Journal of Construction Project Management and Innovation, 11(1): 169-179, 2021
ISSN 2223-7852

CASE STUDY: DEVELOPING TANZANIA'S TRANSPORT INFRASTRUCTURE MANAGEMENT SYSTEM (TIMS)

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ABSTRACT

This case study profiles the steps taken to develop a process for developing a transportation information management system protype. The case study was initiated in response to a pattern of growth whereas, Tanzania is increasingly becoming a mobile society that suffers severely from traffic congestion, delay and mobile source pollution. Meeting the challenges of greater mobility, accessibility, land use development, economic growth and revenue constraints requires that transport investment and maintenance strategies be optimized. In this case study we define transportation information management system (TIMS), in the context of the Tanzania 2014 transportation network. In doing so an argument is made for developing a base line digital transport network analysis, as a starting point. In doing so, we identify a suite of decision-making tools and a stable of performance variables. As well, this case study presents a draft: work plan which emerged during this effort.

Developing effective congestion relief strategies requires going beyond the collection of geotechnical like shoulder width, guardrails, vegetation, road length and width, culverts, volume, drainage, terrain, rail crossing, number of lanes, bridges locations, and type of terrain. A comprehensive analysis of congestion requires a fully loaded transportation database with the following characteristics: regional, trunk line, and local roads; travel, time, ADT, population, employment, landuse, and income data at the regional and ward level and; transit line and multi modal infrastructure data. To test multiple congestion mitigation strategies advanced analysis tools are helpful to analyze the impact that network connectivity, pedestrian flows, population growth, travel demand, landuse, and community have accessibility. Equally important is the need have a skilled professional, and technical workforce that has not only the theoretical knowledge but also the technical training to use buffer, proximity, travel demand and simulation tools to assess the impacts of population concentrations, vehicle travel and goods movement.

List of Acronyms and Abbreviations

GIS	Geographic Information System
JISR	Joint Infrastructure Sector Review
NBS	National Bureau of Statistics
PMO-RALG	Prime Minister's Office Regional Administration and Local Government
SUMATRA	Surface and Marine Transport Regulatory Authority
TAA	Tanzania Airports Authority
Tan T2	Tanzania Transportation Technology Transfer
TANROADS	Tanzania National Roads Agency
TIMS	Transportation Infrastructure Management System
TMS	Transportation Management System

1. INTRODUCTION

Traffic congestion in Tanzania stems from limited capacity in any multi-modal network, where roads are the main mode of transport. In Tanzania roads support approximately 80% of the travel demand.

While it is well known that a variety of measures to deal with congestion available, Meyer (1997), states that no single measure can completely "solve" traffic congestion problems. However, there is a recognition of the need to find solutions that reduce traffic delays while increasing mobility and accessibility. Resolving this "horn of a dilemma" requires an examination of how congestion management measures complement one another and how over the long term these measures will influence future travel patterns, mitigate traffic congestion, and enhance economic development.

In the absence a transport management system, traffic congestion unmitigated will grow the transport infrastructure needs. In 2008, Dar es Salaam had 74,000 private vehicles. By 2015 there will be 180,000, and near 515,000 by year 2030. During that same period vehicle ownership, will more than triple from 25 cars per 1,000 persons in the year 2007, to 89 cars per 1,000 persons by year 2030. Dares Salaam as a major commercial and government activities center has more than 120,000 private vehicles outstripping the road network supply. There are over 6000 commuter buses serving a daily demand of 43% and a new Bus Rapid Transit (BRT). Still congestion persist.

The goal of this project is to implement a process which will lead to the development of an efficient and effective multi-modal information system, that will enable the Ministry of Works, Transport, and Communication to meet the recommendations and targets of Joint Infrastructure Sector Review (JISR), and Transport Sector Investment Program (TSIP), to improve transportation investment decision making. Thus, increasing the number of preserves improve, and expansion projects that modal agencies can initiate and retire in an environment of scarce revenue and budgetary constraints. As the Tanzania government expands to meet the challenges of global warming and other environmental stressors it is critically important to ensure that multi-modal infrastructure is equitable distributed and environmentally friendly. Equally important is the need to addresses the need to develop advance project prioritization intelligence.

