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URBAN ROAD NETWORK PERFORMANCE EVALUATION BASED ON CRITICAL TRAFFIC POINTS

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ABSTRACT

Road traffic congestion is a central problem in most developing regions. Most urban areas have poorly managed traffic networks with several critical traffic points or potential congestion areas. The rapid growth of population in urban areas jeopardize the mobility with the consequences resulting into traffic congestion. Limited studies based on the critical traffic points to access the performance of urban road networks, which allow analytically prediction of for occurrence of traffic congestion exist. The current work evaluates the effectivity of urban road networks in Dar es salaam for easy and smooth distribution of resources and essential services to the public. The study used standard deviations derived from Travel time-delay data to evaluate these road network performances which were collected using test moving cars. Results indicate the critical traffic points that have standard deviations below 0.30 and above 0.10 derived from travel time-delay transition and congestion indices signify lower performance of an urban road network section due to jam and crowded traffic flow condition. whereas, those with higher values greater than 0.3 and below 0.1 for travel time-delay and congestion index respectively indicate high effectiveness due free flow phenomena. It is thus concluded that the road network with high number of critical traffic points indicated to experience jam and crowded traffic flow condition is the one less effective and hence need detailed study aiming at relieving the situations.

KEYWORDS: critical traffic points, travel time-delay, congestion, traffic flow

INTRODUCTION

Road traffic congestion is a central problem in most developing regions. Most urban areas have poorly managed traffic networks with several critical traffic points or potential congestion areas (Jain et al., 2012). Urban life is characterized, mainly by motorized mobility. Amidst the complex urban management problems traffic congestion is one of them. In majority of urban areas, travel demand occasionally exceeds highway capacity during peak periods which under normal circumstances occur in two peak periods at the morning and evening (Kaisheng et al., 2017; Koshy and Arasan, 2005; Mahona et al., 2019). Traffic congestion as a global phenomenon is predicted to get worse in the future (Jain & Vazirani, 2010; Kiunsi, 2013). For instance, traffic congestion in the US has increased substantially over the last 25 years (Texas Transportation Institute (TTI), 2011).

Such situation has obvious implication on productivity and the socio-economic development at large resulting in massive delays, fuel wastage and money loss (Agyapong, Frances; Ojo, Thomas Kolawole (2018); Baffour, 2010; Texas Transportation Institute (TTI), 2011). Events such as crashes, breakdowns, work zones, adverse weather, sub-optimal signal timing and merging/unmerging cause temporary losses in highway capacity. These often deteriorate the situations on already congested road networks (Karuppanagounder and Muneera, 2017; Mahmud et al., 2012). Usually, congestion is not homogeneously distributed around all city area but there are salient locations where congestion is settled, these locations are termed as the Critical Traffic Points (CTPs).

The urban road network plays a key role in the urban spatial structure. It is the main city social-economy activities and transportation carrier. One of the most important problems is how to evaluate the performance of road network. Assessing critical locations—congestion "hot spots"—in urban road networks that will allow urban road system managers to anticipate potential vulnerabilities to congestion propagations at the respective place as well as time instant and take proactive action to avoid congestion rather than react to it is of paramount importance (Santosa and Joewono, 2005;).The quality and efficiency of this infrastructure affects quality of life, the health of the social system, and the continuity of economic and business activity.

Traffic congestion can be perceived as an unavoidable consequence of scarce transport facilities such as road space, parking area, road signals and effective traffic management (Blanco et al., 2009). Urban congestion mainly concerns two domains of circulation, passengers, and freight, which share the same infrastructure. Thus, traffic congestion condition on road networks occurs as a result of excessive use of road infrastructure beyond capacity, and slower speeds, longer trip hours and increased vehicular queuing. Any city that is economically active and vibrant will rarely be free from traffic congestion (Yildirim, 2001). Traffic congestion can be viewed from two main opposing perspectives (Kiunsi, 2013). The first perspective is that it can be considered as an indicator of economic growth and as an urban lifestyle. The second perspective is that it is seen as an indicator of deterioration of urban life.

Studies suggest numerous performance measures for quantifying congestions levels at several places of the road network. These include (i) Highway Capacity Manual (HCM), (ii) queuing-related and (iii) travel time-based related measures (Jain et al., 2017; Wen et al., 2014; Fosgerau and Fukuda, 2012; Quiroga, 2000). Under the Highway Capacity Manual (HCM), three measures are commonly applied and to include volume-to-capacity (V/C) ratio, average intersection delay and level of service (L.O.S): graded from A for best to F for worst. V/C ratios are frequently used because of the easy of traffic volume data collection and average intersection delays normally used on arterial streets as well as their feeder roads. Both of these measurements provide a foundation for measures such as L.O.S (for different levels of service) of the considered road network location at the particular time instant (Agyapong et al., 2018; Jain et al., 2017; Chauhan et al., 2017; Chengcheng et al., 2016; Aftabuzzaman, 2007). While HCM congestion performance measures are simple and easy to understand by the transportation professionals, it tends to cause abstraction to road users requiring detailed, location-specific input data to be computed and hence make them available for design purpose rather than for public consumption.

