No.

Dar es Salaam City Council

The United Republic of Tanzania

Dar es Salaam

Transport Policy and System Development

Master Plan

Technical Report 2

Transport Planning & Development

June 2008

JAPAN INTERNATIONAL COOPERATION AGENCY

PACIFIC CONSULTANTS INTERNATIONAL

CONSTRUCTION PROJECT CONSULTANTS

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PART 1: Road Sector

Chapter 1 Road Sector Synopsis

The previous *Progress Report*[1] presented considerable detail regarding the recent and current status of the road network. The current chapter summarizes, and builds upon, these findings.

1.1 The Network

The Tanzanian road network extends over approximately 85,500 km. Of that total, some 56,600 km fall under local government jurisdiction (district, feeder and urban roads), while the trunk and regional road network, which extends over about 28,900 km, is under jurisdiction of the Ministry of Infrastructure Development (TANROADS). Almost 15% of the trunk and regional road network is paved, and in excess of 80% of the network is classified as being of good or fair condition (**Table 1.1.1**). Conversely, for secondary (district, feeder, urban) roads, near 60% of the network is shown as being of "good or fair" condition (**Table 1.1.2**). The paved extent of the secondary road network was, per 2003/2004 information provided by the-then Ministry of Public Works, some 500 kilometers, almost all of which were located on the urban road network. Thus, in aggregate, it may be surmised that near 6% of the composite Tanzanian road network is paved, with slightly over half of the total network considered in "good" condition.

Table 1.1.1 Recent Extent of the National Trunk and Regional Road Network

Road Type	Surface	Road Condition (km)				Percent of Total
		Good	Fair	Poor	Total	
Trunk	Paved	2,747.5	951.1	223.1	3,921.7	13.6
	Unpaved	2,871.8	2,143.3	1,005.4	6,020.5	20.8
	Subtotal	5,619.3	3,094.4	1,228.5	9,942.2	34.4
Regional	Paved	258.7	58.9	19.8	337.4	1.2
	Unpaved	9,296.3	5,943.0	3,372.0	18,611.3	64.4
	Subtotal	9,555.0	6,001.9	3,391.8	18,948.7	65.6
Combined	Paved	3,006.2	1,010.0	242.9	4,259.1	14.7
	Unpaved	12,168.1	8,086.3	4,377.4	24,631.8	85.3
	Total	15,174.3	9,096.3	4,620.3	28,890.9	100.0
Percent of Total		52.5	31.5	16.0	100.0	

Source: Ministry of Infrastructure Development, 2007. Data as of mid-2006.

[1] Refer *Progress Report:: Dar es Salaam Transport Policy and System Development Master Plan, op. cit. (Chapter 4).*

Table 1.1.2 Recent Extent of the National Secondary Road Network

Road Type	Road Condition (km)		
	Good and Fair	Bad and Poor	Total
District			29,537
Feeder	n.a.	n.a.	21,191
Urban			5,897
Combined	32,400	24,225	56,625
Percent of Total	57.3	42.7	100.0

Source: Ibid.

The road network within Dar es Salaam extends to roughly 1,700 kilometers[2], of which approximately one-fourth is paved. While the total amount of road kilometers is reasonable balanced among the three municipalities, the highest number of paved kilometers are clearly located in Kinondoni and Ilala (**Table 1.1.3**).

Table 1.1.3 Composite Dar es Salaam Road Network

Municipality	Paved Road (km)	Unpaved Road			Total (km)
		Gravel (km)	Earth (km)	Total (km)	
Kinondoni	180 (32.5%)	162	211	373	553
Ilala	139 (26.1%)	63	330	393	532
Temeke	76 (12.0%)	256	300	556	632
Total	395 (23%)	481	841	1,322 (77%)	1,717

Source: *Annual Road Report,* Regional Secretariat, Government of Tanzania, October 2005. Includes all road categories under the jurisdiction of TANROADS and local authorities.

The metropolitan road network is anchored by a series of major roads, most being classed administratively as trunk and regional roads (**Figure 1.1.1**).

- Multi-lane roads account for near 80 kilometers, or some 20 percent of the composite paved road network. These include, all or in part, Morogoro Road, Nyerere Road, Nelson Mandela Road (all being classed as trunk roads), as well as Rashidi Kawawa Road, Ali Hassan Mwinyi Road and Bibiti Road (all being municipal roads, and extending over roughly 20 kilometers).
- The dominant two-lane road, in terms of road length, is New Bagomoyo Road, extending over almost 38 kilometers. A selection of other main two-lane roads includes Kilwa Road, Sam Nujoma Road, Old Bagomoyo Road.

[2] Some differences in data bases exist. For example, year 2007 municipality-specific information suggests, when summed across the metropolitan area, that the total network should be in vicinity of 1,900-2,000 kilometers. These differences are intuitively caused by approaches to classifying minor unpaved facilities (such as community roads).

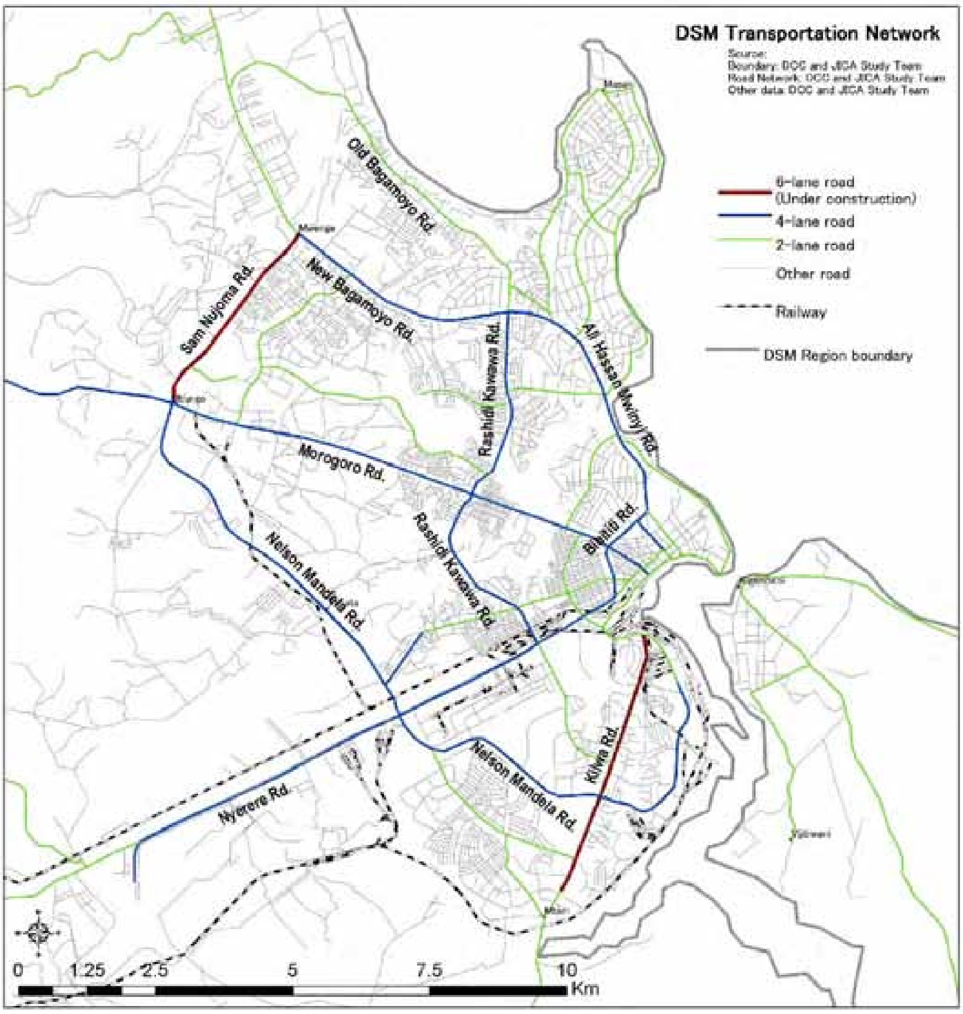


Figure 1.1.1 Major Roads in Dar es Salaam

Several of the previously listed roads are currently in the process of being, or are expected to shortly be, improved and/or widened. Core projects include:

- Sam Nujoma Road is in the process of being widened to dual carriageway standard, two lanes per direction. The project is understood to be behind schedule, but expected to be completed during approximately mid 2008. The project is sponsored by the Government of Tanzania.
- Kilwa Road is being widened over a distance of approximately 12 kilometers extending south of its northern terminus at Bandari Intersection. The cross-section is dual two lane, with sufficient median reserve to accommodate a future BRT busway. The project is being sponsored by the Government of Japan.
- Nelson Mandela Road is being improved, largely within existing alignments. The extent is from vicinity of the seaport to Morogoro Road, or approximately 16 kilometers. The existing multi-lane cross-section will be retained, but considerable enhancements of road surface, drainage and traffic control expected. The project is being sponsored by the European Commission. Completion is expected within approximately two years.

- While not yet definitively committed, it is highly likely that New Bagamoyo Road will be upgraded to a four-lane divided cross-section, with adequate median reserve for the provision of a future BRT busway. The project is expected to extend over some 17 kilometers between Kawawa and Wazo Hill Intersections.
- The BRT Phase I project will extend over approximately 21 kilometers, mostly coinciding with Morogoro Road, but also including sections of Kawawa and Msinbazi Roads (please refer the subsequent Part 3 of this volume for a more detailed discussion of BRT). Reconstruction will allow the installation of dual (one in each direction) BRT busways, as well as median-sited stations every approximately 500-700 meters. The adjustment of the overall road cross-section will vary by sub-section and depending on current configurations and rights-of-way. Project infrastructure is under sponsorship of The World Bank.

1.2 Issues and Opportunities

Reviews and investigations, as well as extensive discussions with specialists knowledgeable with the urban road sector, have given rise to a series of strategic issues, each of which is associated with unique opportunities and constraints. These issue, as summarized below, have been integrated with the formulation of the road planning element of the Master Plan.

- **Issue:** The form of the Dar Es Salaam road network reflects the cities geographic, social and economic evolution which has, historically, centered on the CBD. As such, the road network consists of a radial hub-and-spoke system, linked via a limited number of circumferential roads which circumnavigate, to differing degrees depending on facility, the central area. Two major economic activity centers (CBD and Kariakoo) form the hub of the radial road system. The various elements of the hub and spoke network are subjected to differing demands. An industrial corridor of about five kilometers length is established along Nyerere Road between the city center and the international airport. Nyerere Road also functions as the only access road to the airport. Industrial activities, in addition to major focus points such as the seaport, are noted along Nyerere, Nelson Mandela, Morogoro and New Bagamoyo Roads. New residential areas have been expanding along major radial roads; however, only few interchange points exist between the road network and the residential precincts. Limitations and constraints to movement desires exist already at present, and will surely worsen as land uses expand and intensify, in line with expected increasing vehicle ownership.

  Opportunity: Optimize the supply of road facilities, both in terms of enhanced use of available resources, as well as the provision of additional infrastructure. This approach must be accomplished within a multi-sectorial environment, be justifiable on demand, financing and environmental grounds, and be compatible with near, medium and longer term demand scenarios. This is seen as the central mission in formulating the urban road element of the Master Plan.

- **Issue:** There is a lack of a road network hierarchy; roads are subject to a variety of (often incompatible) uses. The metropolitan road network is anchored by major national trunk roads. Only few primary and secondary urban arterial facilities exist to complement the core national system. Thus, the major metropolitan roads must carry inter-city traffic as well as intra-city traffic. The inevitable result is that road users including non-motorized vehicles, two-wheeled vehicles, passenger cars, buses and trucks (both heavy and light) must share and operate within a common road space. These road users exhibit vastly different characteristics in terms of physical dimensions and performance capability. This invariably results in compromised road safety and worsening congestion.

  Opportunity: The development of a functional hierarchy of roads to improve this dangerous and inefficient situation. The functional classification must balance the competing demands of mobility and accessibility. A hierarchy of roads must also consider specialized requirements such as those posed by heavy commercial vehicles, as well as the provision of an effective public transport (especially BRT) system.

- **Issue:** There are no access controlled motorways in Dar es Salaam. Thus, by definition, all forms of traffic must operate in a mixed-use environment, and be directly impacted by congestion caused by, among others, the extent and mix of the vehicular stream, traffic control devices, pedestrians, as well as activities associated with various forms of roadside development. Motorways and similar higher-order roads have, in other cities of the world, catalyzed considerable improvements in road safety while concurrently enhancing the operating environment of motorists and segregating vehicular from pedestrian traffic.

  Opportunity Consider the implementation of a motorway network. However, such a system must conform to the overall function and hierarchy of the metropolitan road network, as well as demands thereon, and must be justifiable in light of anticipated high implementation costs. The use of tolls should be considered, possibly within the framework of a public-private sectors initiative.

- **Issue:** Severe traffic congestion exists along radial roads, particularly during peak demand hours. This is invariably caused by intersections. However, more ominously, absolute traffic volumes at strategic network focus points are growing to the point where even a well designed and operated intersection will be stressed to provide sufficient capacity.

  Opportunity: The need to provide additional, well designed and efficiently operated intersection configurations, to include state-of-the-art signal systems, is obvious. However, at key intersections, such strategies can be seen as near to mid-term solutions; in the longer term, the grade separation of traffic streams is perceived as being unavoidable. Grade separated flyovers must nevertheless be conceived in a strategic manner, compliant with the established road hierarchy, and as part of a corridor enhancement initiative thus preventing “congestion transfer”.

- **Issue:** There exist discontinuities in the lane profiles within several urban road corridors. An abrupt change in system capacity (change in number of lanes), at either intersections or within the road proper, will invariably cause severe traffic bottlenecks. Some examples in this regard include Bibititi Road (four lanes) and the integration with Ocean Street (two lanes) as well as Ohio Road (two lanes); four lanes along the partial alignment of Ali Hassan Mwinyi Road, as well as varying numbers of lanes along New Bagamoyo Road. Kilwa Road is currently being upgraded to six lanes (including two dedicated BRT lanes); however, Bandari Road (the northern terminus of the Kilwa Road improvement) will retain a two-lane profile. In a similar sense, the current widening (to four lanes) of Sam Nujoma Road will terminate at its northern end at a two lane road (New Bagomoyo Road).

  Opportunity: The urban road element of the Master Plan must conform not only to identified needs as well as hierarchial functions, but also exhibit a logical consistency which, for the more important roads, ensures that quantum changes in capacity, and/or abrupt changes in the road profile, are minimized. A further implication is that, for roads of similar intent and function, physical determinants such as right-of-way and pavement type, be similar.

- **Issue**: current road design standards address trunk and regional roads, while no officially approved design standards are available for an urban arterial system. Likewise, there are no standards for pedestrian facilities in urbanized areas.

  Opportunity: The promulgation of urban road standards, ideally within the framework of the functional road hierarchy.

- **Issue**: the committed implementation of the Phase I BRT system represents an exciting new mode of mass rapid transport for Dar es Salaam. The BRT system will be expanded in future via the gradual implementation of additional system stages. The system has unique needs in terms of road space, station activities and vehicle operation. The BRT busway network will, in virtually all cases, be sited adjacent and/or within the median of urban roads.

  Opportunity: The BRT system is intrinsically and inseparably linked with the change and evolution of the road network. Planning for BRT, and in general public transport, is an integral element in the formulation of an urban road strategy.

Chapter 2 Urban Road Hierarchy

Hierarchy may be regarded as a classification scheme under which road types are ranked in accordance with their function within the composite road network. The classification of roads serves a variety of purposes in the management of a network. From one perspective, classification is basically concerned with the avoidance of conflict, by separating roads serving different purposes from each other and from non-road activities, such as abutting land use. This consideration is not only to do with the functional efficiency of traffic flow, but also to safety, amenity and the environmental quality of the urban area. Classification can allow consistent decisions to be taken about the design and management of a road or street, assist with the allocation of responsibility for upkeep of roads, and serve to identify routes for navigational purposes (for example, truck routes).

While there are many ways of classifying roads for different purposes, at heart, a classification is a strategic tool for prioritizing the use of the different routes in a network for different purposes; or, in the Dar Es Salaam metropolitan region context, prioritizing the use of scarce street space between competing activities, including through movement and other urban activities. In effect, the designation of the "function" of a road leads to a facility-oriented "division of labor", set at the strategic level for the benefit of the system as a whole.

2.1 The Historic Approach in Tanzania

The approach to road classification in Tanzania relies on administrative responsibility, rather than functional use. At the most generic level, two types of roads exist; namely, national roads and those under local government (municipality) jurisdiction. The national roads fall under authority of the Ministry of Infrastructure Development, or, more precisely, the Ministry's executing agency TANROADS. Local roads in Dar es Salaam fall under the jurisdiction of municipalities (Ilala, Temeke, and Kinondoni). In addition, the Dar es Salaam City Council is in charge of cross-border issues among the municipalities, for example, solid waste management, traffic management (traffic police) and some major road development and maintenance.

The national road network consists of major trunk roads of national and regional significance, while local roads are identified as being "district, feeder, or urban" facilities[1]. Road improvements within Dar

[1] Refer *Progress Report: Dar Es Salaam Transport Policy and System Development Master Plan* (Chapter 4), op. cit., for further discussion of extent, type, content and jurisdictional responsibilities inherent to the current administrative road classification system.

Es Salaam are almost exclusively limited to national and regional roads, and whose implementation is guided by the *Road Design Manual*[2] . Thus, several issues emerge:

- Roads are only classed according to administrative responsibility, not functional role.
- Road design standards appropriate to intercity conditions (the basis of the *Road Design Manual*) are not necessarily appropriate to urban conditions.
- There are no consistent design (or use) guideline for local roads.
- Currently employed criteria do not routinely incorporate alternative uses such as pedestrian systems or higher-order forms of public transport. A recent notable exception has been designs associated with development of the Dar es Salaam BRT system[3].

The purpose of the current section is therefore to define, in qualitative and quantitative terms, an approach to functional classification for roads located within the Dar es Salaam urban conurbation (the study area).

2.2 The Basis for Classification

There are many kinds of worldwide road hierarchies in existence, with most ranked by some form of "traffic function". This traffic-oriented impression is reinforced by the stratification of major traffic roads such as primary distributors – or controlled access, higher-order roads such as motorways – at the "top" of the hierarchy, down through intermediate road and street types, to more modest facilities at the "bottom" of the hierarchy. Such hierarchies typically rely on an interplay of mobility and land access (buildings, developments, etc) with high-order roads featuring maximum mobility and limited land access (**Figure 2.2.1**).

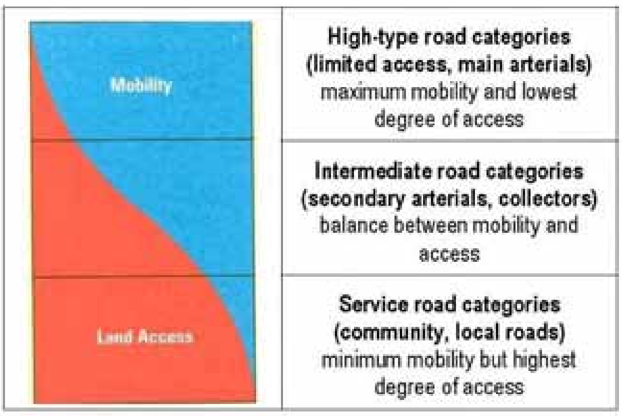


Figure 2.2.1 Interplay of Mobility and Land Access

The designation of road types within these hierarchies varies, with some examples being[4] :

- United Kingdom (London): Primary distributor, district distributor, local distributor, access road, pedestrian street/route, cycle route.
- Denmark (Copenhagen): Motorway, regional road, primary road, distributor street, local street.

2 *Road Design Manual* (draft), Ministry of Works, Government of Tanzania, 1989.

3 Various intermediate reports culminating in *Final Report and Project Review Seminar, Consulting Services for the Conceptual Design of a Long-term Integrated Dar Es Salaam BRT System and Detailed Design of the Initial Corridor*, for the Dar Es Salaam City Council and Prime Minister's Office for Regional Administration and Local Government, by Logit Consultants, in association with Inter-Consult Ltd, March 2007.

4 As summarized in *Evolving Road Hierarchy for Today's Streets-Oriented Design Agenda*, S. Marshall, University College London and University of Westminster, UK, 2004.

- USA (various cities): Freeway[5], expressway, major arterial, collector street, local street, cul-de-sac.
- Belgium (various cities): Motorway, metropolitan road, trunk road, inter-district road, through street, local street.
- Italy: Motorways, principal inter-urban roads, secondary inter-urban roads, urban roads, district urban roads, local roads.

While the classification terminology differs in each case, the basic principles follow the same general pattern, with a spectrum from major roads to minor roads. Major roads tend to be associated with strategic routes, heavier traffic flows, higher design speeds, with limited access to minor roads via frontage access; minor roads tend to be associated with more lightly trafficked, local routes, with lower design speeds and more frequent access points and with access to property frontages (**Figure 2.2.2**). At initial inspection, such rankings may appear to be exclusively based on "traffic function"; however, on closer inspection, the actual criterion for distinguishing and ranking different roads is not only based on traffic flow, or traffic speed, but also based on the geographical scale of significance of the network to which a road belongs and where roads are arranged topologically. The significant advantage of this approach is that road hierarchy is not inscrutable and unassailable, but is in fact based on a nesting of function and location, transparent to all. This guarantees a flexible approach that supports a continuing and responsive framework which can be rapidly adapted to suit evolving needs.

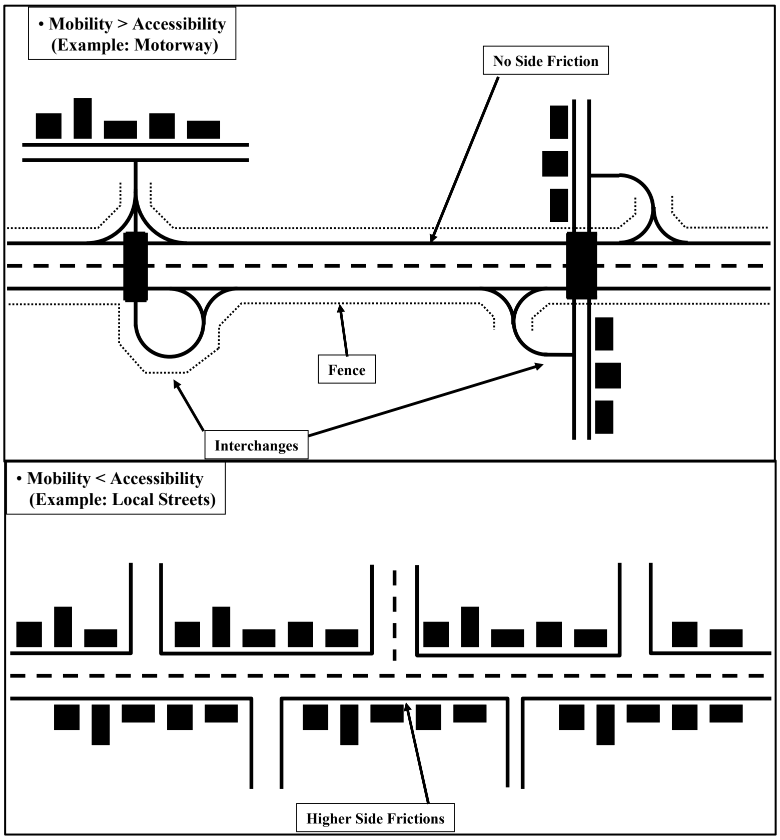


Figure 2.2.2 Mobility and Accessibility Comparisons

5 Freeway (synonymous with motorway and Autobahn) refers to roads "free" of interference from other traffic; that is, of limited access and grade-separated design. Freeways may be subjected to a toll scheme; as such, they are frequently referenced as "tollways" or "tollroads". Expressways in clinical terms mirror the layout and function of motorways, although design may be less rigorous, to possibly include some high-order signalized junctions. However, in common vernacular, the terms freeways, motorways and expressways are often used interchangeably.

2.3 The Way Forward

The derivation of a functional road hierarchy for Dar es Salaam represents a division of the road network, both existing and future, into identifiable road classifications which reflect the functionality of the roads making up the highway network. Each classification has a number of criteria to differentiate it from other classifications. The criteria are based on the purpose and function of the roads making up the particular classification, but can be extended to take into account relevant local characteristics, such as land use.

The functional road hierarchy is intended to form the central planning and administrative framework and assist in meeting the following broad aims:

- Effective design, maintenance and management of the highway network superimposed onto the current administrative classifications;
- Contribute to the minimization of adverse transport impact; and,
- Ensure that the highway network contributes towards continued economic development.

In order to meet the above aims, the objectives of a functional road hierarchy are:

- Identify the mixture and balance of functions to be performed by each class of road;
- Strike a balance between level of service, the environment, speed, safety and road user comfort;
- Create a systematic approach to the design and adaptation of the road network; and,
- Create a road network that safely and conveniently provides for a desired mixture of uses (to include cargo flow as well as the advent of BRT, both for the committed Phase I element plus later stages).

The establishment of a good functional road hierarchy is expected to catalyze the following benefits within the Dar es Salaam context:

- Provides a potential framework for policy, planning, implementation, management and monitoring;
- Assists with establishing design standards and guidance appropriate to an urban environment; and,
- Develops an understanding of road network functions.

The development of the functional road hierarchy, as documented in the following subsection, takes into account several principles:

- Use a manageable number of classifications;
- Use clear terminology;
- Use classifications applicable to the whole network;

- Maintain continuity between functional hierarchy classes;
- Use scaleless classifications; and,
- Avoid confusion between types of road classes.

2.4 The Proposed Scheme

The previous sections have identified opportunities regarding the formation of a functional road classification scheme. Such a revised classification scheme would, in the opinion of the Study Team, form an integral element of the Master Plan. Toward that end, it is proposed that a scheme be defined which includes expressway/motorway, primary arterial road, secondary arterial road, tertiary arterial road, community/local road and special road. The functional intent is:

- Expressway/motorway embodies high-type segregated design, and is to be used exclusively by motor vehicles. This road class will connect, for example, CBD with suburban satellite centers, residential areas, airport, seaport, and other high-activity trip generation precincts. Expressways/motorways may be tolled, should this prove desirable.
- Arterial roads are stratified into primary, secondary and tertiary facilities according to the level of services. Primary arterial roads represent critical road transport spines that anchor future urban evolution and economic activity. BRT, a vital form of urban mobility (mass transit) for Dar es Salaam, is thus seen as an integral part of this road class in that BRT busways may only be placed into primary arterial roads. Secondary arterial roads provide mobility for medium distance traffic, such as between wards or districts within the city. Network bus services may be provided on this type of road (as well as other lower road classes as long as physical and operational conditions so permit), but will operate in mixed traffic. Site-specific public transport priority treatments, for example, queue jumpers or signal priority, are possible on secondary roads. Tertiary arterial roads provide accessibility to defined geographical areas within the city, and are intended to provide linkage with other higher-order roads.
- Community road or local road provide accessibility to and/or between neighborhoods, communities and individual plots. This level of roads lie below the focus of the Transport Master Plan.
- Special roads used for specific purposes, such as pedestrian mall, exclusive BRT road, scenic road, non-motorized vehicle way, and pedestrian way.

The main characteristics of each functional class are summarized in **Table 2.4.1**. The functional elements of the new system embody not only “traffic oriented” considerations, but also the broader aspect of mobility and connectivity between various elements of the urban fabric. For example, primary arterials form the backbone of connectivity involving major urban precincts such as wards or regions. Neighborhoods and communities, in turn, would have a higher reliance on secondary arterials. This, in turn, implies various guidelines in terms of facility interval and/or spacing (**Figure 2.4.1**):

Table 2.4.1 Proposed Urban Road Functional Classification Scheme

Classification	Facility Stratification	Application	Intent
Expressway / Motorway	Tolled or non-tolled	Entire Region	- Exclusively vehicular use; no pedestrian facilities - Access controlled with grade separated interchanges - Accommodate longer and faster trips.
Arterial Roads	Primary Arterial	Entire Region Link to trunk roads outside of Dar Es Salaam	- Form core metropolitan spines - Accommodate longer trips - Connect major trip generators (sub-centers, port, airport, etc.) - Link to national trunk roads - Can accommodate BRT busways
	Secondary Arterial	Between wards. Link to primary arterial	- Accommodate travel demands between wards in the region - Link to primary arterial roads - Network bus services provided - Transit priority (but nor BRT busways) possible.
	Tertiary Arterial (collector roads)	Between neighboring precincts Link to primary and secondary arterial roads	- Provide circulation within, as well as between, wards, sub-wards, and residential areas. - Link to secondary roads - Network bus services (likely smaller vehicles) possible.
Community Roads	Access Roads (local collector roads)	Within community and residential area Link to tertiary arterial roads	- Local circulation and property access. - Can be used by informal forms of public transport
Special Roads	BRT road	Exclusive BRT road excluding other vehicle types	Enhanced BRT operation in support of primary arterial network within unique precincts.
	Transit Mall	Within CBD or busy commercial areas	Only for public transport (buses) and pedestrian uses
	Roads for non-motorized modes	Various locations	Safe roads exclusive for pedestrians and non-motorized vehicles
	Scenic roads/walkway	Along the coast and other scenic areas	Improve landscape, provide comfort and facilitate tourism
	Pedestrian Mall	Within CBD or busy commercial area	Provide exclusive pedestrian space and related amenities

Source: JICA Study Team

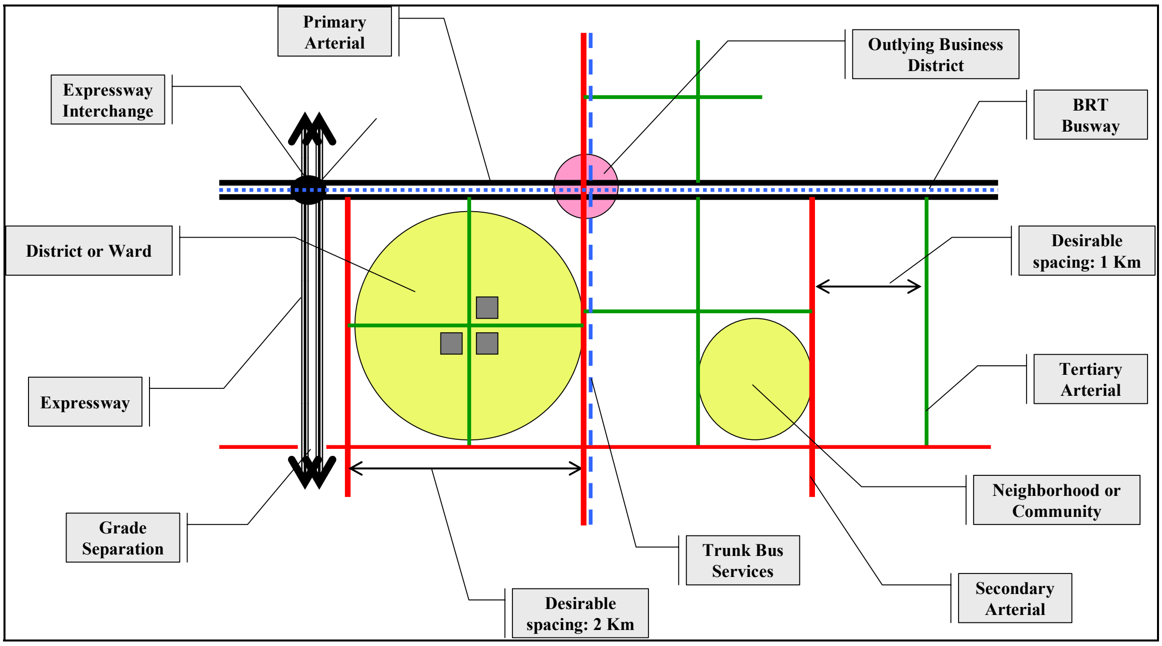


Figure 2.4.1 Interplay of Functional and Spatial Relationships

- Expressways/motorways represent high-order, limited access facilities which, on a composite basis, will represent a very small amount (two to three percent) of the entire urban road network, however, will form high-capacity corridors of movement.
- Primary arterials will appear as major radial roads (such as the current trunk roads), core ring roads and roads directly servicing major trip generators. Also, by definition, BRT busways will only be placed onto primary arterials. However, primary arterials need not always have busways.
- Secondary arterials should appear roughly every two kilometers, and tertiary roads approximately every one kilometer. Of course, this spacing will also be influenced by spatial and geographical realities of the urban fabric.