The objectives of this project are:

1.) To clearly define national multi-modal management procedures that will integrate the modal data that can adequately address the policy and system level analysis requirements of the department.

2.) To develop a first-generation Tanzania multi modal transportation infrastructure management system (TIMS) which will provide modal agencies with information to improve transportation investment decision making.

3.) To integrate the transportation infrastructure procedures to demonstrate how TIMS will help Tanzania optimize investment strategies that combat congestion, reduce travel time delay, improve vehicular safety, broaden accessibility, and increase mobility.

4.) To inform short range (Phase II) and long-range work plans that guide future upgrades to the (TIMS)

5.) To develop a web-based GIS-T tool and procedures defined in Phase I, refined and expanded in Phase II and III for use in the development of modal long-range transportation plans.

2. SCOPE OF DEVELOPMENT

The scope of this case study is layout the architecture for developing a functional prototype. The prototype will be used to seek additional funding for the full development and full roll out of a comprehensive and interactive decision making and data analysis tool

that will support the development of a growing Tanzania's transport infrastructure. The objective of this work is to develop baseline inventory needs assessments tools that can help advance operational awareness and the development of strategic transport funding and maintenance strategies. The geographic scope of this project will include national, regional and local highway network and its associated multi-modal linkages. Based on best practices,

Phase I of this work will develop a Tanzania TIMS prototype with proximity overlay to assess funding and to identify project selection criteria to analyze and evaluate the following components: transportation and infrastructure operations, transportation management system development, intermodal connectivity operations control, academic and professional development and technology transfer.

Phase II expands the architecture developed in Phase I to include all modal data that has been capture. Phase II will conduct sensitivity analysis, additional research, and data collection to ensure the fidelity of the application and to detail the logistics for a proportional roll-out and advance the Tanzania TIMS prototype developed in Phase I into a fully developed application. This will include attributing a highway, transit, rail, water, and air mode compliant application and infusing it into the governmental decision-making fabric.

Phase III implements a full-scale roll out and will expand the application to include attribution of the bridge mode. This is the sustainability phase and involves integrating TIMS into the decision-making process across the Ministry of Works, Transport and Communication, President's Office Regional Administration and Local Government, TANROADS DART, TRL, TAZARA, TPA, TAA, TCAA and all other implementing agencies.

3. METHODOLOGY

This case study describes the Tanzania's 2014 transportation problem and makes an argument for the need to conduct a base line transport network needs analysis. In addition, it identifies a suite of decision-making tools and a stable of performance variables. In doing so, this case study presents a draft: work plan, financing, project management schema, and the institutional organizational structure which emerged during this effort. This work is a direct outcome of the Link Agreement between the University of Dar es Salaam (UDSM) in Tanzania and Morgan State University (MSU) of USA signed in April 2009 and extended in 2014 to 2019 is the development of blueprint to establish a TIMS. The development of TIMS is a response to a pattern of growth whereas, Tanzania is increasingly becoming a mobile society that suffers severely from traffic congestion, delay and mobile source pollution. In the face of constant revenue constraints expected economic growth across Tanzania will require a new way of doing business to optimize transport investment development and maintenance strategies to meet the challenges of greater mobility, accessibility, and land use development.

The Government of Tanzania through the Ministry of Works, Transport and Communication in collaboration with the College of Engineering and Technology, University of Dar es Salaam, Morgan State University of USA and other 12 key stakeholder institutions representing all modes of transport have been working together since FY 2011/2012 in advancing the development of Tanzania's Transport system. As shown in Table 1, through these efforts, the project on development and implementation of Tanzania's Transport System and Inter-Modal Linkages has evolved. The Development and implementation of this Tanzania's Transportation Infrastructure Management System (TIMS) Project capitalize on the existing Link Agreement between the University of Dar es Salaam (UDSM) in Tanzania and Morgan State University (MSU) of USA signed in April 2009 and extended in 2014 to 2019 and demonstrates the value of Technology Transfer.