For queuing-related measure, the queue length and lane occupancy are commonly employed. The queue length and its duration can be directly observed through physical survey, whereas the lane occupancy (the percentage of time a traffic queue is controlled by the traffic) can be measured by employing vehicle detectors that are part of the roadway surveillance and control systems (Karuppanagounder and Muneera 2017; Chengcheng et al., 2016). In developed countries, queueing-related measures are increasingly being used to quantify roadway congestion because of availability of vehicle detectors and other sensors in the roadway (Mahona, 2020; Lamotte and Geroliminis 2017; He et al., 2016; Fazio et al., 2014). Although queue and lane occupancy best reflect the public perception of congestion conditions, measuring queue and lane occupancy remain laborious, site specific and time-specific especially in most of the developing countries where availability of vehicle detectors and other sensors is limited and hence un-appropriate to be applied.

Under travel time-based related measures, travel time, travel speed and delay are commonly applied. Travel time-based measures are easy to understand by both the transportation professional communities and the general public (Chauhan et al., 2017; Chengcheng et al., 2016; Mahona et al., 2019). Travel time-based measures are flexible enough to describe traffic flow variations at various levels of resolution in both time and space (Wen et al., 2014; Ataiwe et al.,2012). This make them appropriate for handling specific locations as well as the entire road network comprising of several CTPs and can be easily converted to their respective indices for analysis. Travel time-based indices measures is an important measure in quality analysis of urban road networks comprising of various problematic links and points that are influenced by their feeder roads and other related factors (Chengcheng et al., 2016; He et al.,

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2016). Karuppanagounder and Muneera (2017; Mahona et al., 2019) used travel time-based indices to evaluate the performance of the urban road links under heterogeneous traffic conditions by assessing traffic flow variations on each critical traffic points (CTPs) in the urban road network and obtained results which were proved to be useful to both the road agents and the general public.

Travel speed and delay data can be derived from the travel time data by using a reference acceptable travel time or speed, thus once you obtain the travel time others can be equally obtained and applied. Acceptable travel time or speed is the travel time associated with a performance goal established for the transportation facility, it should be influenced by the community input, economic activity and environmental issues (Agyapong et al., 2018; Torrisi et al., 2017; Fazio et al., 2014;). Also, a number of studies define the acceptable travel time as that associated with the free flow conditions or posted speed limit normally during off-peak periods normally in the range of 2.8 min/km to 1.2 min/km. The range of 2.8 min/km is used for the arterial located within the central business district (CBD) and 1.2 min/km for the arterial located outside the CBD. This is directly related to the posted speed limit in urban area from 30km/hr to 60km/hr (Mahona, 2020; Lamotte and Geroliminis 2017; Lu, 2017; Wen et al.,2014; Jain et al., 2012; Deardoff et al., 2011; Quiroga, 2000). The acceptable travel time can therefore be used to estimate the free flow speed between any CTPs as well as computing the respective travel time-delay and congestion indices values.

Considering the complexity and dynamic nature of traffic, it is difficult to assess traffic congestion conditions of urban road networks without having a clear view of the flow variation, location as well as the time of occurrence (Zhang et al., 2017; He et al., 2016). Urban traffic variation is usually measured by vehicle average travel time-delay (TD) which can be translated to the corresponding average travel speed and can be converted to their respective travel time-delay and congestion indices to reflect the motorists' behavior on urban road network to comply to changes with the actual status of traffic demand and supply (He et al.,2016; Kiunsi, 2013). The use of travel time-delay based indices like the TD transition index and congestion index to quantify congestion levels at particular places and time allowing for recording the respective flow impeding factors on the links has not been widely employed by the researchers.

This paper analyzes the spatial aspects of traffic flow variation at various Critical Traffic Points (CTPs) on urban road sections typical to developing countries through use of standard deviation values derived from travel time-delay transition (TD_TI) and congestion indices (CI). The analysis of any of these critical traffic points (CTPs) determines the performance of nearby elements that enables the estimation of status of traffic flow of the whole road network.

2. METHODOLOGY

2.1 Study site selection

Aiming at determining data on periods when the Traffic jam occurrence location at worse traffic jam with quantifying factors contributing to the jam on various Dar es Salaam Road network has to be identified. The approach for identifying factors contributing to traffic flow dynamics resulting to traffic congestions in urban areas depend on data that involve selecting the study site based on traffic flow variations in the road network. The selection shall make use of the Dar es Salaam city street map (Fig 1), on the basis of the following set criteria:

(i) The road network which spans from city sub-urban areas (peripheries) into the Central Business District (CBD) and vice versa were given first priority,

(ii) The road network that includes at least ten critical traffic points (CTPs) and that all CTPs must not include the new development aiming to facilitate smooth traffic flow like construction of flyover, high occupancy lanes like special lanes for public buses etc.

(iii) The length of the network must be long enough to have sufficient collector street in order to have substantive traffic volumes.

The selected road networks are a typical representation of urban routes in Dar es Salaam comprising road links of different categories like major arterials and collector streets with varying geometrical and volume levels. The chosen road networks include Bagamoyo, Kilwa and Nyerere road. Nyerere road, despite of having particular feature of recent flyover construction it was included because it is the only route joining several peripheries towards the CBD together with those coming from the only airport terminal in the city. All the road networks selected include various links and salient points known as the Critical Traffic Points (CTPs) where the recurrent as well as non-recurrent traffic congestions are settled.

