pedestrians using roadside displays such as VMS.

It is possible to introduce these measures on a trial basis at signalized intersections on the BRT route in Accra and other locations where traffic accidents are frequent, confirming the effectiveness of the BRT in increasing travel speed and reducing traffic accidents, and then develop similar measures. It is likely to be a technical cooperation project with future developments. Possible counterpart agencies include Ghana Police Service, Motor Traffic and Transport Department (MTTD) and National Road Safety Authority (NRSA). It is important to note that MTTD of the Ghana Police Service operate under the Ministry of Interior but JICA doesn't have any recent cooperation with regard to Infrastructure activities. NRSA is also new to JICA's cooperation.

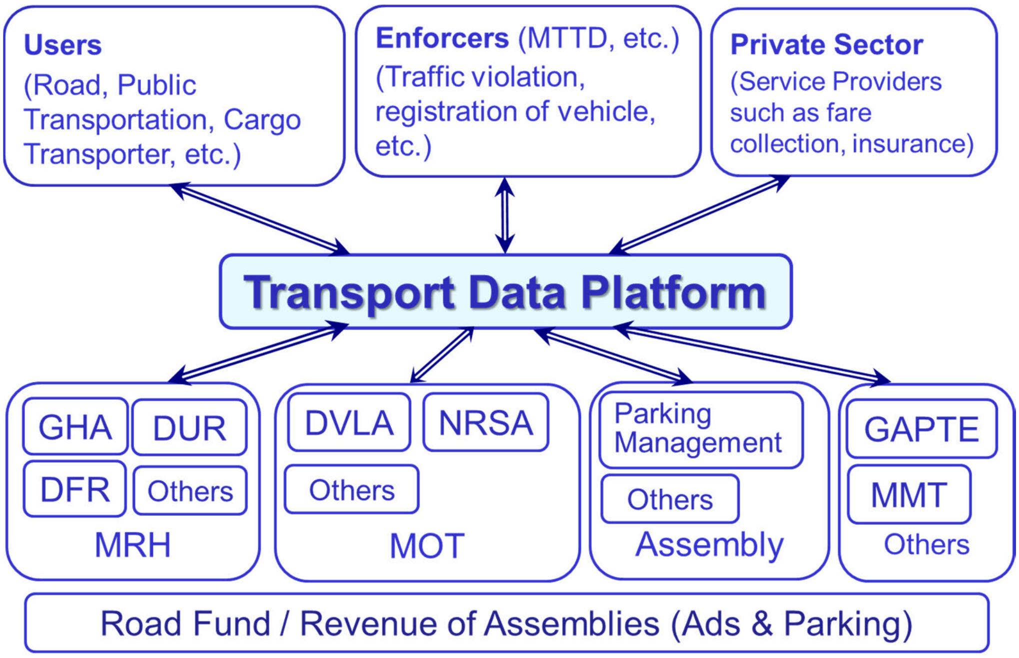
(2) Vehicle Management by using FMS and related Technical Cooperation Project on Road Safety

The implementation of a technical cooperation project aimed at reducing traffic accidents for all long-distance buses between the Accra Metropolitan area and other cities could be considered. In Tanzania, Land Transport Regulatory Authority (LATRA) introduced Fleet Management System for all long-distance buses to monitor the speed and if a driver over speeded, then the fine is automatically imposed to the driver. This system is very effective to reduce the traffic accident. In fact, the number of the accidents of the long distance buses had been reduced approx. 35% per year between 2017 and 2019. As it is one of the successful cases, JST recommends introducing similar system in Ghana too.

Although the distance between Accra and Kumasi is about 250km and is assumed to have a large number of users if the bus is safe, in reality it is predominantly traveled by plane and flights are always full. Therefore, improving the safety of long-distance buses will help to stimulate demand for travel by bus. It would be worthwhile to implement a project to verify the effectiveness of traffic accident reduction by introducing a fleet management system (FMS) for long haul buses and strengthening of enforcement on over-speeding by using FMS. The counterpart agency will be considered from the road safety related agencies such as NRSA, MTTD of Ghana Police Service, and DVLA. It is important to note that MTTD of the Ghana Police Service operate under the Ministry of Interior but JICA doesn't have any recent cooperation with regard to infrastructure activities. NRSA and DVLA is also new to JICA's cooperation.

In addition, the introduction of the FMS to other public transport systems in Accra will help to reduce accidents. The introduction of the FMS to the intra city bus will allow the collection of road traffic information, such as traffic congestion in the Accra metropolitan area, and the exploration of the possibility of providing it to road users, which will contribute to alleviating traffic congestion in the city in the future. In addition, since probe data is collected by FMS, traffic signal control based on the probe data will help to minimize the number of vehicle detectors, thereby creating an environment in which Japanese signal manufacturers can develop advanced traffic signal systems with superior technology.

If this data collection mechanism can be extended to all relevant agencies, it may become a platform for cooperation among agencies through ITS (See the Figure 7.2.4 below) in the future.



Source: JICA Study Team

Figure 7.2.4 Image of Transport Data Platform

Collaboration between organizations is not easy, however it is important to utilize the platform so that each organization can more effectively fulfill its responsibilities and duties through the joint work of collecting, analyzing, and providing various data on road transport. This platform is an opportunity for inter-organizational collaboration. Which organization will manage this data platform will need to be discussed and agreed upon by all parties involved.

7.3 Summary of Project Proposals for Kumasi

As mentioned in the Chapter 3, 1) Introduction of corridor-based control signal, 2) Pilot project for improvement of transport issue in Kumasi were proposed as potential direction for ITS project formulation in Kumasi. The outline of the scope of the project is shown in the following tables.

(1) Short Term Project (Approx. within 3 years)

The JST shows two (2) projects in the following table. The one is related to the traffic signal and the other is related to parking management using ITS.

Table 7.3.1 Proposed Short Term Project

Name of the Project	Outline of the Scope of Work	Executing Agency
The Project for introduction of traffic signal using corridor based control system in Kumasi	• Introduction of corridor based control system to the several major corridor in greater Kumasi Metropolitan Area. • Existing innovative signalized roundabout should be studied how to incorporate into the corridor control • The institutional framework of operation of the signal should be established since there are different owner's signal along the corridor	Department of Urban Roads
Technical Cooperation Project for addressing transport issues in Kumasi including pilot project	• Pilot project, for example, introducing effective parking management system by providing available parking information for the road users • Through the pilot project, aiming enhancement of a coordination mechanism among the stakeholders for addressing various transport issues.	DUR, KMA, KNUST It is required to clarify prior to the project implementation.

Source: JICA Study Team

(2) Middle to Long Term Project (more than 3 years to 10 years)

JST also recommends expanding the area wide traffic signal control from the corridor based control system in Kumasi metropolitan area. In addition, there seems to be a possibility to implementing the technical cooperation project for cooperation among the different government agencies through the data collection, utilization and sharing process by expanding the coordination mechanism mentioned above.

Table 7.3.2 Proposed Middle to Long Term Project

Name of the Project	Outline of the Scope of Work	Executing Agency
The Project for Development of Area Wide Traffic Control System in Kumasi Metropolitan Area	• Introduction of area wide traffic control system by expanding corridor based control system in Kumasi Metropolitan Area. • Introduction of probe car data collection/utilization concept to reduce the traffic counter. • Establishment of Traffic Control Center	Department of Urban Roads

Source: JICA Study Team

The details of each are described in the following sections.

7.4 Project Implementation Scheme for Kumasi

7.4.1 Possibility on Introduction of Traffic Signal Using Corridor Based Control System

(1) Background

In the Study on the Comprehensive Urban Development Plan for Greater Kumasi, the intersection improvement and introduction of traffic signal were recommended in the Figure 3.3.7 as one of the traffic management related projects. However intersection or roundabout improvement projects by construction of flyover has not been implemented shown in the Table 3.3.2. Those intersection/roundabout are located in the crossing point of inner ring road and major radial arterial roads. As for the signalization of the intersection, although the progress is shown in the Figure 3.5.1, those signals are controlled individually. Thus it is hard to ensure the smooth traffic flow in those area's road network.

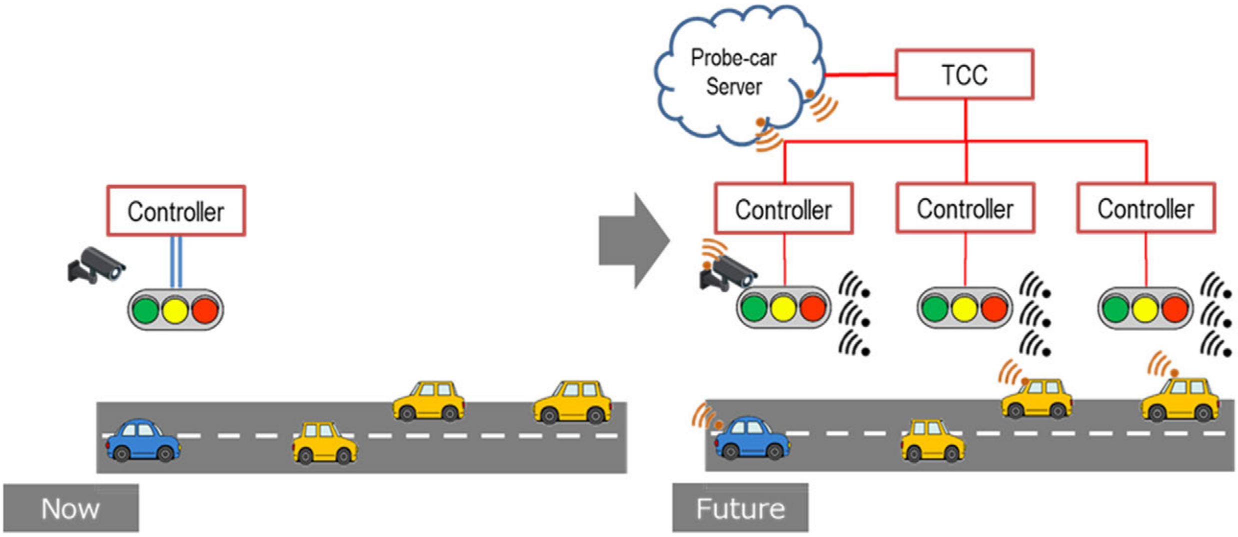
On the other hand, BRT and Type B bus[1] are planned for the inner ring road and the major radial arterial roads as shown in the Figure 3.3.4. Hence it is an important issue to ensure the smooth traffic flow for those major arterial roads.

(2) Technical Approaches for corridor based control

If there is an existing traffic signal using area wide control or corridor based control system, it is necessary to integrate the control method as shown in Figure 7.2.1, however in the case of Kumasi, since none of the methods have been introduced yet, JST recommends introducing the corridor based control signals for the arterial roads. The concept is shown in the Figure 7.4.1. As for the existing traffic signal, it will be incorporated into the corridor based control signals.

In the future, it may be possible to require public transportation vehicles to be obligated to equip with a GPS tracking system in order to monitor traffic conditions, and to utilize the data collected from the tracking system for signal control. However, in order to do so, separate initiatives/project to collect such data from this signal project will be necessary. This corridor based control signal project is recommended to be implemented in Short Term, and realistically, a sensor will be installed to detect the length of traffic congestion for signal control. In the future, when probe data can be used, the number of sensors for signal control can generally be reduced.