Table 1: Phase I and Phase II Products.

Phase I	Phase II
1.) Multi-modal Inventory 2.) Refined Regions, Districts, Wards Boundary Files, and land use point files. 3.) Developed Link, Node, Point, Transportation Analysis Zones, and Intermodal Layers 4.) Multi-modal data variables to support TIMS (TT, Dist. matrix & Speed table. Milepost, and Functional Classifications 5.) Link modal data sets into a National GIS-T Database. 6.) Prototypical Accessibility Graphical User Interface 7.) Phase II proposal	1.) Enhanced project selection criteria based on modal: inventory, needs, and performance data 2.) Integrated multi networks, zone structure and socio-economic databases to compliant with development of the web- based decision-making analysis tool. 3.) Enhanced accessibility graphical user interface 4.) Capability to conduct sensitivity, connectivity, and scenario retesting 5.) Advanced managerial training and functional assessment of TIMS 6.) Fine Tune, continue buildout, and develop Phase III proposal.

In the face of increasing regional competition the need to capture market share for: commodities, agriculture, tourism, industry, mining, and oil refining it is helpful to have in place a strengthen infrastructure intelligence. What has emerged are a number of geotechnical database for managing programs such as the introduction of commuter train, road expansion, introduction of bus rapid transit (BRT), and improving intersections operations. While the appending of new operational data to existing geotechnical data is necessary, however when it is combined with travel demand performance metrics it improves highway planning. This useful technique when used can quickly prove to be a valuable congestion impact tool for evaluating impacts associated with travel delay, emergency response, air quality, noise, safety, and vehicle operating cost at a granular level.

To address this stark reality the Government of Tanzania through the Ministry of Works, Transport and Communication in collaboration with the College of Engineering and Technology, University of Dar es Salaam, Morgan State University of USA and other 12 key stakeholder institutions representing all modes of transport have been working together since FY 2011/2012 in advancing the development of Tanzania's Transport system. The Development and implementation of this Tanzania's Transportation Infrastructure Management System (TIMS) Project capitalize on the existing Link Agreement between the University of Dar es Salaam (UDSM) in Tanzania and Morgan State University (MSU) of USA signed in April 2009 and extended in 2014 to 2019 and demonstrates the value of Technology Transfer.

3.1 System Needs: Current Problems, Weaknesses and Shortfalls in Transport Sub-sectors

Because of the constant threat of projected revenue and budget shortfall the Ministry of Works, Transport, and Communication, its associate ministries involved in the transportation planning and programming process require advanced analysis tools to ensure that maintenance needs are met given current and future budgetary constraints.

The Transportation Infrastructure Management System (TIMS) project anticipates the planning, operational, and maintenance needs and challenges of a growing and expanding Tanzania's multi- modal transportation network. Since 2012 several new projects have been built to address the growing needs of Tanzania expanding local and national economy and require innovative system wide approaches to determining strategic needs and to allocate transportation infrastructure expenditures by mode.

The following reports address the magnitude of Tanzania's transport problems, weaknesses and shortfalls and confirm among others that rural roads provide limited access, urban roads are congested, modal infrastructure is below capacity, and rail system is not competitive and old, and transit service is inefficient and unsafe.

- Current Tanzania Transport sector reviews conducted by the Joint Infrastructure Sector Review (JISR) Meetings
- Transport Sector Investment Program (TSIP), Phase I (2007/08 – 2011/12) Main Report April 2008 and TSIP Phase II (FY2012/13 - FY2016/17) Final Draft Report, March 2013
- The project on Capacity Building of the Transport Sector in Tanzania funded by the European Union, and
- Tanzania Transport Sector Review report of September 2013 funded by African Development Bank.
- Effectively addressing these cross-sector infrastructure challenges require advanced data management tool sets and a skilled professional transport workforce.