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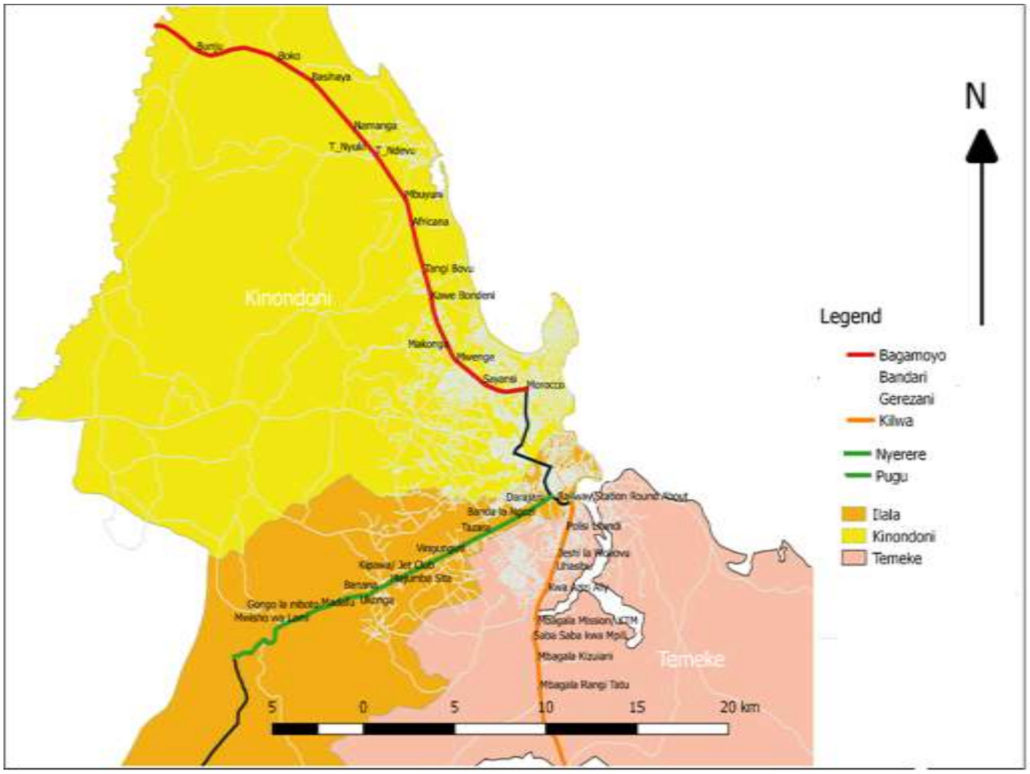

Figure 1: Dar es Salaam city roads indicating the studied CTP's
Source: Adapted from the Google map of the study area (2017)

2.2 Physical Survey to Identification of Critical Traffic Points (CTPs)

A reconnaissance survey on the study areas were carried out at the selected road sections to identify and locate the critical traffic points (CTPs): a point where large traffic flow variations was noticed translating to slow traffic flow movement and thus prompting for the occurrence of recurring as well as non-recurrent traffic congestion at the particular place and time. To identify and locate these locations, the physical observations were conducted daily on weekly basis using public, private and motorcycles transportation mode by driving through all chosen road networks. The observer was taking records employing the stop watch and tally sheet, of the location name and time as well as the travel direction (inbound or outbound) regardless of the existence of congestion or not. When conducting this exercise, it was imperative to identify the peak periods (time slots) during which the important traffic flow variations occurs. The observed data were recorded and summarized showing observation of traffic type, time slots and travel direction as indicated in Table 1.

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Table 1: Showing observation of traffic type, time slots and travel direction

Traffic Type	Time Slot (HOURS)		Travel direction
	Start	End	
Morning peak (Morning Inbound)	05.30	10.00	INBOUND (Towards CBD)
Afternoon non-peak (Noon and Afternoon Inbound)	10.00	16.00	
Evening peak (Evening Outbound)	16.00	21.00	OUTBOUND (From CBD)
Evening non-peak (Night Outbound)	21.00	05.30	

Source: Mahona, (2020)

Furthermore, these road networks were divided into segments termed as the Critical Traffic Points (CTPs) and for this purpose, several CTPs were chosen (Figure 1).

2.3 Travel time-Delay Data (TD) with Associated Factors

Data collected was related to travel time-delay data at each location (CTP), nature of the factor causing disturbances (impeding factors) to vehicle speed and flow as well as the frequency of occurrences. Data collection were done through Travel time-Delay (TD) survey which conducted involving the test moving car method. Data recorded using the stop watch, note pad and the traffic tally sheets for recording data. The data was collected at a minimum of three runs for each time slot in a count time of 45minutes within a period of sixteen (16) weeks during August, September, October and November 2017. For each road sections studied, data was collected on the city inbound and outbound. The designated time slot/frame is depicted in Table 1 these are fixed for data collection with the associated traffic flow impeding factors.

These data were represented in a five working days' average travel time-Delay (TD): Monday, Tuesday, Wednesday, Thursday and Friday for analysis and interpretations. Further, data were reduced considering their average values to follow the time slot identified in Table 1 such as for all morning inbound, noon and afternoon inbound, evening outbound and night outbound. Variations in travel times during peak periods were taken into account by staggering start times within each peak period to represent fairly conditions over the time period as a whole. During the data collection period, the threshold time (sometimes called the acceptable travel time) for travelling on each road network during the free flow regime was conducted and recorded accordingly using the stop watch, note pad and the traffic tally sheets. Threshold time is the time taken to travel from the origin to the destination of the road network during the free flow regime denoted in minutes per one kilometer.