As noted previously, major roads are associated with strategic routes, heavier traffic flows, higher design speeds, with limited access to minor roads via frontage access; minor roads tend to be associated with more lightly trafficked, local routes, with lower design speeds and more frequent access points and with access to property frontages. This can be reflected in anticipated design and cross-section guidelines. Thus, motorways would be expected to feature highest design standards, while community roads would be almost exclusively two-lane facilities of more modest design standards. Indeed, while tertiary facilities would typically be represented by two lane (one lane each direction) cross-sections, with proper paving, markings and other features, community roads could vary across a wide spectrum (**Table 2.4.2**).

Table 2.4.2 Potential Functional Classification Profiles

Classification	Facility Stratification	Design Speed (km/hr)	Lane Width (meters)	Typical Number of Lanes
Expressway / Motorway	Tolled or non-tolled	80-100	3.50-3.75	4-6
Arterial Roads	Primary Arterial	60-80 (less with BRT busway)	3.25-3.50	4-8 (including BRT lanes)
	Secondary Arterial	40-60	3.25-3.50	4 (plus turning lanes)
	Tertiary Arterial	30-40	3.00-3.25	2
Community Roads	Access Roads (local collector roads)	Varies by use	3.00	2
Special Roads		Varies by purpose	Varies by purpose	Varies by purpose

Source: JICA Study Team

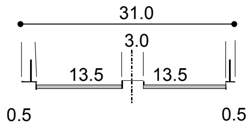
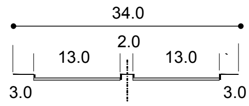
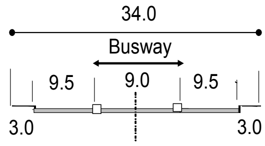
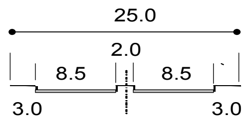
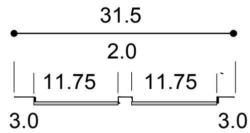
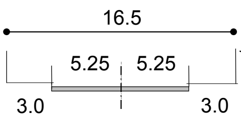
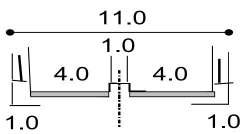
Representative (typical, but not all possible) cross-sections for functional road classifications are depicted in **Table 2.4.3**.

The vehicle capacities of the functional classification categories will vary based on a number of considerations. These include, among others, number of lanes, type and mix of the traffic stream; lane width; lateral clearances; roadside parking; side friction; hourly peaking patterns and the presence of pedestrians. For purposes of the present review, these considerations have been combined into a generic series of geographical groupings. These include:

- Core environment being representative of the Dar es Salaam CBD, or identified corridors of high (CBD-like) activity (such as the future Morogoro Road). Operations are characterized by heavy traffic volumes, considerable roadside friction, extensive parking, constrained road facilities, pronounced pockets of public transport concentrations and heavy pedestrian volumes.
- Urban environment, or what could, in general terms, be roughly considered as the area inside of the Nelson Mandela Road circumferential corridor. Traffic flows are likely less concentrated, and more diffuse, than those found in the core environment. Land uses would be less concentrated, and pedestrian activities are typically less intense. Road facilities would likely be more expansive. The concentration of heavy commercial vehicles is likely to increase[6] .
- Rural environment, or road operations which approximate inter-urban, uninterrupted flow conditions, likely near the periphery of the study area. Capacities under rural conditions would likely be the maximum available for the facilities in question.

[6] Results of the traffic counting program confirm, for example, that heavy vehicle content in the traffic stream on trunk roads in the urban environment average less than 10 percent. However, this gradually increases reaching 40-60 percent of the traffic stream (depending on count location) at the periphery of the study area.

Table 2.4.3 Representative Examples of Functional Road Class Cross-sections

Classification	Number of Indicated Lanes	Cross-section (meters)	Comment
Expressway Motorway	6		Six lanes @ 3.5 meters plus three meter outside shoulders; three meter median; 0.5 meter barriers.
Primary Arterial	6 (without BRT)		Six lanes @ 3.5 meters plus 2.5 meter outside shoulders; two meter median; three meter lateral footpaths
	6 (with BRT)		Four mixed traffic lanes @ 3.5 meters plus 2.5 meter outside shoulders; three meter lateral footpaths; two BRT lanes in median alignment @ all-inclusive 4.5 meters each. Design will require additional widening within BRT station areas to account for platform width (five meters) plus two additional BRT passing lanes.
Secondary Arterial	4		Four lanes @ 3.25 meters plus two meter outside shoulders; two meter median; three meter lateral footpaths
	4 (with curb bus stops)		Addition of two 3.25 meter bus bays located at curbside
Tertiary Arterial	2		Two lanes @ 3.25 meters plus two meter outside shoulders; three meter lateral footpaths
Community Roads	2	Varies	Goal is representative lane width of 3.0 meters but could include paved carriageway of five to eight meters
Special Roads	Varies		Wide variety of designs possible based on intended use. Indicated example is for a two-lane elevated BRT structure. Two lanes @ 4.0 meters, one meter median and one meter flanking barriers.

Source: JICA Study Team

Under uninterrupted (mid-block) conditions, a two-way, four lane (two lanes in each direction) primary arterial (without BRT) is shown as achieving a daily capacity ranging up to some 56,300 passenger car units. These values reflect what might be termed a Level of Service C/D condition reflecting impacts upon capacity associated the types of environment (**Table 2.4.4**). Some 10 to 15 percent higher capacity can be achieved under what might be termed possible capacity; that is, the maximum possible throughput prior to facility failure. LOS C/D is instead generally seen as being a preferred threshold for planning purposes and to allow for a comfort margin of safety.

Table 2.4.4 Indicative Capacity of Functional Road Classes

Classification	Number of Lanes	Daily Capacity (two-way passenger car units) by Type of Environment		
		Core	Urban	Rural
Expressway/Motorway	4	66,500		
	6	99,700		
Primary Arterial (without BRT)	4	36,500	48,500	56,300
	6	59,500	76,400	84,400
Secondary Arterial	4	32,400	43,500	50,600
Tertiary Arterial	2	12,000	14,300	17,500
Community Roads (1)	2	8,200	9,700	11,900

Source: JICA Study Team. Reflects LOS C/D uninterrupted operating conditions and nine per cent peak hour factor. Calculations based on techniques contained in *Highway Capacity Manual, Special Report 209*; Transportation Research Board, National Research Council, 1998 (with updates)

(1) : May be seen as representative capacity. Actual capacity likely to vary considerably depending upon community road conditions.

Road mid-block capacity depicted in the previous table is, as noted, dependent upon various parameters among them vehicle mix, degree of side friction and curb parking. Capacity is also dynamic, that is, variable in a traffic context; for example, through flows opposing unprotected right-turn movements. In the case of interrupted flow conditions, capacity is further impacted by the ability of links to discharge traffic through a node (intersection), given that "competition" for nodal discharge opportunity exists among intersecting flows, and that this "competition" is often regulated by traffic signals, the police or other forms of traffic control devices. The "rationing" of available time for movements through a node, that is, the ability to discharge traffic, will therefore be further reduced from mid-block (uninterrupted) flow conditions based on green time (or police clearance) allocated over time.

Thus, based on the Dar es Salaam experience, it may be expected that available (interrupted) capacity for primary and secondary arterials will be some 20 to 30 percent less than shown in the previous table. Discounts for tertiary arterials and community roads could range up to 60 percent. Expressways, being segregated and access controlled facilities, would retain full capacity from uninterrupted flow conditions as no impedances to movement exist.

2.5 Public Transport and Cargo Considerations

The unique requirements of mass transit (BRT) and commercial vehicles carry distinct implications. The previous discussion notes that BRT busways are to be provided in (and only in) primary arterial roads. The indicated capacity values in the previous table do not account for the presence of BRT, but do reflect a reasonable presence of heavy commercial vehicles (represented by long distance, articulated trucks). Further considerations include:

- In the most general of terms, the retrofitting of BRT lanes will decrease vehicular capacity in that, for example, a primary arterial cross-section featuring six mixed traffic lanes will be reduced to four mixed traffic lanes (plus two BRT lanes). However, it is important to concurrently note that while vehicular capacity will have been reduced, the person movement capacity of the composite cross-section is expected to increase. A BRT system as contemplated for Dar es Salaam can accommodate 10,000 – 15,000 persons per hour per direction: far more than passenger cars in the mixed traffic stream (some 2,000 - 3,000 persons per hour per direction for a four lane road). It is also important to note that the introduction of BRT is, within the specified corridors, largely expected to eliminate the road operation chaos that is currently catalyzed by dala dala activities.

- The Phase I BRT system (Morogoro Road corridor) features two mixed traffic lanes per direction plus the BRT busway. BRT stations are provided every 500-700 meters. Station design requires that passengers entering to, and departing from, the median-sited stations must cross Morogoro Road at-grade. Each station will have two walkways in each lateral direction, protected by elevated design (each walkway will be raised between five and 10 centimeters above street level). This will considerably depress vehicular capacity since, in addition to intersection signals, there will be at least two "speed bump pedestrian crossings" every 500-700 meters in each direction of travel. The typical mixed traffic capacity will therefore be even less than that of a four lane primary arterial without BRT. The presence of frequent raised pedestrian crossings, while intended for traffic calming and the safety of BRT passengers, will also impact emergency vehicles (ambulances, fire trucks) negatively in that the undulating street surface limits speed (i.e. increases response time).

- Later phases of the BRT will, in most cases, feature an alternative BRT station design concept under which passenger movement to/from the median stations is accomplished via elevated walkways. This removes the speed bumps from the mixed traffic lanes, and will catalyze higher capacity and operating speed for the primary arterial in question. Indeed, capacity of a six lane primary arterial with BRT (four mixed traffic lanes plus two BRT lanes) is likely to mirror capacity of a four-lane primary arterial without BRT lanes.

- Arterial roads which accommodate network bus services (that is, standard sized buses operating in mixed traffic) should, whenever possible, feature recessed bus bays at curbside. This removes the stopped bus from the traffic stream while picking up/discharging passengers. The safety (and comfort) of these passengers is concurrently improved.

- Two generic types of trucks may be considered. The first are service vehicles, generally consisting of two and three axle rigid trucks. These provide goods distribution and service to a variety of land uses. Service trucks should be able to use any road assuming physical conditions and operations so permit. The second type is heavy commercial vehicles, generally represented by articulated trucks. These typically do not provide service functions, but move large (and heavy) loads of cargo between major destinations; for example, upcountry Tanzania and the seaport. Consideration should be given to focusing heavy commercial vehicles onto designated roadways (truck routes) in order to expedite the activities of the trucking industry, while concurrently ensuring that trucks do not compromise road safety, nor cause undue blockages and delays to other vehicles in the traffic stream.

These issues are unique to the primary road system. It is therefore proposed that a three-level stratification be implemented. While the overall functional intent of primary arterial roads remains unchanged from previous discussions, increased sensitivity has been achieved on how these roads may operate efficiently and safely.

- Primary Type I arterial does not contain any BRT busway facilities.
- Primary Type II and III arterials contain busways, but with differing station designs. While BRT stations may, at first inspection, be seen in a peripheral light vis-à-vis a functional road classification, there nevertheless exist important efficiency and safety consideration in the interplay of BRT passengers, heavy commercial vehicles and other elements of the traffic stream.

A synopsis of the differentiation is noted in **Table 2.5.1**.

Table 2.5.1 Stratification of the Primary Arterial Classification

Classification	Implications by Vehicle Grouping		
	Bus Rapid Transit	Heavy Commercial Vehicles	Comments
Primary Type I	No BRT busways provided	Use permitted, and particularly encouraged in case of some designated facilities (truck routes).	Network (i.e. non-busway) bus services expected in absence of BRT. Provision of curbside bus bays encouraged. Service truck likely pronounced.
Primary Type II	BRT busway provided. Station design involves at-grade crossing of adjacent traffic lanes by BRT patrons (the Phase I BRT Project Concept)	Not permitted.	Network bus services to be minimal due to BRT service. Service truck activity unavoidable, but should be discouraged.
Primary Type III	BRT busway provided. Station design involves grade separated (pedestrian overpass) crossing of adjacent traffic lanes by BRT patrons.	Use permitted.	Network bus services to be minimal due to BRT service. Service truck activity expected.

Source: JICA Study Team

The issue of truck routes is becoming increasingly relevant. The *Cargo Transport Survey* queried drivers at the Dar Es Salaam seaport as to a number of indicators including routing preferences: 43 percent (the largest subgroup) indicated that the preferred route of travel to/from the port is along Nelson Mandela Road. An approximately additional 25 percent identified Morogoro Road as the preferred corridor of travel. It is of further interest to note that the mix of commercial vehicles servicing the seaport consists of near 80 percent having more than three axles (that is, articulated vehicles) (a more detailed discussion of commercial vehicle activity is contained in the subsequent

Chapter 3). Based on these preferences, an indication of an "immediate action" truck route is depicted in **Figure 2.5.1**, to include a circumferential link with radial connectors.

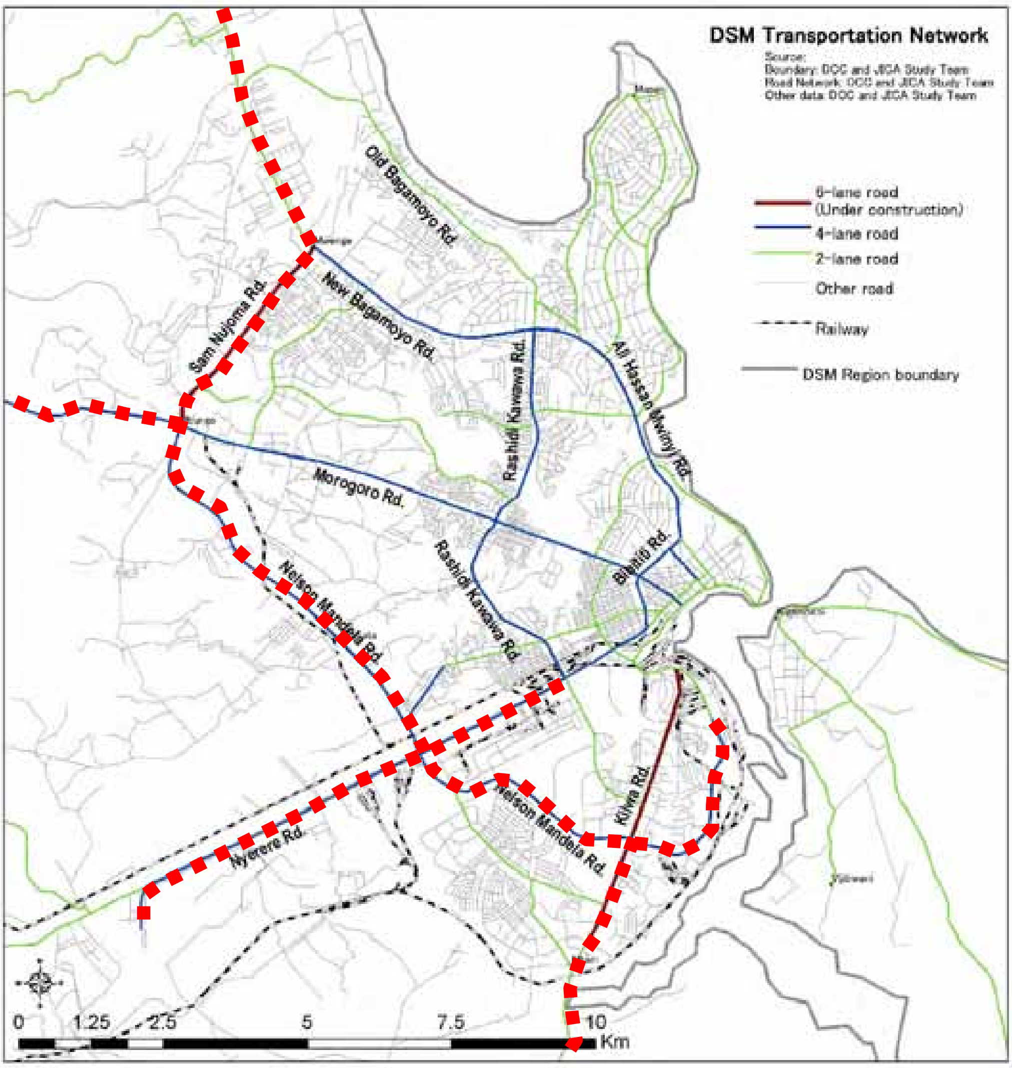


Figure 2.5.1 Potential Near-term Truck Route Network for Heavy Commercial Vehicles

Several important considerations arise from this analogy:

- A truck depot, suitable for transfer of cargo between heavy commercial vehicles and service trucks should be established to support limitations in road facilities available for large trucks (i.e. the truck route concept). The current impetus for such a facility is along Morogoro Road west of Nelson Mandela Road (Kimara truck terminal). This should continue to be encouraged. Furthermore, some truck terminal facilities inside the Nelson Mandela Road ring have already been removed (Janguani truck terminal).
- Discussions are continuing regarding the establishment of an inland container depot. One possible site (various other proposals have also been voiced) is the Ubungo ICD, roughly adjacent to the southeast quadrant of the Morogoro Road-Nelson Mandela Road intersection.

Three comments in this regard (a) it is far preferable that any ICD be sited outside of the Nelson Mandela Road ring, ideally near the perimeter of Dar es Salaam (integration with the Kimara truck terminal should be considered), (b) if the Ubungo ICD is sited as currently proposed, it is absolutely essential that truck ingress/egress be achieved via Nelson Mandela Road, and absolutely not via Morogoro Road, and (c) the Study Team has proposed that a BRT line be sited within the abandoned railway right-of-way which has also been voiced as a connection between Ubungo ICD and the port.

- Morogoro Road east of Nelson Mandela Road is to be classified as a Primary Arterial Type II facility due to implementation of the BRT Phase I concept. Thus, due to BRT station design, movements by heavy commercial vehicles in this corridor will be banned.
- Morogoro Road west of Nelson Mandela Road is included as a key element of the near-term truck route network. Yet, concurrently the BRT Phase I project extends into this area with what is a station design appropriate to a Type II facility. However, truck activity will be pronounced, thus, it is essential that Morogoro Road west of Nelson Mandela Road be designated as a Primary Arterial Type III facility (beyond the western terminus of BRT Morogoro Road will be classed as a Primary Arterial Type I until leaving the urban area at which it will revert to its current trunk road status). Thus, the BRT Phase I concept west of Morogoro Road should be re-designed to permit elevated (pedestrian walkways) access to, and egress from, BRT stations.

2.6 Quantification of the Hierarchy

The transport model developed within the Master Plan framework includes a road system sufficient to achieve simulation of inter-zonal trip demand[7]. The level of detail to which the zone structure and highway network are built must be in balance; thus, not all existing roads need be included, in particular minor facilities such as community roads. The modeled road content aggregates to some 772 kilometers, including near 460 kilometers of national/regional (TANROADS) roads, as well as about 310 kilometers of roads now under jurisdiction of local government.

Under the proposed functional classification, some 19 percent of the simulated road supply would be designated as being primary arterial (some 80 percent of which fall within the TANROADS grouping). Conversely, roughly two-thirds of the simulated network would fall within the tertiary roads category (**Table 2.6.1**).

[7] Refer *Technical Report 7* for further discussion of the Master Plan Transport Model.

Table 2.6.1 Year 2007 Road Network Extent

Functional Classification	Subcategory	Road Kilometers by Administrative Class		
		National	Local	Total
Expressway		0.0	0.0	0.0
Primary Arterial	Type I	53.6	19.3	72.9
	Type II	17.5	10.5	28.0
	Type III	48.0	0.0	48.0
Secondary Arterial		49.2	61.7	110.9
Tertiary Arterial		290.0	221.3	511.3
Special Roads (1)		0.0	0.9	0.9
Total		458.3	313.7	772.0

Source: JICA Study Team.

(1): Excludes alignments within Tabata rail right-of-way.

The derivation of future road networks (please refer the subsequent Chapter 4) is based on a series of road scenarios ranging up to a "do maximum" scenario; that is, full potential build out of road facilities. Under the "do maximum" scenario, some six percent of roads incorporated within the transport model would be classed as motorway/expressway, about 20 percent as primary arterials, 16 percent as secondary arterials, and near 60 percent as tertiary arterials. Type II and III primary arterials, which include facilities for busways, represent some 10 percent of the modeled road network (**Figure 2.6.2**).

Table 2.6.2 Year 2030 "Do Maximum" Network Extent

Functional Classification	Subcategory	Allocation	
		Kilometers	Percent
Expressway		59.8	5.5
Primary Arterial	Type I	101.0	9.3
	Type II	45.1	4.1
	Type III	70.0	6.5
Secondary Arterial		178.8	16.4
Tertiary Arterial		611.3	56.3
Special Roads and other (1)		20.3	1.9
Total		1,086.3	100.0

Source: JICA Study Team.

(1): Excludes alignments within Tabata rail right-of-way.

Chapter 3 Commercial Vehicle Activity

The discussion of commercial vehicle (truck) activities, and cargoes carried by commercial vehicles, is structured into a series of linked topics. An overview of the role of trucks within the traffic stream is reviewed in the first instance. This is followed by a discussion of shipments and loading patterns. Relevant inputs are drawn from findings of the cargo survey[1] as well as other data collection efforts conducted within the framework of the Transport Master Plan review. The final level of the discussion relates to opportunities and constraints, as well as recommendations, for the sector.

3.1 Traffic Volume Profile

An initial insight regarding the relative roles of the various road-based modes can be gleaned from findings of the Master Plan traffic survey program during which traffic counts, stratified by hour, direction and vehicle type, were collected for 16 or 24 hours at some 30 sites throughout the study area[2]. For overview purposes, traffic counts were combined based on two locational criteria: screenline locations, or counts collected roughly within the Nelson Mandela Road corridor, and cordon counts, collected at the outer periphery of the study area.

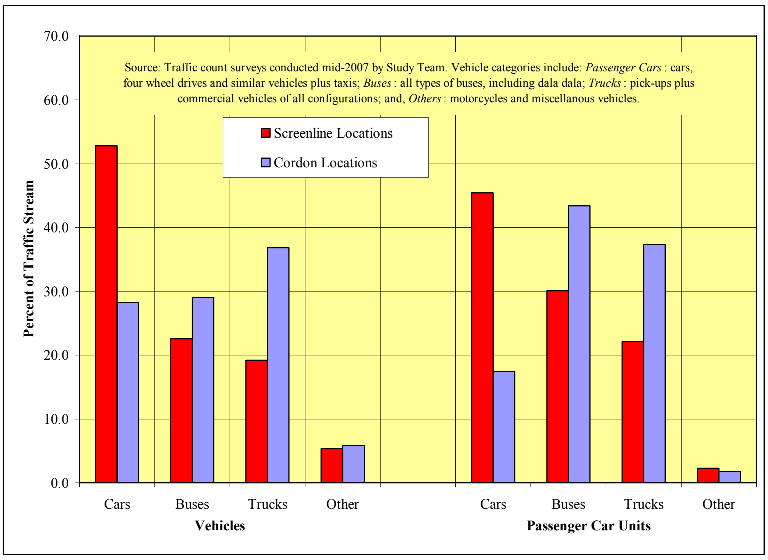


Figure 3.1.1 Composite Vehicle Mix in the Traffic Stream

Passengers cars (including taxis) are, during a representative year 2007 weekday, the dominant vehicle of transport at the summed screenline locations accounting for, on average, some one-half of all counted

[1] Refer *Technical Report Volume 6: Dar es Salaam Transport Policy and System Development Master Plan, op. cit. (Chapter 7)* for further discussion of cargo survey program and results.

[2] Refer *Technical Report Volume 6: Dar es Salaam Transport Policy and System Development Master Plan, op. cit. (Chapters 2 and 3)* for further discussion of traffic counting program and results.

vehicles. Trucks (including pick-ups), buses (all configurations including dala dala) and other vehicles (including motorcycles) accounted for a further 23, 13 and nine percent of counted vehicles, respectively. However, at cordon locations, the relationship differs sharply. Trucks are the majority vehicle type accounting for some 37 percent of counted vehicles, while buses and cars each account for a further 28-29 percent (**Figure 3.1.1**).

Vehicle activity can also be expressed in terms of passenger car units (pcu's). This stratification accepts that vehicle types exert differing impacts upon the traffic stream in which they operate due to both size and engine capabilities. Typical pcu vis-à-vis vehicle equivalents used in Master Plan modeling efforts are motorcycle – 0.3; light vehicle (car, pick-up, taxi) - 1.0; small truck (two axles) – 1.5; medium truck (three axles) – 2.5; large truck (more than three axles) – 3.0; small bus/dala dala – 1.2; medium bus – 1.5; and, large bus – 2.5. The representation of both buses and truck increases when viewed on a pcu basis. While passenger cars still dominate at the screenline counts (45 percent of surveyed pcu's), buses and trucks and buses account for some 30 and 21 percent of pcu's, respectively. At the cordon locations, the pcu representation of buses and trucks hovers near 40 percent each (refer **Figure 3.1.1**).

Pick-ups and 2-axle configurations are the dominant vehicle type noted in the truck stream. Near 60 percent of trucks counted at screenline locations are pick-ups; however, at the cordon locations, 2 axle trucks account for some 50 percent of surveyed vehicles. Trucks of three and more axles are also found in larger quantity at the cordon locations accounting for a total of some 20 percent of vehicles, roughly twice the representation at screenline locations. This representation changes slightly when calculated on a pcu basis. Traffic counts collected along the study area periphery again exhibit a higher ratio of large (three and more axle trucks) accounting for 37 percent of surveyed truck pcu's (**Figure 3.1.2**).

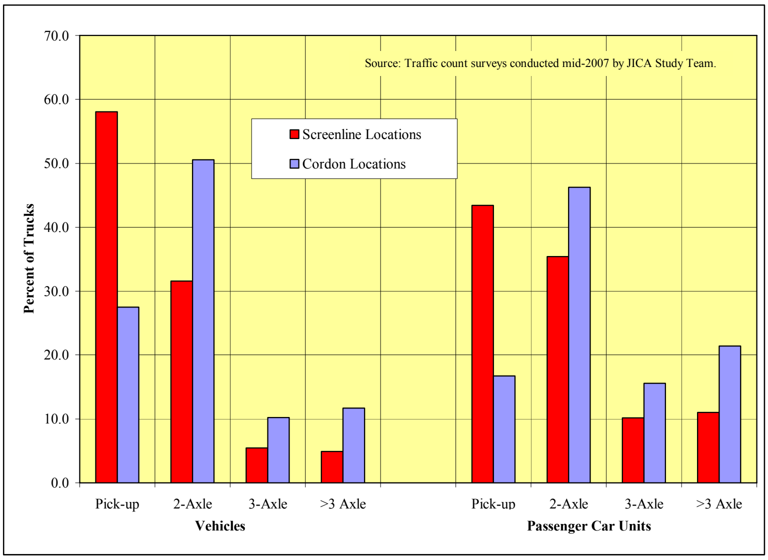


Figure 3.1.2 Composite Truck Mix in the Traffic Stream

An insight into a representative study area hourly truck volume distribution is gained by combining findings all 24 hour count sites. Highest truck volumes were measured during mid afternoon hours at the screenline locations. However, for pick-up trucks, highest peak hours are beginning 1000, 0700 and 1500. This supports that pick-ups, while used in some capacity for cargo transport, are a means of passenger transport. Truck activity rapidly falls off after about 2100 hours (**Figure 3.1.3**).

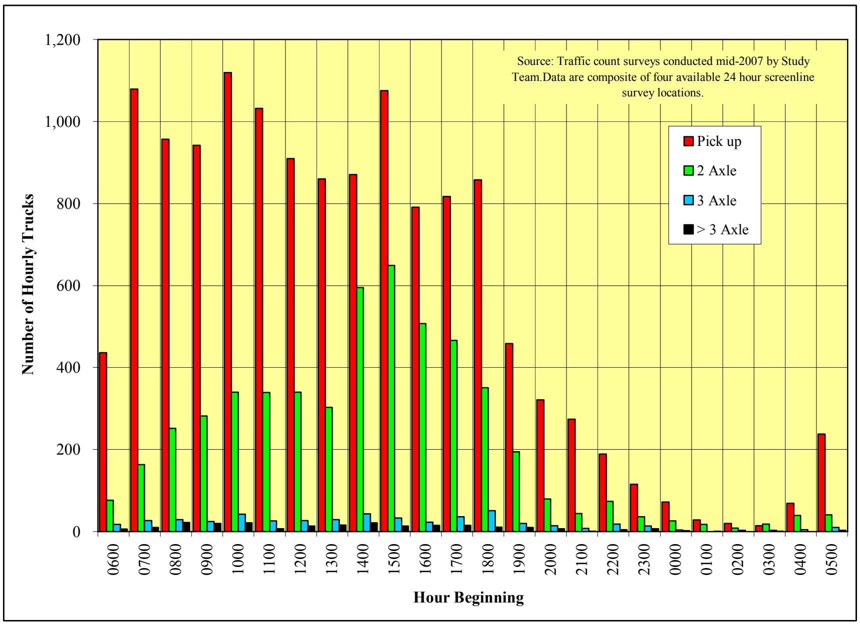


Figure 3.1.3 Composite Hourly Truck Volumes Screenline Locations

Absolute activity at the cordon locations is, as expected, considerably more modest than at the screenline locations. Hourly demand for any type of truck does not exceed 120 vehicles at the cordon station, but can reach more than 1,000 vehicles per hour in case of pickups at screenline stations. On a relative basis, there is also more activity during late night and early morning hours at the cordon station (**Figure 3.1.4**). This relationship can also be seen in pcu terms, and by considering all vehicle classes. Thus, while absolute volume decreases for all vehicle types during early morning hours, the relative rate of involvement for trucks increases. For example, from roughly midnight to 0500, trucks of all types represent 80 percent of the pcu stream. This differs sharply from daytime hours when trucks and buses are in relative balance (**Figure 3.1.5**).