3.2 Key Benefits

A key benefit of building and maintaining TIMS is shown in figure 3. It is an example of the type of a customized interactive information displays that would be generated by TIMS's dashboard. It also shows that unlike optimized strategies associated with TIMS 's the traditional "worst first" maintenance approaches are more expensive over a 10-year time frame. A fully implemented TIMS's saves money.

Another key benefit is on the job training which will produce a cadre of Tanzanian transportation professionals. The "Tanzanian Work Force Development and Transportation Infrastructure Capacity Building and Congestion Relief Solutions Boot Camp" training, submitted on 16 March 2014 is supplemental and not included in this case statement.

3.3 Transportation Infrastructure Management System (TIMS) Solution Components

Tanzania's TIMS will be a comprehensive multi -modal asset management decision making support system made up of a database repository and complementary performance-based infrastructure analysis, risk assessment and decision-making tools. As envisioned the repository will include high-quality and topological line and polygon GIS data structures suitable for sophisticated transportation analysis; and will make quality multi – modal transportation travel demand, inventory, needs, and assessment performance data easily and readily accessible and usable for decision making. The TIMS will create an efficient and productive means of acquiring and working with the data. In its broadest sense TIMS involves managing all the activities related to multi-modal highway network. These activities include, but are not limited to, planning and programming, design, construction, maintenance, and rehabilitation. A TIMS provides effective tools and methods that can assist decision makers in formulating optimum strategies for providing and maintaining a serviceable multi-modal network over the planning horizon. TIMS will help transportation planners, engineers, and top management work together in initiating cost-effective decisions relative to the "what," "where," and "when" of multi-modal system operations, maintenance and rehabilitation.; for example what improvement is cost effective, and where and when to schedule needed enhancements.

3.4 Data Base Configuration

Figure 1 shows the output of Phase 1: a TIMS prototype with travel demand forecasting model inputs, enhanced multi-modal planning network, national GIS-T data base (highway network and Transport analysis zones), web-based accessibility calculator prototype, and an accompanying multi-modal screenshots (Bridge, Highway, Ports, Air, Transit, Rail, Air, Road

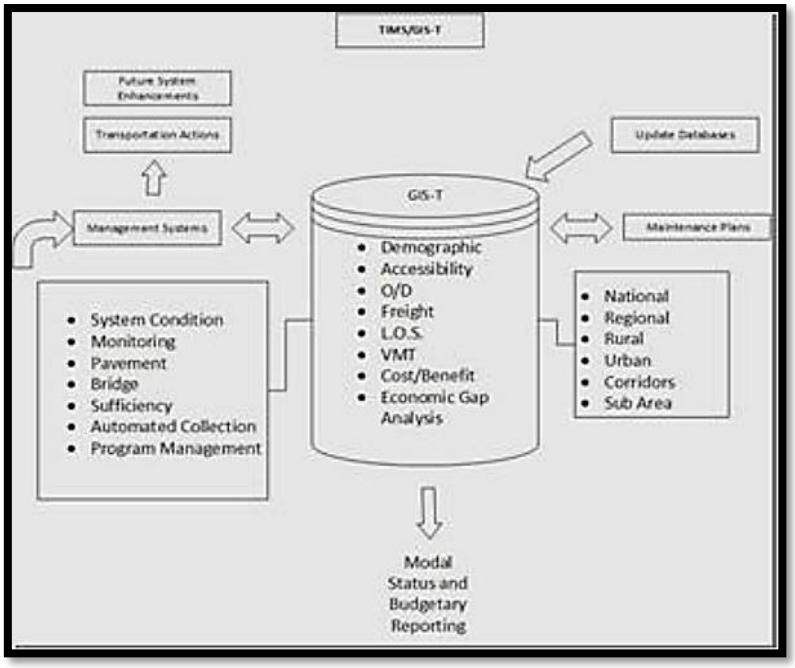
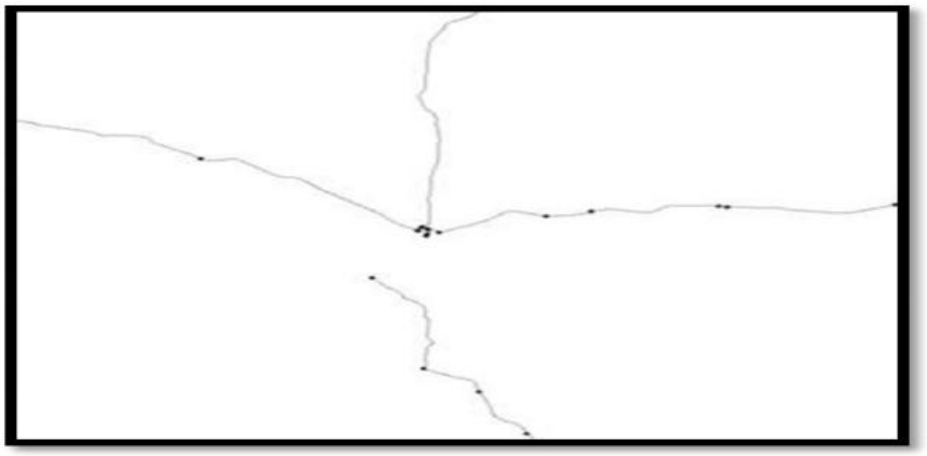