The average threshold time in minutes on each inbound and outbound travel direction were observed to be in average of 35.12, 21.42 and 25.96 minutes for Bagamoyo, Kilwa and Nyerere roads respectively (Table 3) and from this table the travel factor minutes is estimated to be about 1.2 minutes per one kilometer which is the estimated time to traverse a distance of one kilometer within the CTPs. These data were recorded for each road network. The resulting threshold time/ acceptable travel time conform with that obtained from literature for the road network located outside the CBD.

Table 3: Average threshold time to traverse the road network

Road network	Threshold time (min)	Length, D (km)	Travel factor minutes/ 1 km
Bagamoyo	35.12	30	1.17 min/km
Kilwa	21.42	18	1.19 min/km
Nyerere	25.96	22	1.18min/km

2.4 Determination of Travel Time-Delay Transition and Congestion Indices

Manually collected travel time-delay data together with the free flow time at each CTPs were digitized and converted to their respective TD_TI values and congestion index (CI) applying the following relationships:

The observed Free Flow Time (FFT) between each CTP is given by: -

$$FFT = 1.2 \times D \qquad (1)$$

where D is the distance of the responsible Critical Traffic Point (CTP) and 1.2 minutes is the time in minutes taken to traverse a kilometer termed as the travel factor, Table 3.4 occasionally used as recommended average threshold time on each road network divided by the distance of the road network.

The Travel time-Delay Transition Index (TD_TI) at CTP is expressed as: -

$$TD\_TI = \frac{FFT}{TD} \qquad (2)$$

The congestion index (CI) is;

$$CI = \frac{(TD - FFT)}{FFT}$$

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(3)

The values of travel time-delay indices-based (TD-TI and CI) were calculated at each CTPs and converted to their respective standard deviation's for analysis of Traffic flow variations along these road network to obtains those indicated to be significantly affected by the presence of bottlenecks for each roadway.

3. RESULTS AND DISCUSSIONS

3.1 Identified CTPs Along the Urban Road

The CTPs identified on the selected road networks comprised several observed bottlenecks (flow impeding factors) such as bus stops, humps, T-junctions, cross junctions, traffic light points and major intersections as were recorded and summarized in Table 2.

The selected road networks together with their respective stretches (CTPs) form a typical representation of urban routes in Dar es Salaam comprising road links of different categories like major arterials and feeder streets with varying geometrics and volume levels. During this exercise two major time slots indicating the travel direction were observed in which the higher and moderate traffic flow variations are frequently observed. These are Inbound (comprising of morning peak and morning non-peak) and Outbound (comprising of evening peak and evening non-peak) with their time variations were recorded and summarized in Table 2.

Table 2: Indicating Critical Traffic Point (CTP) with Associated Impeding Factors

<table>
<tr><th colspan="2">Bagamoyo Road</th><th>Nyerere Road</th><th></th><th>Kilwa Road</th><th></th></tr>
<tr><th>Location/ CTPs</th><th>Factors</th><th>Location/ CTPs</th><th>Factors</th><th>Location/ CTPs</th><th>Factors</th></tr>
<tr><td>Bunju</td><td></td><td>Mwisho wa Lami</td><td></td><td>Mbagala Rangi Tatu</td><td></td></tr>
<tr><td>Boko</td><td rowspan="2">B1, B2</td><td>Gongo la Mboto</td><td>B2, B4, B5</td><td>Mbagala Kizuiani</td><td>B1, B2</td></tr>
<tr><td>Basihaya</td><td>Madafu</td><td>B1, B2, B4</td><td>Saba Saba kwa Mpili</td><td></td></tr>
<tr><td>Namanga</td><td>B1, B2</td><td>Ukonga</td><td>B1, B2, B3, B8</td><td>Mbagala Mission/ KTM</td><td>B1, B2, B8</td></tr>
<tr><td>Tegeta-Nyuki</td><td>B1, B2, B4</td><td>Banana</td><td>B1, B2, B4, B3</td><td>Mtongani</td><td>B1, B4, B5</td></tr>
<tr><td>Tegeta-Ndevu</td><td>B4</td><td>Majumbasita</td><td>B1, B2 B3, B4</td><td>Kwa Azizi Ally</td><td>B1, B2</td></tr>
<tr><td>Mbuyuni</td><td>B1, B2, B4</td><td>Kipawa/ Jet Club</td><td>B1, B2, B3, B4</td><td>Saba Saba</td><td>B1, B2</td></tr>
<tr><td>Africana</td><td rowspan="4">B1, B2, B3, B4, B5, B7</td><td>Vingunguti</td><td>B1, B2, B4, B8</td><td>Uhasibu</td><td>B1, B2, B4</td></tr>
<tr><td>Tangibovu</td><td>Tazara</td><td>B2, B4, B5, B9</td><td>Salvation Army</td><td>B1, B2</td></tr>
<tr><td>Kawe Bondeni</td><td>Banda la Ngozi</td><td>B1, B2</td><td>Police Ufundi</td><td>B1, B8</td></tr>
<tr><td>Makongo</td><td>Darajani</td><td>B1, B2, B4</td><td>Bandari</td><td>B3, B8</td></tr>
<tr><td>Mwenge</td><td>B4, B5</td><td>Bus Station/ Kamata</td><td>B2, B4, B5</td><td>Railway Station Round About</td><td>B5, B2, B8</td></tr>
<tr><td>Sayansi</td><td rowspan="2">B1, B2, B4, B5</td><td rowspan="2">Msimbazi Gerezani</td><td rowspan="2">B1, B2</td><td rowspan="2">BRT Gerezani</td><td rowspan="2">B1, B2</td></tr>
<tr><td>Morrocco</td></tr>
</table>