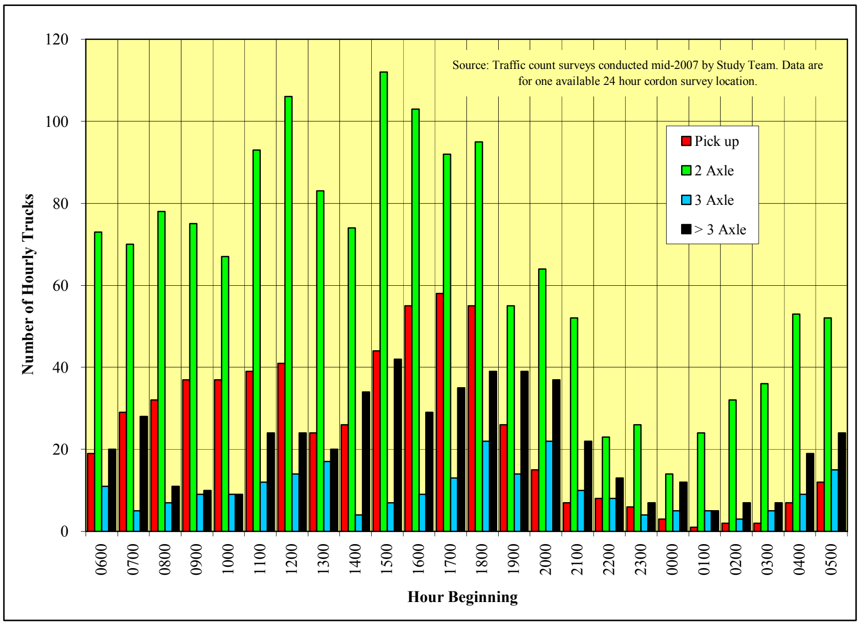


Figure 3.1.4 Composite Hourly Truck Volumes Cordon Location

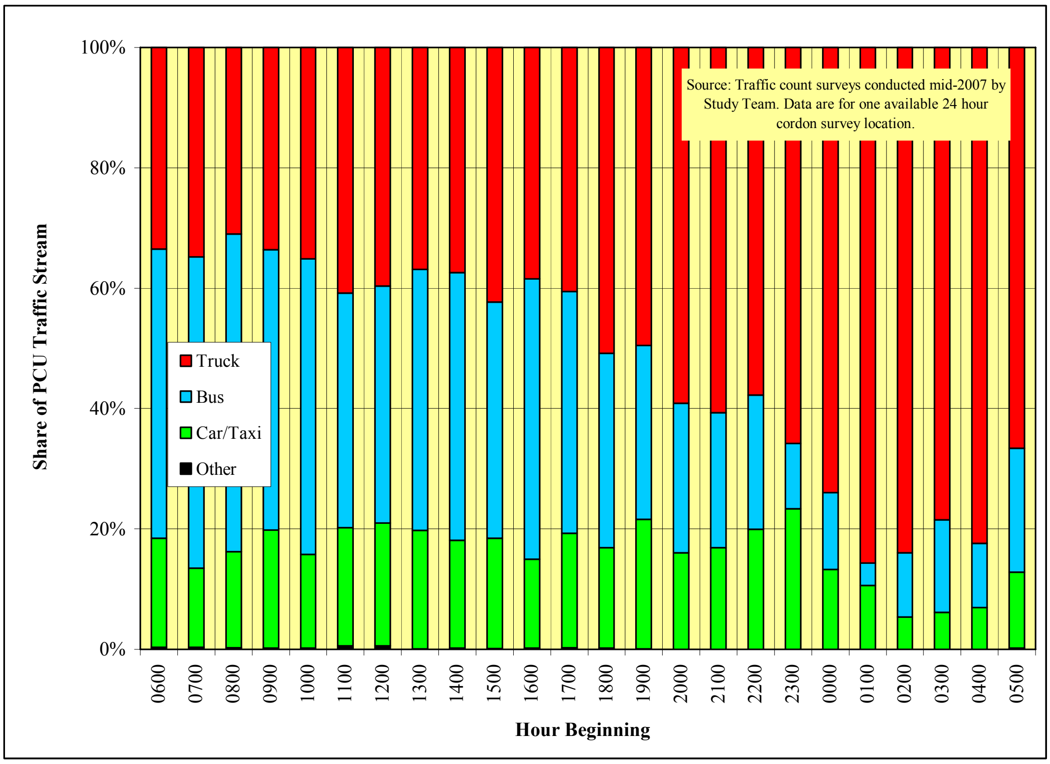


Figure 3.1.5 Composite Relative Hourly Truck PCU Volumes at Cordon Location

3.2 Loading Characteristics

The usage of commercial vehicles (truck types excluding pick-ups) varies by both type of vehicle (number of axles) as well as whether the vehicle is operated by a trucking company or for a specialized function such as the Seaport of Dar es Salaam. Details were obtained during the course of a cargo transport survey administered by the JICA Study Team during mid-2007. Key findings in terms of commodities carried include (**Table 3.2.1**):

- The truck type employed differed radically. In case of trucking companies, almost two-thirds of vehicles had a 2-axle configuration. However, almost 80 percent of vehicles in use at the seaport were large, articulated vehicles having more than three axles.

Table 3.2.1 Type of Cargo Carried by Truck Type; Trucking Companies and Seaport

Commodity	Percent by Company Truck Type				Percent by Seaport Truck Type			
	2 Axle	3 Axle	> 3 Axle	Total	2 Axle	3 Axle	> 3 Axle	Total
Agriculture and livestock	2.4	1.2	4.0	2.4	0.0	0.0	2.4	1.8
Food stuff and animal food	41.3	48.6	22.2	40.1	53.8	18.2	5.9	14.6
Solid fuels	0.9	1.7	1.0	1.1	0.0	0.0	1.2	0.9
Petrol and petrol distilled products	0.7	0.0	22.6	3.7	0.0	9.1	0.0	0.4
Metal residues and mining products	1.2	3.7	0.0	1.5	15.4	0.0	2.4	4.4
Metallurgical products	4.2	5.2	4.6	4.5	0.0	0.0	7.1	5.5
Raw materials and derivations	2.6	3.5	14.9	4.5	0.0	0.0	10.6	8.3
Fertilizers	0.0	0.6	0.4	0.2	0.0	0.0	1.2	0.9
Chemical Products	9.9	7.3	10.7	9.5	0.0	0.0	8.2	6.4
Diverse non-classified cargo	26.3	10.2	8.5	20.4	23.1	45.5	37.6	35.6
Unknown	10.5	17.9	11.1	12.2	7.7	27.3	23.5	21.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Representative Percent Trucks by Type Based on Survey Results	64.8	21.1	14.1	100.0	16.9	4.8	78.3	100.0

Source: JICA Study Team; *Cargo Transport Survey.* Percentages exclude empty vehicles. Data derived from 2,831 interviews.

- The dominant type of cargo transported by trucking companies was "food stuff and animal food". This was consistent across all truck types, with exception of trucks having more than three axles: within this category, 22.6 percent carried "petrol and petrol distilled products", while 22.2 percent carried "food stuff and animal food".
- The most dominant category at the seaport was "diverse non-classified cargo" (this category also includes machines and vehicles): in total slightly more than one-third of trucks. The exception was two axle trucks, slightly more than half of which carried "food stuff and animal food".

The relative loading conditions of trucks was focused on "empty" or "fully loaded". This is particularly, and understandably so, in case of the seaport (about 80 percent of trucks "full or empty"). Trucks either pickup or discharge typically full loads in line with financial expectations. In case of trucking companies, about 60 percent of vehicles were "full or empty" (**Figure 3.2.1**).

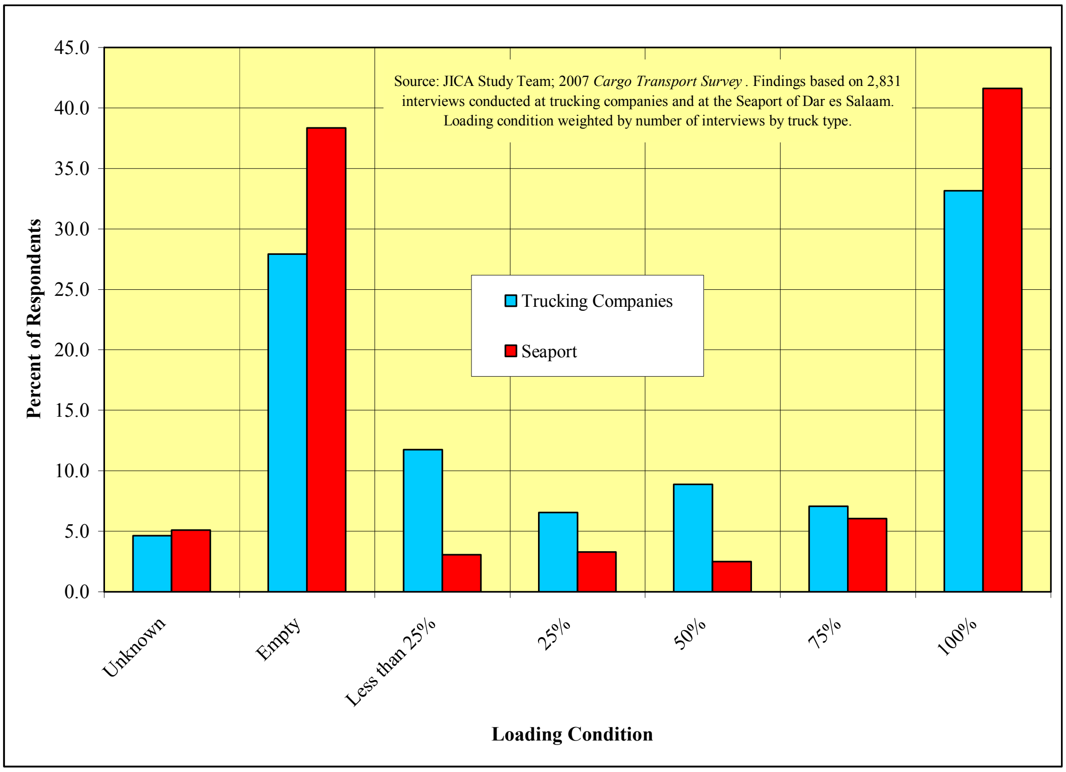


Figure 3.2.1 Representative Loaded Condition of Commercial Vehicles

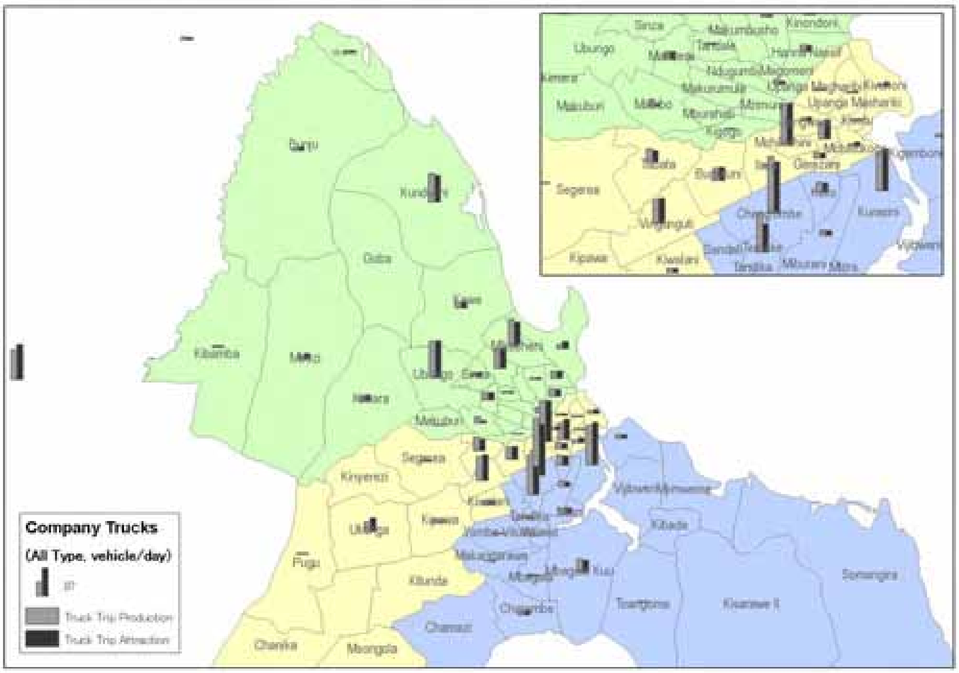
- The typical two axle truck, per permitted plating, exhibited an unloaded weight of 3.3 tons. The average permitted cargo capacity was 2.5 tons. That is, at 100 percent load, a total vehicle weight of 5.8 tons.
- The typical three axle truck exhibited an unloaded weight of 6.5 tons. The average cargo capacity was 6.4 tons, leading to a maximum vehicle weight of 12.9 tons.
- The typical commercial vehicle having more than three axles featured an unloaded weight of 15.2 tons. The average cargo capacity was 14.9 tons, or a composite weight of 30.1 tons.

3.3 Trip Patterns

The truck (cargo) trip origin-destination patterns are derived via results of the cargo transport survey, as well as application of the Master Plan transport model. Several findings are of considerable interest. These highlight the differences between cargo flows as transported by trucking companies vis-à-vis seaport-related transport.

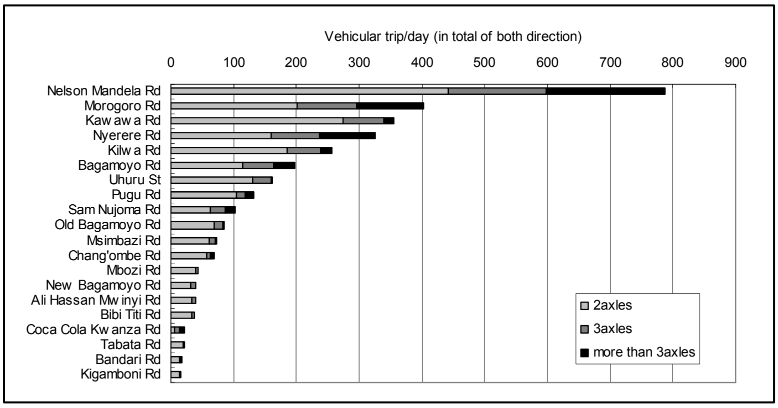
Trip patterns for trucking companies reflect:

- The major truck trip generators (wards); that is, places where cargo movements originate or are destined to, include Chang'ombe, Mchikichini, Temeke, Kurashini and Ubungo wards as well as the western external region (exiting the study area via Morogoro Road). In general, the trip pattern is diffuse, but basically focused on the urbanized area lying within the Nelson Mandela Road corridor (**Figure 3.3.1**).



Source: JICA Study Team

Figure 3.3.1 Truck Trip Generation Profile: Trucking Companies



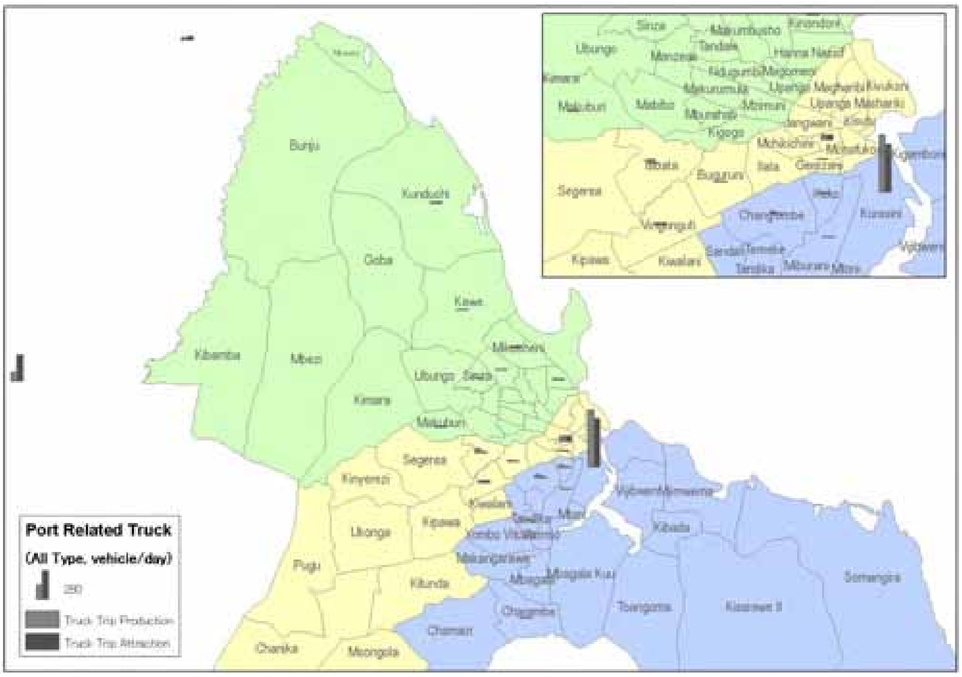
Source: JICA Study Team

Figure 3.3.2 Indicated Routes of Travel Trucking Company Vehicles

- When queried regarding route of travel to fulfill cargo pickup/delivery obligations, drivers noted they most frequently use Nelson Mandela Road (43 percent of cases); Morogoro Road (22 percent of cases), Kawawa Road. (19 percent of cases), and Nyerere Road (18 percent of cases). Also, as noted previously, the dominant truck type used by trucking companies is a two-axle configuration. Thus, in case of Nelson Mandela Road trips, for example, roughly 440 trips are via two-axle trucks, 160 via three axle trucks and 190 via commercial vehicles of more than three axles. In case of Kawawa Road, on the other hand, usage is dominated by trucks of two axles only (**Figure 3.3.2**). This is quite logical as truck drivers will, if possible, tailor their trip route via the type of road that is most appropriate to the size of vehicle being driven.

Patters differ in case of seaport activity.

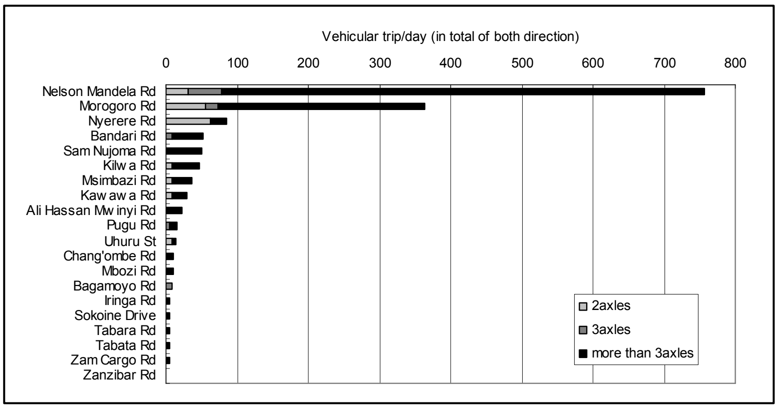
- The major truck trip generator is Kurasini ward (which includes the seaport) and the western external region (leaving the study area via Morogoro Road). Indeed, there is only very little interaction between the port and other parts of Dar es Salaam, and in those cases, is basically focused on the area within the Nelson Mandela Road ring (**Figure 3.3.3**).



Source: JICA Study Team

Figure 3.3.3 Truck Trip Generation Profile: Seaport of Dar es Salaam

- Driver interviews at the seaport support the dominance of the western axis in that some 77 percent of seaport truck drivers indicated using Nelson Mandela Road. A secondary preference among drives is Morogoro Road, noted in 37 percent of cases. Furthermore, in keeping with type of vehicle preferences noted previously, approximately 80 to 90 percent of truck activities on the noted two roads is made by commercial vehicles with more than three axles (**Figure 3.3.4**).



Source: JICA Study Team

Figure 3.3.4 Indicated Routes of Travel Seaport Trucks

The truck trip patterns are fully reflected in the Master Plan transport model, in which truck balanced origin-destination matrixes contain truck/cargo trips, which are subsequently assigned to the road network along with other road users. As a point of interest, the base year (year 2007) matrix was stratified by type of truck, regardless whether trucking company or seaport activity. For presentation purposes, the 170 analysis zone system was collapsed to a series of superzones reflective of major urban catchments within Dar es Salaam, plus a series of superzones for upcountry destinations.

The year 2007 origin-destination (in balanced format; that is, zonal production being equal to zonal destinations on a daily basis) pattern clearly confirms that, in case of commercial vehicles with two axles, there exists considerable diffusion in demand among the superzones. One of the highest activity linkages is "within the outer southwest" superzone; that is, western areas of Ilala municipality. This superzone begins basically at Nelson Mandela Road, thus confirming the importance of the Nyerere Road corridor as a hub activity for two axle trucks (**Figure 3.3.5**).

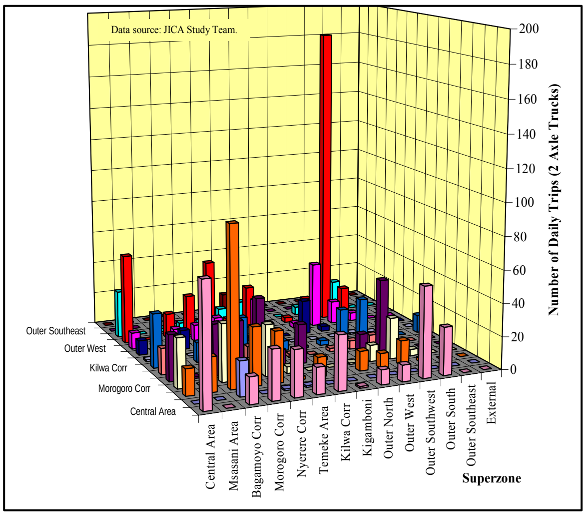


Figure 3.3.5 Superzone Trip Pattern Commercial Vehicles with Two Axles

The role of the Nyerere Road corridor is also noted in case of trucks having three axles. Destinations exist to most other zones within Dar es Salaam, principally those located within the Nelson Mandela Road ring (**Figure 3.3.6**). Trip patters are, as expected, very different in case of commercial vehicles having more than three axles. Two main activity precincts exist: The Kilwa Road corridor, which includes the seaport and adjacent operators, as well as external (upcountry) destinations (**Figure 3.3.7**).

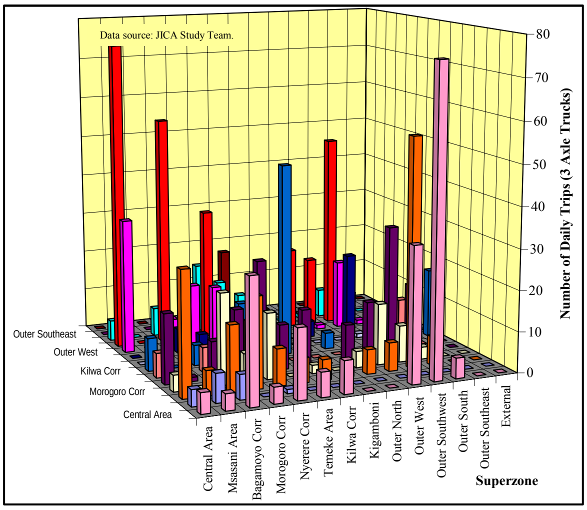


Figure 3.3.6 Superzone Trip Pattern Commercial Vehicles with Three Axles

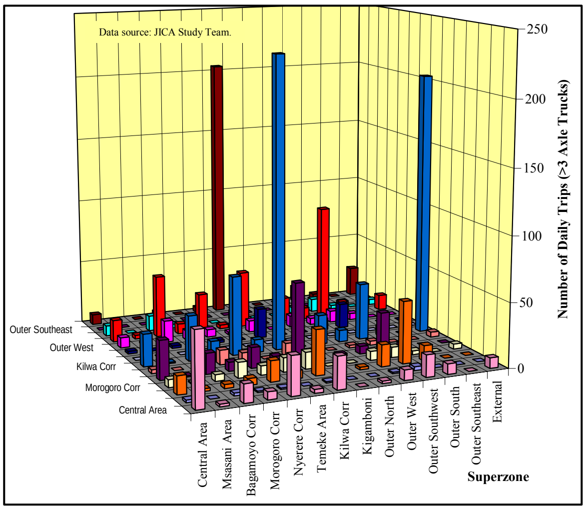


Figure 3.3.7 Superzone Trip Pattern Commercial Vehicles More Than Three Axles

3.4 Opportunities and Constraints

The review of commercial vehicle/cargo operations gives rise to several opportunities and constraints for the sector. These are discussed in following paragraphs, which, in turn, lead to recommendations as contained in the final section of this chapter.

3.4.1 Infrastructure Development

Future traffic problems (congestion) in the study area will, to an extent, be fueled by cargo transport. However, the dominant increases in vehicle activity, and consequent road demands, will be catalyzed by passenger car activity. Thus, from a cargo transport perspective, the proposed Master Plan road infrastructure is sufficient to accommodate future increases in absolute vehicular activities. **This does not mean that the new infrastructure is not necessary, nor that the needs of commercial vehicles should be slighted; indeed, proposals promulgated within the framework of the Transport Master Plan are intended to benefit all road users**. Nevertheless, in order to optimize the use of the infrastructure, measures oriented towards the cargo sector should be considered to facilitate truck movements, therewith providing more space for, and minimize conflicts with, other road users.

Several considerations are of particular relevance in this regard.

- Trucks, particularly heavily loaded vehicles, cause a disproportional amount of damage to road surfaces as opposed to damages caused by the much more numerous buses and cars[3]. Thus, it is desirable from a road maintenance point of view that heavy commercial vehicle activity be focused onto those road segments whose construction standards support heavy truck loadings.
- Designation of a network suitable for heavy loaded vehicles is desirable. However, this must reflect "reality"; that is, compatible with an engineering perspective on one hand, while, on the other hand, concurrently recognizing the needs of the trucking industry. Furthermore, such routes must be closely integrated with designation of a functional road hierarchy (as noted in the previous chapter).
- BRT is expected to emerge as a pivotal mode of transport within Dar es Salaam. Different designs will be adopted regarding the movement of BRT passengers to/from system stations. In some instance, this movement will be at grade, in some instances, grade separated. Designated corridors for heavy vehicle movement are, on road safety and road capacity grounds, incompatible with BRT alignments featuring at-grade BRT station access. Conversely, in corridors designated for truck activities, BRT stations should feature grade separated movement for BRT passengers traveling to/from the median-sited stations.
- Intense urban activity already exists within the CBD, and is expected to intensify in future. Furthermore, anchored by BRT, the Morogoro Road corridor is likewise expected to evolve as a corridor of high urban activity, similar to intensities within the CBD. This carries two implications from an infrastructure point of view: that heavy commercial vehicles are not suitable for operation in densely developed areas, and that business within the urban precinct have a strong need for service access. This is largely carried out by smaller trucks (typically

[3] The deterioration of a road is often expressed in Equivalent Standard Axle Loads (ESAL) of 10 tons, with higher ESA implying more damage potential. The relationship between load, axle grouping (single, tandem, tridem) and tires (single, double, wide) is exponential. While loadings and axle configurations vary considerably, some representative values for ESA's are 0.1-0.2 for cars and buses; 0.3-0.5 for pick-up trucks; 1.1-1.5 for two-axle trucks (although this can be considerably more in case of overloading) and 1.5-2.5 for articulated and truck/trailer combinations. Thus, cars and buses

two axles) but nevertheless points out a need for proper access, either in the form of additional infrastructure or operational controls.

3.4.2 Goods Vehicle Demand Management

The desirability of implementing control measures on the trucking industry have been voiced to the Study Team at various stages during conduct of the Master Plan study. Demand management measures, which directly or indirectly affect the operations of economic actors (industry and commerce), are realized in the form of metropolitan-wide prohibitions or limitations of activity. However, caution is urged in such "blanket controls" as more detailed reviews will first be needed to:

- clearly identify the specific target areas for such measures;
- assess the economic, financial and operational consequences of the measures; and,
- formulate recommendations for the affected industries and commerce on how to incorporate the measures in their operations.

It is in that context strongly recommended, before any of the proposed structural measures are imposed, that careful consideration is given to alternative measures which manage the demand of goods by industry and commerce. Local, or problem-specific, solutions may often be preferable to defining broader, metropolitan wide control measures.

For example, in streets around schools, traffic is particularly high during beginning and end of school hours. This traffic is generated by parents bringing their children to school and by school buses. If at the same time commercial goods are delivered to small shops and kiosks in these streets, the combined effect on traffic throughput is substantial. One low cost and easy to implement solution is to prohibit the delivery of goods to these shops and kiosks during these particular hours (beginning and end of school). The direct and / or indirect effects for the shops in question of this demand-oriented measure are low to negligible, while the positive effects on traffic can be highly positive.

What might be form of more common demand management measures?

- A **daytime total truck ban** (say between 0700 and 2000) will control access of small trucks (pick up and two axle trucks) in certain areas (such as the CBD or central area) and/or on certain roads where traffic is (will become) particularly heavy. This measure limits the access of trucks in certain areas or on certain roads where trucks have a higher than normal traffic stream content and/or where volume to capacity relationships are particularly acute. The objective is to reduce their impact on private and public traffic at times when the flow is particularly dense. A variant of the scheme is not a total daytime ban, but only during certain hours of the day. These would typically coincide with the morning and afternoon peak periods, say 0600-0900 and 1500-1800.

  A drastic measure such as an all-day ban (but not necessarily a peak hour ban) should

cause virtually no road damage if pavement is maintained to adequate standard.

concurrently be supported by necessary coordination as well as liaison with impacted establishments, shops and industries. Of course, any ban must concurrently be supported by the provision of alternative routes of travel circumventing the ban area to permit continued flow of the economically critical goods stream.

- **Introduction of a night delivery system**. The supply of stores and factories could be regulated in areas where the total truck ban is imposed and traffic is particularly dense. The principle is not new but applied in many European cities, where shops are supplied during night time or early in the morning and trucks are banned from the streets during daytime. The precincts where such measures are typically introduced are within areas/corridors of intensive urban activity. In a second phase, the measure could be extended to some other areas where truck traffic reaches higher than average representation in the traffic stream, or where congestion is particularly pronounced.

  It should be noted that the truck ban generally does not apply to final consumer delivery of foodstuff and household utilities to private households.

  Some shops or enterprises may apply for an exception on the truck ban. In some cases, their demand might be valid and an exception could be considered. But it would be unfair to the others that apply the truck ban if no alternative measures are imposed that make applying for an exception less attractive.

- **Daytime service licenses**. Shops and industries in areas with a total daytime truck ban and night delivery system that apply for an exception will need to purchase a daytime service license. The introduction of such license is to avoid that the truck ban and night delivery system is weakened by a high level of exceptions. The high cost of the license will guarantee that applying for an exception to the system is unattractive and shops and factories will only apply if they really need to.

  The principle is based upon the recuperation of congestion costs. Such congestion implies "….a 'dead-weight' welfare loss and … [reduces] the economic efficiency of any transport system"[4]. One of the measures to recuperate this loss is via the introduction of the license for storeowners and factories in districts where total traffic is particularly dense and who apply for an exception of the imposed truck flow control measures.

  For the above three measures (day time truck ban, night delivery and daytime service license), it is emphasized again that in-depth studies are required to assess the economic and operational consequences of these measures for storeowners and industries in the areas where the measures are to be imposed.

[4] Further discussion of this topic is contained in *Transport Economics (Second Edition)*, by Button, K.; Edward Elgar Publishing Ltd, 1993, pp 109 - 121, and 243 – 260.

3.4.3 Law Enforcement

An important comment should be made at this point. Measures such as the demand control strategies outlined in the previous section, or the designation of unique truck routes, for example, can only generate a positive effect if they are actively enforced and controlled. Indeed, enforcement and control does not only relate to truck measures, but extends to all traffic rules and regulations for all road users.

The reason is that congestion in the streets is not only caused by one type of vehicle or one type of activity or traffic movement, but by a combination of interacting factors.

According to Vickrey[5], several types of congestion can be observed:

- Simple interaction congestion is caused by slow moving vehicles;
- Multiple interaction where vehicles, added to dense traffic, causes substantial delays to all infrastructure users. On average, every minute the marginal user is delayed, the other users are suffer a delay of three to five minutes;
- Bottleneck situations emerge when infrastructure capacity reduces either as compared to a previous or subsequent section or as a consequence of vehicles blocking throughput traffic. If maximum capacity is reached or traffic flows are blocked, the bottleneck will immediately generate congestion because of its incapacity of dealing with the traffic levels and flows;
- Trigger neck situations occur in relation to bottleneck situations and consist of delays imposed upon infrastructure users, which not using the bottleneck that is causing the congestion but suffer because of multiple interaction by vehicles that avoid the blocked area and use an alternative road;
- Network and control congestion is generated through artificial means such as traffic lights, police intervention and other control methods. If properly used, they can structure traffic, but if improperly used of one of the other types of congestion occurs, these control devices can be the cause of additional or increased congestion.

Based upon above differentiation, traffic inside, for example, the Nelson Mandela Road belt presently generates different types of congestion and the supply of goods to stores, shops and (small) production enterprises only add to the problem. But measures that affect commercial truck traffic are useless without simultaneously controlling the behavior of other road infrastructure users.

Some important reasons for traffic congestion inside Dar es Salaam are the badly maintained vehicles, outdated and often malfunctioning traffic control systems, illegal and uncontrolled parking, and chaotic behavior of drivers (in particular dala dalas)[6]. These factors are not only directly responsible for congestion but also "trigger" additional bottlenecks for small trucks and pick ups while supplying commercial establishments.