[1] High capacity public transport system (bus) as the backbone of the transportation system is called Type B bus system

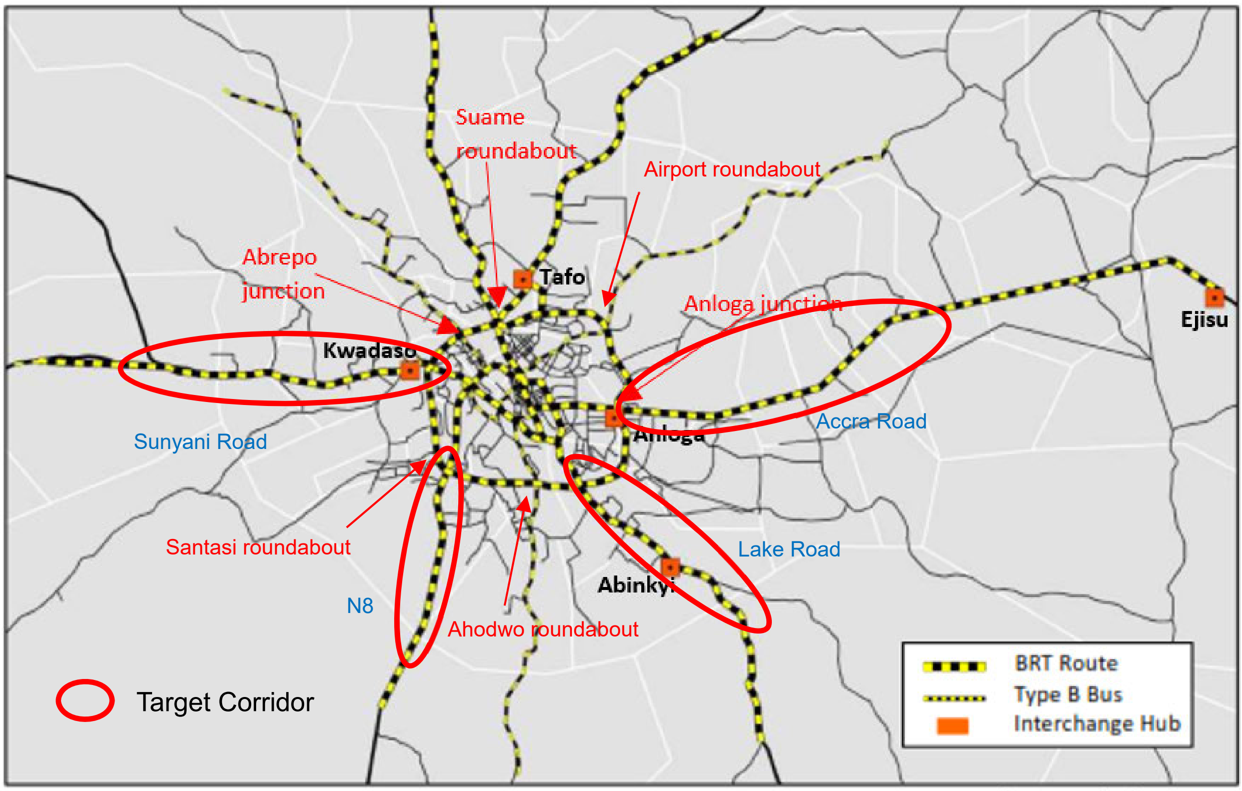


Source: JICA Study Team

Figure 7.4.1 A Model for the ITS/Traffic Management System Development for Kumasi Case

The target routes for the project will be selected from the radial corridors that connect to Inner Ring Road, where BRT bus system are planned to be introduced, as priority routes for the study, taking into consideration the necessity, urgency, and relevance of the project.

In the next study in which the project scope will be materialized is planned to focus on the route shown in Figure 7.4.2.



Source: JST add information to the study on the Comprehensive Urban Development Plan forGreater Kumasi by JICA, 2013

Figure 7.4.2 Target Corridors for the Corridor Based Control Signal (Tentative)

The target corridors are Sunyani Road, Accra Road, Lake road and N8. As for N8, it is selected as it will be a good case for checking of effectiveness of traffic control in addtion to the past infrastructre based countermeasure. In fact, JICA has been contributed to enhance the infrastructure capacity of this corridor. Others are selected as prioritized corridors for BRT plan according to the recent study.

The area within the Inner Ring Road will not be the target of the scope of the next study since the area is considered to be beyond the limits of control by traffic signal and it would be required to reduce the in-flow traffic volume or other counter measures.

According to the Study on the Complehensive Urban Development Plan for Greater Kumasi by JICA (2013), flyover construction was recommended for 5 locations of the Inner Ring Road. Those are Anloga Intersection, Airport Roundabout, Suame Roundabout, Santasi Roundabaout and Ahdowo Roundabaout described in Chapter 3, Table 3.3.2. However as those grade separation plan was still not implemented yet, the effectiveness after introduction of traffic signal using corridor based control system would be limited.

The ITS including coordinated traffic signal control is able to enhance the traffic flow within the existing road capacity. Hence if the traffic demand exceeds the current road capacity, hard infrastructure construction such as grade separation or road widening is required as an countermeasure.

As for the innovative signalized roundabout described in Chapter 3 Cluase 3.5.1 (2), it will be examined whether it is effective to adopt this method or to convert it into an intersection at locations that are currently roundabouts in the next stage study. In this regard, it is essential to have the cooperation of KNUST.

Noted that due to COVID-19 outbreaak, the consultant team members could not visit Kumasi. Hence it was difficult to understand the micro features of the traffic problem and to consider what would be a more appropriate way of addressing it. For example, those are geometrical improvement idea for individual intersection by checking at site, appropriateness of the innovative signalized roundabout for the road users in Kumasi, maintenance capability and challenge for the existing similar equipment in Kumasi and so on. Hence in the next stage study, those matters should be taken into account.

(3) Project Implementation Structure including O&M stage

As shown in Chapter 3 Figure 3.5.1, there are signals managed by DUR and GHA on the same Accra Road. When these signals are integrated into the same controlling system, it is necessary to clarify the responsibilities of individual tasks for the operation of the control system, maintenance of the signals, and cost sharing. To clarify the allocation of responsibility to each organization is also important in the project implementation. For the recommended project's case, referring to the demarcation of responsibility of the tasks in signal control project which was already introduced in Accra, it is considered appropriate for DUR to take the lead in the implementation of the project and operation & maintenance of the signals and the control center.

The suggested responsible tasks of the executing agency and related organizations during project implementation and operation and maintenance are shown in the table below.

Table 7.4.1 Executing Agency and Related Organizations in the Project Implementation and O&M Stage (Tentative)

Supervisory Agency	Organization	Responsible Tasks in Project Implementation	Responsible Tasks in Operation and Maintenance
MRH	DUR	Executing agency and counterpart for overall management and implmentation of the project	Operation of the Traffic sugal using corridor based control system Parameter setting by engineering aspect Maintenance of center controller, equipment of the siganls except for the GHA's property
	GHA	Coordinating with DUR for the signals under GHA's management	Responsible for the maintenance of the GHA's signal
Ghana Police Service	MTTD	Traffic enforcement by law	Traffic enforcement by law Traffic control if vehicles are getting stuck in a intersection
MOT	NRSA	Regulation support for the project plan	Regulation support for the operation
MLGRD	KMA	Provision of information on one way plan or other traffic management plan at design stage	Coordinating with others on traffic management (parking management, etc.)
KNUST	RTREC Kumasi	Support on evaluaton of innovative signalized roundabout at design stage Provision of recent traffic data	Research and recommendation on traffic management Data analysis HR contribution

Note) MTTD: Motor Transport and Traffic Directorate, MLGRD: Ministry of Local Government and Rural Development, KMA: Kumasi Metropolitan Assembly, RTREC: Regional Transport Research and Education Centre

Source: JICA Study Team

(4) Further measures to ensure the sustainability

In order to make full use of the signal equipment to be installed, and ensure the sustainability, the following points are recommended also.

1) Utilization of probe data collected from the probe car

The technical cooperation project on the probe data including collection of probe data, introduction of traffic signal control by using it, and development of human resources for data analysis is recommended. If possible, establishment of a system for continuous use of probe data is also considered. With the possibility of the BRT being introduced for the major radial corridors and possibility of construction of outer ring road, it is expected that traffic demand will continue to change even after the traffic signal control system is introduced. Therefore, the program aims for the signal operator to enhance the capacity of traffic signal control by utilizing prove car data.

2) Cooperation on operation and maintenance of traffic signal control

Technology transfer that aims to improve maintenance capabilities, including preparedness for sudden events such as cable disconnection, points to check during periodic inspections, and visualization of the process of securing a budget for spare parts.

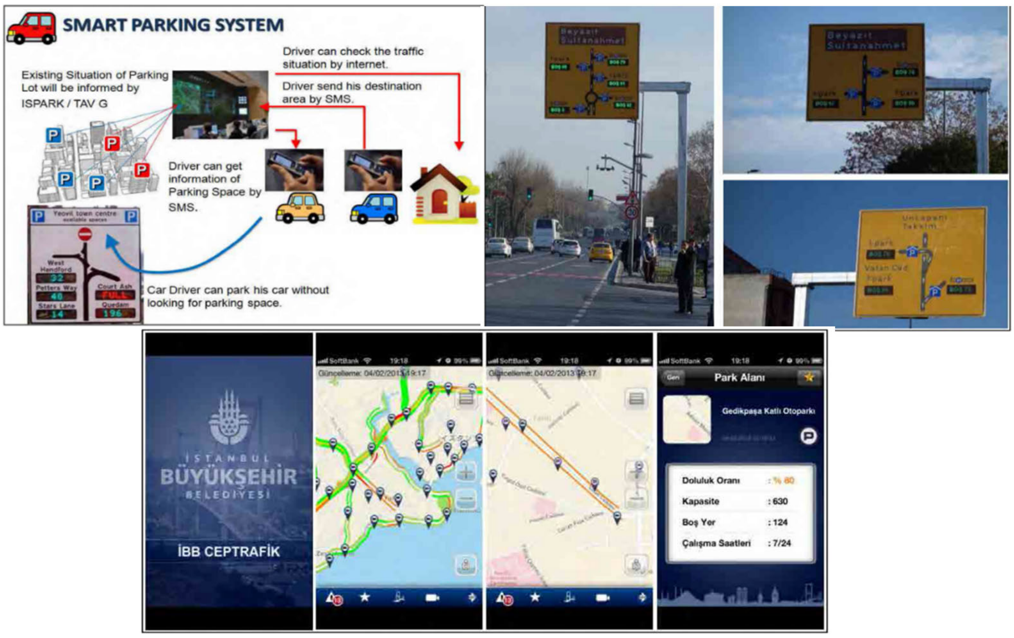
It includes basic maintenance knowledge including the strengthening of the management skill for the outsourcing maintenance work. It also includes improvement of maintenance budget estimation skill both for normal maintenance and emergency cases.

3) Support for the Operator to expand the traffic signal control area by itself

After the traffic signal control system is introduced, the coverage area of the signal control will be required to expand in the future. For such cases, it will be required the capacity development for signal control area expansion planning. The program may include the trial study on cost efficient system including wireless communication between traffic control center and on-site controller and/or possibility of reducing the on-site traffic sensor.