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Key: Remarks

B1 –T-Junctions B2 - Bus Stops B3 - Road Humps B4 - Traffic Lights B5 - Cross-Junctions B6 - Work Zones B7 - Incidents /accidents B8 - Road Zebra cross B9 – Major New Constructions

3.2 Standard Deviations of Travel time-Delay and Congestion Indices-Based Results

Standard deviation values were derived from the Travel time-Delay Transition Index (TD_TI) and congestion index (CI) values which calculated at all CTPs along the studied road networks. TD-TI and CI were calculated applying the relationship indicated in Equations 1, 2 and 3, the results are presented in Figure 2, 3, 6 and 7. These values distributions were further interpreted for the traffic flow variations at each CTPs based on Table 4 in which they are tabulated in ranges with their respective descriptions at various locations and time on the studied road network.

Table 4: Interpretations of Indicated Range of Values for TD_TI and CI

Traffic Status	Stabilization of Driving	Remarks	
		STD of TD_TI	**STD of CI**
Free Flow	Good	TD_TI > 0.30	CI < 0.10
Crowded Flow	Bad\ alarming situations	0.10≤TD_TI≤0.30	0.50 ≤CI ≤0.10
Jam Flow	Depends on vehicle in front	TD_TI < 0.10	CI > 0.50

The standard deviation derived from TD_TI and CI values and their variations at each CTPs on each road network are discussed at each studied road network as follows.

a) Bagamoyo Road

The evaluation of the CTPs performances along Bagamoyo road was done by analyzing the variations of standard deviations values at each CTP. The low values (below 0.3 for TD-TI) and higher values (above 0.1 for CI) are associated with traffic jam and crowded vehicle flow characteristics being the result of high traffic flow variations at these CTPs (Figures 2 and 3). During morning inbound most of the CTPs shown to experience high traffic flow variations indicating the low performance of these road network stretches, while noon and afternoon inbound shown the high performance as most of them indicated to experience free flow characteristics. Again, during noon & afternoon and night most of the CTPs indicated to exhibit free flow characteristics indicating for high performance. Hence the one showing to have low performance need urgent attention aiming at relieving the situations.

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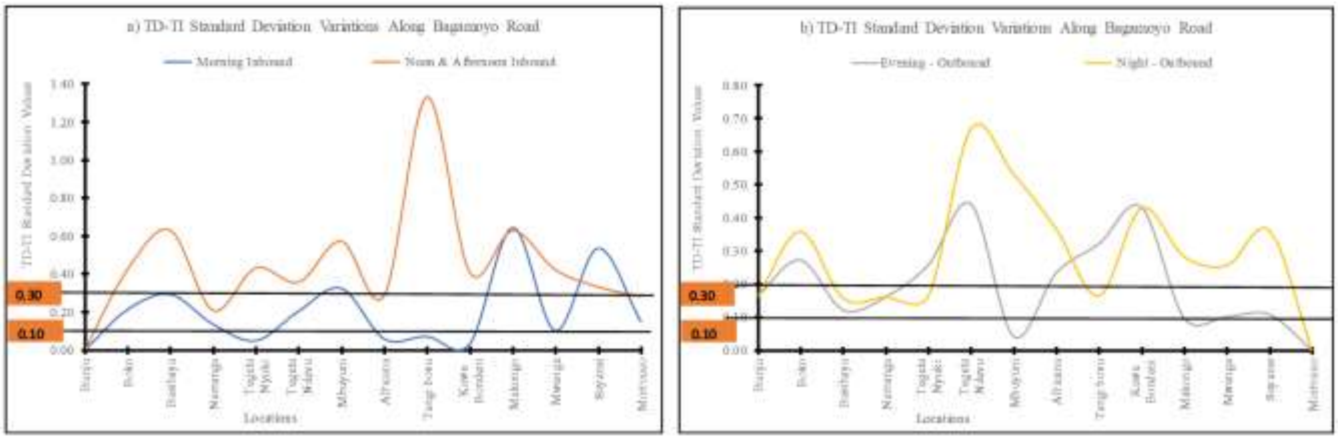

Figure 2(a) and (b): Standard Deviation of TD_TI Variations along Bagamoyo Rd

For the case variations of congestion Index (CI) standard deviation values, results are presented in Figures 3 (a) and (b) for inbound and outbound respectively. Here, the lower values range above 0.10 correspond to jam and crowded flow characteristics. From this Figure most of the CTPs indicated to have higher values during morning inbound and evening outbound signifying for lower performance of this urban road network. Whereas, during noon & afternoon inbound and night outbound most of them indicated to have low traffic flow variations with high standard deviation values. Again, the urban road network indicated to have lower performance levels during morning inbound and evening outbound requiring for detailed analysis to alleviate the situations.