[5] *Congestion Theory and Transport Investment* in "American Economic Review Number 59", by Vickery, W., pp. 251-260, as noted p. 116 ibid.

[6] Additional detail contained in *Study of Traffic Management on Trunk Roads in Dar Es Salaam Region*, op. cit.

Enforcement is one aspect only, of course, in mitigating these shortfalls. However, it is an important consideration; indeed, based on field observations, interventions, if not properly applied, have the ability to themselves catalyze congestion. An example of this frequently voiced to the Study Team is manual police control of congested intersections, while over-riding existing (albeit often inadequate) signal controls.

3.4.4 Redirecting the Flow of Large Trucks

The current review suggests that, inside the Nelson Mandela Road ring, the presence of large trucks (having more than three axles) is low except within identified areas (such as the Kilwa Road corridor vicinity of the seaport), or along segments of Nyerere Road. On, or beyond, this belt the concentration of heavy vehicles increases, largely in response to the need for shipments between upcountry destinations and the port. However, the interplay of industrial precincts and/or trucking operators, such as along Nyerere Road, also plays a part in this pattern.

Further ameliorating the flow of heavy trucks (other than the application of bans) could be achieved via three supporting measures, namely the relocation of industries, the reorganization of truck movements and the development of terminals/inland container depots (ICD).

- **Industrial relocation**. Many of the industries located inside the Mandela ring are conceivably situated there due to historic reasons. Traffic was likely modest and population density relatively low at the time of their founding. Gradually the urbanized area expanded and the factories/establishments were gradually surrounded by habitat, with traffic problems as a consequence. Many if not most of these concerns have no direct relationship with their surroundings in terms of supply or consumption and could in theory easily relocate to areas outside the (now) core. Surely one the reasons why potentially interested establishments have not relocated can be found in the high costs of relocation.

  Measures that are applied in other parts of the world to exit industries from populated areas are relocation premiums, land price measures and in a longer term penalizing tax measures. (a) In case of relocation premiums, enterprises can be stimulated to relocate their business via a financial premium. The amount of the premium can be defined upon the total investment cost or the land value of the present industrial site. Independent of the approach, the level of the premium should be sufficiently high to have an effect on the decision of companies to relocate their activities. (b) A second measure that could be applied in combination with the relocation premium is a land price measure. The purchase of land to develop the new industrial site is together with the construction of the factory itself one of the most important costs. While the relocation premium compensates to a level for the construction cost of the factory, measures on the level of land price will add to the attractiveness to relocate. Land price measures depend upon the ownership of the land. If the land is predominantly in private hands, a premium equal to a certain percentage of land purchase cost could be given to the industrial investor to purchase the land. If land is owned by government, the price of the land could be kept artificially lower than its actual value. In addition, government could ensure that the land is foreseen of all utilities (water, electricity, telephone, etc…) so that the industrial investor does not need to invest in these provisions. (c) Positive tax measures can be used at the beginning of the policy implementation to stimulate industries to relocate their activities to particular locations. For example, companies planning to relocate outside of the Mandela belt could be exempted from land taxes and reductions in social charges if new employment is created, making the relocation for companies highly attractive from a tax and personnel charge point of view. Conversely, after a (limited) number of years, the policy could be inversed and tax measures could now be introduced to "punish" companies that have not, for example, relocated outside the Mandela belt.

- **Restructuring (positively reinforcing) the flow of heavy trucks**. Heavy trucks at present are only a problem at limited locations, and the impact may well become even more diffuse in the future as more, and higher-order, road facilities are introduced. Furthermore, and again at present, large commercial vehicles voluntarily are using what can be seen as one of the more suited roads for their carriage; that is Nelson Mandela Road itself (it can also be argued that little exists in terms of alternative roads and, indeed, conditions degrade once heavy commercial vehicles leave Nelson Mandela Road and utilize Morogoro Road for completion of their upcountry routings). But total congestion inside the Mandela belt could argue for formalizing this pattern.

  The analyses demonstrated that, at present, only few road sections accommodate dominant levels of heavy trucks (other than immediately adjacent to the generator proper). However, site-specific concerns due exist, with but one example being Ubungo Intersection which exhibits considerable volumes of turning heavy commercial vehicles. Limiting heavy trucks to identified road segments can be considered an effort to increase the capacity7 and could , if implemented, simultaneously support the proposed relocation policy. In case of Dar es Salaam, the policy is less of a "limitation" but more of an "inducement" in that de-facto truck routes already exist at present. These could be positively reinforced by formally acknowledging their role, and providing positive engineering as well as operational support to ensure their attractiveness and appropriateness for heavy commercial vehicles. One example of very positive support would be the provision of grade separations along the truck movement axis.

  The concurrent implication is that outside of a designated "truck route system" activities by heavy commercial vehicles are essentially banned. In particular, within the Mandela belt. However, much as with the above discussion on "daytime service licenses", exemptions are possible with proper permits and with payment of an appropriate fee. But, again, fees should

[7] Heavy trucks are banned from central city highways in many countries in Europe and North America, and limited in effect to ring road systems or higher-order (including motorway) road classes. Temporal limitations also frequently exist concurrently. These measures are not only imposed to reduce congestion, but also to increase safety on the roads at times when traffic is dense and many private cars are using the road infrastructure. Refer also *White Paper: European Transport Policy for 2010- Time to Decide,* Brussels, 12/09/2001; COM(2001) 370 for a discussion of measures to standardize and

be sufficiently high to discourage widespread exemptions from the regulation and enforcement must be of sufficient, on-going and honest magnitude to prevent abuse of the system.

- **Terminals and ICD’s.** Given that supply and delivery with heavy trucks will only be during certain hours and for defined purposes (indeed, most heavy vehicle activity in Dar es Salaam consists of movement between the seaport and upcountry destinations), supporting terminal infrastructure (truck stops, ICD’s) needs to be developed in order to provide trucks the necessary infrastructure to park their vehicles or “breakbulk” large loads into smaller consignments suitable for final delivery via small (say two axle) trucks. These terminals should be located outside the Mandela belt and the development of these terminals should be parallel to the enforcement of truck-related initiatives within the ring. The primary function of the proposed terminals is a truck stop but in time, these truck stops could be transformed in value added terminals.

  In particular, these truck stops could be transformed into cargo transfer points that support the introduction of the above suggested measures. These terminals could be equipped with low-cost material to transfer cargo that enters the terminal from large trucks to small trucks that will ensure final delivery inside the Mandela belt (stripping). Also in the opposite direction, these terminals could collect cargo that enters the terminal in small trucks and consolidate the cargo into large trucks that bring it to their destination outside the Dar es Salaam region such as upcountry locations or containerization for sea shipment.

3.5 Recommendations

The previous discussions have presented an overview of cargo activity within the Dar es Salaam urban conurbation, and identified a broad range of measure which may be appropriate within the local scenario.

- The issue of truck routes is becoming increasingly relevant already within the current context. The *Cargo Transport Survey* confirmed the importance of Nelson Mandela Road as a primary choice as corridor of heavy vehicle travel, and, to a lesser extent, Morogoro Road, Nyerere Road and Kilwa Road. Each have important implications for cargo movement by heavy commercial vehicles. Based on these preferences, as well as reviews conducted within the framework of the Master Plan, an indication of an “immediate action” truck route is depicted in **Figure 3.5.1**, to include a circumferential link (the Nelson Mandela Road belt) with radial connectors along main corridors of heavy vehicle activity.

expand such policies to uniformly ban truck traffic during the week-ends and holidays

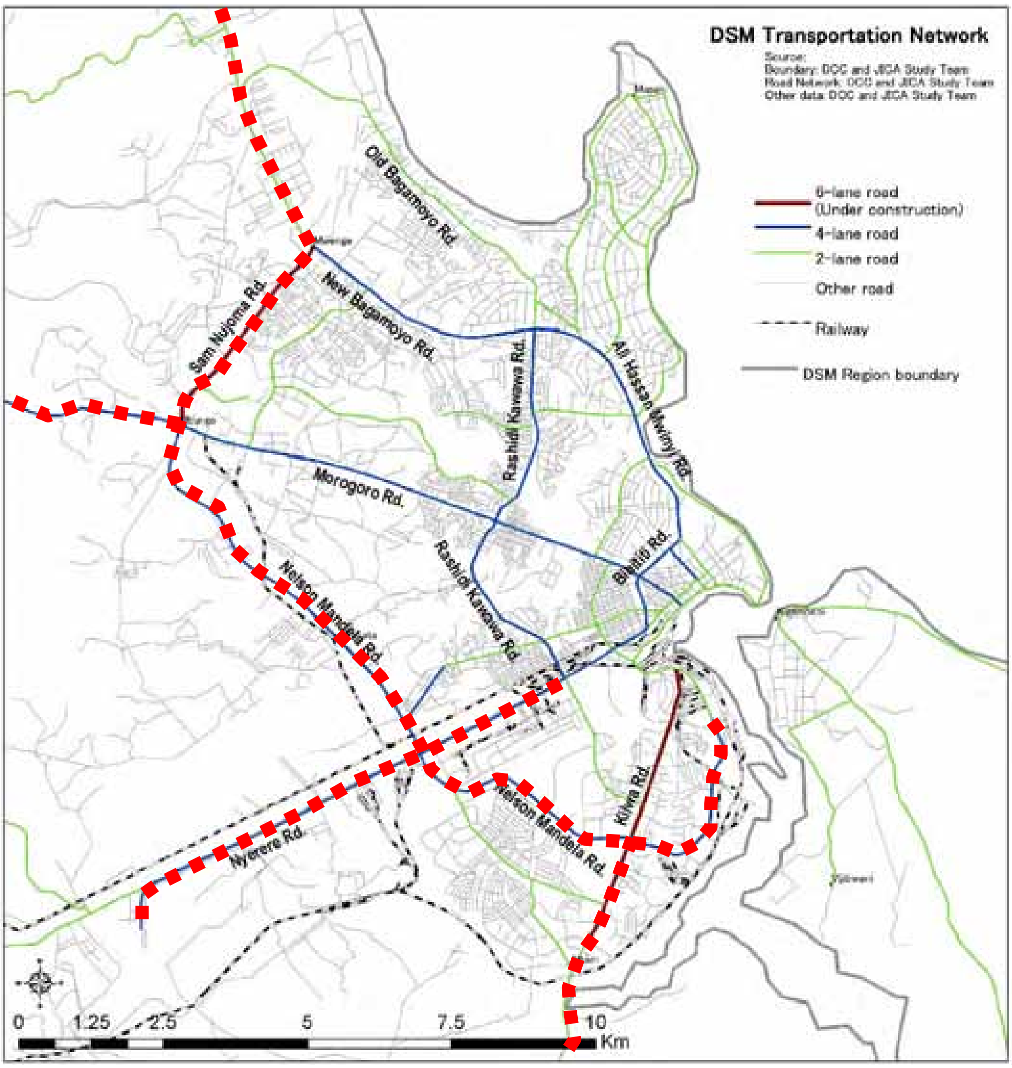


Figure 3.5.1 Proposed Near-term Truck Route Network for Heavy Commercial Vehicles

Several important considerations arise from this analogy:

- Heavy commercial vehicles would be restricted from penetrating within the Mandela belt on roads other than the truck route network. A “service license” exemption for qualifying enterprises is possible with proper permits and with payment of an appropriate fee. But fees should be sufficiently high to discourage widespread exemptions from the regulation and enforcement must be of sufficient, on-going and honest magnitude to prevent abuse of the system.
- A truck depot, suitable for transfer of cargo between heavy commercial vehicles and service trucks should be established to support restrictions in road facilities available for large trucks (i.e. the truck route concept). The current impetus for such a facility is along Morogoro Road several kilometers west of Nelson Mandela Road (Kimara truck terminal). This should continue to be encouraged. Furthermore, some truck terminal facilities inside the Nelson Mandela Road ring have already been removed (Janguani truck terminal) thus providing

de-facto support for the proposed truck route concept.

- Discussions are continuing regarding the establishment of an inland container depot. One possible site (various other proposals have also been voiced) is the Ubungo ICD, roughly adjacent to the southeast quadrant of the Morogoro Road-Nelson Mandela Road intersection. Three comments in this regard: (a) it is far preferable that any ICD be sited outside of the Nelson Mandela Road belt, ideally near the perimeter of Dar es Salaam (integration with the Kimara truck terminal should be considered), (b) if the Ubungo ICD is nevertheless sited as currently proposed, it is absolutely essential that truck ingress/egress be achieved via Nelson Mandela Road, and absolutely not via Morogoro Road, and (c) a linked element of the Ubungo ICD concept is the use of the disused rail-right-of-way for implementing a rail link with the seaport. However, the Study Team has proposed a much more productive use in that a BRT line should be sited within this right-of-way.

- A functional road classification system has been developed as part of the Master Plan review (refer previous Chapter 2). This classification is fully sensitive toward the proposed truck route network.

- The placement of BRT, heavy vehicle truck route network and urban activity are closely linked within the functional classification system. For example, Morogoro Road east of Nelson Mandela Road is identified as a Primary Arterial Type II facility due to implementation of the BRT Phase I concept and anticipated intense urban activity. Due in part to BRT design, movements by heavy commercial vehicles in this corridor should be banned. However, Morogoro Road west of Nelson Mandela Road is included as a key element of the near-term truck route network. BRT Phase I concurrently extends into this area as well. However, truck activity will be pronounced, thus, Morogoro Road west of Nelson Mandela Road is designated as a Primary Arterial Type III facility. The implication of this is that the BRT Phase I concept west of Morogoro Road must be re-designed to permit elevated (pedestrian walkways) access to, and egress from, BRT stations.

The future urban structure as promulgated by the Master Plan confirms that Morogoro Road (within Nelson Mandela Road) will emerge as a corridor urban activity precinct, anchored by the BRT Phase I system. The level of activity is expected to rival that of the current CBD. Several important considerations emerge:

- As the urban nature of the corridor intensifies, there will be an increasing need to service establishments via what will be smaller (two axle) trucks. Heavy commercial vehicles, in line with the proposed truck route scheme, are not expected to be an issue along Morogoro Road inside of the Mandela belt.

- Three issues complicate the role of service trucks: firstly, the lack of alternative road space other than Morogoro Road itself (that is, there are no paralleling facilities or minor roads via which “backdoor” service could be provided using other than Morogoro Road); secondly, the urban form of BRT within this corridor, that is, access to/from BRT stations via at-grade pedestrian crossings of Morogoro Road, will depress vehicular capacity and, lastly, overall congestion is expected to increase.

- The Master Plan is conscious of these issues and, as part of longer-term solutions, various new road facilities (or upgraded existing facilities) have been proposed to overcome the lack of sufficient road space in the corridor.
- Nevertheless, there may well emerge justification for considering a peak hour (during hours of heaviest vehicular activity) ban on service truck activity within the Morogoro Road corridor. This would suggest an increase (vis-à-vis present practices) of off-peak (likely evening) goods delivery.

Such a measure would be seen as an interim step to controlling congestion until additional road space can be provided in the longer term.

Chapter 4 Evolution of the Future Road Network

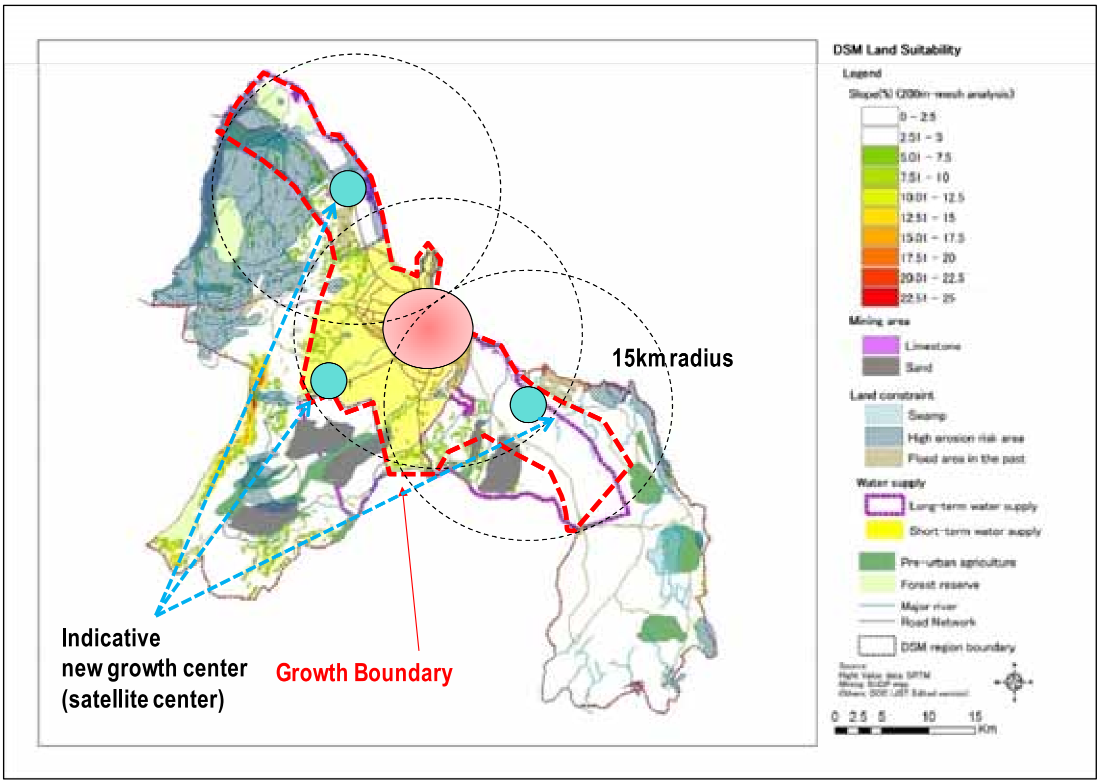
This chapter discusses the evolution of the road network within the study area. That is, the process by which, via a series of linked and cascading reviews, the adequacy of the current road network is analyzed vis-à-vis forecast levels of year 2030 demand. Requirements for road infrastructure, to include improvement of existing roads as well as construction of new facilities, are determined in the first instance for longer-term (year 2030) conditions, and subsequently for the medium-term (year 2015) planning horizon. These forecasts rely upon a variety of factors, to include the forecast socio-economic framework, feasibility reviews as well as the computerized simulation model. These sectors are discussed in other technical reports, and the interested reader is urged to consult relevant documents for additional detail[1]. Some succinct highlights found in these documents are repeated in the current chapter for completeness of presentation. More immediate action needs, to include suggestions for pre-feasibility reviews, draw upon findings of the longer-term planning horizons, but also utilize more immediate (year 2007) issues founded upon the extensive series of surveys undertaken by the Study Team. The priority (near-term action) locations, with the focus being intersection-specific solutions, are discussed in the subsequent Chapter 5 of this volume.

4.1 Rationale and Methodology

The urban road network system in the study area can, in a general sense, be addressed via four generic groupings.

- The Urban Growth Boundary (UGB) is the socio-economic framework which guides the future distribution and intensity of activity, with the vast majority thereof being, spatially speaking, within the UGB (**Figure 4.1.1**). The first grouping are roads located outside of, or at the northern and southern periphery of, the UGB. Thus, roads design and capacity is expected to be at its highest, mirroring uninterrupted flow conditions, as permitted by the requirements of traffic demand among more outlying precincts of the study area, or between the study area and other parts of Tanzania.

[1] Refer *Technical Report Volume 1: Dar es Salaam Transport Policy and System Development Master Plan, op. cit.* for further discussion of urban and regional planning considerations; *Technical Report Volume 6* for economic and financial reviews of the Master Plan; and, *Technical Report Volume 8* for detailed descriptions of transport models and demand forecasting methodologies.



Source: JICA Study Team

Figure 4.1.1 Proposed Year 2030 Urban Growth Boundary

- The second grouping of roads lies, generally speaking, between the UGB boundary and the Nelson Mandela Road ring. Urban activity intensifies, with road supply having to diversify accordingly. The main requirements are expected to include service to the northern and southern growth poles within the UGB, as well as a (likely) focus on radial corridors of demand, mainly for those corridors (such as Morogoro Road) expected to play a more prominent future role in terms of land use activities and intensities. Road capacity on all but limited access facilities will reduce as increasing needs to provide intersection traffic control (signals) arise.

- The third grouping involves roads in the core metropolitan area, that is, between roughly the Mandela ring and the CBD. Road demand will be more complex, and solutions will call for a variety of approaches involving various road classes. However, it is concurrently important that network consistency be maintained for the upper-tier road classes to ensure logical capacity continuation with other parts of the study area. The mix of traffic is expected to change. As noted in the previous Chapter 3 of this volume, for example, heavy commercial vehicles should not, with few exceptions, be permitted to travel inside the Mandela ring. Also, as discussed beginning in Chapter 10 of this volume, the needs of public transport, in particular BRT, will play an increasingly important role in defining the types of road infrastructure located within this grouping. It is expected that this road areal grouping will exert the most severe demands for increased and enhanced road infrastructure.

- The fourth grouping of roads involve those within the CBD. While demand is expected to continue being substantial, the focus moves away from providing new infrastructure towards optimizing operational aspects of the network (refer Chapter 8, this volume, for the CBD plan). The needs of public transport and pedestrian networks assume considerable prominence in this area.

It is noted at this juncture that issues pertaining to road capacity (hence follow-on requirements for infrastructure) are coordinated among the various Master Plan sectors to ensure logical and consistent quantitative and relational guidelines for planning of roads (principal focus: road and intersection analysis), public transport systems (principal focus: bus capacities in mixed flow and within priority treatments); and, modeling functions (principal focus: simulated network development and associated speed, capacity and volume interactions).

The traffic volume on the road network will be influenced by the changes of other network modes, such as BRT. This system is expected to catalyze a notable impact on traffic flow within those parts of the metro area in which BRT is provided. That is why it is important to analyze road traffic flows concurrently with other forms of transport within the framework of the Master Plan transport model. The Master Plan transport model is, to ensure full sensitivity across a wide spectrum of modal choice and modal preferences, based on person trips, with each trip initially choosing its preferred transport interchange based on the mobility needs of that trip. The estimation of road based traffic is done to the same level of detail as bus transit estimation because it is the differences in levels of service, travel costs and travel times among the modes that determine the proportions of trips (modal split) carried by each mode. For example, a decline in the level of service of the road system (ie increasing congestion) will cause modal shift changes towards the BRT services both from private vehicles and likely users of other mixed-traffic bus services. It is essential that the transport model quantifies these effects. At conclusion of the modal choice process, resultant vehicle trips (that is, trips using private modes of transport such as passenger cars) are distributed (assigned) onto the road network. This is the demand against which future infrastructure supply is compared.

The modal choice of future person trips will be influenced by various elements. One of the most important considerations is vehicle ownership. It is expected that the current 74,000 private vehicles located within the study area will increase to 225,000 by year 2015, and near 498,000 by year 2030. This means the study area vehicle ownership will more than triple from 25 cars per 1,000 persons in year 2007, to 84 cars per 1,000 persons by year 2030. This is clearly mirrored by the African experience where vehicle ownership may be considered an excellent surrogate measure for road traffic growth (**Figure 4.1.2**). Pronounced impacts on Dar es Salaam congestion, and the need for additional road infrastructure, are consequently expected. The construction of BRT will certainly be a key mitigating factor in defining the modal choice relationship in terms of inducing mode-switching and providing increased mobility for transit-dependent elements of the population. However, demand on the road network is nevertheless expected to dramatically increase in future in line with rising socio-economic well being of the population.

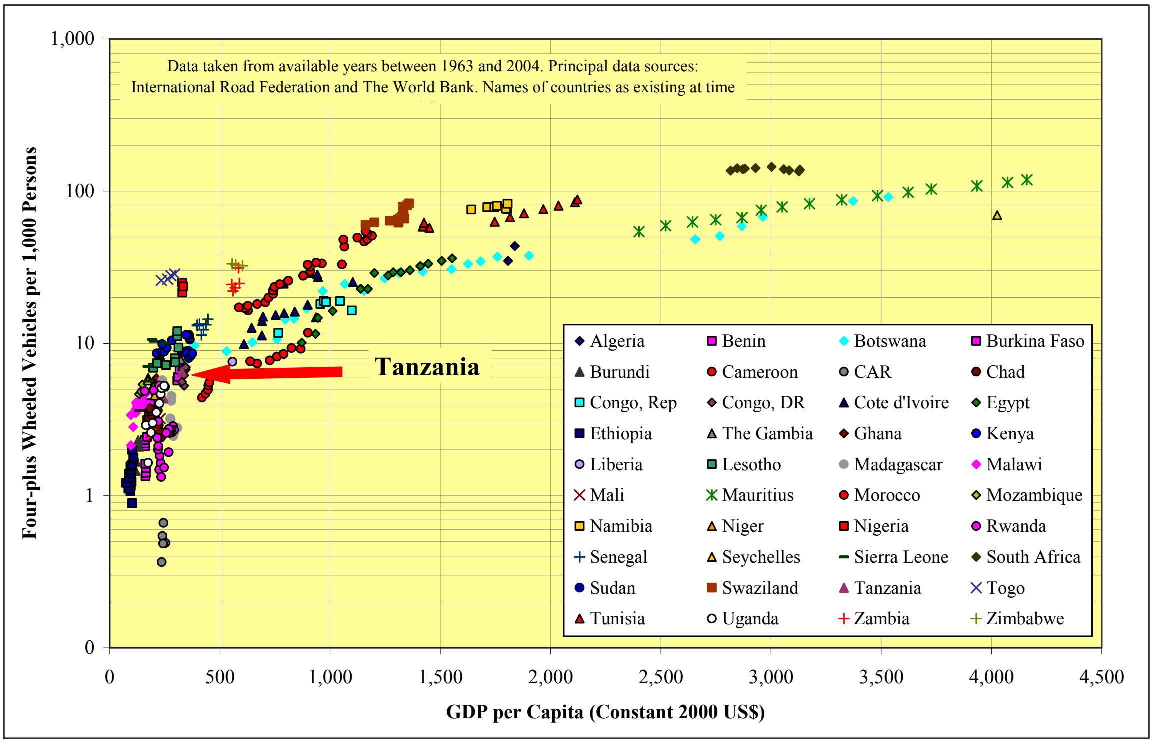


Figure 4.1.2 African Four-plus Wheeled Vehicle Ownership and Unit National Income

The previous discussion alluded to the proposed UGB. The degree to which this concept is, or is not, adopted, will have a direct impact upon the person trip pattern. In the simplest of allegories, the UGB contains a population distribution pattern that differs from other forms of urban structure (**Figure 4.1.3**); hence, the intensity, distribution and mode choice of person trips will also differ from other alternatives. For example, under the UGB scenario, considerable additional population is forecast in the southern part of Temeke municipality. It may therefore be expected that additional trip demand, both for public and private modes of transport, will originate in that area thus necessitating a proper supply of transport infrastructure to ensure that land use and transport planning are compatibly linked.

To recapitulate, the demand forecasts upon which road infrastructure needs are based rely on a variety of mechanisms:

- The underlying socio-economic framework defining the distribution of, among others, population and employment opportunities.
- Changes in well-being of the populace, in the form of increasing personal wealth and private vehicle ownership.

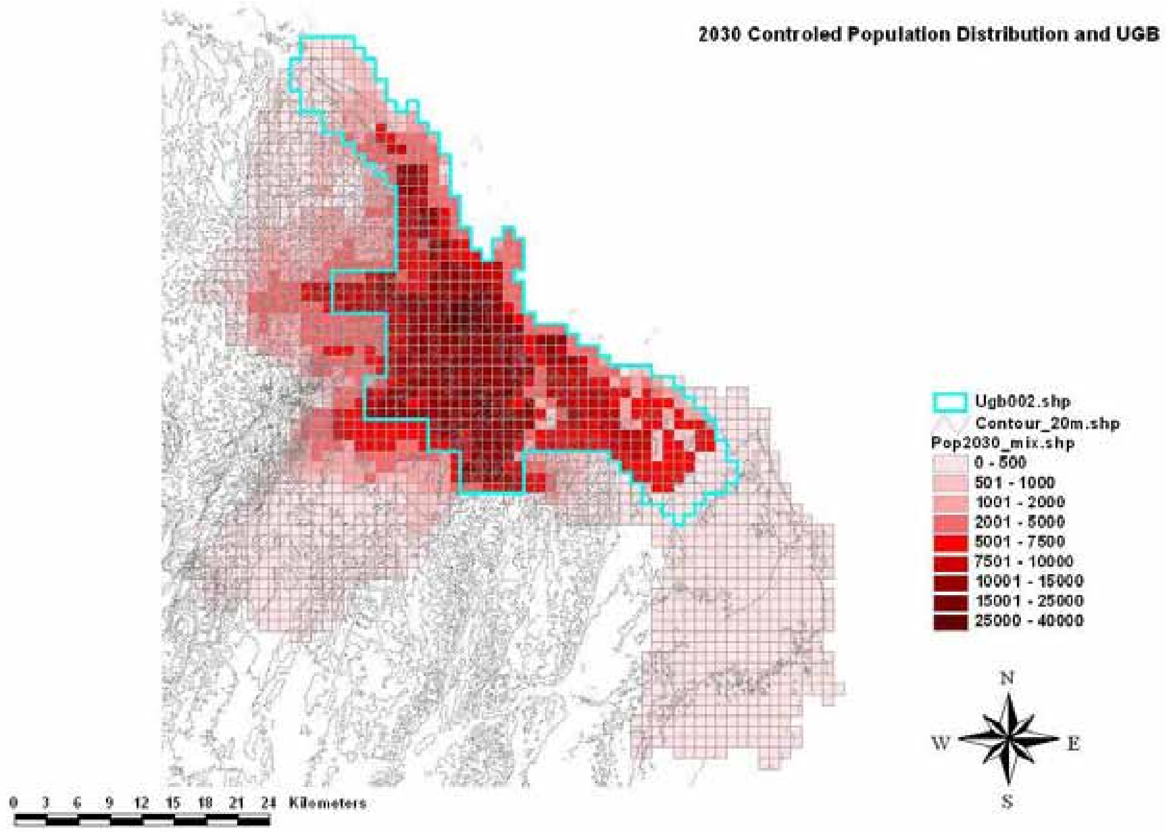


Figure 4.1.3 Year 2030 Alternative Population Distributions

- The multi-modal role and interaction between the various modes of transport, with core players being the road sector and public transport (especially BRT). All demand forecasts are fully reflective of this symbiotic relationship via intermediate steps of person trip generation, trip distribution, modal choice and trip assignment.
- Integration of previously discussed road sector initiatives such as the needs of heavy commercial vehicles (Chapter 3, this volume) as well as the application of a functional road classification scheme (Chapter 2, this volume). In the latter case, this includes a hierarchy of roads encompassing expressway/motorway, primary arterial road, secondary arterial road, tertiary arterial road, community/local road and special road (**Table 4.1.1**).

Alternative network scenarios are structured to test the road and public transport network alternatives in the multi-modal Master Plan transport model. The scenarios are first developed at a long term view based on the target year of 2030 situation, taking into account urban development evolution and the expected transport demand structure. Alternative road development plan are then derived and tested concurrently with the public transport development plan.

Table 4.1.1 Overview of Road Functional Classification Groupings

Classification		Function
1. Urban Expressway		Exclusive for motor vehicle; connecting whole Dar es Salaam Region; high speed traffic
	2a. Primary Arterial Road (Type I, II, and III)	Long distance traffic; connecting major trip generations; link to national trunk roads; BRT can be placed
	2b. Secondary Arterial Road	Connecting between wards; trunk bus services operating in mixed traffic; rransit priority possible (but not BRT busways).
	2c. Tertiary (Collector) Road	Major distributor and access roads within wards; public transport services operating in mixed traffic.
3. Community Roads		Within neighborhood or community Access to individual plots or houses
4. Special Roads		Use for specific purpose, such as BRT, Scenic, Bicycle roads and pedestrian mall

Source: JICA Study Team

The alternative scenarios are structured as follows:

- Scenario A: "Do Minimum" network consisting of existing roads plus major road improvements which are currently on-going, or have been committed to proceed in the near-term future.
- Scenario B: "Do Maximum" network (year 2030) encompassing the most extensive public transport and road network plans from capacity building points of view.
- Scenario C: Core network which, while still addressing year 2030 needs, "steps down" the type and extent of enhancements based on sufficiency of the "do maximum" network.
- Scenario D: Master Plan network being the result of the testing procedure, and likely to be (or very close to being) the eventual proposed master plan. The road network is modified based on the results of Scenarios B and C sufficiency reviews.