Figure 1. Proposed National GIS-T Database Structure and Outputs. Source: Michigan Department, 2012

3.4.1 Baseline Network Needs Assessment

A baseline needs assessment data is functional requirement for an optimal transportation management system (See Table 2). Our approach is to repair the network problems shown below in Figure 1; in advance of merging transport, demographic, land use and economic factors into a national GIS_T database architecture that adheres to best practices and complies with Tanzania transportation system requirements. After a brief review of the existing GIS line data for Trunk and Regional Roads in Tanzania, several serious discrepancies were noted. The illustration below demonstrates the lack of trunk line connectivity in the current line structures. Such critical Proceeding of the 5th International conference on Transportation in Africa-America (ICTAA2019)



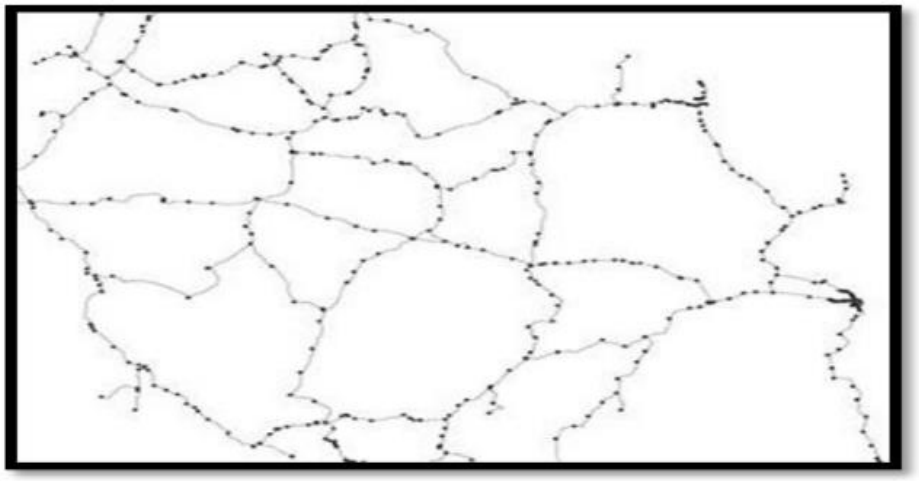


Figure 2. Illustration of Network Problems. Source: Morgan State University, Baltimore, Maryland, USA

Deficiencies are noted in every line segment. The line layer appears to be connected, however when viewing it at a zoomed-out scale, but a closer examination reveals the problem clearly. As shown in figure 2 zooming into the center of the map reveals disconnected links. The cost of traversing these line segments cannot be quantified if the road segments are not routable. As it stands, they are not suitable for network analysis.