7.4.2 Possibility on Technical Cooperation Project for Addressing Transport Issues

The recommended technical cooperation project aims to improve the stakeholders' cooperative relationship through the implementation of the specific pilot project. A specific pilot project could be something like providing road users with information on the availability of parking spaces in the inner ring road area of Kumasi, as an example. The reason for this is that there is both on-street and off-street parking within the Inner Ring Road in Kumasi, however, there is a lack of information on the availability of parking spaces, and therefore, reducing the number of vehicles looking for parking spaces could lead to an improvement in traffic congestion. A system to inform drivers of available parking spaces, introduced by JICA in Istanbul in 2014, as a sample, is shown in Figure 7.4.3.



Source: JICA Traffic Demand Management of Historical Area in Istanbul (iSTDM) Final Report: Vol.1 2014

Figure 7.4.3 Sample Case: Social Experiment of Smart Parking System in Istanbul (2014)

There are several technologies that can be used to provide road users with information on available parking space, and it seems possible to have private companies in Ghana develop such a system. Organizing the requirements for this, however, will require consultation with the parties involved in parking management. There is also room for consideration of converting payment from a manual system to a cashless system. To address such issues and to proceed with the pilot project, we recommend a technical cooperation project in which experts will be dispatched. In Kumasi, there is the Kumasi Business Incubator (KBI), an Incubator Hub established by the eGhana Project. An augmented eTransform Project for that is also ongoing. The pilot project will be implemented with consideration of utilizing these resources. Through the implementation of the pilot project, it is aimed to strengthen the relationship between the stakeholders involved so as to apply to addressing of other traffic issues in Kumasi area. The recommended executing agency will be considered from DUR, KMA and KNUST. It is important to note that KMA operates under the Ministry of Local Government and Rural Development but JICA doesn't have any recent cooperation with regard to infrastructure activities. KNUST is also new to JICA's cooperation.

7.4.3 Possibility on the Project for Development of Area Wide Traffic Control Systems

After the implementation of the corridor-based signal control project, the construction of part of the outer ring road and the introduction of BRT and quality bus system are expected to be gradually implemented. On the other hand, as predicted in JICA's 2013 study, traffic demand is estimated to gradually increase.

Even with the implementation of measures such as freight transportation and traffic management in the CBD area, it is estimated that area wide traffic signal control system will be necessary in the mid to long term, not only on a corridor basis, considering the growth in traffic demand. Therefore, it is important to collect traffic data in preparation for the introduction of area wide traffic signal control. It is also important to make use of the stakeholders described in the previous section, and to collect traffic data in creative ways, for example, by requiring public transportation to be equipped with GPS tracking systems, by using cell phone location data called CDR and so on.

CHAPTER 8 DEVELOPMENT NEEDS AND PROJECT FORMULATION FOR DAR ES SALAAM

8.1 Summary of Project Proposals

In Dar es Salaam, the Revised M/P[1] required to achieve traffic management inside the Nelson Mandela Road until 2025, and in order to achieve this, this study recommends that ITS be used in conjunction with infrastructure development such as grade separation for major intersections. In addition, in the draft DART ITS Master Plan, it showed that there is a high demand for coordinated traffic signal control, PTPS and traffic information provision, thus there is also a high demand for coordinated traffic signal control system development projects in line with the progress of BRT projects.

Considering the mentioned conditions, this study recommends the following projects in the short-, medium-, and long-term.

(1) Short Term Project (Approx. within 3 years)

JST recommends implementing the following projects;

Table 8.1.1 Prpposed Short Term Project

Name of the Project	Outline of the Scope of Work	Executing Agency
The Project for development of coordinated traffic signal control system along the BRT corridor	• Comprehensive and area-wide coordinated traffic signal installation concept with priority to the BRT corridors. • PTPS function is required for BRT corridor • Variable Message Sign (VMS) introduction at strategic locations in the road network • Establishment of comprehensive Traffic control center	TANROADS DART Traffic Police
Passenger Information System for BRT	• Introduction of Passenger information system for BRT users via on-station, on-board, individual users via smartphone, drivers and station staffs. • The system will be a part of above Traffic Control Center function	DART

Source: JICA Study Team

(2) Middle to Long Term Project (more than 3 years to 10 years)

JST also recommends implementing the technical cooperation project for cooperation among the different government agencies through the probe car data collection, utilization.

Table 8.1.2 Proposed Middle to Long Term Project

Name of the Project	Outline of the Scope of Work	Executing Agency
Probe vehicle data utilization and sharing project	• Introduction of fleet management system (FMS) to the public transportation in Dar es Salaam for collecting probe car data. • Utilization of collected probe car data for traffic management and traffic information sharing among stakeholders • Establishment of data collection/ management center for it. • Implementation under PPP scheme	LATRA/TRA TANROADS Private companies

Source: JICA Study Team

[1] JICA, the Project for Revision of Dar es Salaam Urban Transport Master Plan, Final Report, July 2018

The details of each are described in the following sections.

8.2 Project Implementation Scheme for DSM

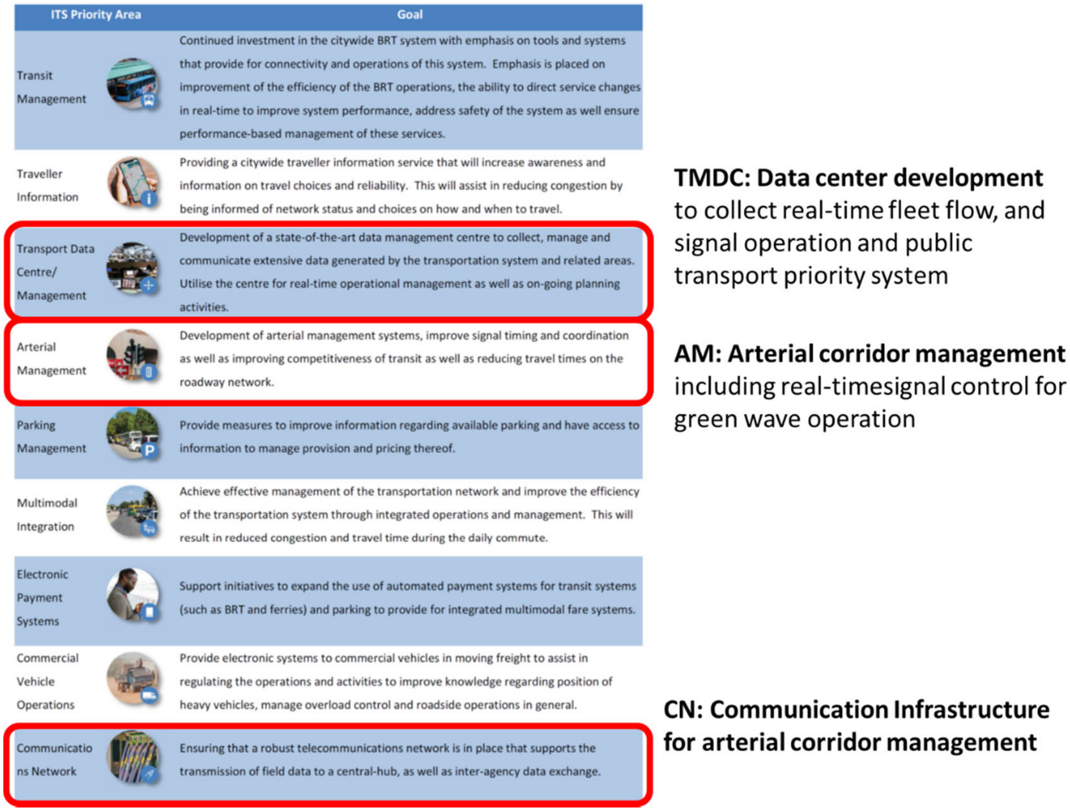
The study team needs more discussion on proposals of the DSM ITS strategic paper and DART ITS scoping, however, the following proposals could be itemized for further consideration.

8.2.1 Coordinated Traffic Signal Installation Project for BRT Corridors

Comprehensive and area-wide coordinated traffic signal installation concept with priority to the BRT corridors with the PTPS function is the expected goal of the project proposal in this section. The following points are several separated components.

(1) Project Package Idea

This package concept follows the DCC ITS Strategy package, covering three items of prioritized ITS development areas, i.e., TMDC (Data center and traffic control center development), AM (Arterial corridor management), and CN (Communication Infrastructure), as shown in below.



ITS Priority Area	Goal
Transit Management	Continued investment in the citywide BRT system with emphasis on tools and systems that provide for connectivity and operations of this system. Emphasis is placed on improvement of the efficiency of the BRT operations, the ability to direct service changes in real-time to improve system performance, address safety of the system as well ensure performance-based management of these services.
Traveller Information	Providing a citywide traveller information service that will increase awareness and information on travel choices and reliability. This will assist in reducing congestion by being informed of network status and choices on how and when to travel.
Transport Data Centre/ Management	Development of a state-of-the-art data management centre to collect, manage and communicate extensive data generated by the transportation system and related areas. Utilise the centre for real-time operational management as well as on-going planning activities.
Arterial Management	Development of arterial management systems, improve signal timing and coordination as well as improving competitiveness of transit as well as reducing travel times on the roadway network.
Parking Management	Provide measures to improve information regarding available parking and have access to information to manage provision and pricing thereof.
Multimodal Integration	Achieve effective management of the transportation network and improve the efficiency of the transportation system through integrated operations and management. This will result in reduced congestion and travel time during the daily commute.
Electronic Payment Systems	Support initiatives to expand the use of automated payment systems for transit systems (such as BRT and ferries) and parking to provide for integrated multimodal fare systems.
Commercial Vehicle Operations	Provide electronic systems to commercial vehicles in moving freight to assist in regulating the operations and activities to improve knowledge regarding position of heavy vehicles, manage overload control and roadside operations in general.
Communications Network	Ensuring that a robust telecommunications network is in place that supports the transmission of field data to a central-hub, as well as inter-agency data exchange.

Source: JICA Study Team

Figure 8.2.1 Proposed Project Background for Coordinated Signal Installation

Those three ITS prioritized areas are infrastructure for traffic management, which require public investment. The other 6 areas are applications for BRT and passenger service operation, not related to direct public interest, need coordination with private sectors, and WB DUTP has initiated implementation of several sectors already.

The following components (2) ~ (8) are required to realize the three selected areas.

(2) Traffic Control Center Development Component with proper I/F development

As mentioned in section 4.6.2.(2), the TCC for DSM should be designed to realize area-wide control by overarching the existing traffic signal controllers from various manufacturers with multi communication protocols. The software development of the I/F for multi communication protocols will be the technical challenge for this package. The capacity of the TCC should be properly designed as it should cover all major corridors in DSM.

The TCC should be delivered in a proper building, therefore, a building component should be included in the package. The DART premises in Ubungo intersection have enough spaces, and is located at a strategic place for construction. The DART also has a new HQ office in DES with 9 stories[2], which will minimize the cost for building and can accommodate the expected TCC function for various stakeholders involvement in a place[3]. However, the team may recommend avoiding concentrated system design for resiliency and security. The following concept should be considered, i) sub-TCC in TANROADS regional office in small scale, ii) data backup center in government server, iii) etc.