Once the preferred scenario has been defined based on year 2030 demand, intermediate year 2015 solutions will be identified, as will a staging plan which ensures logical transition from the current to, ultimately, year 2030 network.

The results of each scenario testing will be summarized and evaluated by several indicators. These indicators will be average vehicle speed (km/hr), the share of private (vehicle) transport (percent), daily vehicle-kilometers (in terms of pcu-km), and average congestion on the selected screenlines (interplay of volume and capacity). The screenline analysis is seen as an important detailing which permits a review of congestion within selected corridors, as opposed to the entire road network. The selected screenlines are depicted in **Figure 4.1.4**, superimposed onto the "do maximum" road scenario.

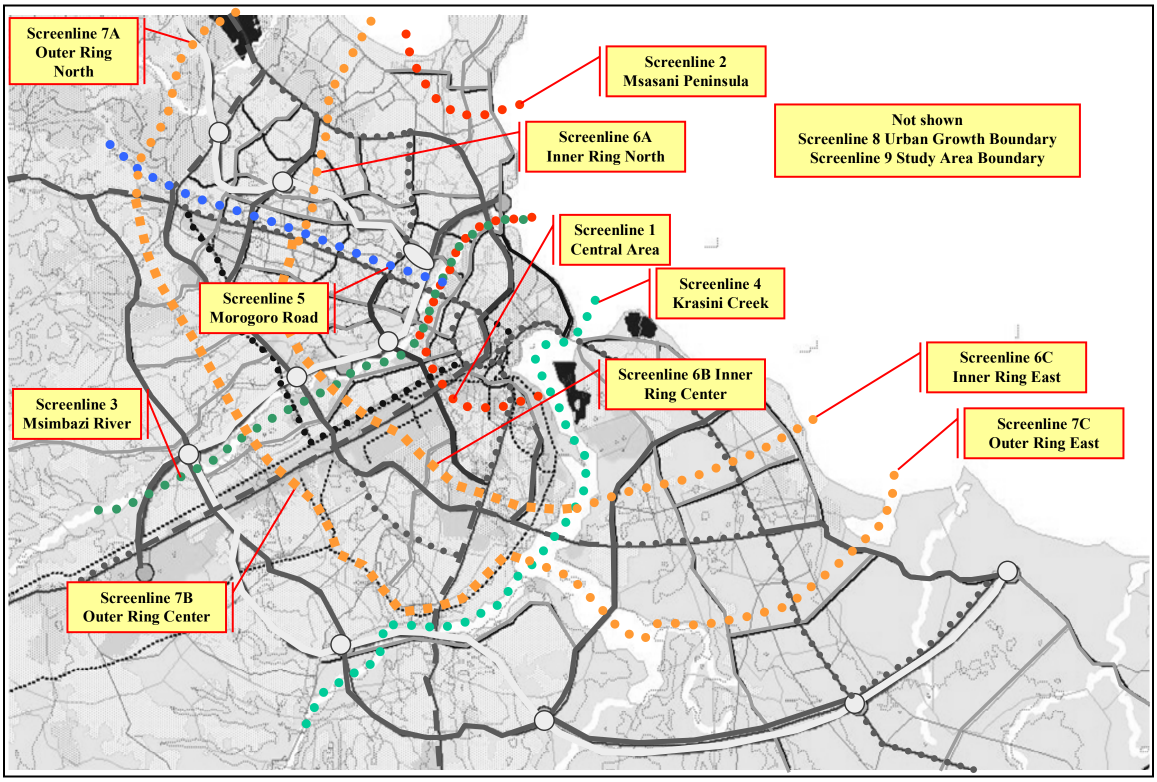


Figure 4.1.4 Demand Analysis Screenlines

4.2 Scenario Formulation

Four alternative roadway network scenarios were defined and tested.

4.2.1 The "Do Minimum" Network

The first scenario, Scenario A, consists of existing roads plus those road improvement projects which are already committed by the government, or foreign financing/lending institutions, and which are certain to be realized. The main purpose of testing Scenario A is to analyze what would occur if nothing ("do minimum") were to be initiated in addition to these committed projects. This is a somewhat unrealistic assumption in that most surely some form of network improvements would transpire over the next two decades. However, the results of the Scenario A testing provide very valuable benchmark performance indicators against which those derived from other road scenarios may be compared.

The entire extent of the year 2007 road network extends to some 770 kilometers. It is noted this refers to the network utilized in the computer model; however, practically speaking, all major Dar es Salaam roads are included in the review, as are their link parameters (speed, capacity, number of lanes, road condition, among others).

Under the proposed functional classification, some 19 percent of the simulated road supply would be designated as being primary arterial (some 80 percent of which fall within the TANROADS grouping). Conversely, roughly two-thirds of the simulated network would fall within the tertiary roads category (**Table 4.2.1**).

Table 4.2.1 Year 2007 Road Network Extent

Functional Classification	Subcategory	Road Kilometers by Administrative Class		
		National	Local	Total
Expressway		0.0	0.0	0.0
Primary Arterial	Type I	53.6	19.3	72.9
	Type II	17.5	10.5	28.0
	Type III	48.0	0.0	48.0
Secondary Arterial		49.2	61.7	110.9
Tertiary Arterial		290.0	221.3	511.3
Special Roads (1)		0.0	0.9	0.9
Total		458.3	313.7	772.0

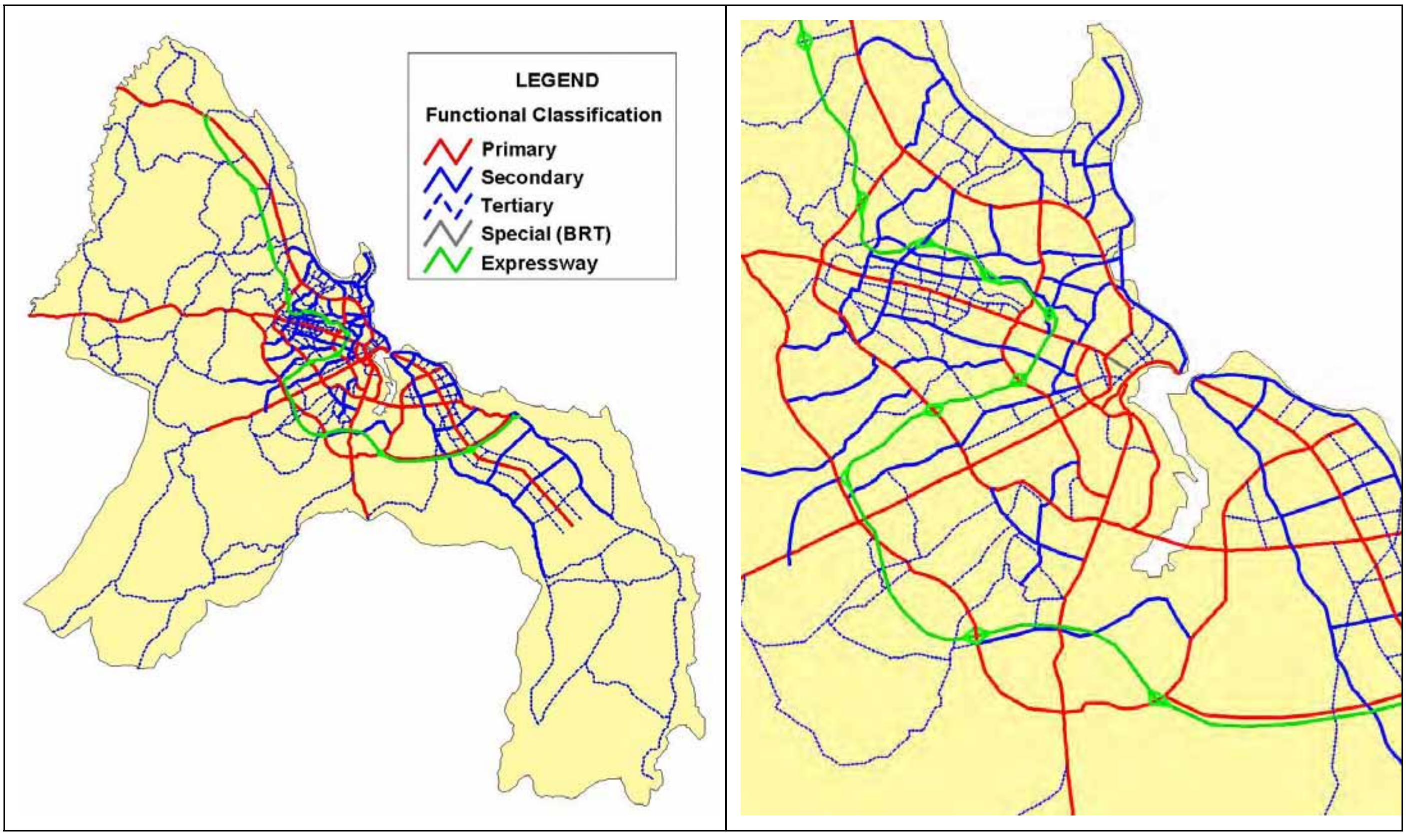
Source: JICA Study Team.
(1): Excludes alignments within Tabata rail right-of-way.

The committed road improvements to supplement the year 2007 network include:

- Sam Nujoma Road is in the process of being widened to dual carriageway standard, two lanes per direction. The project is understood to be behind schedule, but expected to be completed during approximately mid 2008. The project is sponsored by the Government of Tanzania.
- Kilwa Road is being widened over a distance of approximately 12 kilometers extending south of its northern terminus at Bandari Intersection. The cross-section is dual two lane, with sufficient median reserve to accommodate a future BRT busway. The project is being sponsored by the Government of Japan.
- Nelson Mandela Road is being improved, largely within existing alignments. The extent is from vicinity of the seaport to Morogoro Road (Ubungo Intersection), or approximately 16 kilometers. The existing multi-lane cross-section will be retained, but considerable enhancements of road surface, drainage and traffic control expected. The project is being sponsored by the European Commission. Completion is expected within approximately two years.
- It is expected that New Bagamoyo Road will be upgraded to a four-lane divided cross-section, with adequate median reserve for the provision of a future BRT busway. The project is expected to extend over some 17 kilometers between Kawawa and Wazo Hill Intersections, and will likely be sponsored by the Government of Japan.
- The BRT Phase I project will extend over approximately 21 kilometers, mostly coinciding with Morogoro Road, but also including sections of Kawawa and Msinbazi Roads. Reconstruction will allow the installation of dual (one in each direction) BRT busways, as well as median-sited stations every approximately 500-700 meters. The adjustment of the overall road cross-section will vary by sub-section and depending on current configurations and rights-of-way. Project infrastructure is under sponsorship of The World Bank.

4.2.2 The "Do Maximum" Network

The "Do Maximum" network (year 2030) encompasses the most extensive public transport and road network plans from capacity building points of view. The network includes a variety of elements supporting the UGB concept, including a spine motorway. Other road segments link the various regions within the study area, as well as between the study area and other parts of Tanzania (**Figure 4.2.1**).

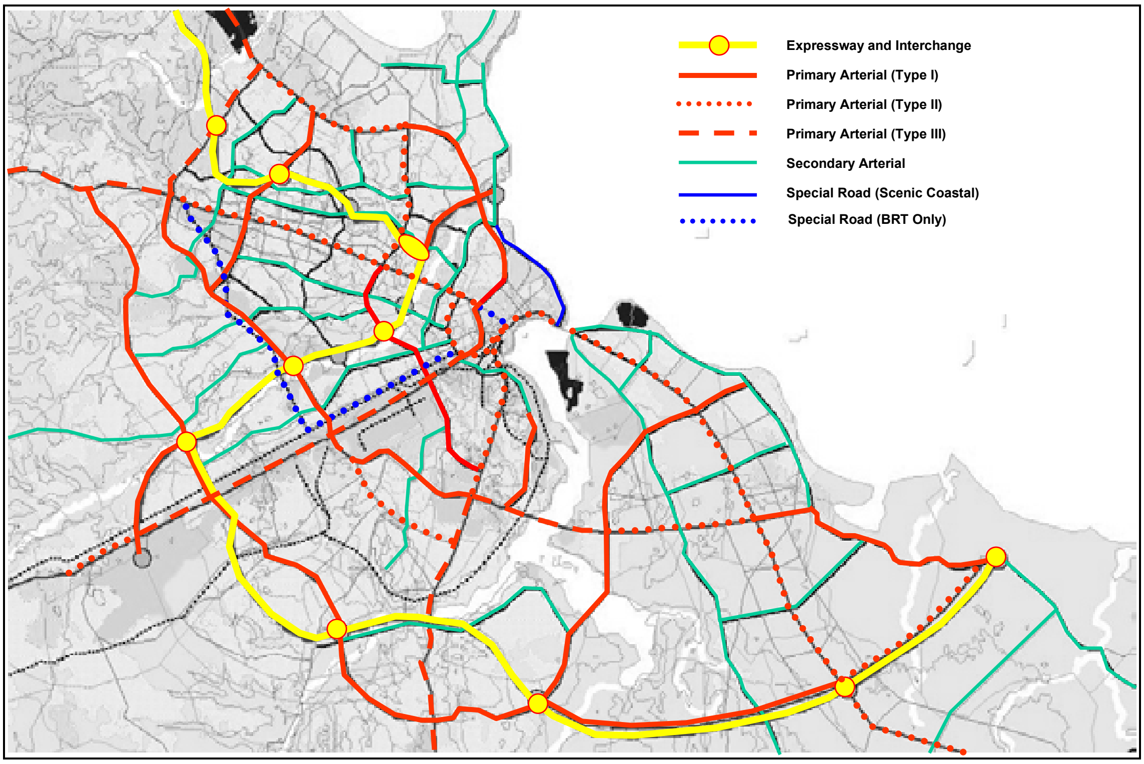


Source: JICA Study Team

Figure 4.2.1 Year 2030 "Do Maximum" Road Network

Other network aspects include (**Figure 4.2.2**):

- A balanced system of circumferential and radial facilities in line with guidelines contained in the functional classification scheme.
- Comprehensive five phase BRT network.
- Urban motorway serving the northern and southern extremes of the UGB, growth poles therein, as well as core activity precincts within the metropolitan area.
- An outer ring road (primary arterial) located west of the Mandela ring. This facility offers increased dispersion and diversion opportunities, while concurrently providing a key extension to the Kigamboni peninsula.



Source: JICA Study Team

Figure 4.2.2 Year 2030 "Do Maximum" Road Network: Central Area

- Provision for a Kigamboni bridge, as an extension of the Mandela belt.
- Road infrastructure within Kigamboni Peninsula in line with its new role in the UGB.
- Strong support of areas and road corridors expecting to contain intense urban activity in future (such as Morogoro Road).
- A Selander Bridge bypass on reclaimed land.

Under the "do maximum" Scenario B, some six percent of roads incorporated within the transport model would be classed as motorway/expressway, about 20 percent as primary arterials, 15 percent as secondary arterials, and near 60 percent as tertiary arterials. Type II and III primary arterials, which include facilities for busways, represent some 10 percent of the modeled road network (**Table 4.2.2**).

Table 4.2.2 Year 2030 "Do Maximum" Network Extent

Functional Classification	Subcategory	Allocation	
		Kilometers	Percent
Expressway		59.8	5.5
Primary Arterial	Type I	101.0	9.3
	Type II	45.1	4.1
	Type III	70.0	6.5
Secondary Arterial		178.8	16.4
Tertiary Arterial		611.3	56.3
Special Roads and other (1)		20.3	1.9
Total		1,086.3	100.0

Source: JICA Study Team.
(1): Includes alignments within Tabata rail right-of-way.

Two types of improvements are contemplated under Scenario B: new construction, or widening of existing facilities. Current estimates for the near 1,100 kilometer network is an approximately one third new construction, two-thirds widening need (**Table 4.2.3**).

Table 4.2.3 Year 2030 "Do Maximum" Network Enhancement (to be revised soon)

Functional Classification	Activity	Allocation	
		Kilometers	Percent
Expressway	New	59.8	5.5
Primary Arterial	New	75.2	6.9
	Widening	153.2	14.1
Secondary Arterial	New	49.8	4.6
	Widening	107.5	9.9
Tertiary Arterial	New	143.1	13.2
	Widening	478.2	44.0
Special Roads and other (1)	*	20.3	1.9
Subtotal	New	347.3	31.9
	Widening	739.7	68.1
Total	All	1,087.1	100.0

Source: JICA Study Team.
(1): Includes alignments within Tabata rail right-of-way.

4.3 Opportunities for a Tolled Motorway System

The demand forecasts have identified that traffic volume on the streets of Dar es Salaam is substantial already at present, and is expected to increase in future. Improving traffic bottlenecks continues to be an important issue to solve local traffic problems, as is the provision of arterial links to enhance both the extent and function of the road network.

The provision of an urban expressway network represents an important alternative means of transport.

It will give a bypass function to longer-distance vehicular trips, and at a better level of service. The resultant increase in road capacity will benefit all motorists, and in particular commercial vehicles. The expressway will also greatly enhance shorter inter-urban trips by providing a series of "mini ring roads" circumnavigating major activity precincts within the metropolitan area. Road safety will be enhanced through the provision of a "vehicles only" facility, designed to high standard.

The Study Team has, correspondingly, included a 60 kilometer north-south urban expressway within the road planning process, as first shown and tested in Scenario B. It is, however, not easy to contemplate an expressway network via the conventional method of direct funding through the government budget. Many other pressing road sector obligations exist. Even if possible, would such an approach be considered fair to all tax payers? The main users of the contemplated urban expressway are passenger car owners; citizens of more modest means obliged to use public transport cannot enjoy the benefit arising from such an investment.

From these points of view, if the urban expressway network is to be realized, it is highly recommended that more direct road user charge system be applied for financing these projects. One way of direct road user charge system can be toll system, under which all users pay the established toll when using the expressway. Realized revenue will, in turn, be applied to financing the project, possibly within the framework of a public-private partnership.

Chapter 5 Priority Locations

The evolution of the future road network is guided by the interaction of longer-term (years 2015, 2030) catalysts such as type and intensity of urban structure, increasing well-being of the populace as well as evolving patterns of trip making. This interaction will, in turn, imply various threshold of mobility demand, both for public and private modes, which form the basis for future infrastructure strategies.

However, and concurrently, there is merit to also examining priority intersections based on currently perceived issues, opportunities and constraints. While such a review cannot consider each and every intersection in Dar es Salaam, an integration of issues based on operational sufficiency, truck activity, BRT plans, functional classification and programmed enhancements can lead to the identification of particularly critical locations. These locations are discussed in this chapter, whose conclusions should be seen within the overall context of the longer-term formulation of Master Plan road networks.

5.1 Intersection Sufficiency

Considerable data were collected by the Study Team during the course of the Master Plan survey program, to include traffic counts at some 30 locations throughout the study area, inventory of key intersections as well as travel time monitoring during morning, off-peak and evening peak hours[1]. In addition, close coordination was maintained with the DCC and TANROADS regarding existing data bases and previous reviews, to include the *Trunk Road Traffic Management Project*, whose objective[2] was to analyze traffic control operations at identified intersections along selected trunk roads in Dar es Salaam.

This information was combined to conduct a volume to capacity analysis[3] reliant upon observed traffic movement volumes and current operational practices. As an example of calculation procedures, the review of Ubungo Intersection (detail of which follows in Section 5.2) is presented in **Table 5.1.1**. Conclusions include:

1 Refer *Technical Report Volume 6: Dar es Salaam Transport Policy and System Development Master Plan, op. cit.* for further discussion of survey program content, methodologies and findings.
2 *Study of Traffic Management on Trunk Roads in Dar es Salaam Region*, op. cit.
3 Approach and methodology per *Planning and Design of At-grade Intersections*, The Japan Society of Traffic Engineers, 2002.

- Peak hour operations are very difficult to quantify given that manual control by traffic police is typically practiced. The volume to capacity review therefore approached the analysis from a slightly different perspective; that is, given observed traffic volumes, signal capabilities and geometric layout, might an optimum operations profile (in terms of intersection saturation) be possible? Similar approaches were required at other locations subject to manual police control.

- The peak afternoon peak hour (1615-1715 hours) catalyzes considerably less negative impact than the morning peak hour (0645-0745 hours). The PM peak hour is shown as achieving an acceptable saturation rate of less than 0.6[4]. The better performance is not surprising in that morning peak hour activity is very concentrated into a single hour (or two hour period) while afternoon demand is much more diffuse extending, in fact, over most of the entire afternoon.

Table 5.1.1 Sample Calculation Ubungo Intersection 2007 AM Peak Hour Sufficiency Analysis

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

Source: JICA Study Team

- The morning peak period is operating at critical levels with intersection saturation at unity. Indeed, an optimum allocation of cycle time and phasing is no longer possible. Particularly critical approaches include Nelson Mandela Road (northbound) as well as Morogoro Road (eastbound). The latter performance shows strong demand for both the through (west to east) and right turn (west to south) movements.

- Intersection operations are complicated by abutting land use activities, to include Dala Dala ingress/egress maneuvers to/from Ubungo terminal, as well as pronounced pedestrian activity

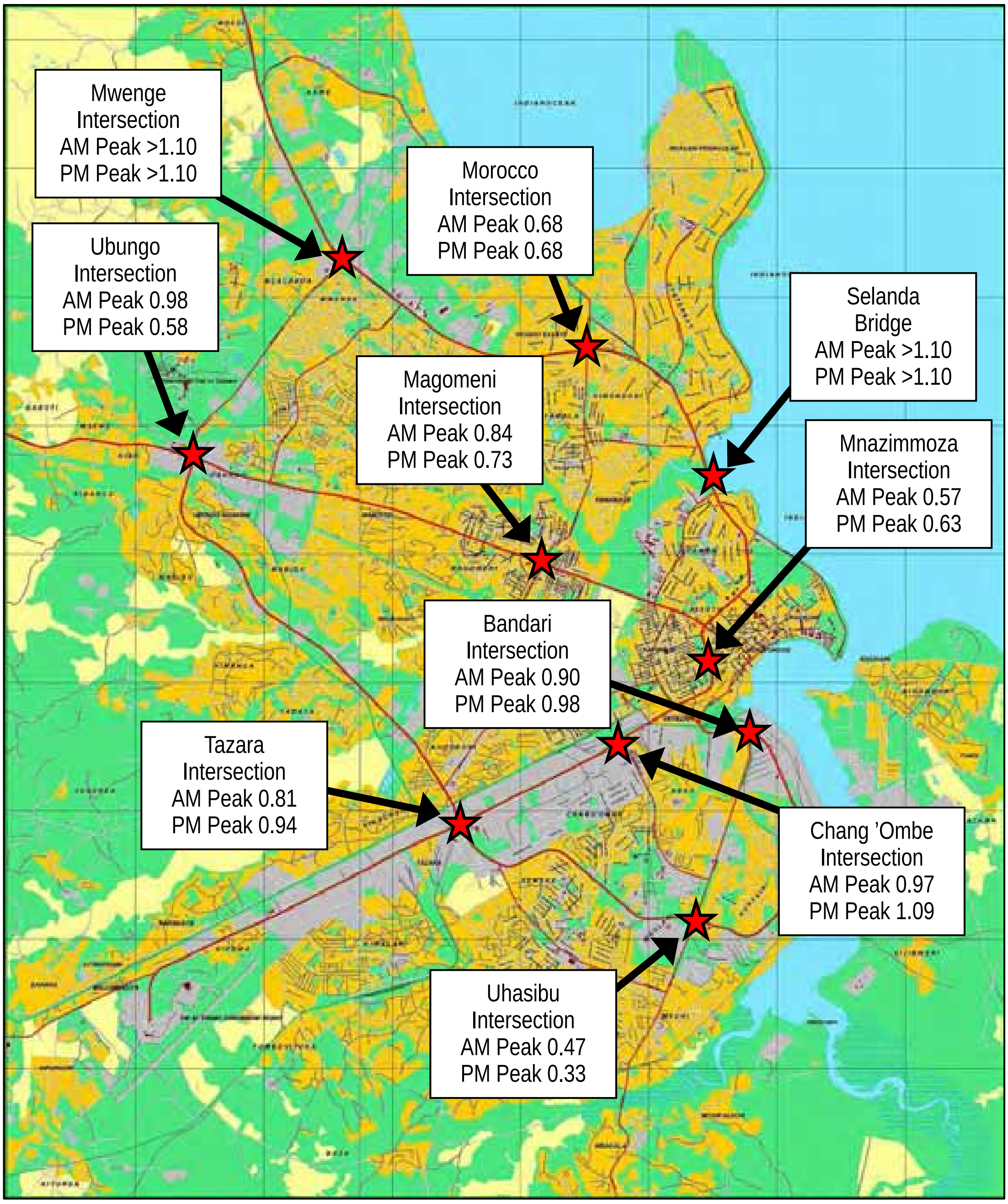
[4] Guidelines suggest that a ratio of less than 0.85 implies acceptable intersection operation while a ratio of near unity indicates that the intersection is operating at full saturation and likely to experience unstable performance. A ratio in excess of 1.0, to say 1.4 approximately, implies intersection failure.

in all quadrants. The critical ingress/egress point for Dala Dala operation is located along Morogoro Road about 150 meters west of the intersection proper; unruly and unsafe driver behavior dominates at this location. This condition is again observed (almost universally so) at other intersections.

The composite findings of all monitored intersections[5] is noted in **Figure 5.1.1** in terms of the AM and PM peak hour sufficiency ratio (representative of volume to capacity ratio). Several conclusions emerge from this review:

- The saturation ratio is very high at several locations, such as Mwenge Intersection and Chang Ombe Intersection. However, in the former case this deals with a junction involving an under-construction road (Sam Nujoma Road) while in the latter case Chang Ombe Road is a two-lane facility. Thus, peak hour operations will likely always be critical, most certainly for the side street, until some form of road widening takes place.
- The Selander Bridge location was, at time of counting, operated on a tidal basis. That is, the off peak profile of 2x2 lanes was transformed into a directional 3x1 lanes. However, this has since been discontinued due to safety concerns, and congestion at the tidal terminus points.
- Several of the intersection results have since been negated. For example, Bandari Intersection, which exhibits high ratios, is now part of the Kilwa Road widening project. However, there exists a concern at this location: current designs call for the termination of the six lane Kilwa Road improvement (four arterial lanes plus two BRT lanes) at Bandari Road intersection. Bandari Road consists, at present, of a two-lane (one lane per direction) cross-section; quantum changes in resultant capacity are likely to catalyze considerable congestion at this location. It is seen as urgent that solutions be identified in the general precinct (Gerezani area).
- Morocco Intersection and Mwenge Intersection will soon be modernized as part of the anticipated New Bagomoyo Road widening project.
- The advent of the BRT Phase I busway along Morogoro Road and reaching to Morocco terminal will imply major road reconstruction which will directly impact Ubungo and Magomeni Intersections.
- The two intersections of particular concern are **Ubungo Intersection and Tazara Intersection**. Both are located along major, multi-lane roads, controlled by signalized systems (except when under manual police control) and accommodate major arteries of movement. Ubongo Intersection experiences one of the highest AM peak hour ratios, while Tazara exhibits a very high PM peak hour ratio. Ubungo Intersection is also of very topical interest due to performance shortfalls, and the rectification thereof, of the proposed BRT Phase I concept at this location.

[5] The noted intersections were culled jointly with the DCC as being representative of high-demand locations along busy roadways. Detailed turning movement information, and intersection operating conditions, were subsequently obtained at each location.

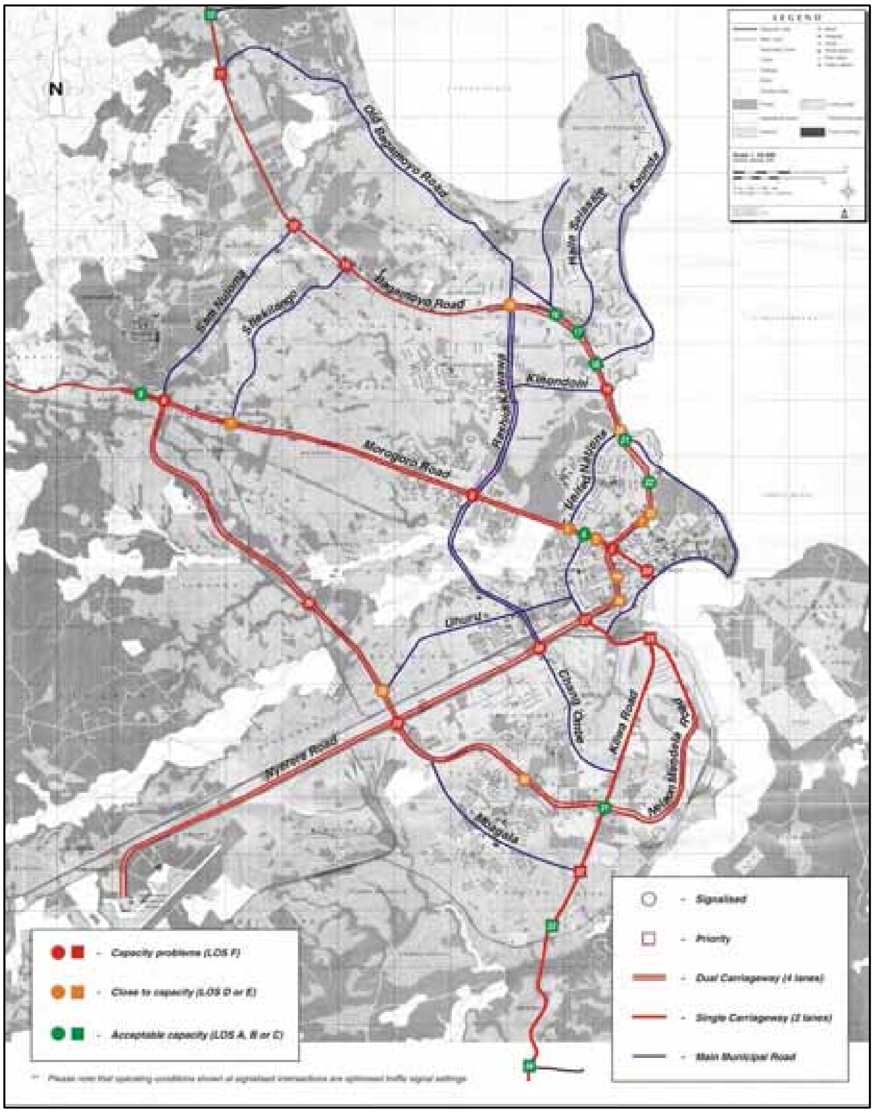


Source: JICA Study Team

Figure 5.1.1 Year 2007 Weekday Peak Hour Intersection Sufficiency Analysis

A comparison to year 2003 intersection level of service confirms similar results to the year 2007 analyses (**Figure 5.1.2**). Ubungo and Tazara Intersections are again identified as operating at LOS F, which can be seen as approximately the same as sufficiency ratio of unity or slightly above. The intersection of Nelson Mandela Road and Tabata Road is indicated as operating at LOS F. At present, this location (which consists of a two-lane side street) is functioning without the benefit of signal control. This location is expected to be improved and signalized as part of the on going upgrading of Nelson Mandela Road, under sponsorship of the European Commission. Other LOS F locations are noted in the same reference frame as the 2007 analysis; namely, on-going or expected construction along Kilwa Road, Morogoro Road and New Bagomoyo Road, thus negating the indicated values.