Table 2: Tanzania Network Attributes and Decision-Making Variables

Inventory	Area Datum	Line and Point Datum	Point Datum
Modal Condition, Need and Sufficiency Data	Transportation TAZ Social Economic Variables	Infrastructure, Geo., &Travel Demand	Activity Centers
Demographic	TAZ area	Link length	
	Total Population	Link Lat. and Lon.	
	Sub Jurisdiction Population Within TAZ	Node Lat. and Lon.	
	TAZ and Sub Jurisdiction	Link Jurisdiction	
Housing	# of Housing Units by TAZ	Node Jurisdiction	
Economic	Total Employment	Link Speeds	
	Retail Employment		
	Non-Retail Employment		
	Auto Dwelling per Unit		
	Census Data on Income		
Inter modal	Modal Facilities by Type	Choke Points	Node Lat/Lon
			Activity Centers
			# of Interchanges
			O/D
			Wait time

1. Travel Demand Model Inputs and Modeling Capability

The TIMS will provide a basis for the development of travel demand modeling capability. The capability and its complexity will ultimately depend on the reliability of the collected socioeconomic and demographic data, along with the employment data. Ideally, the modeling capability would allow Ministry of Works, Transport and Communication to produce origin-destination matrices sufficient for assigning to a transportation network. The modeling capabilities will be incorporated into a tool that interactively allows Ministry of Works, Transport, and Communication, and staff from other implementing agencies to work together effectively and efficiently.

2. Network Analysis

Once a topologically correct and connected line database is created, staff of the Ministry of Works, Transport and Communication and other implementing agencies will be able to perform various levels of network analysis. Network analysis will include such applications as generating travel time bands with polygon overlay, analyzing travel effects for major construction both for system improvement and during construction. Network analysis capabilities are envisioned at the local, regional, and national levels.

3.5 Accessibility Calculator Overlays

As stated earlier TIMS is a series of planning tools. TIMS as envisioned by the project team would provide an interactive proximity analysis tool that when combined with the example shown in figure 3, will enable staff from the Ministry of Works, Transport and Communication and other implementing agencies to analyze road inventory through a lens of accessibility to transit and highway modes to or from point locations. In addition, non-motorized modes of travel will be considered, such as walking and biking. The underlying data will support all available modes in a region, provided that the data can be reliably collected and generated for those regions. The accessibility calculator will utilize a similar dashboard approach described above for interaction with TIMS.