A proper operation institutional design should be considered to accommodate the proper technical and operational staff in the TCC, including which organization should have the representative office for enforcement. DART, TANROADS (with TEMESA), BRT operators and Police are essential stakeholders, and a private company office for technical support staff should be considered.

The operation cost for the TCC including the communication cost should be calculated. The RFB of Tanzania has experience to secure the maintenance budget continuously.

This project can be implemented by the TANROADS, which 100% public investment basis, as TCC has little essence for private investment. Financial assistance should be considered.

(3) Coordinated Signal Control along the BRT Phase 1

The individual controlled signals installed by the WB DUTP Package A4 can be used as it is. There are two ways to realize the coordinated signal control along the BRT Phase 1, i.e., i) software development compatible to the present control panels for existing traffic signal, which is challenging for international contractors due to unclear various engineering protocols of signal control panel setting, and ii) replacement of the present control panels compatible with the TCC, which is simple and secured in implementation. The JST recommends the latter option for further consideration.

(4) Traffic signal delivery packages along the BRT Phase 2

Traffic lights and ITS components have not yet considered in the coming BRT phase 2 alignment, funded by the AfDB. The project will develop the pipelines and technical holes for cabling; however, it has no cabling components, therefore, the BRT Phase2 requires ITS components to create smooth traffic flow along the corridors for its 19.3 km operation routes.

This package will contain i) a design for a proper traffic control system and geometric improvement, ii) delivery of signal components with proper sensors and controllers, and a communication system along the target corridors, iii) construction work for geometric improvement. Necessity of on-site sensor detection should be assessed with the following package (3).

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[2] Locating along the Sokoine Drive. Previously the building was used by Ministry of Constitutional Affaires, however, due to the moving of central government ministries to Dodoma, the DART has received the building. The building is under safety and structural assessment and DART will rehabilitate the building.

[3] According to DART Chief Executive, on 25 Nov 2020.

The pedestrian accessibility and safety to BRT is key issues. The signal packages should consider installing pedestrian signals as necessity.

This project can be implemented by the TANROADS, 100% public investment basis, as the traffic signal component has less essence for private investment.

(5) VMS for Vehicle Traffic Diversion

Delivery of the variable messaging signboards (VMS) at strategic locations in the network should be considered. When the TCC detects congestion or problems in the network, the TCC can broadcast a message for stimulating diversion from the target section.

It is mainly designed for vehicle traffic flow. VMS can present not only such urgent notice to drivers, but also traffic safety promotion, notice of major events in the city which may cause congestion, marketing notice of BRT and public transport services, including P&R promotional message from vehicle use to BRT, etc.

The VMS operation will require electricity and maintenance. Advertisement components could be considered to cover the operation cost. A certain percentage of the presentation periods on VMS can be shared for private advertisement, or a permanent panel could be attached as advertisement.

This project can be implemented in a PPP basis if the advertisement package is included. The infrastructure portion should be public investment. The TRA will collect the advertisement revenue, which will be reimbursed to the road agency. The expected private operator under PPP scheme will undertake the advertisement business management including revenue control and sales.

(6) Probe vehicle data center

Traffic data collection via probe-vehicle can minimize the on-site delivery of the traffic detection sensor system, which will minimize the initial operation cost. This component proposes to deliver the data collection system through the probe vehicles system and delivery of the data center.

This project can be implemented by the LATRA/TRA, TANROADS and private companies. LATRA/TRA are the regulation agency for vehicle roadworthiness, LATRA can order the public transport vehicles to equip the on-board unit (OBU) for probe vehicles. JST considers Daladala operators and taxis in the city can be the partners for the probe vehicle operation.

This project can be implemented in a PPP basis. The infrastructure packages should be public investment and the operational cost including OBU should be subsidized by the public side, but the private side may cover some portion of the operation cost.

(7) Cabling or Communication System

A proper communication cable network infrastructure can be delivered along the BRT corridors, for signal control, sensor development and CCTV delivery. It should be noted that the present Phase 1 and phase 2 has no budget and pipelined commitments with any development partners for cabling system installation, though the civil infrastructure for BRT are already executed.

(8) Implementation Coordination

The stakeholder meeting on 20 Nov 2020 confirmed that DART, TANROADS and Traffic Police should organize a core implementation function for the above projects. LATRA and TARURA will support the implementation. JST recommends those agencies in Tanzania to organize implementation bodies for traffic management beforehand of JICA further study, presenting its strong commitment and interests in DES zonal traffic management.

8.2.2 Passenger Information System for BRT

The DART ITS study may have a detailed proposal on this component. The main component is software development for a messaging system on the TCC. The message system should be properly designed to provide accurate and real-time information for the passengers, through the collected real-time operational data of BRT and road traffic conditions. The media of the information provision can be classified as i) on-station, ii) on-board (bus fleets), iii) smartphone devises for general users, and iv) for drivers and station staff.

The components should be packaged with the TCC delivery services and supervised with DART.

The information delivery for the smartphones should be carefully studied, as DART and U-DART has started some actions. The JST recommends DART not to monopolize the BRT operation data, to share the operation data to multi platforms expecting various transport MaaS service generation in the market, as the TCRA involved 5 communication companies in the market.

The information panels should be delivered to the BRT fleets and stations along the BRT phase 1 and phase 2; however, it can be delivered through the local component, as they are commodities through the local market, can promote the local market, and can expect vandalism.

CHAPTER 9 DEVELOPMENT NEEDS AND PROJECT FORMULATION FOR DODOMA

9.1 Summary of Project Proposals

Dodoma has been developing as the capital of Tanzania. Currently, traffic congestion is limited, however as development along the Dar es Salaam road progresses and the ring road will be developed in the near future, there is concern that traffic will increase along the roads to be developed. Along with that, there are concerns that some congestion will be concentrated. Even in the current situation, there are intersections where traffic accidents are a concern, and there is a need to ensure traffic safety. In view of these circumstances, the JICA Study Team (JST) recommends the following projects.

(1) Short Term Project (Approx. within 3 years)

JST recommend implementing the following project;

Table 9.1.1 Proposed Short Term Project

Name of the Project	Outline of the Scope of Work	Executing Agency
The Project for Development of Traffic Management in Dodoma City	• Introduction of Coordinated Traffic Signal control in Dodoma city • Establishment of Traffic Control Center (TCC) • Necessary communication system between roadside controller and TCC	TANROADS

Source: JICA Study Team

9.2 Project Implementation Scheme for Dodoma

9.2.1 Signal Installation Project

(1) Present status of intersections and traffic accidents

As mentioned in section 4.4.1, there is only one active signalized intersection in Dodoma. The study team observed the following intersections along the inner ring road and identified issues on traffic operation.

1) Wajenzi / Area C

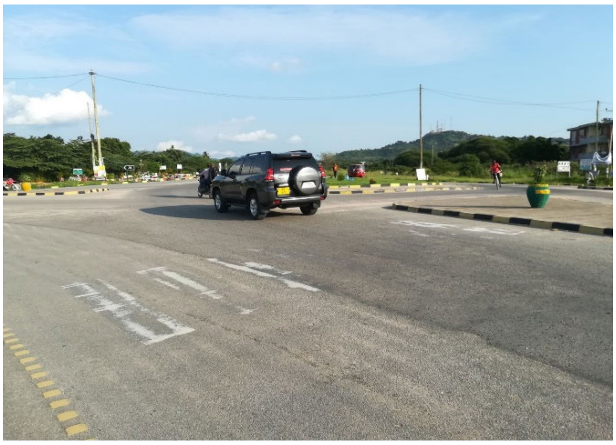
Wajenzi junction is located at the northwest corner of the inner ring road, connecting Arusha road and the access road to the Prime Minister's office. As shown in the section 1.3.2, traffic at this road section is the second heaviest in the city. The Area C junction has truck terminals along the area and the surface of the junction is too rough to realize smooth traffic flow.

Wajenzi junction

Area C junction

Posta junction

Bahi junction



Maua junction

Imagi junction

Source: JICA Study Team

Figure 9.2.1 Existing Junctions in Dodoma

2) POSTA junction, BAHI junction

These are quite large roundabouts. Posta junction is located next to the airport. Bahi junction accommodates both the Arusha road and Singida road traffic. Both are close to schools and students have difficulty in crossing the wide road. The heavy traffic ratio is high as it is a part of the central corridor. The AfDB outer ring road development may divert the heavy goods vehicles inland.

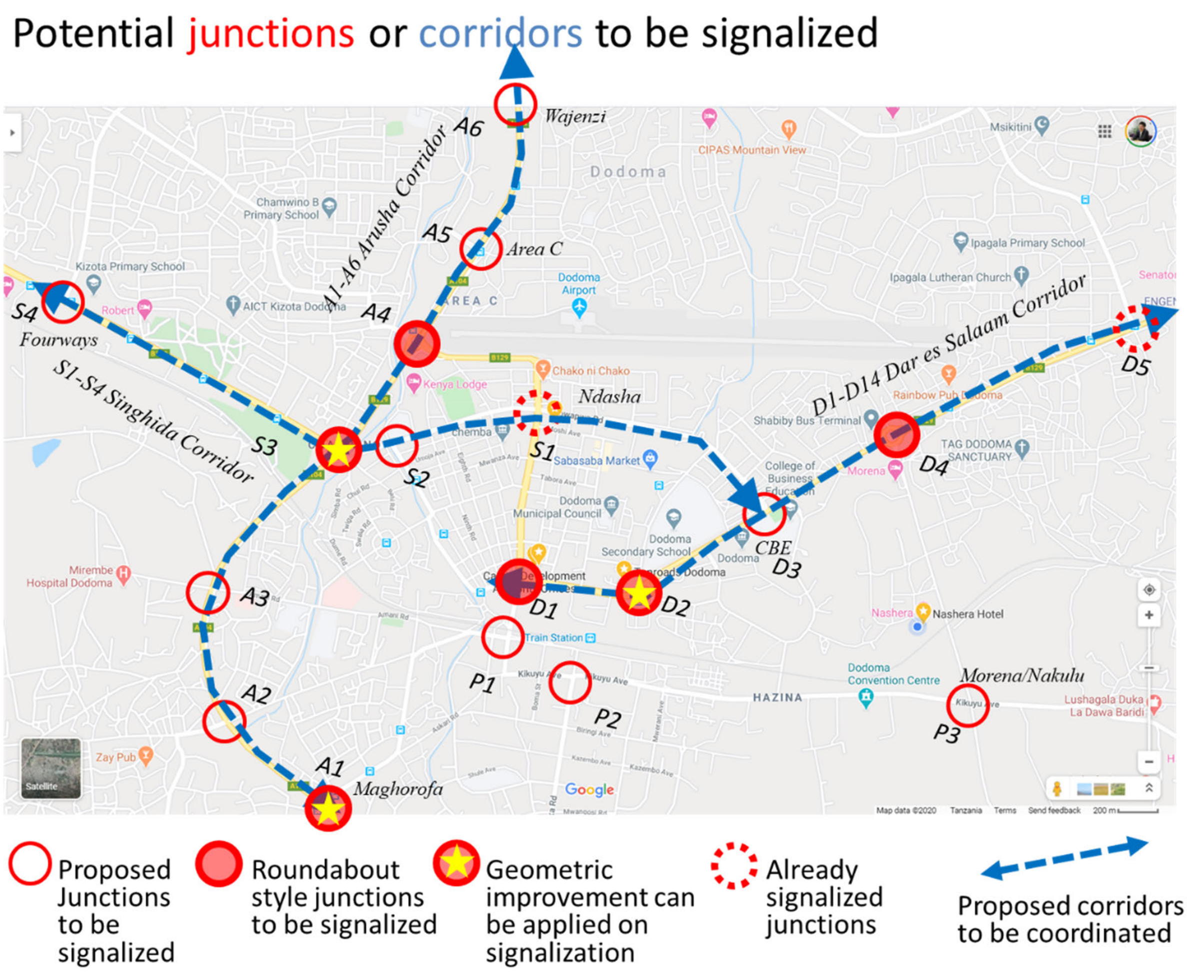
3) Maua RA, Imagi RA

These are small scale roundabouts, connecting to Iringa road. Traffic is not so busy, as shown in section 1.3.2. It seems the road and junctions along this section were improved in 2014.