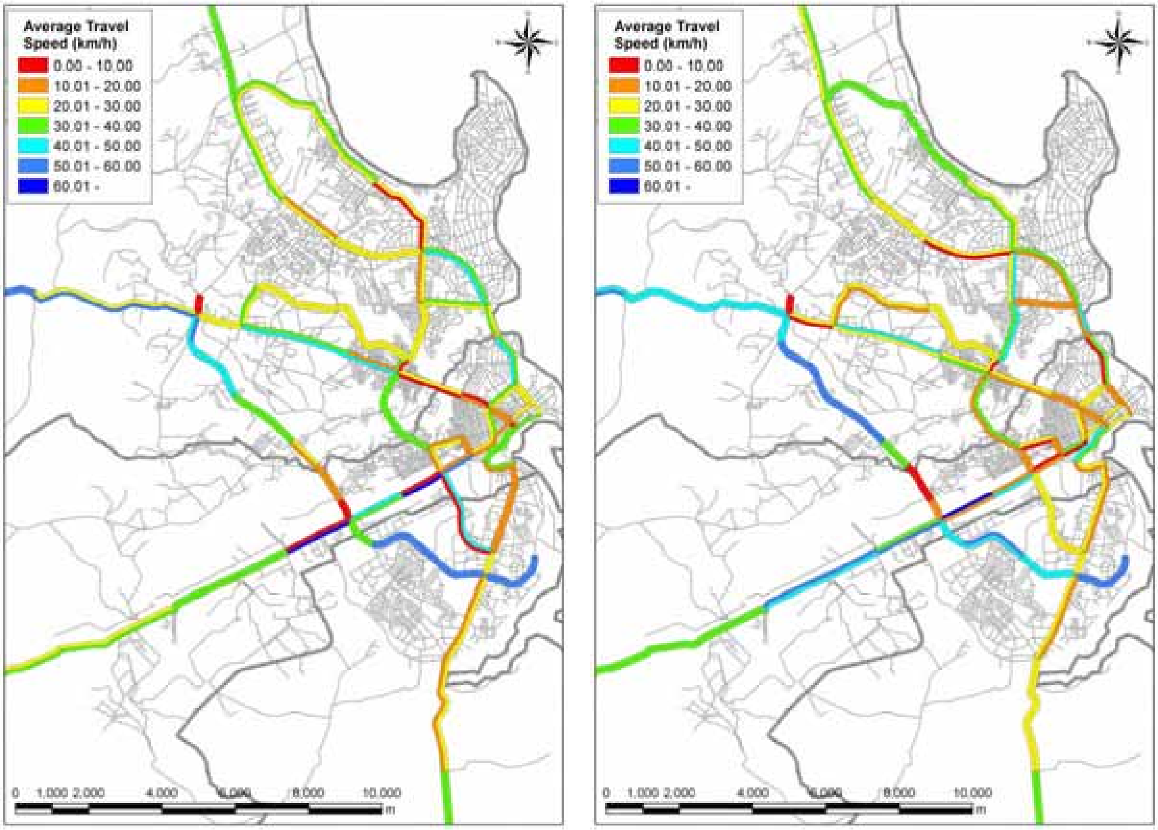
The functioning of intersections can, in addition to the previously referenced sufficiency and level of service analysis, be examined from the point of approach speed. Thus, any intersection at which one or more of the approach legs are operating at an average of, say, 10 km/hr or less over an extended period of time would suggest considerable congestion and delays.



Source: *Study of Traffic Management on Trunk Roads in Dar es Salaam Region*, op. cit.

Figure 5.1.2 Year 2003 Weekday Peak Hour Intersection Level of Service

The findings of the peak period speed and delay survey, which measured actual operating speed on discrete segments of the road network, confirms that several intersections feature approach legs with very low average operating speed (**Figure 5.1.3**). These include, excluding the CBD:



Source: JICA Study Team

Figure 5.1.3 Year 2007 Weekday Peak Period Average Operating Speed

- During both three hour peak periods: Tazara, Ubungo, Chang Ombe, Magomeni, Morocco Intersections.
- During one peak period: Tabata Intersection and the Selander Bridge area.

5.1.1 The Role of Truck Routes

The issue of truck routes is becoming increasingly relevant. The Master Plan cargo (truck) analysis presented in the previous Chapter 3 of this volume confirmed the importance of Nelson Mandela Road as a primary choice as corridor of heavy vehicle travel, and, to a lesser extent, Morogoro Road, Nyerere Road and Kilwa Road. Each have important implications for cargo movement by heavy commercial vehicles. Based on these preferences, as well as other reviews conducted within the framework of the *Master Plan*, an indication of an "immediate action" truck route is depicted in **Figure 5.1.4**, to include a circumferential link (the Nelson Mandela Road belt) with radial connectors along main corridors of heavy vehicle activity.

Heavy commercial vehicles would be restricted from penetrating within the Mandela belt on roads other than the truck route network. A "service license" exemption for qualifying enterprises is possible with proper permits and with payment of an appropriate fee. But fees should be sufficiently high to discourage widespread exemptions from the regulation and enforcement must be of sufficient, on-going and honest magnitude to prevent abuse of the system.

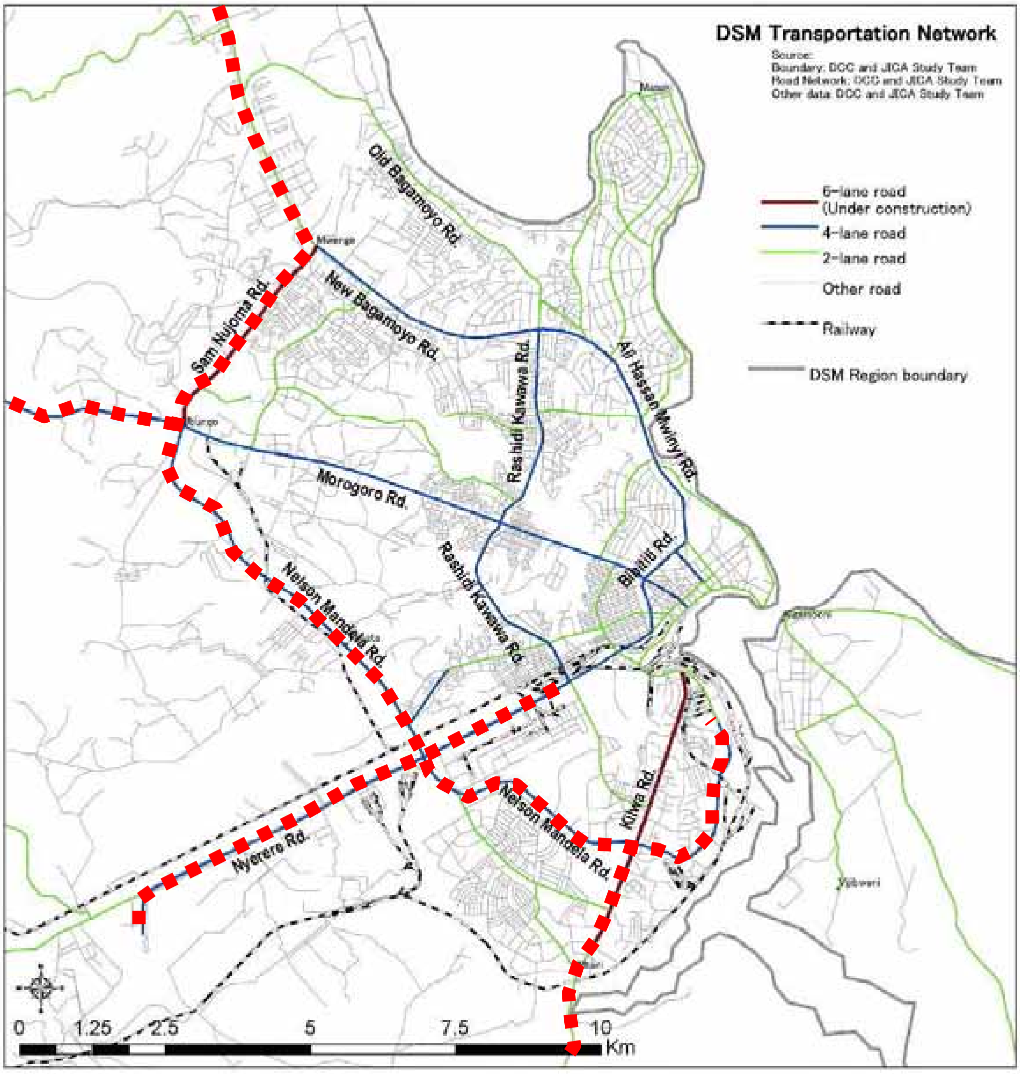


Figure 5.1.4 Proposed Near-term Truck Route Network for Heavy Commercial Vehicles

A truck depot (and potentially Inland Container Depot), suitable for transfer of cargo between heavy commercial vehicles and service trucks should be established to support restrictions in road facilities available for large trucks (i.e. the truck route concept). The current impetus for such a facility is along Morogoro Road several kilometers west of Nelson Mandela Road (Kimara truck terminal). This should continue to be encouraged. Furthermore, some truck terminal facilities inside the Nelson Mandela Road ring have already been removed (Janguani truck terminal) thus providing de-facto support for the proposed truck route concept.

Selected priority intersections should support, if possible, the functioning of the truck route network. Implications for major locations are:

- Mwenge Intersection (New Bagomoyo Road and Sam Nujoma Road):on-track for improvement. Sam Nujoma Road is currently under construction, and New Bagamoyo Road will be widened in the near future.

- Ubungo Intersection (Morogoro, Sam Nujoma and Nelson Mandela Roads): topical location part of the BRT Phase I concept. However, modifications needed due to inefficiencies in the proposed design. Ubungo Intersection is also the prime “turn” (west to from south) for heavy commercial vehicles traveling between upcountry destinations and the Seaport of Dar es Salaam. Morogoro Road BRT infrastructure financed by World Bank; Nelson Mandela Road upgrade (planned scope largely a resurfacing with enhancements of existing four lane cross section) financed by European Commission (refer subsequent Section 5.2 for further discussion).
- Tabata Intersection (Nelson Mandela Road and Tabata Road): congestion at present due to two-lane side street and lack of signal control. Signalization and channelized intersection layout expected as part of EC-sponsored Nelson Mandela Road upgrade.
- Tazara Intersection (Nelson Mandela and Nyerere Roads): critical location along both the truck route and only connection for Nyerere International Airport. It is the only location within the truck route network where heavy commercial vehicle movements can be expected in all intersection quadrants (refer subsequent Section 5.3 for further discussion).
- Uhasibu Intersection (Nelson Mandela and Kilwa Roads): not critical location in sufficiency terms; Kilwa Road currently being widened under assistance by the Government of Japan.
- Chang Ombe Intersection (Nyerere and Chang Ombe Roads): identified capacity issues, and end intersection of truck route; thus large commercial vehicles not expected to pass through the intersection.

Based on the above considerations, the Ubungo and Tazara Intersections emerge as core elements of the truck route network.

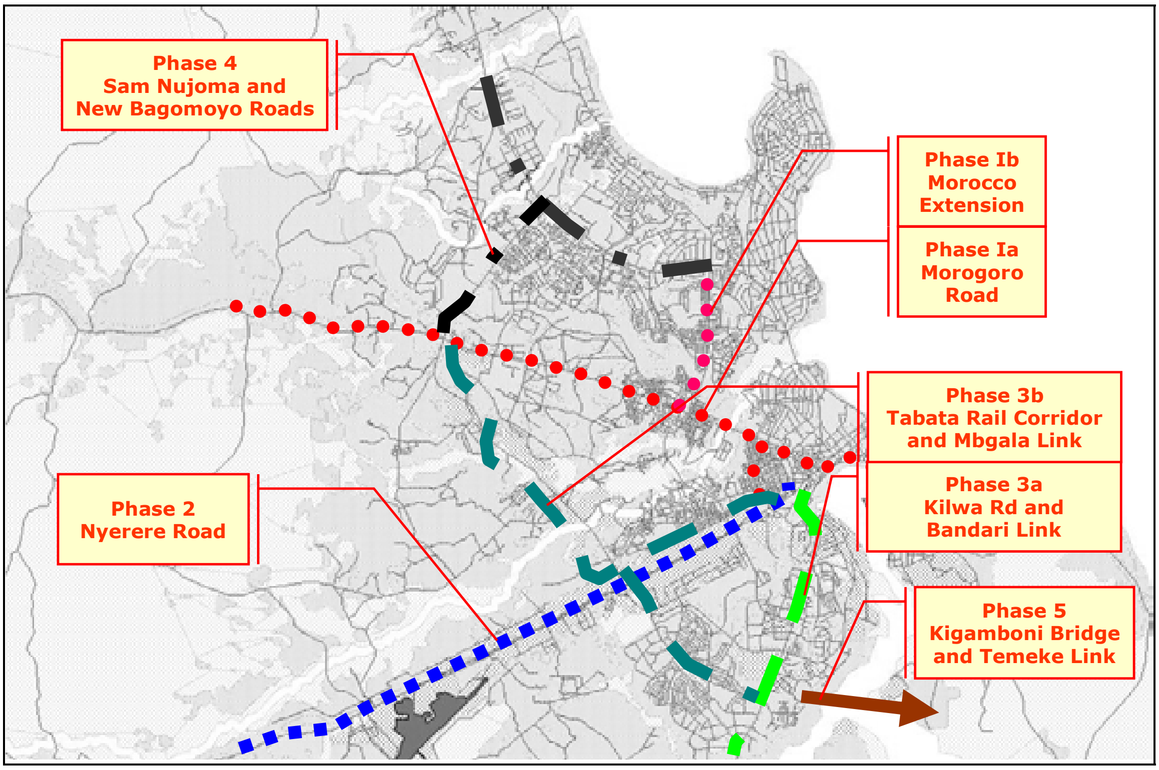
The truck route network also represents an initial step towards an “inner ring road” circumnavigating the central area of Dar es Salaam. This argues that, should more advanced solutions emerge such as grade separations, that the direction of the separations be structured along the Nelson Mandela Road belt; that is, in support of circumferential routing and the truck route. The alignment of any flyovers along the belt in a consistent circumferential direction will also preclude “congestion transfer” (that is, speed and capacity benefits gained at a flyover will become liabilities at the next signalized junction encountered). The circumferential flyover alignment is also preferred to radial-direction flyovers in that the latter approach simply encourages more to/from CBD traffic; this will increasingly, and considerably, burden the numerous traffic signals located within the core area.

5.1.2 The Impact of Bus Rapid Transit

The BRT bus network, to include both the on-going implementation of the Phase I system, as well as further build-out (Phases 2 through 5) proposed by the Study Team is discussed in detail beginning Chapter 10 of this volume. There are two essential considerations in terms of the intersection review: location of BRT busways, consisting of dual median-sited BRT lanes plus stations; and, supporting routes outside of the busway. In the latter case, this includes regular sized buses operating in mixed traffic; thus, from a road operations point of view, do not represent a critical issue. However, the actual location of busways is of considerable interest as these directly impact, both in physical and operational terms, functioning of intersections and road segments.

The staged busway locations are noted in **Figure 5.1.5**. Specific points are:

- Phase 1: Morgoro Road and the Morocco Extension. This element of the BRT is committed and funded; implementation is expected to be complete during 2009. The Master Plan Steering Committee has requested the Study Team to review what is seen as a critical location; namely, the intersection of Morogoro, Nelson Mandela and Sam Nujoma Roads (Ubungo Intersection). The existing Phase I design is seen as catalyzing several concerns. A detailed review of this location is presented in Section 5.2.
- Phase 2: Nyerere Road. The busway coincides, over a considerable portion of its extent, with the proposed heavy truck network. The critical intersection will be Tazara Intersection (Nyerere and Nelson Mandela Roads) in that considerable movement demands will occur.
- Phase 3: Kilwa Road and the disused Tabata rail corridor. In the latter case, the busway will share a rail right-of-way with minimal road interaction. The on-going widening of Kilwa Road already includes provision for the BRT busway. However, both busways face a similar concern: treatments at the northern (central area) termini. In case of the on-going Kilwa Road improvement, current designs call for the termination of the six lane improvement (four arterial lanes plus two BRT lanes) at Bandari Road intersection. Bandari Road consists, at present, of a two-lane (one lane per direction) cross-section; thus, it is critical that a proper transition alignment be defined for both road and BRT through the Gerezani area. A similar issue exists for the CBD terminus of the Tabata route: that is, linkage with the BRT system proper would require a Nyerere Road flyover. Again, a linked approach to integrating both busways with Gerezani area road strategies is needed.
- Phase 4 involves Sam Nujoma Road and New Bagomoyo Road. In the latter case, upgrading is expected to be imminent to a six lane cross-section (four arterial lanes and two BRT lanes). A similar alignment is foreseen for Sam Nujoma Road, although it is unclear whether the on-going (and considerably delayed) widening to four lanes includes provision of a busway. The Ubungo Intersection (Morogoro, Nelson Mandela and Sam Nujoma Roads) is an important location in that proper coordination is required between the imminent implementation of the Phase I busway, as well as the future requirements of the Sam Nujoma Road busway.
- Phase 5 is considered a long-term project and very dependent upon the realization of major new road infrastructure (Kigamboni Bridge).



Source: JICA Study Team

Figure 5.1.5 Master Plan Phased BRT Busway Network

5.1.3 Road Functional Classification Considerations

The Study Team has proposed a scheme to functionally (as opposed to the current jurisdictional classification system) class road be adopted which ranks roads according to various criteria, to include mobility and accessibility. The functional hierarchy, detailed in Chapter 2 of this volume, includes:

- Expressway/motorway which embodies high-type segregated design, and is to be used exclusively by motor vehicles. This road class will connect, for example, CBD with suburban satellite centers, residential areas, airport, seaport, and other high-activity trip generation precincts. Expressways/motorways may be tolled, should this prove desirable.
- Arterial roads stratified into primary, secondary and tertiary facilities according to the level of services. Primary arterial roads represent critical road transport spines that anchor future urban evolution and economic activity. BRT, a vital form of urban mobility (mass transit) for Dar es Salaam, is thus seen as an integral part of this road class in that BRT busways may only be placed into primary arterial roads. Secondary arterial roads provide mobility for medium distance traffic, such as between wards or districts within the city. Network bus services may be provided on this type of road (as well as other lower road classes as long as physical and operational conditions so permit), but will operate in mixed traffic. Site-specific public transport priority treatments, for example, queue jumpers or signal priority, are possible on secondary roads. Tertiary arterial roads provide accessibility to defined geographical areas within the city, and are intended to provide linkage with other higher-order roads.

- Community roads or local collector roads provide accessibility to and/or between neighborhoods, communities and individual plots. This level of roads lie below the focus of the Transport Master Plan.
- Special roads used for specific purposes, such as pedestrian mall, exclusive BRT road, scenic road, non-motorized vehicle way, and pedestrian way.

The full extent of the functional classification is strongly linked with the ultimate long-term road configuration, and thus not deterministically linked with individual intersections. Some facilities, such as the proposed motorway system, may well embody particularly longer-term planning horizons.

The existing (year 2007) functional road network extends over some 770 road kilometers, including some 150 kilometers of primary roads (of which 76 kilometers house BRT busways) and 110 kilometers of secondary arterial roads. The vase majority of the network is composed of tertiary roads (more than 500 kilometers).

In line with the hierarchical approach, it would seem prudent that, at present, any intersection-specific reviews should focus on the primary road network.

5.2 Managing BRT Options at Ubungo Intersection

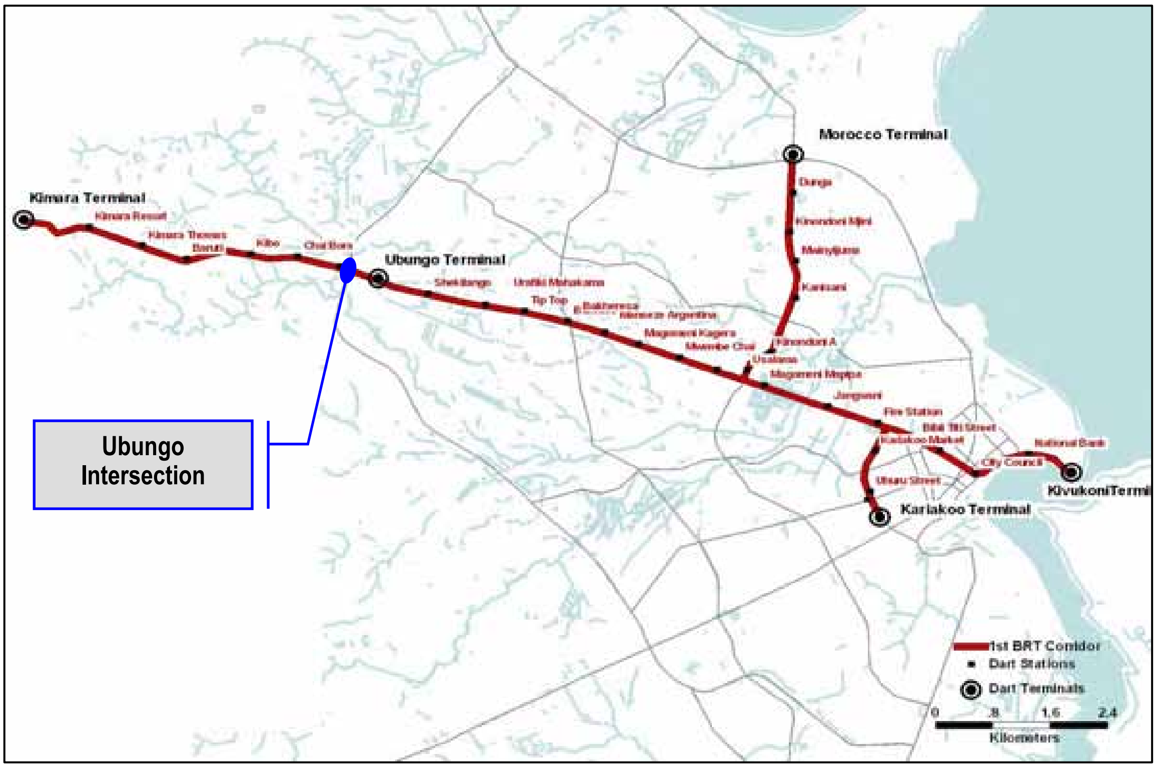
This section examines, in response to a request from the Project Steering Committee to the Study Team, the role of the intersection of Morogoro Road, Nelson Mandela Road and Sam Nujoma Road (Ubungo Intersection) within the BRT Phase I[6] route structure.

Additional intersections exist within the Phase I project. However, at present, the discussion focuses upon the critical Ubungo Intersection given its prominent role in the regional road network. Furthermore, many of the issues highlighted at this location are mirrored at other intersections within the corridor.

5.2.1 Orientation

Ubungo Intersection is an integral component of the Phase I BRT route structure (**Figure 5.2.1**). Located in the western part of the city, the intersection accommodates two major trunk roads, each carrying considerable traffic volumes.

[6] For additional BRT detail, refer various intermediate reports culminating in *Final Report and Project Review Seminar, Consulting Services for the Conceptual Design of a Long-term Integrated Dar es Salaam BRT System and Detailed Design of the Initial Corridor*, for the Dar es Salaam City Council and Prime Minister's Office for Regional Administration and Local Government, by Logit Consultants, in association with Inter-Consult Ltd, March 2007. Background design information for the current discussion has been drawn from *Bidding Documents, Dar Rapid Transit Project-DART, Volume IIA-1, Road Works Drawings (Kivukoni-Ubungo).*



Source: Logit Consultants, op. cit.

Figure 5.2.1 Location of Ubungo Intersection within the BRT Phase I Project

Both facilities feature four-lane cross-sections, with right-turn bays provided on all approaches. Left-turn slip-ramps exist in all four quadrants (**Figure 5.2.2**). The Ubungo Dala Dala bus terminal is sited south of Morogoro Road some 150 meters west of the intersection, while the Ubungo Inter-city

Bus Terminal is located adjacent to the northeast intersection quadrant. The intersection is constrained by the presence of considerable drainage and water courses, both natural and man-made. Intersection control is via a traffic signal or, during peak demand periods, intermittent police intervention.

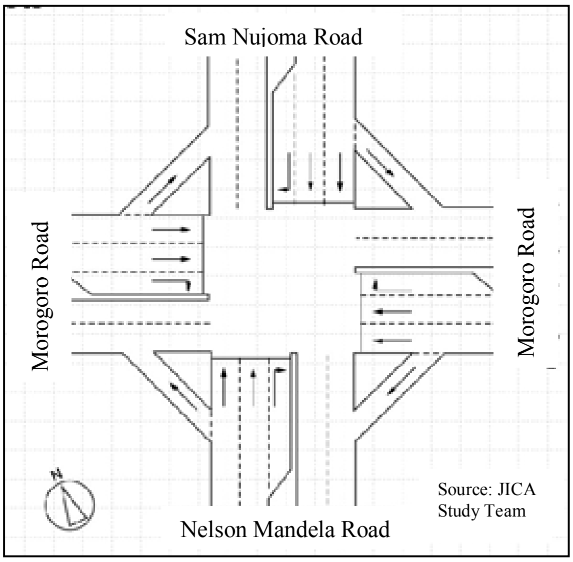


Figure 5.2.2 Schematic of Current Intersection Layout

The intersection environment is slated for a series of improvements. Three entities are involved:

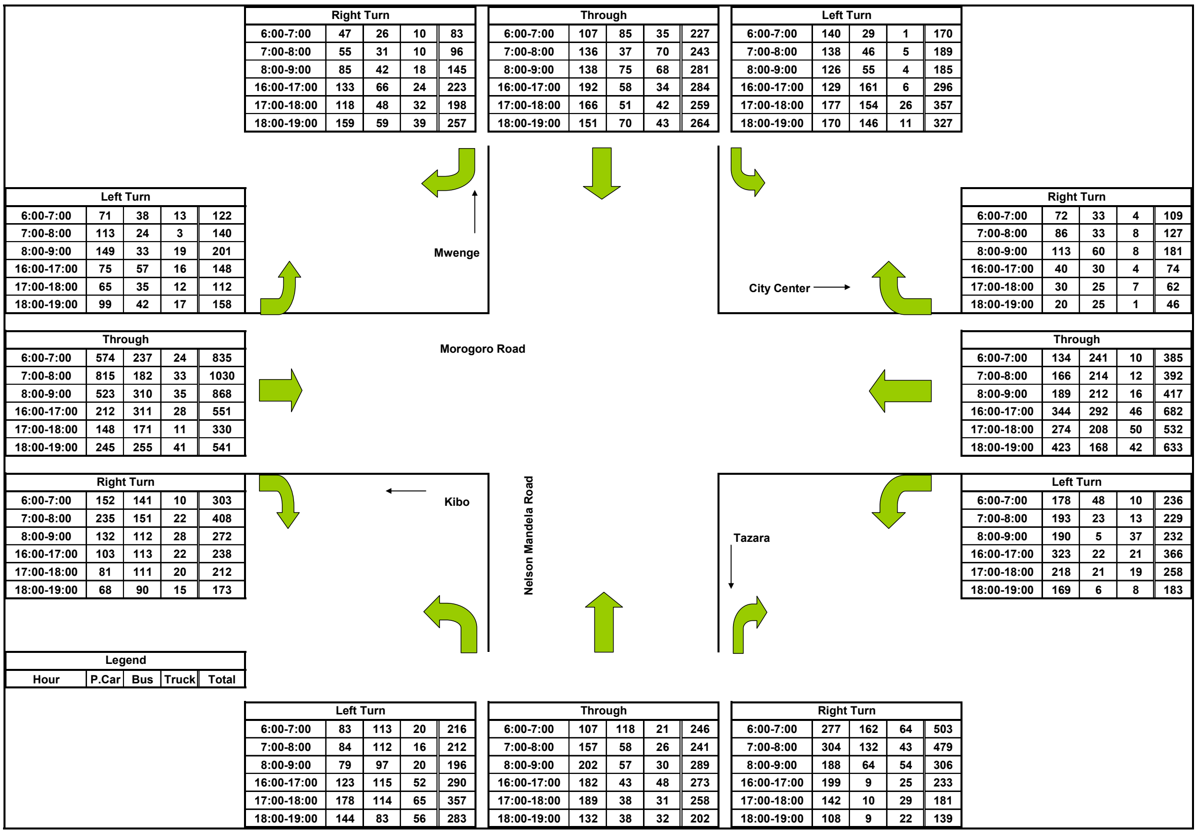
- Nelson Mandela Road north of the intersection (Sam Nujoma Road) is currently under construction (and understood to be considerably behind schedule).

- Nelson Mandela Road south of the intersection has recently (October, 2007) been approved for upgrading within the current basic configuration under sponsorship of the European Commission.
- The implementation of BRT Phase I, with infrastructure financed by the World Bank.

The status of coordination among these entities to ensure consistency of plans and profiles is unknown at present.

The construction status of the northern approach (Sam Nujoma Road) is influencing, as expected, traffic volume within the intersection. However, weekday peak hour turning movements obtained during June, 2007, confirm several important relationships (**Figure 5.2.3**):

- During the course of the six morning and afternoon peak hours surveyed, Morogoro Road carried the highest traffic volume. The peak morning hour (0700-0800) western approach in the straight-through direction totaled 1,030 vehicles consisting of 815 cars, 182 buses and 33 trucks. An additional 140 vehicles turned left (to the north) and a substantial 408 vehicles turned right (to the south).
- The southern approach of Nelson Mandela Road during the same hour aggregated to 241 through and 212 left-turning vehicles, as well as 479 right turning vehicles.
- Right turns represent a critical element of intersection flow. Particularly strong movements are encountered along the south to east axis and west to south axis. The under-construction north to west axis right turn is already noticeable, and may well increase once Sam Nujoma Road construction is completed.
- Truck activity along the west-south axis generally exceeds similar modal movements in other quadrants, reaching 50-65 hourly vehicles during the afternoon peak period. Furthermore, this movement lies astride the upcountry-seaport goods movement corridor. Thus, a prevalence of heavy, articulated commercial vehicles (to include container transports) in the traffic stream may be expected.
- The importance of the Nelson Mandela Road corridor to seaport cargo movement should not be underestimated. The Cargo Transport Survey conducted by the Study Team during June, 2007, queried drivers at the Dar es Salaam seaport as to a number of indicators including routing preferences: 43 percent (the largest subgroup) indicated that the preferred route of travel to/from the port is along Nelson Mandela Road (**Figure 5.2.4**). It is of further interest to note that the mix of commercial vehicles servicing the seaport consists of near 80 percent having more than three axles (that is, articulated vehicles).