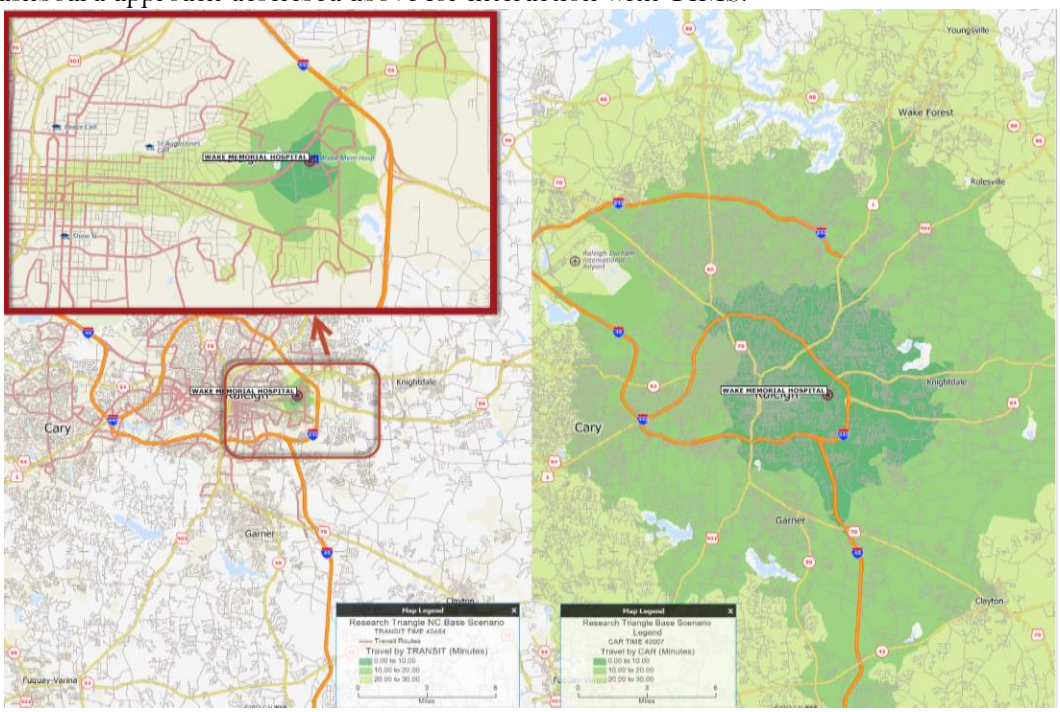


Figure 4: Interactive Map Overlays. Source: Caliper Corporation

30 Minutes from WAKE MEMORIAL HOSPITAL, DUKE RALEIGH HOSPITAL by CAR: TriangleBase

Minutes	0–5	5–10	10–15	15–20	20–25	25–30	Overall
Population	72,641	204,697	193,281	185,713	221,661	216,998	1,094,991
Population 2040	98,785	302,087	357,535	333,551	436,833	411,550	1,940,341
Households	30,256	83,064	76,467	69,962	77,552	79,121	416,422
Households 2040	41,811	130,041	141,626	128,612	163,658	155,959	761,707
Jobs	105,802	230,211	141,860	164,435	194,347	140,909	977,564
Household Income	53,255	48,896	70,239	78,389	67,587	53,676	62,007
Family Income	60,516	67,980	80,916	88,841	76,956	61,088	72,716
Per Capita Income	30,120	29,271	32,378	36,395	30,293	25,224	30,614
Hispanic Origin	11,784	25,625	19,736	13,752	18,287	22,017	111,201
Black	28,782	63,751	43,508	23,877	36,533	60,396	256,847
White	29,500	104,862	116,448	135,790	146,355	122,142	655,097
American Indian	266	902	1,023	981	1,234	1,136	5,542
Asian	1,716	7,855	10,988	9,921	17,562	9,583	57,625
Other Race	116	508	474	468	488	511	2,565
Multiple Races	447	1,070	995	826	1,045	1,112	5,495
College/Univ	1	6	—	1	—	2	10
Grocer	0	—	—	—	—	—	0
Hospital	1	1	—	—	—	—	2
Hospital Beds	870	266	—	—	—	—	1,136

30 Minutes from WAKE MEMORIAL HOSPITAL, DUKE RALEIGH HOSPITAL by TRANSIT: TriangleBase

Minutes	0–5	5–10	10–15	15–20	20–25	25–30	Overall
Population	668	1,497	2,468	4,714	9,665	16,996	36,008
Population 2040	1,306	2,373	3,313	6,828	14,111	23,594	51,525
Households	169	494	978	2,104	4,469	7,441	15,655
Households 2040	500	960	1,388	3,028	6,324	10,725	22,925
Jobs	5,213	6,499	8,075	11,100	15,622	56,233	102,742
Household Income	39,158	36,877	42,897	45,505	53,213	45,097	43,791
Family Income	30,392	30,477	42,276	49,526	63,858	76,962	48,915
Per Capita Income	23,271	21,899	25,028	26,240	30,507	29,486	26,072
Hispanic Origin	329	564	798	1,131	1,305	1,860	5,987
Black	164	528	1,052	1,931	3,126	6,089	12,890
White	153	362	550	1,491	4,937	8,508	16,001
American Indian	3	6	9	17	33	74	142
Asian	12	21	36	96	190	327	682
Other Race	2	3	4	7	16	31	63
Multiple Races	2	7	16	35	54	96	210
Hospital	1	—	—	—	—	—	1
Hospital Beds	870	—	—	—	—	—	870
Grocer	—	0	—	—	—	—	0
Locale	—	—	1	—	—	1	2

3.6 Work Plan

Phase 1: develops prototype to fine-tune the TIMS's framework, decision-making dashboard, refines the Phase II proposal, and establishes a training program.