(2) Signalization Projects

The JST visited the major sites in the Dodoma city, and proposed the following signalization packages with coordination signal control for traffic flow improvement. Some independent signalization from the coordination operation are improved for traffic safety purposes.

1) CBD area and Coordinated functions



Source: JICA Study Team

Figure 9.2.2 Signalization Concept for Dodoma

Three major corridors are specified for coordination control with signal installation, as shown in Figure 9.2.2. The priority corridor is Dar es Salaam road, and junctions with D1-D5 are the first targets. The second priority groups are Arusha corridor with A1-A6, and Singhida corridor with D3-S1-S4.

The DSM corridor is required to accommodate private car traffic between the CBD and government city, however, the residential developments along the DSM road are active and merging points will be difficult to manage in near future even though the heavy good vehicles would be diverted to outer ring roads. It should be noted that the DSM road is ready for widening, which will induce uncontrolled traffic increase, and higher speed operation.

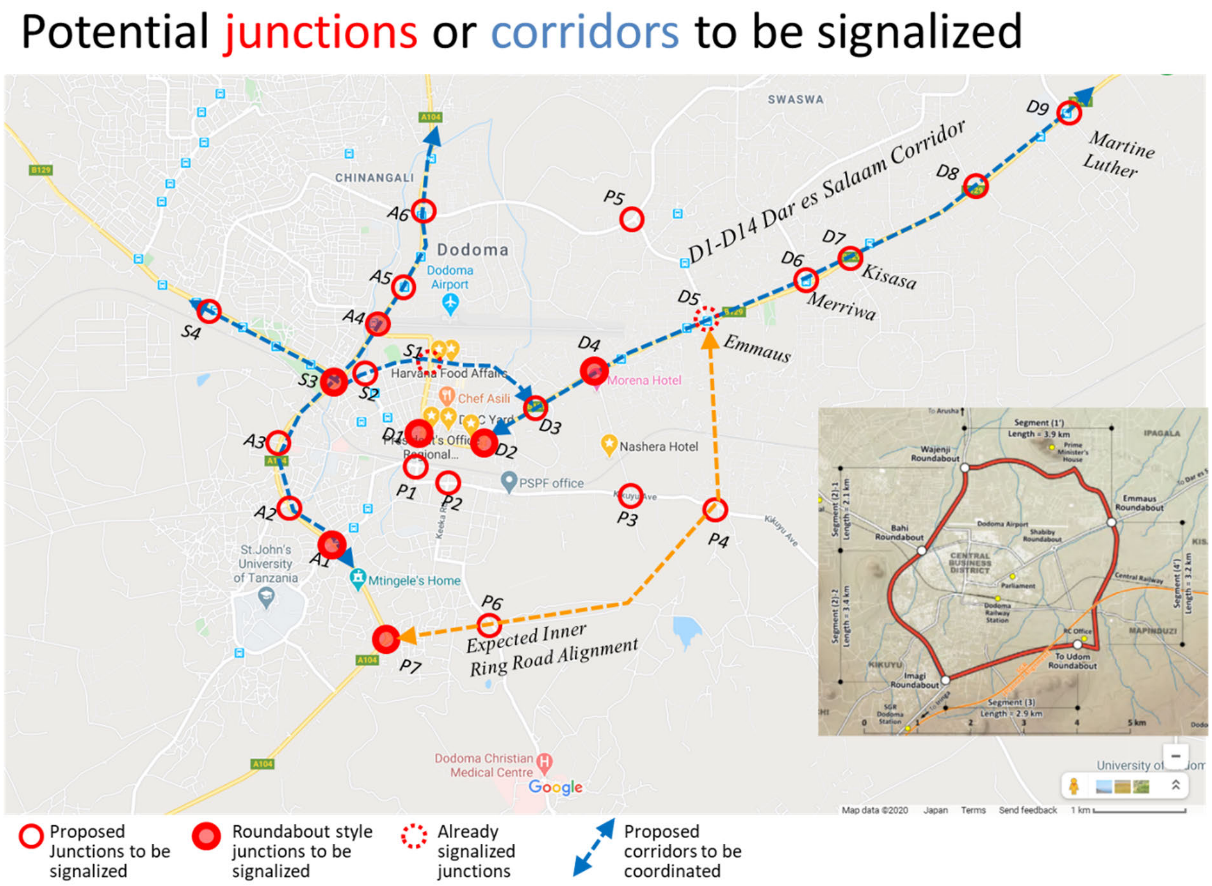
The Arusha road is the second target for coordinated signal installation and geometric improvement. The northern part is residential development along the Arusha road, which is active. The new airport development along the Arusha road is also pipelined. The passenger car ratio in the existing traffic is also higher than other roads. This corridor has the potential of traffic growth and needs for traffic flow management. Also, this is the part of the inner ring road section, which will be combined

The Singhida corridor will be directly influenced by the outer ring road development, which will divert the existing heavy good vehicles along the Shingida corridor. The city road development along the existing airport (as well as town development after the airport closure) will divert the traffic flow from Shingida corridor. However, this section is important as an alternative connection between CBD and Government city.

Some supplemental junctions P1, P2 and P3 should be installed as independent signals with adaptive control function. The present demand is relatively small; however, the traffic safety concerns are high at those junctions. Proper geometric improvements should be considered together with the signal installation.

The D1, D2, D4, A1, A4 and S3 are designed and being operated as roundabout junctions, particularly since S3 and D4 are large ones. Removal of roundabout and geometric improvements are required for efficient operation of traffic signal, and TANROADS Dodoma agreed that the roundabouts at D2, A1, S3 can be removed to realize the proper traffic operation with signaling, however, D1 intersection is the local symbolic junction with a statue and TANROADS Dodoma recommended to keep the present operation. D4 and A4 are large size intersections, and difficult to make decision in this stage. JST recommends considering in later stage.

2) DSM corridor coordination and Inner/Middle ring road



Source: JICA Study Team

Figure 9.2.3 DSM Corridor Coordination and Inner Ring Road

The coordinated signals along the DSM corridor would be installed for a 10 km stretch to realize the consecutive smooth traffic flows along the corridor, and the study identified the necessary junctions to be coordinated as shown in Figure 9.2.4 and Figure 9.2.5.

The junctions D6 to D14 are the merging points of incoming traffic flows from the peripheral residential development in Dodoma. D10-14 are also merging locations of the newly developed bus terminal and market funded by the World Bank. The Middle ring road will be developed along the new market and crossed with DSM road at D10.

The independent signals (P1 to P7) proposals are also shown in Figure 9.2.3. The P4-P7 are proposed at the junctions along the expected inner ring road, where proper traffic management are necessary.

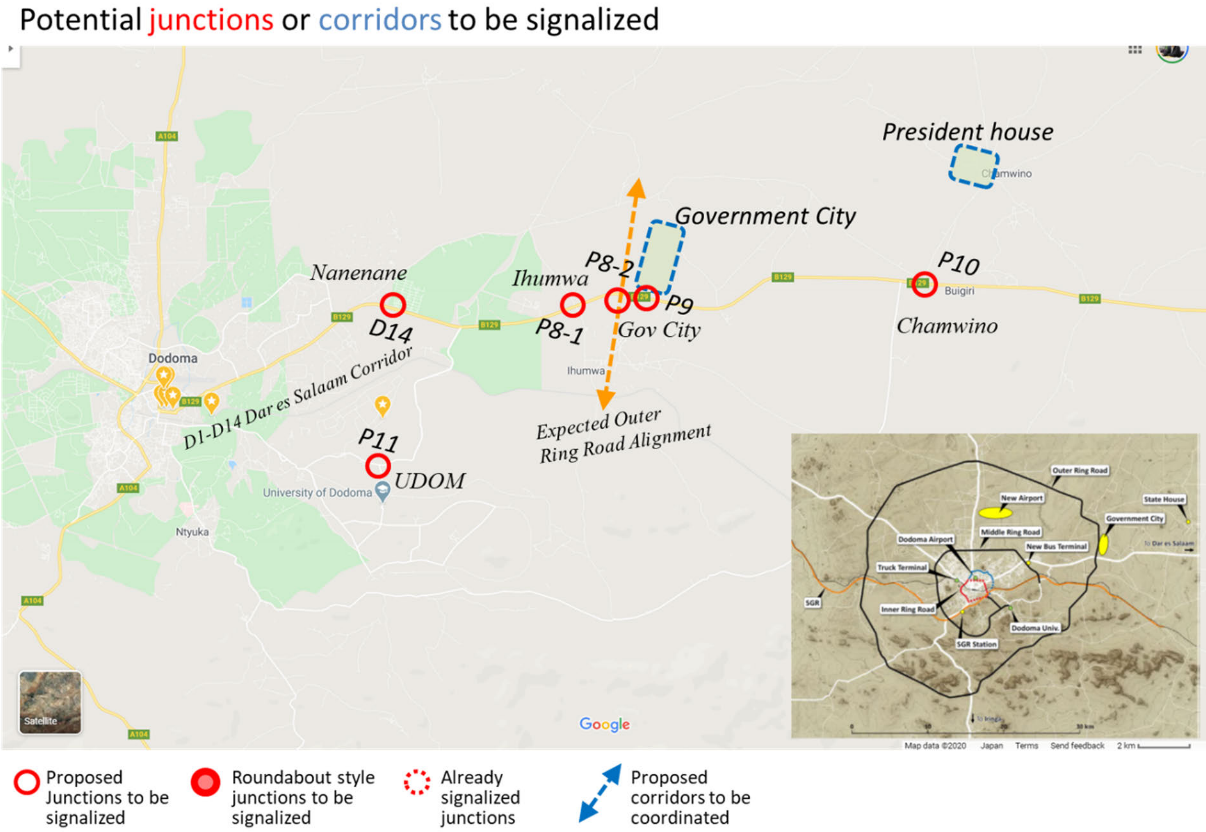
Potential junctions or corridors to be signalized

Proposed Junctions to be signalized | Roundabout style junctions to be signalized | Already signalized junctions | Proposed corridors to be coordinated

Source: JICA Study Team

Figure 9.2.4 DSM Corridor Coordination

3) DSM corridor coordination and Outer ring road



Source: JICA Study Team

Figure 9.2.5 DSM Corridor Coordination

Beyond the Nanenane junction (D14), DSM signal coordination are not necessary as the merging points are less frequent. The remaining junctions are proposed as individual junctions with sensor adaptive control. P9 and P10 are important for government city and president office access. The junction with outer ring road (P8-2) will be designed as level crossing (roundabout shape), which was originally considered as a grade separated crossing, the signalization can be considered.