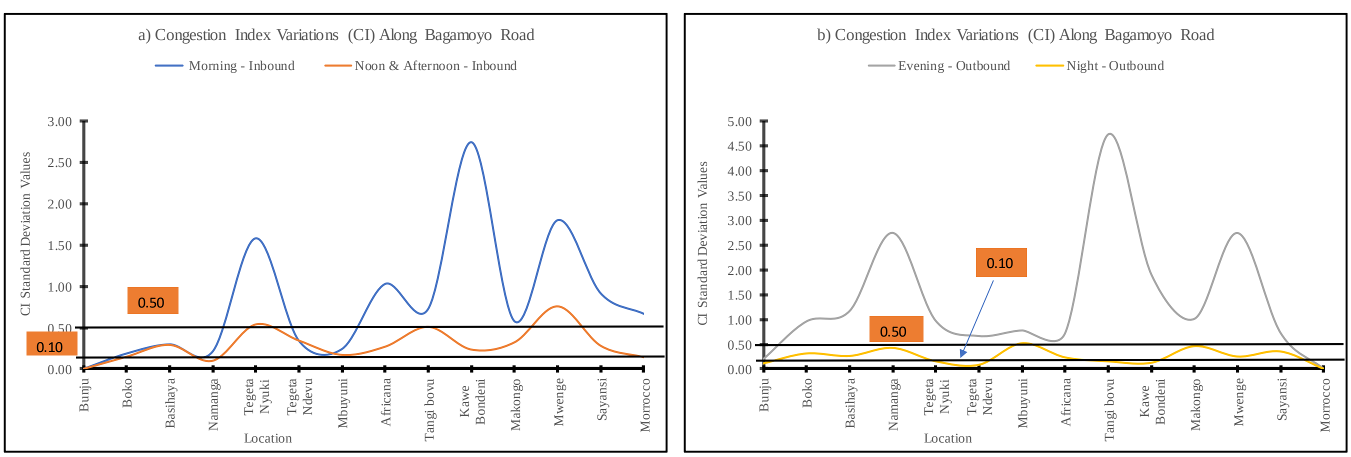

Figure. 3(a) and (b): Standard Deviation of CI Variations along Bagamoyo Road

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b) Nyerere Road

The evaluation of the CTPs performance along Nyerere road conducted by analyzing the variations of TD_TI standard deviation values at each location. The evaluated CTPs results given in Figure 4 (a) and (b) for inbound and outbound show low values (below 0.3). These results are associated with the jam and crowded vehicle flow characteristics due to high traffic flow variations at respective locations (CTPs). Along this road network only few CTP indicated to exhibit free flow characteristics entailing for high performance on these stretches. These CTPs are identified to be Banana, Majumba Sita, Kipawa/Jet Club, Tazara and Banda la Ngozi during inbound and outbound. General observations show that the road performs poorly during the morning inbound and evening outbound due to the reason that high number of vehicles are plying on the road by commuters to and from their daily undertakings.

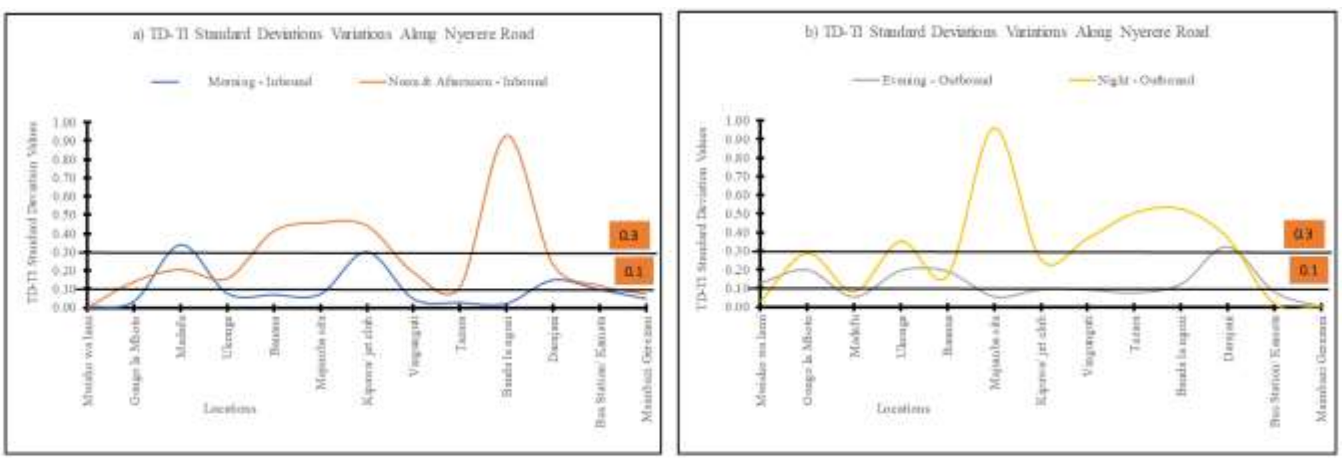

Figure 4(a) and (b): Standard Deviation of TD_TI along Nyerere Road

Whereas, the results of congestion Index (CI) standard deviation values for studied road network are presented in Figure 5 (a) and (b). The higher values range from 0.1 and above correspond to jam and crowded flow characteristics. These results show that during inbound almost all CTPs indicated to have CI values above 0.10 signifying medium and high traffic flow fluctuations leading to either crowded or jam flow at various stretches of the road network. Whereas, during outbound almost few CTPs are observed to indicate higher values but with slight differences as shown on the Figure 8 (b). The CI distributions during noon and afternoon inbound and night outbound in most of the CTPs along Nyerere Road indicted to have low values (below 0.10) signifying for free flow characteristics.