Legend

Hour	P.Car	Bus	Truck	Total

Right Turn (top)

Hour	P.Car	Bus	Truck	Total
6:00-7:00	47	26	10	83
7:00-8:00	55	31	10	96
8:00-9:00	85	42	18	145
16:00-17:00	133	66	24	223
17:00-18:00	118	48	32	198
18:00-19:00	159	59	39	257

Through (top)

Hour	P.Car	Bus	Truck	Total
6:00-7:00	107	85	35	227
7:00-8:00	136	37	70	243
8:00-9:00	138	75	68	281
16:00-17:00	192	58	34	284
17:00-18:00	166	51	42	259
18:00-19:00	151	70	43	264

Left Turn (top)

Hour	P.Car	Bus	Truck	Total
6:00-7:00	140	29	1	170
7:00-8:00	138	46	5	189
8:00-9:00	126	55	4	185
16:00-17:00	129	161	6	296
17:00-18:00	177	154	26	357
18:00-19:00	170	146	11	327

Left Turn (left)

Hour	P.Car	Bus	Truck	Total
6:00-7:00	71	38	13	122
7:00-8:00	113	24	3	140
8:00-9:00	149	33	19	201
16:00-17:00	75	57	16	148
17:00-18:00	65	35	12	112
18:00-19:00	99	42	17	158

Through (left)

Hour	P.Car	Bus	Truck	Total
6:00-7:00	574	237	24	835
7:00-8:00	815	182	33	1030
8:00-9:00	523	310	35	868
16:00-17:00	212	311	28	551
17:00-18:00	148	171	11	330
18:00-19:00	245	255	41	541

Right Turn (left)

Hour	P.Car	Bus	Truck	Total
6:00-7:00	152	141	10	303
7:00-8:00	235	151	22	408
8:00-9:00	132	112	28	272
16:00-17:00	103	113	22	238
17:00-18:00	81	111	20	212
18:00-19:00	68	90	15	173

Right Turn (right)

Hour	P.Car	Bus	Truck	Total
6:00-7:00	72	33	4	109
7:00-8:00	86	33	8	127
8:00-9:00	113	60	8	181
16:00-17:00	40	30	4	74
17:00-18:00	30	25	7	62
18:00-19:00	20	25	1	46

Through (right)

Hour	P.Car	Bus	Truck	Total
6:00-7:00	134	241	10	385
7:00-8:00	166	214	12	392
8:00-9:00	189	212	16	417
16:00-17:00	344	292	46	682
17:00-18:00	274	208	50	532
18:00-19:00	423	168	42	633

Left Turn (right)

Hour	P.Car	Bus	Truck	Total
6:00-7:00	178	48	10	236
7:00-8:00	193	23	13	229
8:00-9:00	190	5	37	232
16:00-17:00	323	22	21	366
17:00-18:00	218	21	19	258
18:00-19:00	169	6	8	183

Left Turn (bottom)

Hour	P.Car	Bus	Truck	Total
6:00-7:00	83	113	20	216
7:00-8:00	84	112	16	212
8:00-9:00	79	97	20	196
16:00-17:00	123	115	52	290
17:00-18:00	178	114	65	357
18:00-19:00	144	83	56	283

Through (bottom)

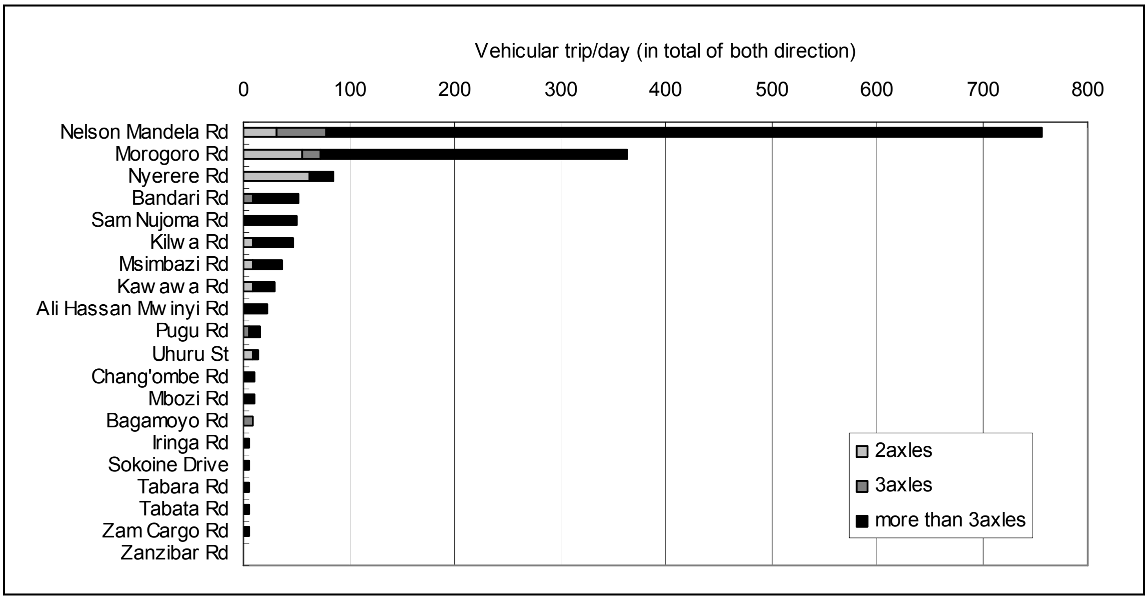
Hour	P.Car	Bus	Truck	Total
6:00-7:00	107	118	21	246
7:00-8:00	157	58	26	241
8:00-9:00	202	57	30	289
16:00-17:00	182	43	48	273
17:00-18:00	189	38	31	258
18:00-19:00	132	38	32	202

Right Turn (bottom)

Hour	P.Car	Bus	Truck	Total
6:00-7:00	277	162	64	503
7:00-8:00	304	132	43	479
8:00-9:00	188	64	54	306
16:00-17:00	199	9	25	233
17:00-18:00	142	10	29	181
18:00-19:00	108	9	22	139

Source: JICA Study Team

Figure 5.2.3 Vehicular Turning Movement Activity: Weekday Peak Hours, June 2007

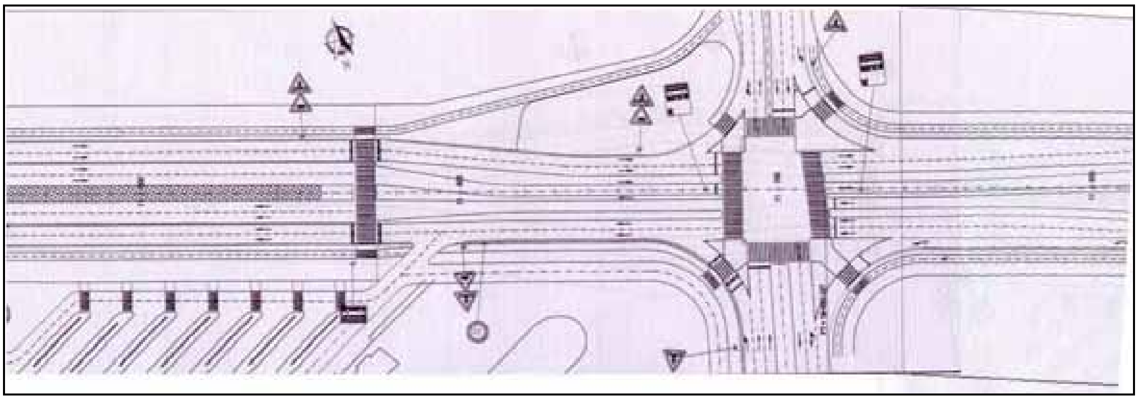


Source: JICA Study Team, Cargo Transport Survey

Figure 5.2.4 Preferred Routes of Travel To/from Dar es Salaam Seaport

5.2.2 The BRT Phase I Plan

The proposed Phase I BRT plan includes several important elements (**Figure 5.2.5**):



Source: Logit Consultants, op. cit.

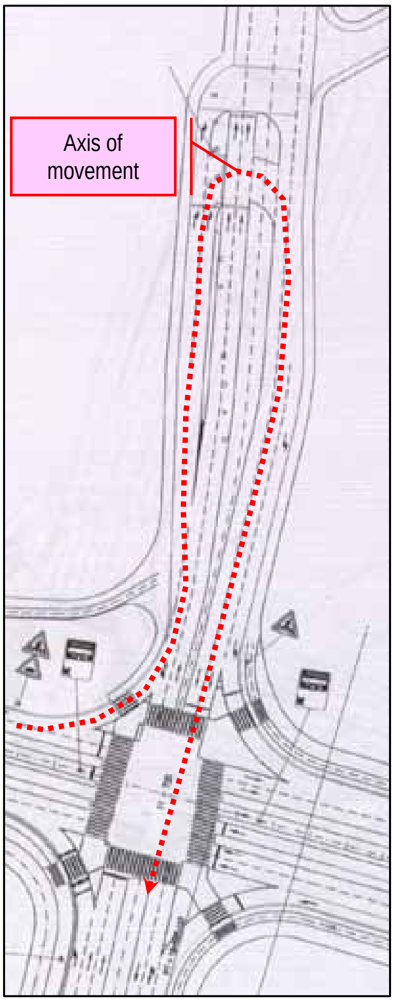
Figure 5.2.5 BRT Phase I Proposal at Ubungo Intersection

- An exclusive access road for Ubungo Dala Dala bus terminal will be provided in the southwest intersection quadrant. The intent is to remove as many Dala Dala as possible from the intersection traffic stream.

- BRT will be provided per established criteria in a median alignment along Morogoro Road. Dual directional traffic lanes will be located adjacent to the BRT lanes for other traffic. The Ubungo BRT station is located some 150 meters west of the intersection. Again as with established criteria, passing lanes will be provided in the station area for BRT operation thus requiring a temporary flaring (outward widening) of Morogoro Road.

- Right turns will not be allowed for any intersection approach. Right turns from Morogoro Road to Nelson Mandela or Sam Nujoma Roads are to be accomplished via a diversion which involves initially a left turn from Morogoro Road, then, after some 150 meters along Nelson Mandela/San Nujoma Roads, a U-turn. The proposed U-turn facility configuration for Sam Nujoma Road (north of Morogoro Road) is depicted in **Figure 5.2.6**. A largely identical design is proposed for Nelson Mandela Road U-turns (south of Morogoro Road).

- Significantly, the proposed design makes no direct provision for right turns from Nelson Mandela Road or

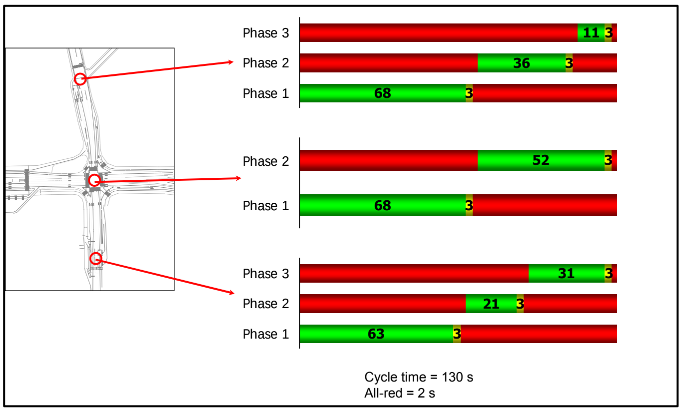


Source: Logit Consultants, op. cit.

Figure 5.2.6 Proposed Sam Nujoma Rd U-turn Facility

Sam Nujoma Road onto Morogoro Road. Presumably these would be permitted to concurrently utilize the proposed U-turn facilities located north and south of Morogoro Road via (essentially) slip ramp access.

- Ubungo Intersection proper is governed by a two-phase traffic signal. The phases would allow for through and left turn flow in the north-south and east-west cardinal directions, respectively. BRT would flow concurrently with the east-west (Morogoro Road) green phase indication.
- A total of three primary traffic signals would be provided within the intersection environment. These control, in addition to the intersection proper, the cross-traffic U-flows along Sam Nujoma and Nelson Mandela Roads, respectively. The signals controlling the U-turns would operate according to three phases (**Figure 5.2.7**).



Source: Logit Consultants, op. cit.

Figure 5.2.7 Locations and Phasing Plan: Traffic Signals At and Adjacent to Ubungo Intersection

- However, a secondary signal is also required to manage the proposed Dala Dala ingress/egress for Ubungo terminal. The location would be along Nelson Mandela Road, south of Morogoro Road, and in between the main intersection and southern U-turn traffic signals.

A further consideration is relevant to the current discussion. First and foremost, the requested review pertains to the workability of the proposed BRT Phase I traffic system modifications. However, concurrently, it is desirable that the ultimate configuration of the BRT system be kept in mind. Thus, physical changes proposed for the Phase I system should be compatible with ultimate needs of infrastructure needed during subsequent phases of implementation.

The Study Team is has proposed subsequent (post-Phase I) BRT phases within the framework of the overall *Transport Master Plan*. A recommendation is that the future BRT system include a dedicated BRT way north of Morogoro Road along San Nujoma Road to link with the New Bagamoyo Road system (refer discussions beginning Chapter 10, this volume).

The consideration for the current review would therefore be that, in future, BRT vehicles would be required to make a left turn movement from the southbound Sam Nujoma BRT lane onto the eastbound Morogoro Road BRT lane, and a right turn from the westbound Morogoro Road BRT lane onto the northbound Sam Nujoma BRT lane. This carries the implication that, in all likelihood, signal cycles would require additional phases and, depending on volume, the provision of a right-turn bus storage lane along the westbound Morogoro Road BRT way may be needed.

It is concurrently noted that no BRT is contemplated on Nelson Mandela Road south of Morogoro Road. Instead, the proposed Master Plan concept is to operate BRT in an exclusive alignment within the disused Tabata rail corridor.

5.2.3 Intersection Sufficiency: Existing Condition

The Study Team utilized several approaches to evaluate the operations of the Ubungo Intersection environment. These include a volume to capacity review as well as the application of VISSIM micro-simulation software (refer following section).

The volume to capacity analysis relies on observed traffic movement volumes and thus represents a snapshot in time. Several conclusions emerge from this review (**Table 5.2.1**):

- Peak hour operations are very difficult to quantify given that manual control by traffic police is typically practiced. The volume to capacity review therefore approached the analysis from a slightly different perspective; that is, given observed traffic volumes, signal capabilities and geometric layout, might an optimum operations profile (in terms of intersection saturation) be possible?

Table 5.2.1 Ubungo Intersection 2007 AM Peak Hour Sufficiency Analysis

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

Source: JICA Study Team

- The peak afternoon peak hour (1615-1715 hours) catalyzes considerably less negative impact than the morning peak hour (0645-0745 hours). The PM peak hour is shown as achieving an acceptable saturation rate of less than 0.6[7]. The better performance is not surprising in that morning peak hour activity is very concentrated into a single hour (or two hour period) while afternoon demand is much more diffuse extending, in fact, over most of the entire afternoon.
- The morning peak period is operating at critical levels with intersection saturation at unity. Indeed, an optimum allocation of cycle time and phasing is no longer possible. Particularly critical approaches include Nelson Mandela Road (northbound) as well as Morogoro Road (eastbound). The latter performance shows strong demand for both the through (west to east) and right turn (west to south) movements.
- Intersection operations are complicated by abutting land use activities, to include Dala Dala ingress/egress maneuvers to/from Ubungo terminal, as well as pronounced pedestrian activity in all quadrants. The critical ingress/egress point for Dala Dala operation is located along Morogoro Road about 150 meters west of the intersection proper; unruly and unsafe driver behavior dominates at this location.

5.2.4 Simulation of Intersection Concepts

The VISSIM micro simulation examined three cases of intersection operation:

- The existing situation, as described in subsection 5.2.3;
- The BRT Phase I base case, consisting of intersection layout and design as described in subsection 5.2.2. This includes the revision to Dala Dala operation involving drastic reductions in Dala Dala activity along Morogoro Road after introduction of BRT as well as a revised access point to the Ubungo Dala Dala terminal; and,
- A BRT modified case. This simulation represents a potential alternative intersection treatment. Parameters include BRT mainline operation as proposed by the Phase I base case to include post-BRT Dala Dala activity. However, the key difference is that right-turns are permitted at the intersection proper via a four-phase traffic signal. This negates the need for the U-turn facilities proposed by the BRT Phase I base case north and south of Morogoro Road.

Results of each simulation are described in following subparagraphs.

1) Existing Condition

The initial simulation relates to current conditions; that is, four phase signal cycle, existing intersection layouts, observed traffic volumes and existing Dala Dala terminal ingress/egress (**Figure 5.2.8**).

[7] Guidelines suggest that a ratio of less than 0.85 implies acceptable intersection operation while a ratio of near unity indicates that the intersection is operating at full saturation and likely to experience unstable performance. A ratio in excess of 1.0, to say 1.4 approximately, implies intersection failure. Approach and methodology per *Planning and Design of At-grade Intersections*, The Japan Society of Traffic Engineers, 2002.

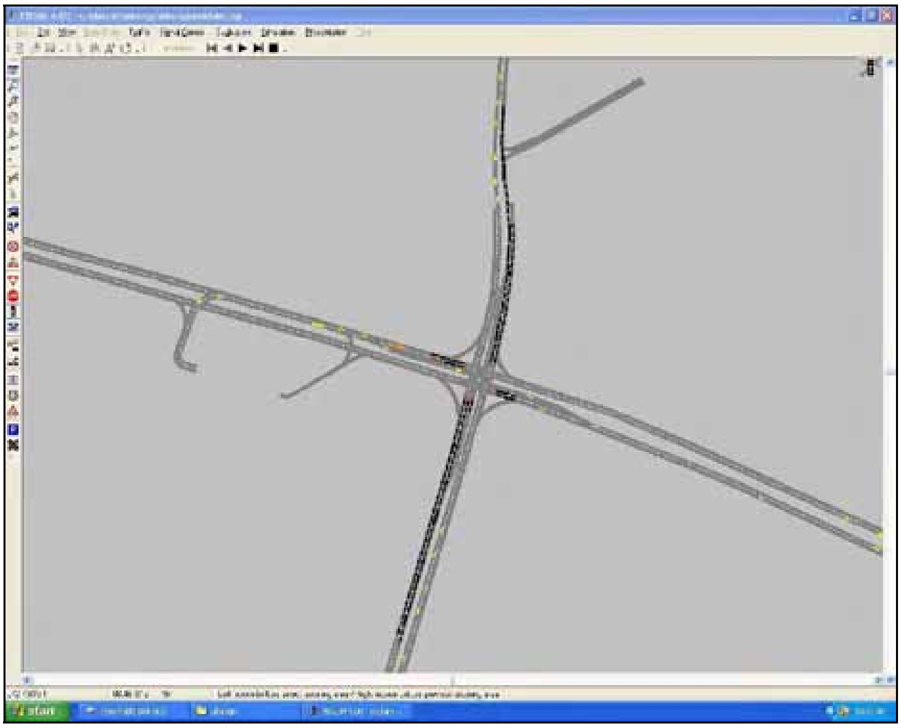


Figure 5.2.8 Simulation Topography: Existing Condition

The volume to capacity review (refer previous section) has already determined that existing AM peak hour conditions are saturated bordering on operational breakdown. The main intent of the first VISSIM simulation is to quantify the existing operational conditions within the intersection as a baseline to compare other intersection layouts.

The simulation confirms that, over a three hour AM peak period (0600-0900) some 11,100 vehicles pass through the intersection. These travel a total distance of near 17,900 kilometers for an average model boundary condition of 1.61 km per vehicle. The average travel time for passing through the modeled precinct is 2.82 minutes, to include roughly one minute of delay. The average network speed (that is, for all movements on all approaches through and within the intersection area) was some 34 kilometers per hour (**Table 5.2.2**).

Table 5.2.2 Simulation Quantification: Existing Condition

Parameter	Amount
Number of vehicles processed	11,071
Total distance traveled (km)	17,850
Average travel distance (km/vehicle)	1.61
Total travel time (hours)	520
Average travel time (min/vehicle)	2.82
Average simulation speed (km/hr)	34.3
Total simulation delay (hour)	180.3
Average delay (min/vehicle)	0.98

Source: JICA Study Team

A further benefit of the simulation is the ability to view, in simulated time, actual conditions of intersection operation. That is, a “snap shot” at a particular time. It is, for example, confirmed by the model that queue build-ups on high-demand approaches degrade intersection operation (**Figure 5.2.9**).

Figure 5.2.9 Queue Build-up along Morogoro Road West Approach Simulation of Existing Condition

2) BRT Phase I Base Case

The BRT Phase I base case consists of intersection layout, signal operation and design as described in subsection 5.2.2; i.e. the currently existing BRT Phase I design concept (**Figure 5.2.10**). Operations include drastic reductions in Dala Dala activity along Morogoro Road after introduction of BRT as well as a revised access point to the Ubungo Dala Dala terminal (to be located along Nelson Mandela Road several hundred meters south of Morogoro Road in immediate vicinity of the U-turn facility).

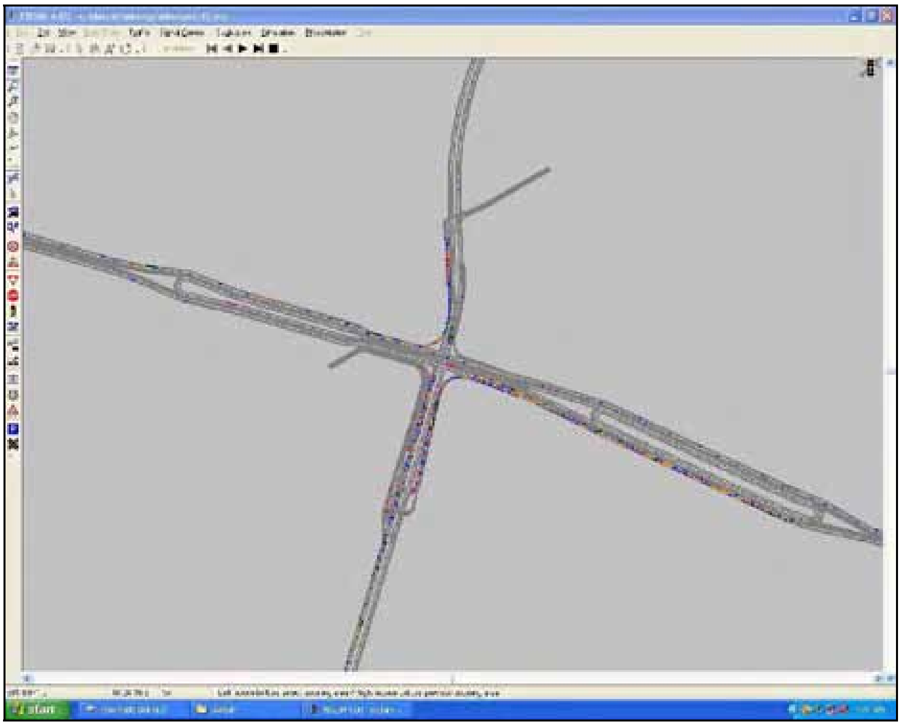


Figure 5.2.10 Simulation Topography: BRT Phase I Base Case

The simulation confirms a paradox:

- Operation at the intersection proper; that is, the core Ubungo Intersection, has actually improved. This is due to two reasons: signal phasing has been reduced from four to two cycles per the base case plan, and right turn movements have been removed from consideration becoming, in effect, left turn and through movements. Also, the number of vehicles has been reduced in that Dala Dala operation along Morogoro Road has been considerably modified following the introduction of BRT.
- However, operation of the overall intersection area has worsened. This is due to the introduction of the U-turn requirement, which in itself, while helping the intersection proper, introduces considerable delays and congestion at the signalized U-turn facilities south and north of Morogoro Road. The southern U-turn is particularly congested due to "double duty": providing U-turns for vehicles turning toward the northbound direction, and ingress/egress needs at the relocated Dala Dala terminal access point.

The composite simulation confirms that, while fewer vehicles need be processed and average travel distance has increased only modestly vis-à-vis the existing condition (from 1.61 to 1.70 kilometers per vehicle though the simulation precinct), average time has increased considerably to 4.50 minutes including 2.17 minutes per vehicle of delay. The average network speed has sharply dropped to some 23 kilometers per hour (**Table 5.2.3**).

Table 5.2.3 Simulation Quantification: Existing Condition and BRT Base Case

Parameter	Amount	
	Existing	BRT Base Case
Number of vehicles processed	11,071	10,629
Total distance traveled (km)	17,850	18,114
Average travel distance (km/vehicle)	1.61	1.70
Total travel time (hours)	520	797
Average travel time (min/vehicle)	2.82	4.50
Average simulation speed (km/hr)	34.3	22.7
Total simulation delay (hour)	180.3	383.7
Average delay (min/vehicle)	0.98	2.17

Source: JICA Study Team

The simulation identifies areas of particular concern:

- The Sam Nujoma Road U-turn facility sited north of Morogoro Road. This routing must accommodate right-turns from the Morogoro Road eastbound approach (which contain considerable numbers of heavy commercial vehicles) plus right turns from the Nelson Mandela Road northbound approach. As confirmed by the simulation, U-turns by articulated vehicles are problematic due to limited space. In addition, the heavy turning volumes, and constrained cycle time, catalyze a queue build-up extending into Morogoro Road proper (**Figure 5.2.11**).
- The Nelson Mandela Road U-turn facility sited south of Morogoro Road. While the number of U-turning heavy commercial vehicles is less than at the Sam Nujoma facility, a different series of problems develop. These include not only pronounced volumes, but also a concurrent need for signalization to accommodate both U-turning vehicles as well as ingress/egress movements to/from the relocated access point to the Ubungo Dala Dala terminal. Considerable queues and conflict points develop (**Figure 5.2.12**).

Figure 5.2.11 Queue Build-up along Sam Nujoma U-turn Facility Simulation of BRT Phase I Base Case

Figure 5.2.12 Queue Build-up along the Nelson Mandela U-turn Facility Simulation of BRT Phase I Base Case

3) BRT Phase I Modified Case

The final simulation represents a potential alternative intersection treatment. Parameters include BRT mainline operation as proposed by the Phase I base case to include post-BRT Dala Dala operating conditions and relocated access point for the Ubungo Dala Dala terminal. However, the key difference is that right-turns are permitted at the intersection proper via a four-phase traffic signal. This negates the need for the U-turn facilities proposed by the BRT Phase I base case, and the operational problems identified via the BRT Phase I base case simulation (**Figure 5.2.13**).

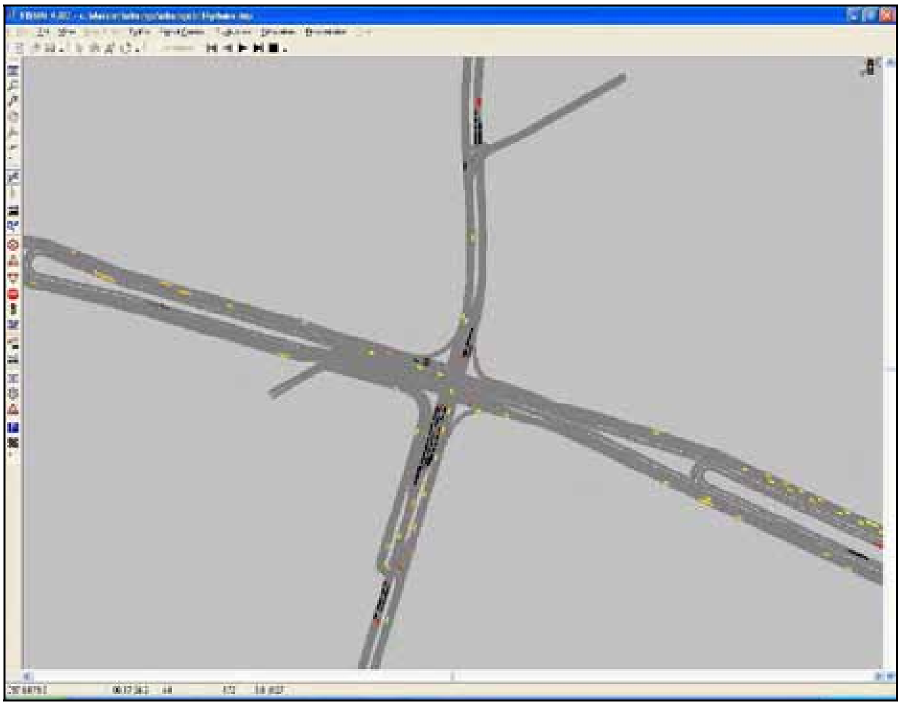


Figure 5.2.13 Simulation Topography: BRT Phase I Modified Case

The simulation indicates that operations are roughly on par with those of the existing case simulation (**Table 5.2.4**). Total travel time has increased marginally to 2.94 minutes per vehicle, at an average simulation speed of 33.0 km/hr. However, this represents a sharp improvement over the BRT Phase I base case.

This may be attributed to several considerations:

- The provision of proper right-turn bays having sufficient storage length for observed demand and vehicle mix.
- The reduction in the number of Dala Dalas operating in the traffic stream (roughly one-third less) due to limited services along Morogoro Road under the post-BRT scenario.
- Removal of the Ubungo Dala Dala terminal access point from Morogoro Road (west of Ubongo Intersection) and its relocation to a point several hundred meters south of the intersection along Nelson Mandela Road.

- Elimination of the extensive delays catalyzed by the base case U-turn facilities along Nelson Mandela and Sam Nujoma Roads.

Table 5.2.4 Simulation Quantification: Existing Condition, BRT Base and Modified Cases

Parameter	Amount		
	Existing	BRT Base Case	BRT Modified Case
Number of vehicles processed	11,071	10,629	10,707
Total distance traveled (km)	17,850	18,114	17,319
Average travel distance (km/vehicle)	1.61	1.70	1.62
Total travel time (hours)	520	797	524
Average travel time (min/vehicle)	2.82	4.50	2.94
Average simulation speed (km/hr)	34.3	22.7	33.0
Total simulation delay (hour)	180.3	383.7	126.6
Average delay (min/vehicle)	0.98	2.17	0.71

Source: JICA Study Team

5.2.5 Discussion and Possible Ways Forward

The review of the proposed BRT Phase I concept leads to several conclusions. In the first instance:

- It is important to emphasize that the Study Team is fully supportive of the BRT concept, and is in full agreement with the implementation of BRT for Dar es Salaam.
- The BRT concept has been fully adopted and integrated with the framework of the *Transport Master Plan*; indeed, will form a cornerstone for the provision of enhanced and improved urban mobility.
- The current proposal for the BRT Phase I system is the result of considerable and thorough professional investigations but contains a BRT-centric series of solutions.
- However, in the opinion of the JICA Study Team, broader perspectives in addition to BRT-focused solutions are needed to ensure that other modes of traffic (to include cargo movement) are not unnecessarily penalized by the introduction of BRT.

The JICA Study Team is fully aware of the need for a quick resolution of the identified concerns as the Phase I system is rapidly moving towards implementation. Yet, concurrently, alternative solutions require more detailed review to ensure that physical and operational criteria are fully met to the satisfaction of the World Bank and the Government of Tanzania. In the opinion of the Study Team, this is possible with a concerted "fast track" approach to problem solving.

Several potential solutions would appear to offer promise.

1) BRT Phase I Modified Case (At-grade Near-term Solution)

The core tenet of this solution is to provide right-turn lanes at the intersection proper in order to overcome operational constraints identified by the BRT Phase I Base Case simulation. The solution represents the lowest-cost modified solution. The provision of right-turn lanes (i.e. continuation of current practices) will ensure that, in principle, all traffic streams are allotted a "fair share" of movement opportunity at this intersection. However, more complex (likely four phase) signalization will be required. While this poses no problems technically, the implication is that less time will be available for BRT movements during any given cycle. It may be argued that BRT-priority ("on call phasing") can be programmed within the signal cycle to enhance sensitivity toward BRT operations. However, the efficiency of priority calls are impacted by the number of buses and other vehicles; it is unlikely that more than one BRT priority cycle will be granted by the controller during any one signal cycle. An alternative BRT management approach of priority signaling is discussed later Section 5.2.6 following the Traffic Management discussion.

Traffic Management of Right-turn Traffic

There are two alternative options for adjacent operation of a BRT lane and a right turn lane. One option is to keep the bus lane as the innermost lane as shown in **Figure 5.2.14** (exclusive design) so that right turn traffic has to "cross" the bus lane within the intersection proper. The exclusive design retains the segregation of the BRT lane but right turning traffic and bus traffic must be discharged from the stop line at different times within a signal cycle. The phase sequence must be bus phase (plus through) followed by through and right turn (as shown at the top sequence in the figure), or through traffic and through bus followed by right turn (the bottom sequence in the figure). Exact phase sequence is typically determined based on turning movement and bus demand.