9.2.2 Project Implementation Scheme

On formulating the ITS and traffic signal development project in Dodoma, the following technical and institutional issues should be specified with several options.

- Implementing Organization Setting
- Signal Coordination Technical Standard
- System Communication Method
- Data Center Function
- Control Center/System Operator
- Project Implementation Coordination

(1) Implementing Organization

TANROADS should be the owner of the project. The demarcation between HQ and regional offices should be coordinated before organizing the project. A project implementation unit is necessary as the

TANROADS regional office has no capacity for additional new projects and signal installation.

The academic sector (Institute of Dar tech or Arusha tech) should be involved as technical advisors for planning and design stage.

The TARURA regional office or Dodoma City Council road division and the National Police should be involved for traffic management.

(2) Signal Coordination Technical Standard

The JICA team recommends adopting MODERATO for the following reasons.

- High utility in various traffic situations
  - In light traffic, it forms a safe traffic flow by not only reducing delays and stops, but also controlling speed.
  - When close to saturation, it will increase the green-signal time efficiency of the major junctions to maximize the processing of traffic volumes and thus reduce the occurrence of traffic congestion.
  - In super saturation, it directly determines the split and cycle length by taking into consideration of the traffic congestion length calculated from the detector information.
    - In addition, from the viewpoint of traffic management at major junctions, priority control is performed on conflicting traffic flow.
- The green-split-optimization in the cycle
  - To minimize the occurrence traffic congestion, appropriate green-signal time allocation is extended in coordination basis.

(3) Communication System

As for the communication network sections between roadside signal controller and traffic lights, and between roadside controllers and vehicle detection sensors, the high quality communication network is required within the acceptable delay of the data in order to avoid the Green – Green displaying condition to the different direction. Thus, it is common to apply the wired communication network for those sections.

However, there seems to be several options of communication systems, with institutional options for the network section between roadside controllers and the traffic control center. The study team compared major options between roadside controllers at each signalized intersection and a traffic control center shown below:

Table 9.2.1 Options of Communication Systems between Roadside Controller and Traffic Control Center

Communication System	Merit	Demerit
Optical Fiber Cable (OFC) owned by TANROADS Dodoma Regional Office	• It will be TANROADS' own facility. Thus, there will be no running cost to the communication service operator. • OFC is widely used for signal control, thus there will be no concern of interface with the equipment components.	• Installation cost is relatively expensive. • A cut cable incident may happen due to road construction work. Thus, the immediate cable repair work will be required • Required data traffic volume is very small compared to the OFC's transmittable capacity
Wireless Communication (4G) provided by communication service provider	• Installation costs are very low. • There will be no concern of communication failure due to cut cables during the road construction work	• Running cost is required to pay to the data communication service provider • There is no Japanese manufacturer to deliver the traffic signaling system with wireless communication between the traffic control center and roadside controllers (No actual deployment). • Since the delay of data communication is critical, a dedicated service will be required (The cost will be high).

Source: JICA Study Team

As for the institutional task demarcation among the related parties of traffic signal control, the prospective conditions are shown in the following table.

Table 9.2.2 Prospective Institutional Task Demarcation (Tentative Draft)

Communication System	Owner of the communication facility/equipment	Operator/ User	Maintenance Responsibility
Optical Fiber Cable (OFC) owned by TANROADS Dodoma Regional Office	TANROADS Dodoma Regional Office	TANROADS Dodoma Regional Office	OFC network: Outsourcing from TANROADS Dodoma Regional Office
Wireless Communication (4G) provided by communication service provider	Data communication service provider (Terminal Equipment will be the asset of TANROADS Dodoma Regional Office or leased by the operator)	TANROADS Dodoma Regional Office	Data communication service provider

Source: JICA Study Team

Table 9.2.3 Points to Be Considered

Communication System	Major cost during operation	Technical preparedness	Necessary technical knowledge for the personnel of TANROADS Dodoma Regional Office
Optical Fiber Cable (OFC) owned by TANROADS Dodoma Regional Office	• aintenance cost • Repair cost for cut cable	• Network Monitoring System/Network Management System • Testing machine, repair material, and its stock management	Operation and Maintenance on Wired Communication Network (relatively high)
Wireless Communication (4G) provided by communication service provider	Subscription cost for communication service provider	Technical personnel should manage the subscription contract condition between TANROADS Dodoma Regional Office and communication service provider	Contractual condition check capability on wireless data communication (not so high)

Source: JICA Study Team

There will be merits and demerits for both communication systems to be applied between the roadside controller and the traffic control center. If the TANROADS Dodoma Regional Office hopes to obtain its own optical fiber cable network, the necessary budget for operation & maintenance, and immediate repair work should be secured and the required technical skill for the their personnel should be transferred from the contractor to be installed in such a network system. If they consider outsourcing a part of O&M operation or incident response, the necessary budget should be secured.

If the TANROADS Dodoma Regional Office selects the wireless communication service provided by the communication service provider, they should secure the budget for the subscription of the service and require the management of the service level agreement between TANROAD Dodoma Regional Office and the service provider.

(4) Data Center Function

A National Data Center under the e-Government Authority (EGA) could be utilized to minimize the expenditure of the operation and maintenance cost if the center server is introduced under the ITS introduction project. In Tanzania, the center system of axle load measurement monitoring system managed under TANROADS is using the government data center. It is in a better condition compared to individual servers installed and managed by each government agency. However, if the data center is physically far from Dodoma, an appropriate private data center should be considered for utilization in the proposed project.

(5) Control Center/System Operator

The study team shall recommend to develop the control center in the existing TANROADS regional Office for the following reason:

Located close to the D2 junctions along the DSM corridor, strategic place for maintenance and cabling

(6) Project Implementation Schedule Coordination with other projects

The Dodoma inner ring road project is under preparation for JICA grant funding. The schedule of this project is unclear; however, the signal installation project should be synchronized with opening of the inner ring road and outer ring road project, and opening of the widening of the DSM road.

CHAPTER 10 SUMMARY AND FINDINGS

This study conducted a cross-cutting observation of the ITS and ICT application in the transport sector, mainly urban transport, in Kenya, Tanzania, and Ghana. The findings and further proposals for ITS development in each city are summarized in the previous sections, however, the cross-cutting assessment for state of practice on ITS, including the best practices which can be disseminated to the other cities, and proposals for region-wide cooperation can be summarized as follows:

10.1 Outlook of ITS/Traffic Signal Needs

The interests in traffic signal installation varies among the four cities, due to each city's population, urban function, development stage and progress of the pipelined projects. Not only in the target cities, it is common that the ITS application is needed in the second most populated cities.

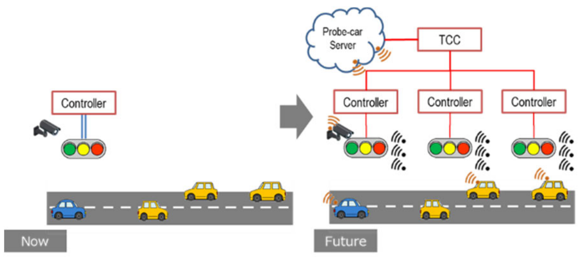
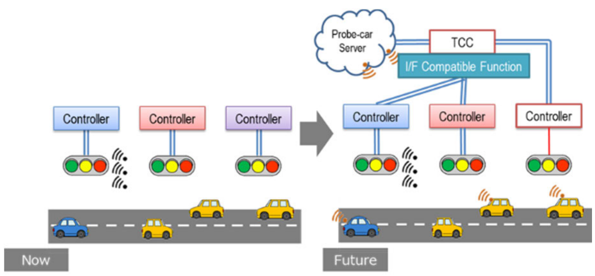
- **Mombasa**: Both CGM itself and other stakeholders acknowledge that the city's traffic management administration is led by the Municipal Government of Mombasa. Traffic management is skillfully divided between the Department of Transport, Infrastructure and Public Works, which is the planning and investment management entity, and the Department of Traffic Inspectorate, which is responsible for operational and monitoring activities. CGM has experience in applying timed one-way and reversible lane regulations at three to four locations in the city and is proactive in traffic management. The three signals currently in operation are independently controlled, and there is no prior coordinated signal control. The remaining roundabout intersections are to be reshaped when the signals are introduced. CGM is not negative on the removal of the roundabout, which requires coordination with the national road agencies, KeNHA and KURA.
  - Besides Mombasa, KURA recommends signal development in Kisumu, Eldred and Nakuru, the second-largest-cities group.
  - KOICA committed on the Nairobi's 25 coordinated traffic signal development as 1st phase.
- **Accra Metropolitan Area:** The coordinated signals have been introduced along the Amasaman corridor in July 2019; additionally, individual control signals have already been introduced on other trunk roads. Arterial intersections in the city are already grade-separated, and the penetration degree of grade-separated intersection is much higher than Nairobi and DSM. Because of the good state of road development, the introduction of additional signals also requires minimal civil engineering work. However, the presence of the coordinated signal system in place will influence the technical interface coordination if the city requires whole coordinated signal system.
  - Ghana government seems to be negotiating with China for a 2nd phase signal development in Accra, which may require more technical complexity for whole city management.
- **Kumasi:** There are no coordinated signals, however, there are 36 individual signalized intersections in the city. ITS plans for coordinated signals with the BRT operation were proposed by the World Bank study. The expected outer ring road construction shall be a key for further traffic management in Kumasi.
- **Dar es Salaam:** BRT Phase 1 along the Morogoro corridor has installed signals, but no coordinated control or PTPS, it's just a fixed timing operation; DART is preparing for the coordinated signal implementation projects at the same time of the BRT improvements, and DART's ITS study report is being finalized. The current TANROADS is in the position to follow DART's ITS plan; TARURA

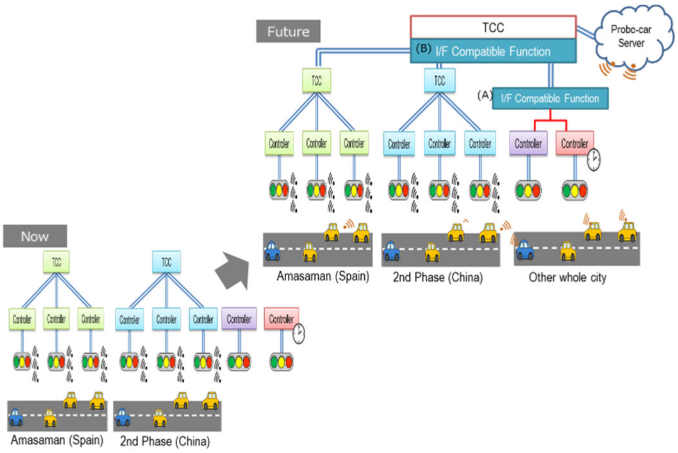
doesn't have much capacity and will follow DART/TANROADS; Technically, ITS system needs to follow SATTC's (SADC's Transportation and Communication Technology Committee) technical standards, but it is probably a signal outlook visibility standard.

- **Dodoma**: Although the city is small in size and traffic volume is low due to a reduction in passing traffic attributed to the future construction of the ring road, the need for road safety is high and the demand for adaptive control is high. There is an interest in coordinated signaling in anticipation of the future.
    - ➢ Other cities such as Mwanza and Arusha are in high demand, more than Dodoma, some may say.