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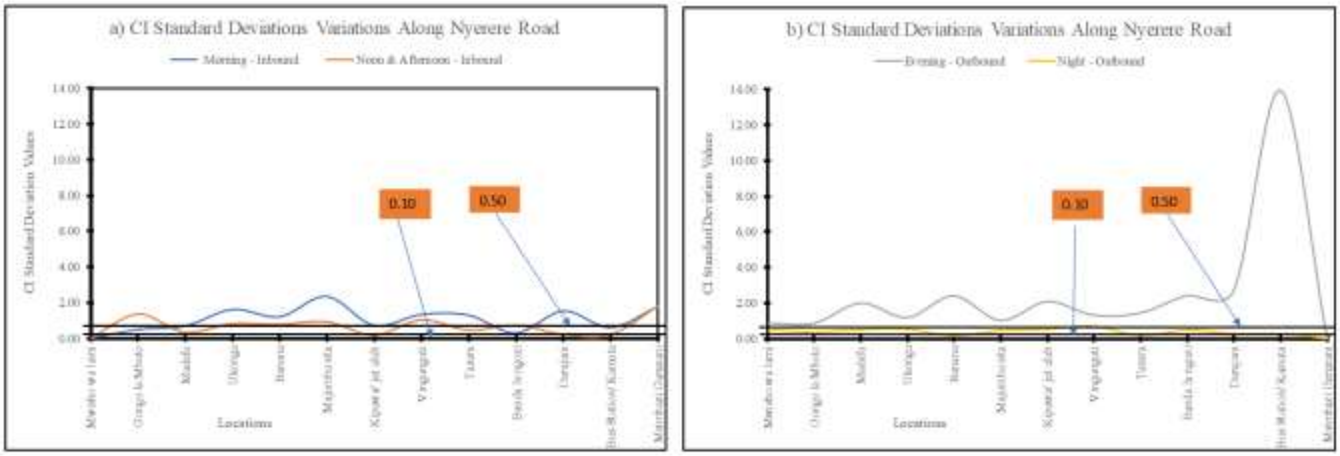

Figure 5(a) and (b): Standard Deviation of CI along Nyerere Road

c) Kilwa Road

The evaluation of the CTPs performance along Kilwa road conducted by analyzing the variations of TD_TI and CI standard deviations values at each location (Figure 6 and 7). From Figure 6 (a) and (b), the low values (below 0.3) are associated with the jam and crowded vehicle flow characteristics being the result of high traffic flow variations at corresponding CTPs. These results correspond to lower performance of the road network stretches during morning inbound and evening outbound. Only few CTPs were shown to exhibit free flow characteristics during both morning inbound and evening outbound and listed to be at Mbagala Kizuiani, Saba Saba kwa Mpili, Mbagala Mission/ KTM. It is observed that during noon & afternoon inbound and night outbound most of the CTPs experience low traffic flow variations except at few identified locations. These locations have shown to experience higher traffic flow fluctuations entailing for occurrence of traffic congestions due to other factors like defective motor vehicles, incidents or extended use of road stretches by commuters etc.

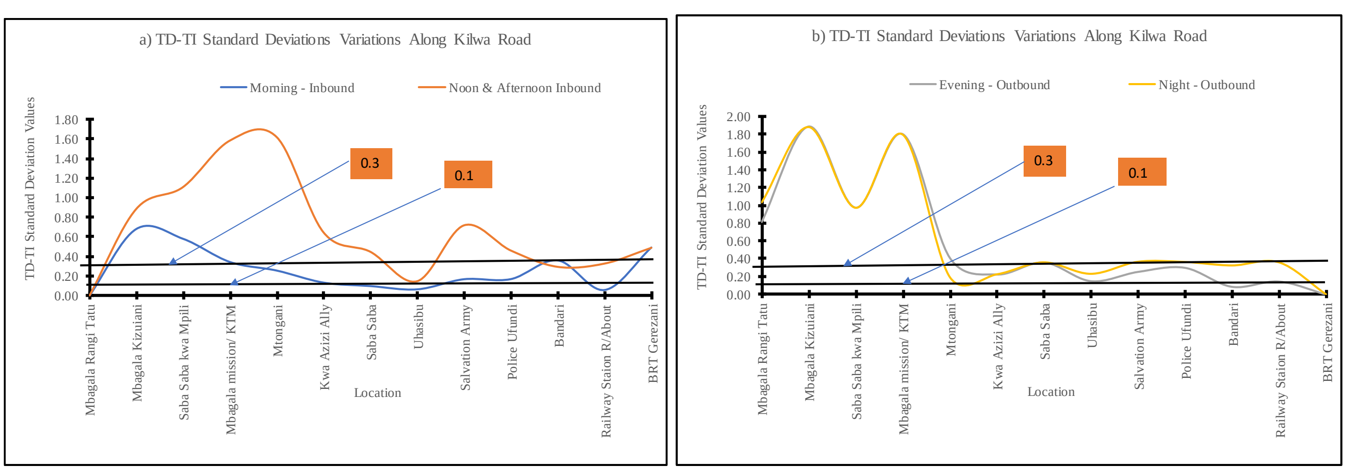

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Figure 6(a) and (b): Standard Deviation of TD_TI along Kilwa Road