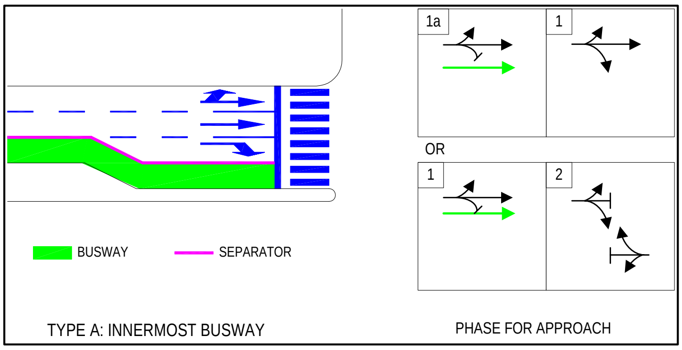


Figure 5.2.14 Exclusive Lane Arrangement

Another configuration is a permissive design (**Figure 5.2.15**) under which right turn traffic crosses the bus lane before the stop line. If the right turn lane is placed according to a permissive design, all movements (through traffic, through bus and right turn traffic) can be discharged at the same time and no additional signal phase is required. Crossing of the bus lane by other vehicles near the intersection could, however, create a hazardous situation. Furthermore, operation of the BRT lane can be blocked if the right turn queue "spills back" across the bus lane.

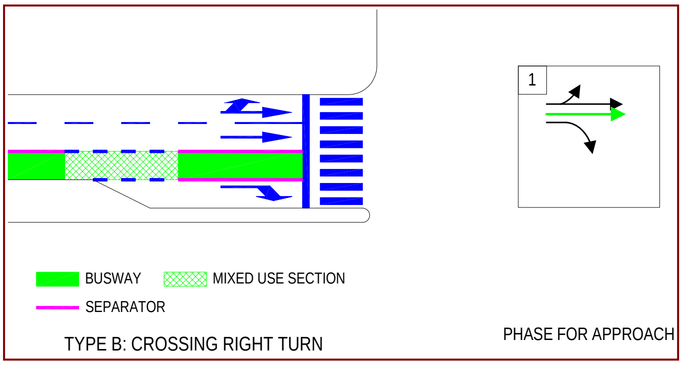


Figure 5.2.15 Permissive Lane Arrangement

Considering the likelihood of accidents involving buses and other traffic, the desire to maintain the exclusiveness of the BRT system, and expected BRT hourly volumes, the exclusive design (refer **Figure 5.2.14**) is preferred.

However, while being appropriate in the near and medium term future, this solution does not "fix the intersection" in the longer term future due to anticipated growth in traffic demand. The provision of right-turn lanes would also require on the order of four additional meters along each approach, plus storage bays of appropriate length. Issues may result due to physical constraints posed by flanking drainage and water courses.

2) BRT-only Grade Separation Solutions

The thrust of the solution is to separate BRT from other movements at the intersection proper. However, such a solution, while definitely assisting BRT operation, would not, in isolation, "fix the intersection" in that BRT operation, on a volume basis, is not a critical movement vis-à-vis signal requirements. Other intersection movements are expected to incur similar operations as those identified during the simulation of the BRT Phase I modified case. Nevertheless, options for BRT flyovers may include:

- Provide a single structure BRT flyover along Morogoro Road. One of the best solutions for BRT, although costs will escalate vis-à-vis at-grade solutions. A single east-west BRT system is contemplated along Morogoro Road as part of the Phase I concept. Thus, it is readily possible to implement a flyover, with transitions an appropriate distance (some 150 meters) along both Morogoro Road approaches. The design will require marginally more space than the Phase I concept due to the width of the structure. However, right turn movements for mixed traffic can be retained; indeed, assuming proper grades and elevations, it is likely that the Morogoro Raod right-turn lanes can be placed under the BRT flyover. During later phases of BRT operation a bus line is foreseen between Morogoro Road and Sam Nujoma Road. Thus, BRT operation will no longer be limited to the east-west Morogoro Road flyover. Instead, in the westbound direction, buses must transition past the end of the ramp nose in order to reach their right turn lane (to northbound Sam Nujoma Road), while in the eastbound direction a lane must be provided for buses coming from southbound Sam Nujoma Road. It is likely also that the latter movement will require some form of priority allocation in that two lanes of BRT buses will merge into one lane east of the ramp nose (**Figure 5.2.16**).
- There exists a further possibility for flyover design which utilizes a split structure construction. Each BRT direction would feature its own flyover structure (**Figure 5.2.17**). The advantage of such a design would not accrue until realization of the Phase II system. BRT vehicles traveling between the north and east approaches would no longer be required to divert around ramp noses, but instead travel between ramp structures via a continuation of the protected BRT way. Eastbound BRT merge priority allocation would still be desirable. The disadvantage of the design is higher cost (two structures, two sets of supports) plus a net widening within the intersection proper. Roughly speaking, the widening effect would be similar to BRT lane

diversions required at BRT stations.

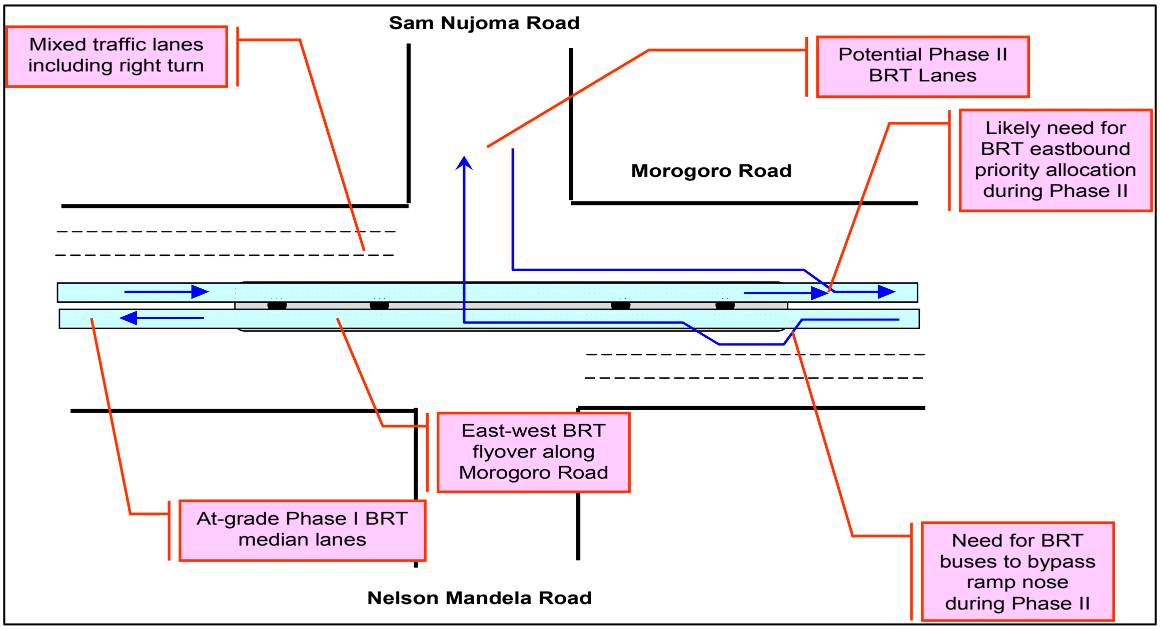


Figure 5.2.16 Schematic of Single Structure BRT Flyover

- Provide a BRT underpass along Morogoro Road. Similar to the flyover solution but less aesthetic impact. Some efficiencies can be achieved in terms of design by placing intersection facilities on top of the underpass/tunnel. However, considerable difficulties are likely due to utilities and water courses. Considerably more expensive than flyover options.

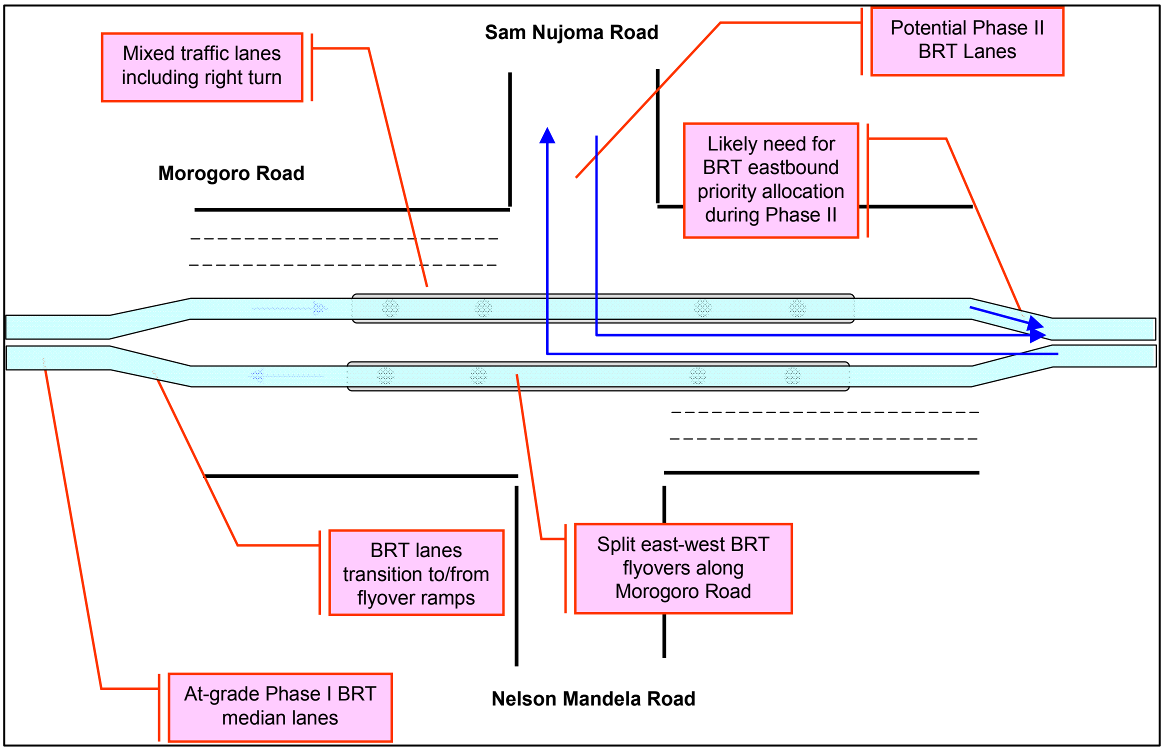


Figure 5.2.17 Schematic of Split Structure BRT Flyover

3) Mixed Traffic Grade Separation Solutions

This solution provides an overpass for all traffic. Two options would exist: Morogoro Road overpasses Nelson Mandela Road, or Nelson Mandela Road overpasses Morogoro Road. This solution somewhat transcends the issue of BRT and focuses more on "fixing the intersection" in the longer term. While this solution would require considerable additional review as well as design (and would likely emerge as an expensive option vis-à-vis short/medium term at-grade solutions), there is considerable merit to considering a flyover along the Nelson Mandela axis. This would require, however, additional inter-agency coordination given that at-grade improvements are now being implemented on both approaches by differing stakeholders. The flyover would carry "through" Nelson Mandela/Sam Nujoma Roads traffic in both directions; right and left turn maneuvers would continue to be carried out at-grade. Likewise, for Morogoro Road, all movements would take place at-grade, including the BRT. Given the removal of north-south through movements, and the requisite reallocation of signal time, considerable reserve cycle time would now be available for allocation to other movements. However, while overall intersection operations are likely to be improved at this particular junction, the solution may in fact catalyze "congestion transfer". That is, north-south through traffic flows faster and in greater unit volume through the subject location; however, this Ubungo Intersection benefit could change to reappear as additional congestion at the next traffic signal encountered. Further consideration should thus be given to establishing a Nelson Mandela Inner Ring Road, with grade separations at New Bagamoyo, Morogoro, Nyerere and Kilwa Roads.

Two core options exist for the flyover. The first is a single-structure north-south flyover, of multiple lane width (presumably four lanes), to carry through traffic along the Nelson Mandela/Sam Nujoma Roads axis. As pointed out, other movements would continue to occur at grade (**Figure 5.2.18**).

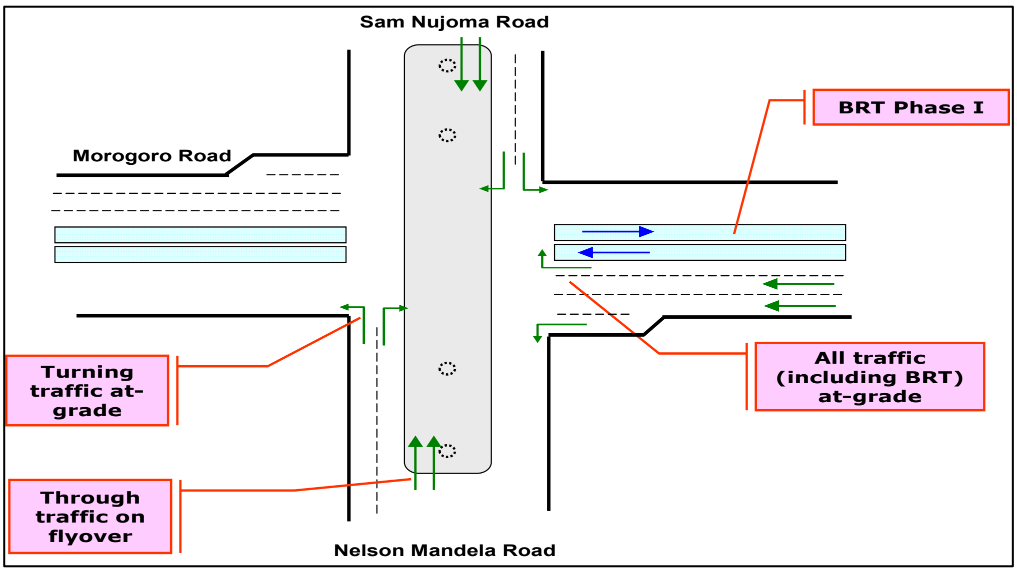


Figure 5.2.18 Schematic of Potential Longer-term Solution Single Structure Nelson Mandela Road Mixed Traffic Flyover

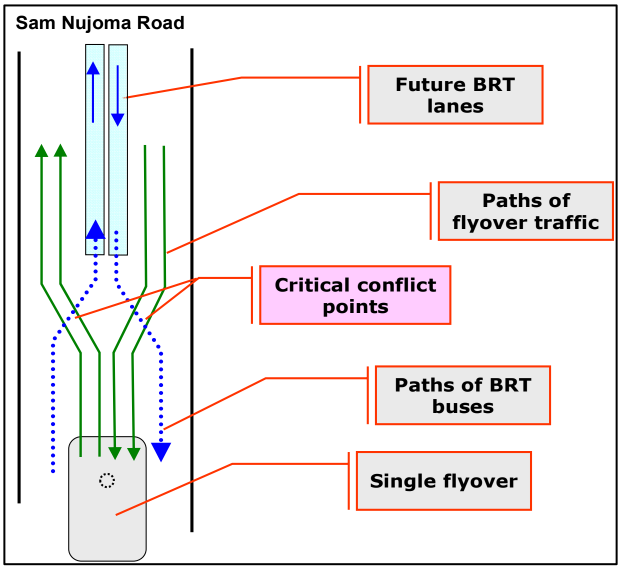


Figure 5.2.19 Traffic Conflict Points Northern Terminus of Single Structure Flyover

The single-structure flyover design may be seen as typical for its function. However, in case of Ubungo Intersection, a further issue exists. As pointed out previously, during future phases of the BRT, it has been proposed that a BRT busway be implemented along Sam Nujoma Road north of Morogoro Road, linking with the New Bagamoyo Road system. This busway will house a BRT route traveling between east Morogoro Road and Sam Nujoma Road. There will therefore exist a need to provide for bus movements between these axes.

A core issue to be resolved relates to merging and cross-over activity between BRT and mixed traffic north of the flyover terminus on Sam Nujoma Road. In case of a northbound bus, for example, the right-turning vehicle coming from Morogoro Road must stay "outside" the flyover until reaching a point north of the flyover nose at which time a transition to the median-sited BRT lane takes place. This introduces an unwelcome crossing of (at least) two mixed traffic lanes carrying somewhat higher-speed traffic descending from the flyover. A similar situation exists in the reverse direction in that BRT buses must leave the busway and cross mixed traffic flows destined for the flyover (**Figure 5.2.19**). While some form of signage and/or signalization could be provided to ameliorate these conflicts, the introduction of such controls would, in fact, degrade the purpose and intent of the flyover itself. Any form of traffic control sited immediately at the foot of a flyover is also not desirable and seen as an accident potential due to perception/reaction times of flyover users.

It is therefore urged that, should a flyover option be pursued, consideration be given to employing a split-structure design. While this carries certain cost implications, and would require additional right-of-way in the intersection-area proper (but not north thereof as a busyway will in any case be installed), considerable operational and safety benefits result. A split design would allow all turning BRT movements to flow "between" the flyover structures, and would thus be completed without any form of interaction with mixed traffic flows. Both BRT movements, that is from Morogoro Road to Sam Nujoma Road and from Sam Nujoma Road to Morogoro Road, could take place concurrently with the mixed traffic right-turn signal phase, if storage for right-turning buses can be provided (**Figure 5.2.20**).

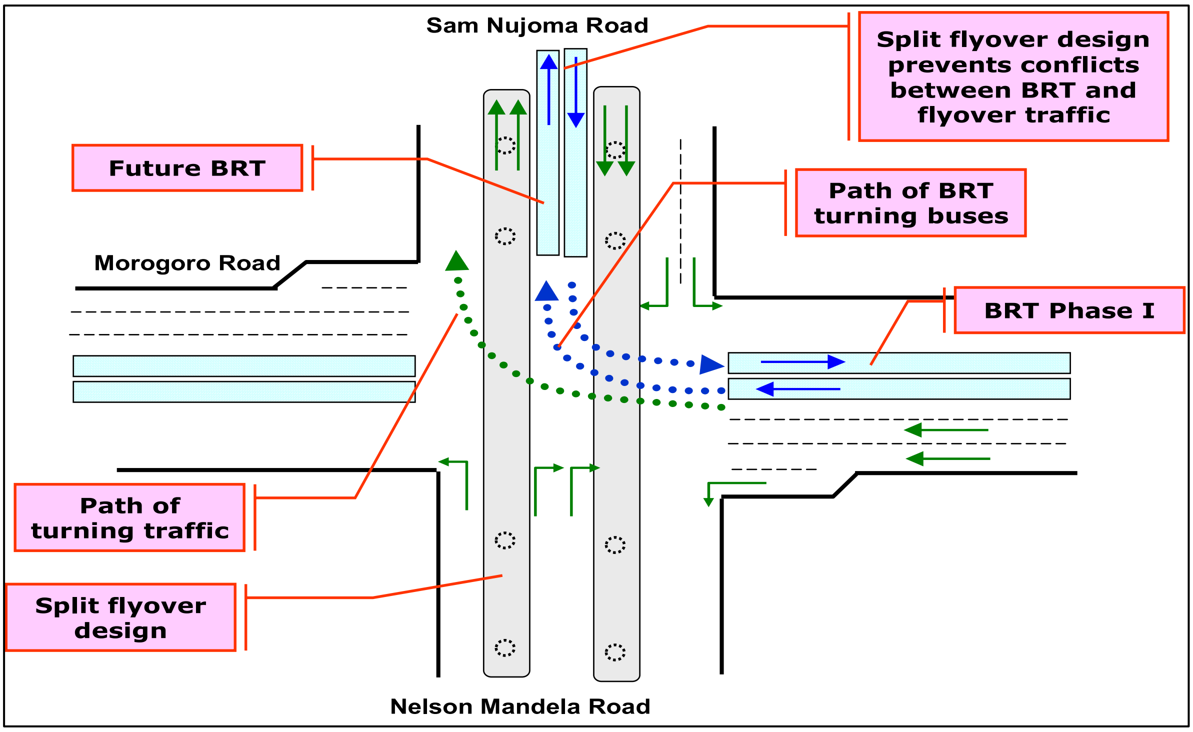


Figure 5.2.20 Schematic of Potential Longer-term Solution Split Structure Nelson Mandela Road Mixed Traffic Flyover

Further reviews are needed to ascertain, as with any flyover solution, as to the availability of needed rights of way, and status of utilities. There also exists an option for providing dual northbound right turn lanes for mixed traffic given the unbalanced layout for north and south approaches. South of Morogoro Road the gap between through lanes will be eliminated by transitioning the flyover lanes to an adjacent alignment, since there are no BRT lanes south of Morogoro Road. It is possible to achieve this transition already with the flyover structure itself, however, this is likely to increase cost. Further review will also be needed to ensure the relocated entry point for the Ubongo Dala Dala terminal, located several hundred meters south of Morogoro Road on Nelson Mandela Road, can be safely integrated with this (or any) flyover solution.

The importance of concurrently examining engineering and operational requirements of both the adopted short term (at grade) and long term (flyover) solutions, as part of preparing short-term at-grade designs, is again emphasized. This is necessary to prevent duplication and obviation of effort, as well as wastage of scarce financial resources.

4) Summary

The identified options are summarized in **Table 5.2.5**. The following are the conclusions of the Study Team.

- The solution can follow two generic paths. Firstly, if only the needs of BRT are considered, to the exclusion of other modes in the mixed traffic stream, then the current BRT Phase I concept fulfills these expectations and no concept adjustments are needed. However, if the broader needs of all intersection users are considered, there indeed exists a need to "fix the intersection".
- An optimization of Ubungo Intersection from the existing Phase I concept is possible considering current levels of demand. Proposed adjustments include the adoption of four-phase signalization, inclusion of right-turns at the intersection proper (hence no U-turn facilities as currently proposed by the BRT Phase I concept), the reduction of Dala Dala activity per a post-BRT scenario, and the relocation of the Ubungo Dala Dala terminal access point (both as proposed by the BRT Phase I concept). This conclusion is based on an expansive simulation of the entire intersection impact area; that is, not only the intersection proper but also approach and departure legs, as well as traffic controls therein.
- Implementation of the above change will entail modification of the BRT Phase I concept. However, adjustments to the Phase I-proposed layout, in particular removal of the proposed U-turn facilities and the retention of right-turn lanes, are not seen as being technically difficult (assuming physical conditions so permit) nor excessively time consuming. However, three foreign sponsoring entities, in addition to the Government of Tanzania, are stakeholders in intersection improvements; thus immediate coordination (and cooperation) is essential.
- The indicated modification is likely, in the short to medium term future, to cater for anticipated intersection demand. However, in the longer term, increasing traffic may overwhelm this at-grade solution. More robust cures will be needed to "fix the intersection". The current investigations suggest that construction of a mixed traffic split structure flyover is likely to offer most benefit in terms of intersection (and indeed corridor) traffic operations. It is suggested that the flyover be constructed along the Nelson Mandela-Sam Nujoma Roads axis, thus reinforcing the "inner ring road" concept whose realization will preempt "congestion transfer" to downstream junctions.
- The potential construction of a future flyover carries two important implications: (a) to ensure that the final Phase I layout (at-grade solution) is, as practical and possible, compatible with future intersection configurations to prevent duplication of effort and wasted use of scarce financial resources; and, (b) timely agreement among stakeholders regarding intersection improvement implementation strategies.

Table 5.2.5 Synopsis of Options and Recommended Solutions

Option	Issue		
	BRT Operation	Mixed Traffic	Cost and Implementation
Phase I Base Case (Current Plan)	Solution very BRT-centric, to the perceived detriment of some other traffic movements. Simplified signal and core intersection operation favors BRT.	Elimination of right turns very problematic. U-turn maneuvers problematic, particularly for heavy commercial vehicles. Delays due to 3-signal concept. Congestion at relocated Dala Dala terminal access point at southern U-turn facility.	Largely budgeted and programmed via World Bank support, although some constraints exist. Approvals largely in-place.
Phase I BRT Modified Case At-grade Solution (**Recommended for near and mid-term future)**	Less time to negotiate intersection due to more complex cycling. Marginal increase in average BRT delay. However, this may not be an issue depending on demand.	Increased opportunity for all-direction movements provided. Decisions required for the interaction of right turn and BRT lanes. Enhanced efficiencies due to removal of U-turns and associated signalization, reduction in Dala Dala post-BRT activity and proper lane channelization.	Likely the least-cost of possible alternative (to base case) solutions. Will require checking to see if sufficient space is available for turn lanes given constraints of abutting land uses and water courses. Signal system more complex.
Single structure BRT flyover along Morogoro Road	BRT operation will improve considerably as any delays due to signals will have been eliminated.	Mixed traffic operations will be impacted only marginally in that the needs of BRT have been discounted from at-grade intersection operation. Mixed traffic operations likely to mirror existing levels of operation.	Costs escalate due to flyover. Additional time needed for flyover design. Potential utility impacts. Modification of funding mechanisms needed. Flyover only for use of BRT.
Split structure BRT flyover along Morogoro Road	Improved operation in that Phase II system would remain at all times within a segregated BRT environment.	Very similar to single structure flyover operation.	Costs higher than single flyover design. Additional right-of-way likely needed within intersection proper.
BRT underpass along Morogoro Road.	Similar to BRT flyover option.	Similar to BRT flyover options.	Aesthetic benefit. But considerably increase in costs and design requirements. Utilities and water courses likely issues
Single-structure flyover for mixed traffic along Nelson Mandela and Sam Nujoma Roads axis	BRT will benefit, along with all other traffic, due to increased availability of approach green time within signal cycle. However, serious conflicts with mixed traffic expected to arise on Sam Nujoma Road with implementation of future north-leg BRT busway.	Considerable improvement in operating conditions in that the signaling requirements of north-south through movements have been removed. Solution compatible with a Nelson Mandela Road corridor "inner ring road", featuring multiple flyovers to prevent "congestion transfer"	Financing issues; any flyover will incur higher costs than at-grade solutions. As with all flyovers, issues of utilities and water courses.
Split structure flyover for mixed traffic along Nelson Mandela and Sam Nujoma Roads axis (**Recommended for longer-term future)**	Considerable improvement for integrated future BRT operations. Conflicts with mixed traffic on Sam Nujoma Road at northern flyover terminus have been eliminated.	Similar to single structure flyover option. Requires additional lane transitioning south of Morogoro Road. This (an all) flyovers to consider Ubongo dala dal terminal ingress/egress.	Marginal increase in cost expected due to split design.

Source: JICA Study Team

Other solutions may be considered. For example, the designation of a new axis of movement for the critical upcountry-port cargo flow corridor. This may be possible should an alternative road facility present itself, or the port be relocated. However, both these considerations are very long term in nature and incompatible with the more immediate needs of implementing BRT.

5.2.6 Alternative BRT Management Approach

The above section examined conventional traffic management approaches to solving the issues of Ubungo intersection. It concluded that (unless grade separation is implemented) a four phase signal is required to manage the turning traffic to avoid a much greater disruption to general traffic caused by using a two phase signal. The modeled outcome showed that under the four phase scenario, the performance of the intersection would be similar to present; require storage lanes for turning traffic but incur possible short delays for the BRT.

One aspect that has been ignored is the use of traffic signal priority for BRT, where the BRT control system can initiate a green signal for an approaching bus. This is a common BRT feature to ensure smooth service flow using the vehicle management system of the BRT (ITS) to initiate a green phase (or extending a green phase) to give the bus free passage.

However, with a relatively high bus frequency, this also is very disruptive to other traffic, as it creates a 'VIP motorcade effect' for buses; giving complete priority to BRT (and stopping all other traffic) and then requiring the signals to re-orientate themselves into a routine cycle once the bus has passed. With bus frequencies at one minute or less, the outcome for surrounding traffic is likely to be chaos.

One solution is to use the vehicle management system of the BRT (ITS system) to manage bus movements by synchronizing the bus timing to coincide with the natural green signal phase. It means holding the bus momentarily at a preceding station and releasing it so it arrives at the next intersection at a natural green phase. This gives the bus unhindered passage and does not interfere with the traffic signaling. It is likely that on a single corridor, the bus only needs to be held momentarily once or twice to maintain its synchronization and also relies on the signals along the corridor to be synchronized along the route.

Technically this is not a difficult signaling technology, and it is well within existing capability and if integrated with the management of the control centre can be easily achieved. An 'error' would only mean that the bus is held momentarily at a red signal.

In effect this scenario allows the operation of a four phase signal, giving sequential phases to all traffic but assists to avoid the delay to BRT. It can be implemented in the short term with the introduction of the Phase 1 BRT as part of the ITS component.

5.2.7 Road Safety Considerations - west of Ubungo intersection

A safety issue exists on the BRT section west of the Ubungo intersection, being that Morogoro Road west of Nelson Mandela Road, while being classed as a Primary Arterial road, will operate in a much less urban manner than segments east of Nelson Mandela Road. A significant amount of truck traffic operates on this section and is seen as incompatible with the present design of Phase 1 BRT that involves 'at-grade' level crossings for pedestrians to the median BRT stations. See **Figure 5.2.21** being the near-term truck route scheme for large trucks.

The placement of BRT stations every 500-700 meters and the "speed bump crossings" will be also disruptive to heavy traffic. These raised pedestrian crossings will also only offer marginal safety to pedestrians. Considering that some 42 percent of recent national road fatalities in Tanzania consisted of pedestrians and cyclists (*Progress Report* by the JICA Study Team) it is important to rethink this design for Phase 1 BRT.

For road and community safety it is recommended that:

- The Phase I stations west of Nelson Mandela Road should be re-designed to permit elevated (pedestrian walkways) access to, and egress from, BRT stations. **Figure 5.2.22** shows a segregated passengers walkway to a median BRT designed by Pacific Consultants International in Bangkok, Thailand.
- Movements by heavy commercial vehicles in the section of Morogoro Road east of Nelson Mandela Road be banned.

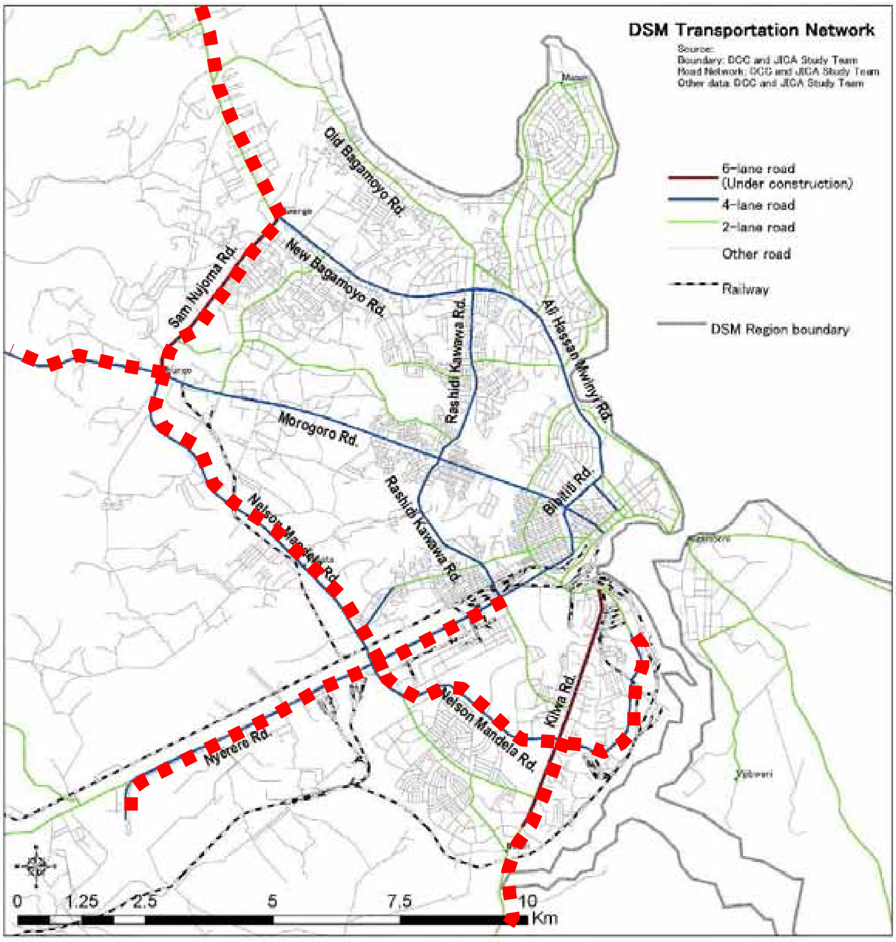


Figure 5.2.21 Potential Near-term Truck Route Network for Heavy Commercial Vehicles

Figure 5.2.22 Station Design Concept: Bangkok BRT