Task 1 - Create multi-modal Inventory

Task 2 - Refine Regions, Districts, Wards Boundary Files, and landuse point files. Develop Link, Node, Point, Transportation Analysis Zones, and Intermodal Layers

Task 3 - Develop multi-modal data variables to support TIMS (TT, Dist. matrix & Speed table. Milepost and Functionally Classify National GIS-T Database.

Task 4 - Develop and Test Prototypical Accessibility Graphical User Interface

Task 5 - Develop Phase II Proposal

Phase 2: Conduct careful review of the phase 1 work effort and develop proposals which seek funding support for its full development and rollout in phase 2 and phase 3 as originally envisioned. Additional research is conducted to support a proportional roll-out and refines the Phase III proposal

Task 1: Performance and connectivity sensitivity testing

Task 2: Identify and repair application gaps

Task 3: Fine Tune and continued buildout of application

Task 4: Conduct user training and functional assessment of TIMS

Task 5: Expand training to include manager and executive training

Task 6: Fine tune Phase III proposal

Phase 3: Implement a full-scale roll-out. This is the sustainability phase and involves integrating TIMS into the decision-making process across the Ministry of Works, Transport and Communication, President's Office Regional Administration and Local Government, TANROADS DART, TRL, TAZARA, TPA, TAA, TCAA and all other implementing agencies.

4. RESULTS AND OUTCOMES

TIMS ach are more expensive over a 10 years' time frame. Strategically connecting the modal pieces-bikeways, pedestrian facilities, transit services, and roadways into an intermodal, interconnected system saves money and offers key benefits which include the development of high-quality public transportation that foster economic development.

TIMS is a decision support system that is designed to offer community, residents, and workers the full range of transportation choices. Arterial management systems can potentially reduce delays between 5% and 40% with the implementation of advanced control systems and traveler information dissemination. Freeway management systems can reduce the occurrence of crashes by up to 40%, increase capacity, and decrease overall travel times by up to 60%. Freight management systems reduce costs to motor carriers by 35% with the implementation of the commercial vehicle information systems and networks.

5. CONCLUSIONS

This case study concludes that the development of a TIMS is needed to build a robust decision –making platform. Its three interrelated components: coordinated communications, data retrieval, and data exchange tools are customized to establish budgetary efficiency. As shown in the above figure 2 they include a graphical user interface for modal systems, GIS-T database, and a graphical user interface for national planning and systems management. This agency shared control platform supports operational and service delivery for the modal agencies. Modal data pushed to the GIS-T data base and deployed for national, regional, rural, urban, corridor, and sub area analysis. The result of this work will be a fully loaded Transport network with a broad array of Transport, planning, engineering, equity, and transport economic development datum which is required for the Phase 2 attribution per mode and Phase 3 buildout of the bridge mode to complete the rollout. The outcome of Phase 1 will be a functional TIMS architecture that supports: travel demand forecasting model inputs, enhanced multi-modal planning network, national GIS-T data base (highway network and Transport analysis zones), web-based accessibility calculator prototype, and accompanying multi-modal screen shots. As well, the phase I work for development of a Transportation Infrastructure Management System will result in a cadre of administrative decision makers, planners, analysts, and technicians with advanced knowledge and capability to enable the deployment of powerful analytical transportation management system (TMS) tools that will: support, improve, and sustain transportation infrastructure development, maintenance, and management.

6. ACKNOWLEDGEMENTS

Special thanks to representatives of all Development Partners attending a Stakeholders' Meeting organized by the Ministry of Works, Transport and Communication on Development and Implementation of the Proposed Project on Advancing and Managing Tanzania's Transport System and Inter-Modal Linkages held on 27 February 2014 at Double Tree by Hilton Hotel in Dar es Salaam endorsed this project and have pleaded to help, support, participate and finance the initiative and the project. However, the Representative of all Development Partners expressed the importance for the government of Tanzania to allocate counterpart funds towards implementation of the TIMS project.

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