The approach for the ITS development could be classified by the progress of signalization and characteristics of the transport. According to this 4 cities survey, the following approach could be proposed as a kind of ITS development guideline (see chapter 5.4 for detail).

Table 10.1.1 ITS Approach by City Category in Africa

Type	Approaches (Advantage of Japan to minimize the O&M expense)	Expected targets in Africa
Small/Medium and little signalization (Dodoma/Mombasa)	 • Identify major corridors for signalization • Traffic lights and on-site controllers, and cabling for communication are necessary. • Instead of putting sensors, probe information can be collected from probe vehicles and CCTVs to minimize the initial and O&M cost. • TCC can be developed, but existing public-owned server can be used. • Additional to coordinated signals development along main corridors, individual signals installation for safety purpose in its suburb are necessary.	Cities with 500 thousand to 1 million population Secondary populated cities in the country Kenya: Mombasa, Kisumu, Eldred, Nakuru, Tanzania: Arusha, Mwanza, Dodoma Capital cities with less population
Large population with individual signaling (Dar es Salaam)	 • Identify major corridors for additional signalization or Area for signalization • Traffic lights and on-site controllers, and cabling for communication are necessary for new signal installation. The existing signals and controllers can be connected to the TCC through an I/F. • Instead of putting sensors, probe information can be collected from probe vehicles and CCTVs to minimize the initial and O&M cost. • The TCC can connect any signals from variety of manufacturers with I/F, but additional technical study for compatibility is necessary. • TCC can be developed, but existing public-owned server can be used.	Cities more than 2 million populations (Kumasi in Ghana) Capital cities with more than 1 million populations

Type	Approaches (Advantage of Japan to minimize the O&M expense)	Expected targets in Africa
Large population with coordinated signaling (Accra)	• Identify major corridors and areas for traffic control • Traffic lights and on-site controllers, and cabling for communication are necessary for new signal installation. • The existing coordinated systems can be connected to the TCC through an I/F. • Instead of putting sensors, probe information can be collected from probe vehicles and CCTVs to minimize the initial and O&M cost. • The TCC can connect any signals from variety of manufacturers with I/F, but additional technical study for compatibility is necessary. • Need to assess efficiency of investment and assistance if coordinated signals has been implemented to major corridors. 	Cities more than 2 million populations Capital cities with more than 1 million populations (Nairobi)

Source: JICA Study Team

10.2 Best Practices

BEST PRACTICE

The study team found the nine best practices on ITS through the study. These are summarized as follows.

Table 10.2.1 ITS Approach by City Category in Africa

Project	Summary	Section in Report
1. CCTV installation and Operation, Mombasa	The CGM DTIPW installed 90 CCTV cameras at 15 intersections and roundabouts for remote monitoring since June 2019. The DTIPW developed the main monitoring room in the DTI facility. The operation of the CCTV is managed by the monitoring team of DTI, working together with on-site inspectorate staff through SNS (What'sUp) and walkie-talkies.	2.3.3
2. E-parking Operation, Mombasa	CGM DTI started cashless parking fee collection in March 2019. Before the installation, cash-based collection was implemented, however, there were many omissions and leakages, and the average daily revenue was approximately 400,000 KES per day. After the installation, the collection status can be reported in real time, and the daily collections amount reaches 850,000 to 1 million KES.	2.3.4
3. Traffic Signal Installation along the QBS Corridor, Accra	With AFD support, a signal system controllable from the Traffic Control Center has been installed for the main QBS corridor, Amasaman Corridor. The project included procurement and installation of 15 traffic lights, 37 CCTV cameras, and electromagnetic sensors (embedded in the pavement) to measure the traffic flow at each intersection.	3.4.1
4. Bus operation management in GAPTE using Fleet Management System, Accra	Buses for QBS was procured from SCANIA, and the company's Fleet Management System (FMS) was also introduced along with the buses. By this function, bus real-time movement, fuel consumption, driving distance, driving time, idling time, etc., are collected as data on the buses. These are mainly used to assess the driving skills of drivers.	3.4.6
5. Vehicle registration and Driving License registration in DVLA, Accra	The previous vehicle registration system was designed by a paper basis. This project on an electronic registration system consisted of two components: (1) scanning conventional paper-based data to confirm and correct its contents, and (2) development of a vehicle registration database. The project was prepared in 2016, then became operational in 2018. The data between 2017-2019 registrations was input, and work on retroactive registration continues.	3.4.8
6. Weighbridge Operation Monitoring System of TANROADS, Tanzania	The TANROADS, the national intercity road agency, has developed CCTV based weighbridge control center monitoring system since 2015 and started its operation in 2018. The incentives for introducing this system are to be able to check the measurement results later and to monitor that the staff are doing their job properly.	4.4.2
7. LATRA's Vehicle Tracking System, Tanzania	LATRA developed the Intercity bus operation management system with its own budget, which has reduced the number of accidents and fatalities by more than 70% since installation, which is highly appreciated by private bus operators and the surrounding countries.	4.4.5
8. On-Street Parking Management System in Mwanza	TARURA, the on-street parking manager for all cities in Tanzania, has implemented a pilot on-street parking management system with number-plate scanning ICT technology integrated with e-payment collection arrangement since 2019, in Mwanza, the second largest city in Tanzania.	4.4.6
9. Open Policy of the Vehicle Registration Database, Tanzania	TRA, Tanzania Revenue Authority, manages the vehicle registration for vehicle tax levying purpose. TRA opens the database access for various public and private transport service operators to enhance the charging accuracy as well as TRA's enforcement of vehicle registration.	4.4.6

Source: JICA Study Team

10.3 Issues on ITS/Traffic Signal Development

(1) Necessity of Regional Transport Authority for the ITS application

- The study team found the concept of regional transport authority establishment are proposed to the target cities. Commonly, those proposals for such authority accelerate the coordination of ITS project implementation, however, some experiences show delay of establishment of authorities made influence on the ITS application.
  - ➢ Accra was advocated by GAMA as a regional administrative body, and the idea of establishing Accra through the World Bank's UTP was never fulfilled. The DUR proceeded to introduce system signals on the QBS route, but the timing was not suitable to secure funding, so the QBS was introduced in November 2017 and the coordinated traffic signals in July 2019. In addition, Accra was a relatively large municipality within the metropolitan area, but in 2019, the city split into smaller municipalities.
  - ➢ For DSM, the Revised MP proposes a wide-area DUTA, but it is still unclear how DUTA were successfully established by coordination of MoWTC and PO-RALG. Traffic administration in Dar es Salaam is under the direct control of TANROADS and TARURA, which are government agencies, and the city's traffic administration is limited to the maintenance of off-street parking lots, while DART, the main BRT project, is also under the direct control of PO-RALG and has strong government involvement. The city of Dar es Salaam itself is also a collective of five municipalities, and the mayor of DSM is a rotation of municipal mayors.
  - ➢ For Mombasa, the size of the single administrative unit (CGM) in Mombasa is fit to the current urban traffic management demand, making it easy to regulate urban traffic and form ITS businesses. Kenya's decentralization and the presence of the stable Governor of Mombasa have also boosted the capacity of CGM.
    - ✧ In Nairobi, on the other hand, NAMATA, a wide-area traffic management authority, was advocated at the same time as the BRT concept was proposed, but it took a long time to set up, and there was a corruption case involving Nairobi Governor at present, so it is practically nonfunctional. National agencies such as KeNHA and KURA are also seeking ways to improve the Nairobi transport administration under the decentralization movement.
- The same could be said for Southeast Asian cities. For example, the MMDA in the Manila Metropolitan remains just a coordinating body and does not actually carry out urban development projects. In Europe and the United States, regional transit organizations (RATP in Paris and MTA in NYC) have been established to manage metros, buses, etc., in a comprehensive and mutually supportive manner, and many studies have proposed the establishment of regional transit organizations, but they do not simply work in every city or country. The same is true for ITS-related projects, and it is necessary to choose proper organization and optimize the scale of the government that is easy to promote ITS projects.

(2) Proposals for Sustainability: Revenue development together with signal installation

- In all three countries, the maintenance budgets are allocated by the Road Fund Board according to the amount of road maintenance, In Dar es Salaam, the signals that were introduced under the grant basis in 1994 continues to be in use. In Accra, there is a mechanism in place for each municipality to report signal failures in the city to the DUR.

- Mombasa has installed its own CCTV for 90 locations, but it had been halted due to the cable cutting incident during road widening work, and it took more than a few months to recover. There is a case that in Nairobi City (under the Governor Sonko governance), the road maintenance budget was diverted to new road construction. These incidents show the difficulty in sustainability.
- The study team proposes that road advertising revenues be used to budget for the maintenance and renewal of ITS facilities. Moreover, the study team proposes the new visible advertisement space should be delivered on the poles of the signal equipment, for securing additional revenue.
- It could be introduced in each city. In Kenya in particular, the DPWTI integrally manages the advertising revenue management and the road maintenance. Ghana DUR has access to the advertisement revenue, but once it goes into the treasury, so the DUR has to claim the budget. Tanzania has a different geographical area of control in TARURA/TANROADS. In Tanzania, the advertisement revenue is allocated to each road agency directory through Tanzania Revenue Authority not via Road Fund.

(3) "Infrastructure heavy" situation: Conversion from sensors to probe cars by Japanese technology to utilize probe car data

- The recent technical trend in Japan suggested the real-time information for traffic flows collected by the "probe cars" can combine with the data collection function of the on-site sensors, as shown in the section 5.3.1(3).
- Therefore, by utilizing Japan's superior technology, the system will enable advanced traffic signal control while reducing the number of vehicle detectors needed for traffic signal implementation, rather than the overabundant infrastructure that has been used to date.
- As mentioned on other chapter, the Fleet Management System for public transport has been introduced in Tanzania and Ghana, and in addition to the collection of probe data, it is expected that the system will continue to spread not only to public transport vehicles but also to logistic vehicles.
- The study team proposes the "Japanese Technology to utilization of probe car data" in addition to the reduced number of sensors even though it requires communication cost, the probe car information can be used for other purposes for ITS and "smart city" operation.
- However, signal control using probe data collected from "probe cars" has been technically verified in Japan, but not in developing countries, which is a different traffic environment. Therefore, it is essential to verify through a technical cooperation project before deploying it in practice.
- In addition, to reduce the number of vehicle detectors required for traffic signal implementation, the existing CCTV video data with image recognition function can also be used to collecting probe data of a certain section.
- Mombasa CGM owns the CCTV, so it can be used for its ITS service, however, the Accra police group are trying to integrate the on-street CCTV but the inter-ministerial coordination between Police and DUR is required. For Tanzania, CCTV penetration is not so high.

(4) 5G is too early, cabling is still major solution

- It is apparent that 5G characteristics are not suitable for the communication in the local signal operation, because of its restriction in the communication range and other technical difficulties. Penetration in African cities are not envisioned yet. The communication between local controllers and vehicle detectors is materialized with Wi-Fi in Accra.
- Also, the communication between the TCC and sensors, cabling is essential due to its operation

cost minimization requirement and reliability, rather than applying 5G or 4G. Mombasa has its own cables, Tanzania has a national cabling company or the cable can be shared for BRT operation, therefore, the ITS project should be developed in partnership for cable usage.