Similar results of CI standard deviation values for Kilwa road are presented in Figure 7 (a) and (b). The higher values ranging from 0.1 and above correspond to jam and crowded flow characteristics indicating the lower performance of the road network stretches. These results show that almost all CTPs indicated to have higher CI values (above 0.1) during inbound suggesting that most of the locations during inbound are observed to experience either crowded or traffic jam of different magnitude depending on the effect of the road bottleneck at the respective place and time. It is observed during the morning and outbound peak periods only few CTPs indicated to experience free flow phenomena hence almost the whole road network shows low performance level requiring for mitigation measures to relieve the situations.

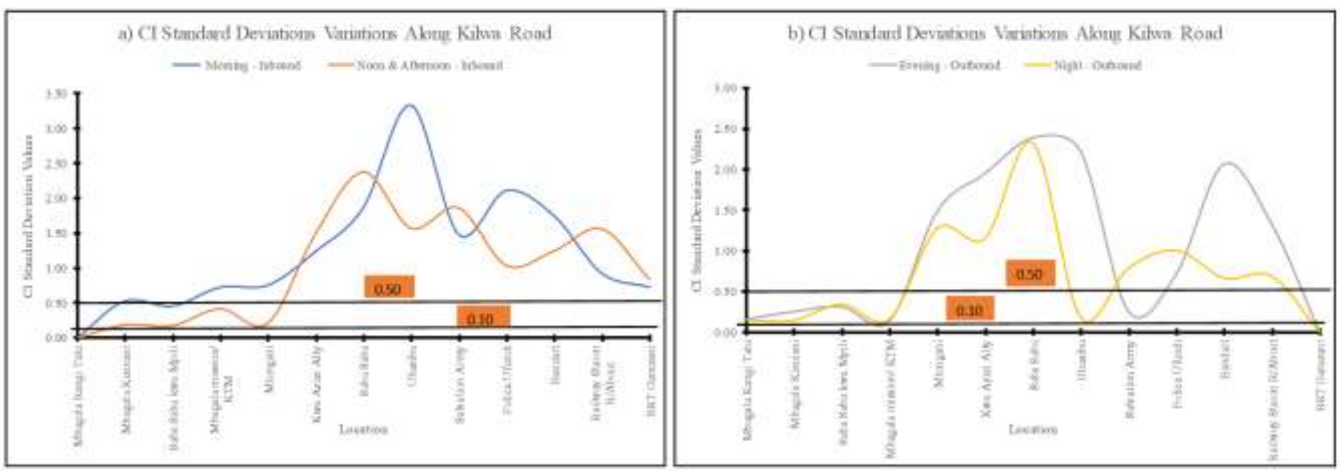

Figure 7(a) and (b): Standard Deviation of CI Values along Kilwa Road

Based on the analysis to the data of standard deviation values derived from TD-TI and CI indices of all studied road networks, it can be observed that the performance of its road network stretches can definitely affect the effectivity of the whole road network. In so doing disrupting the road network efficiencies in the specified peak periods. Furthermore, it is observed in other analyzed CTPs in the studied road networks indicated to exhibit more high traffic flow fluctuations requiring for clear adjustments as well as time slot demarcations of the peak periods used in the study.

3. CONCLUSIONS

Traffic congestion impose burden to the society and therefore it is important to reduce their impact. The studied road networks comprised of several salient locations called Critical Traffic points (CTPs) where the recurrent and non-recurrent traffic congestions are settled. Before analyzing various CTPs for variation

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of traffic flow dynamics, firstly the study surveyed various road networks using Dar es Salaam city road map, the result shows that Bagamoyo, Nyerere and kilwa roads were chosen to be the suitable study areas. From these road networks various CTPs could be investigated to observe their effectivity in terms of traffic flow variations and thus traffic congestion propagations. These road networks were observed to have several salient locations (CTPs) where the recurrent and non-recurrent congestion is said to exist due to high traffic flow variations. When identifying these locations, the peak periods (time slot) during which the important traffic flow variation occurs leading to either propagation or non-propagation of traffic congestion were observed to include morning peak inbound (05.30AM – 10.00AM), noon & afternoon peak inbound (10.00AM – 16.00PM), evening peak outbound (16.00PM – 21.00PM and night peak outbound (21.00PM – 05.30AM).

On analyzing the identified CTPs along these road networks, the results show that those indicated to have low standard deviation derived from travel-delay transition index below 0.30 signify the jam and crowded traffic flow condition thus entail low performance of the said road stretches, while with higher values greater than 0.30 indicate free flow phenomena. On the other hand, high standard deviation from congestion index values (above 0.10) indicate jam and crowded flow conditions whereas the low values (below 0.10) signify free flow conditions. All those shown to experience jam and crowded flow phenomena urgently need in-depth study on factors that lead to propagations of traffic congestions and hence decreasing the performance levels of the road network under study. In so doing the traffic congestions mitigations measures are thought for relieving the situations.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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