(5) New building development is essential for TCC?

- The Accra's DUR traffic control center development (AFD funding) is included in the development of a new two-story building to accommodate the TCC functions. Meanwhile, the Tanzanian LATRA intercity bus VTS was developed in an existing "no-frill" house. The Mombasa's CCTV monitoring room also utilized the existing office building and its function be distributed and shared commonly among the Inspectorate department and Road Infrastructure Department. The former is foreign funded and the latter two are self-funded projects.
- In the past, the TCC development may have been required to have a "building development" portion, but with the simplification of communication infrastructure, the decentralization of servers, and the commoditization of display panels, it may be a good idea to utilize existing buildings instead of building new ones.

(6) Gap on Grant Aid scheme with "Subscription" oriented Market

- Grant-aid financial support is expected for the application of the ITS project development, the mechanism of which covers a large initial investment for the infrastructure. However, the signaling services also require operation cost, and moreover, replacement will be the responsibility for municipalities.
- The market developed a new system to ease the initial payment, which is known as "lease" or "subscription" services or "SaaS", and the such concept has been applied to the TCC services facilities and software. A coordination control service can be purchased as an API software through the internet by subscription contract, for Israeli cases. In Japan, the TCC system is procured by lease contract, to avoid the large replacement cost. (see section 5.4.3)
- It can be said the grant-aid scheme in the ITS project may force the municipalities to carry the burden of replacement cost. The grant aid system should be reformed and optimized for the ICT system procurement, to accept the subscription expenditure, lease contract, etc.

10.4 Interests on ICT Application in Urban Transport

(1) Strong Interests in Parking Management with ICT

- All four cities in the study have adopted ICT in their parking fee collection. Each is a different solution and interesting. Parking fee collection is a lucrative "day-to-day" business for local governments, a sector where it is easy to introduce ICT as a measure against leakage, and payment media such as M-PESA in Kenya, GePG in Tanzania are also supporting this. On the other hand, there is resistance to the reduction in employment for the introduction of ICT. In this study, parking fee revenue was expected as a financial source for the operation and renewal of ITS facilities, but the parking management is also expected to be the target of ITS application.
    - Mombasa: Change from cash collection to collection by M-PESA from April 2019. The reason for the introduction is the large number of levy leaks. Payment is on a USSD basis, and parking wardens reassign existing personnel. The collection status can be aggregated in real time. It was increased by 80% after introduction. Monthly contracts, etc., are also

introduced, with 100% of the revenue coming from Mombasa (USSD-based payments are ahead of Nairobi).

- Accra: There are 1,590 on-street parking slots in the city, and about 4,000 are planned for the future. Each inspector group for street by street is directly controlled by the municipality or outsourced to a private company for management. The local government manages the project, but management know-how is dissipated due to the division of the local government. Private companies have also introduced technology such as magnetic nails (sensors) installed in each parking slot to collect information on full occupancy. Payment is mainly made in cash, and each manager has a POS terminal. The revenue goes into the national treasury, but is returned as a municipal budget if billed.
- Dar es Salaam and Dodoma: Basically, it is done by manual handling with cash receipts through POS terminals. No municipality will be involved, TARURA is directly responsible. TARURA installed advanced parking management in Mwanza (license plate scanning on motorbikes, querying payment information in the TRA database, charging through GePG). If the Mwanza approach were applied to DSM, it may wipe out some 1,000 parking inspectors in DSM. The revenue from the parking fee goes into the state treasury, but becomes TARURA's revenue.

(2) Regional FMS for intercity bus service

- The intercity bus FMS application for over speeding enforcement by LATRA in Tanzania was one of the noteworthy findings in this study. The LATRA system was also applied to international bus services from neighboring countries, and the neighbor governments visit the LATRA for further application in their countries. However, such dissemination of the international system should be initiated by the regional economic communities (RECs).
- JICA has contributed the RECs in Africa, EAC, ECOWAS and SADC. For EAC, JICA has more than 10 years supporting records for one-stop border post (OSBP) promotion with the WCO (World Customs Organization) and harmonization of axle loading standard in 2010-12. The FMS of the intercity bus enforcement should be initiated by RECs with support of JICA similar to OSBP and axle load harmonization.
- It should be noted that the regional bus service demand in African countries are growing. During the study team visits in Ghana, there was a severe traffic accident of an intercity bus which resulted in 35 fatalities. The LATRA’s FMS achieved a more than 70% decrease of traffic accidents of intercity bus passengers since 2015 for Tanzania’s long haul buses, which will contribute to the satisfaction of the SDGs goal 3.6, saying “halve the traffic accidents and fatalities by 2030”.
- This study’s interest is mainly for urban transport, but the study team found strong needs for traffic safety enforcement for intercity transport services and found the good experience in Tanzania. The study team would like to propose that the Tanzanian’s system should be expanded to EAC region with EAC coordination, and transferred to other regions, SADC, ECOWAS, etc.

(3) PTPS using V2X technology for Smooth public transport and emergency vehicle traffic

- V2X technology is one of the latest technologies to support vehicle-related safety and automated driving in smart cities. Toyota, VW and Ford are already manufacturing and selling vehicles equipped with communication devices that use V2X technology. In the Japanese market alone, approximately 200,000 vehicles are already equipped with the system, and there is no doubt that its use will continue to grow in the future. These applications are explained in the section 5.3.3.

- In developing countries where there is a large market for importing and selling used cars from Japan, it is expected that vehicles equipped with V2X technology will become popular in the near future.
- Under these circumstances, the introduction of Public Transportation Priority System (PTPS), which enables priority traffic signals for public transportation such as BRTs and emergency vehicles such as ambulances by utilizing V2X technology, will support the rapid spread and utilization of V2X technology, which in turn will support the realization of smart cities in the target countries.

(4) Data Sharing/Utilization can be seen but imperfect

- Tanzania has the advantage in data sharing/utilization. The revenue authority, police and vehicle registration authority always share the vehicle registration records in digital format and utilize the records for taxation, road-worthiness, and enforcement respectively. The data are opened for private entities (insurance companies, etc). The payment account of the vehicle owners registered to the vehicle registration records was also used for the parking fee charging system for TARURA. It seems the strong e-government leadership of the President Office and GePG payment platforms accelerate the implementation of data sharing/utilization.
- Ghana has a similar payment infrastructure (GhIPSS), digitized vehicle registration data, etc., but JST assesses less leadership for data sharing/utilization. For Kenya, it can be assessed that private investment improves the retail services but it does not overarch all of the transport services. KURA's trial for the e-police would be a good trial though.
- Of course, there are pros and cons for the Tanzanian interventions and data sharing/utilization which seems influenced by the traditional socialist country background; however, the traffic management system always requires strong governance and enforcement.

(5) More Variety and Potential in Road Infrastructure Management

- The study team observed strong interests of axle load control in Ghana and Tanzania. TANROADS has developed latest facilities with weigh-in-motion functions including CCTV monitoring and e-payment fee collection system. TARURA has their advanced web-based pavement database, but they are suffering about drainage and road damage. The Ghana GHA presented their road-side over-loading enforcement base along the major corridors, and always updates road pavement database system.
- JICA is supporting the i-DRIMS project in Ghana and Kenya, applying smartphone-based pavement monitoring system and drone-based bridge monitoring techniques.
- This study presented potential development technologies to be applied, which may change the existing road infrastructure management. For example, LPWA communication system with sensors can minimize the flooding monitoring in their road network. The smartphone-based pavement monitoring system can be shared with private freight operators to realize more frequent measurement. On-road CCTVs can be shared not only for traffic safety and security, but also for monitoring of landslide and flooding.

(6) Delays in Passenger and User-oriented ICT Application

- ICT applications in parking fee collection in Mombasa, Accra and Mwanza were only cases involving passengers or users of the services. Other ICT applications were developed and utilized for administrators and operators. Tanzania has the advantage in data sharing/utilization. The revenue authority, police and vehicle registration authority always share the vehicle registration records in digital format and utilize it for enforcement, road-worthiness inspection and taxation, but information provision function in BRT are not yet ready.

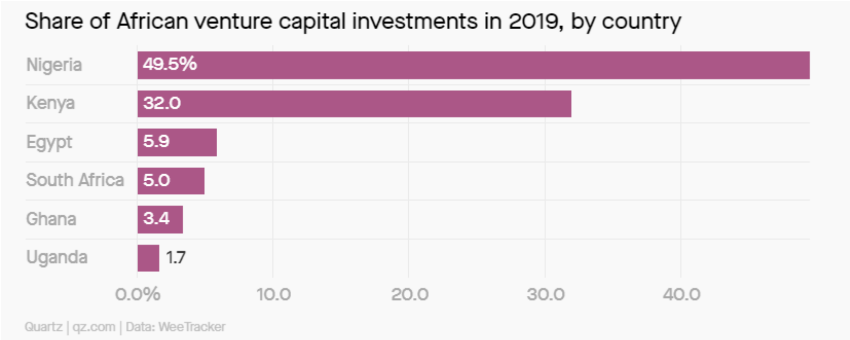
- The intercity bus FMS in Tanzania can be utilized for a passenger information service for real-time bus approaching; however, it is not yet ready. Accra's Quality Bus Service also equips the FMS, however, there is no service of real-time information provision for passengers. Anyway, necessary data for real-time approaching information are ready in some cities because of high penetration of on-board GPS units.
- The trials of cashless payment are also unsuccessful in all three countries. Ghana has two bus stored-fare card applications and toll road card application, but they are limited penetration. Toll collection system in DSM toll bridge was well-designed, but there is no toll roads other than the bridge in Tanzania.
- The ICT applications for passenger are inactive in all three countries so far. Design of ICT system and application of the passenger-oriented service will require proper marketing analysis with proper technical application and involvement of experienced private developers who can respect user-experiences. So far, the JST cannot expect successful plan in the four cities in ICT application for passenger services.

(7) Utilization of JICA Training Program on ITS

- Since 2013, JICA has been conducting group training program on ITS in Japan called "Knowledge Co-creation Program on Practical Technology on ITS". In some of the cities JST visited this time, JST found that the participants of the training program fulfill important roles in the ITS field after their completion of the program.
- JST recommends utilizing of this training program as a capacity building opportunity to deepen understanding of the recent trends in ITS and the importance of data utilization/sharing as described in this report.
- For those who already have good practices, it will be an opportunity to learn about the challenges in other countries/cities, and it will be a good opportunity for knowledge co-creation on how to improve to address to the transport problems.

(8) Startup / venture capital interests does not match to the ITS progress?

- In terms of the ITS business, generally, the study team appreciates achievements in Tanzania, rather than Kenya and Ghana.
- Based on the recent share in African venture capital investment, as shown in Figure 10.4.1, it was expected that ICT services and application in the transport sector was relatively well developed in Kenya, but with lax regulations on private investment and foreign participation, it could be said that private IT start-up investment is the only thing that stands out in Kenya.
- In terms of the ITS business where ICT applications in the transportation sector are practically being embodied.
- Traffic management is a "regulation" business, and because Tanzania has a socialism background, the existing transport service regulations are stricter than those in other countries, so it can be said that a regulated business format was more open to accept the ICT application.



Source: JICA Study Team

Figure 10.4.1 Share of African Venture Capital Investment in 2019, by Country