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Accessibility, congestion and travel delays in Dar es Salaam – A time–distance perspective

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ABSTRACT

This paper addresses the current state of the transport infrastructure in the city of Dar es Salaam providing both a methodological, a planning and a spatial accessibility perspective. Initially, a short background section describes the growth and spatial transformation of the city area based on spatially disaggregated data from the most recent inter-census period from 2002 to 2012. This period is characterized by extensive growth in terms of area, population and car use, while the road network largely maintains status quo except for ad-hoc development in new urban areas. The paper moves on to present a review of research into travel speed levels and congestion in Dar es Salaam. A set of city-wide maps of accessibility and delay levels are constructed based on available speed data and road network data obtained from the OpenStreetMap project and the findings are discussed with respect to the need for more efficient transport planning and implementation of plans.

Introduction

Recent growth trends

Dar es Salaam, the capital of Tanzania, is a prime example of a rapidly growing city in sub-Saharan Africa. The population of Dar es Salaam has grown with an average rate of 5.8% per year in the most recent inter-census period from 2002 to 2012. In absolute figures the population increase has been 1.9 million people, with the total population growing from 2.5 million inhabitants in 2002 to 4.4 million in 2012 (National Bureau of Statistics Tanzania, 2006; National Bureau of Statistics Tanzania, 2013).

It is well-documented that population growth in Dar es Salaam has translated into widespread spatial expansion and urban sprawl. Kombe (2005) describes the growth of Dar es Salaam as "complex organic urban structures which expand horizontally". Spatial expansion of Dar es Salaam in the 1970s and 1980s followed a star-shaped pattern along major roads (Briggs & Mwamfupe, 2000; Owens, 2010). In recent years, the surface area of the city has increased dramatically. While the maximum distance from the center to the edge was 6–10 km in 1969, it was up to 30 km in the late 1990s (Olvera, Plat, & Pochet, 2003). Sawio (2008) argues that geographical expansion is even up to 50 km in some directions when using a functional view of the city.

Recent population growth has fueled the widespread spatial expansion. The peripheral parts of the city have grown most rapidly and received the largest shares of the absolute population increase. Rapid growth combined with large absolute population increases is primarily found in peripheral areas north, west and south-west of the city center. It is also found in the southern areas along Kilwa Road which are relatively closer to the center than the rapidly growing areas in the other directions. The spatial distribution of the recent population increase has affected the overall spatial distribution of the population, with those peripheral areas becoming much more populous and experiencing significant increases in population densities (Andreasen, 2013). Population growth in the southern coastal areas, which are not serviced by any major roads, is quite insignificant compared to all other directions, likely because of the estuary of Mzinga Creek separating Kigamboni peninsula from the city center, with the two latter only connected through a ferry service (Andreasen, 2013).

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Motorized transportation

Dar es Salaam is currently facing a major challenge of coping with extreme levels of traffic congestion. There are a number of reasons for this 1) the rapid population increase, 2) the spatial expansion of the city with increased levels of commuting, 3) the sharply increasing use of motorized vehicles, 4) the mononuclear city structure with few radiating main roads, and 5) virtually no construction of new ring roads or high levels roads to meet the increased demand.

Despite the fact that large parts of the urban population are affected by poverty, the amount of motorized vehicles has increased rapidly within the latest decade. The total number of privately owned cars has escalated from approximately 220,000 in 2000 to 600,000 in 2012, and since 2009 the number of cars has grown by 50,000 annually. This growth rate is much higher than the population growth, and this tendency is expected to continue (Mrema, 2011).

Dar es Salaam is the main traffic junction in Tanzania due to the city's functional role as the national economic center. The city contains a major industrial port, and the national railway system as well as a major road network emanates from the city. Dar es Salaam is characterized by a relatively large manufacturing industry, which entails a notable industrial road transport of raw materials (Marcel 7 Ngewe, 2011). However, only one fourth of the urban roads are paved, though most commercial transport is dependent on the paved routes. The unpaved roads are poorly maintained, lack drainage and hence create limited accessibility and traffic congestion when precipitation is high (Mrema, 2011). The quality and supply of the road network in Dar es Salaam is consequently insufficient and the road capacity is far from adequate.

As Dar es Salaam is the most important economic and commercial center of Tanzania, the frequent and extensive queuing, low speed levels, traffic jams and exhaust emissions are additionally problematic to national economic growth. 16 pct. of the national GDP are generated within the city (NBS, 2010) and the major universities, educational institutions and financial district of Tanzania are located in Dar es Salaam. Moreover, Julius Nyerere International Airport, which is located south of the city center, constitutes an important connecting linkage to the global market. Good traffic conditions and high accessibility are important aspects of economic development, and a necessity if Tanzania is to attain an efficient business structure and economic growth (Mrema, 2011). However, every day thousands of man-hours are lost and transport of goods and services are delayed due to congestion. The massive traffic congestion is thus a major development problem as it causes notable economic losses and impedes the national growth (CEP, 2010).

These conditions of congested roads are not unique to Dar es Salaam. As noted by Arku (2009) the shift from a state-controlled to a market-oriented economy over the last decades has caused most major cities in Africa to experience rapid spatial expansion, as well as population growth rates higher than those in more developed regions. In most cases this has led to increased levels of congestion. Gakenheimer (1999) points out that mobility and accessibility are declining rapidly in most of the developing world and ascribes this mainly to the rapid pace of motorization, that local demand far exceeds the capacity of facilities and lack of adequate road maintenance as well as planning strategies. Relatively few city-wide analyses of congestion and mobility exist, however, for Sub-Saharan African cities. One example is a study of accessibility and mobility levels in Accra, Ghana, by Møller-Jensen, Kofie, and Allotey (2012) in which conditions similar in magnitude to those of Dar es Salaam were found.

Measuring accessibility to urban areas

The main objective of the research behind this paper is to spatially analyze and visualize the level of road network accessibility to different parts of the city. As also argued by Krizek (2010) accessibility is regarded as an important measure of the level of sustainability of a city's transportation system. The local levels of accessibility are established using GIS-based network analysis that takes the road pattern as well as speed and delay levels into account. The latter is done by comparing currently reported speed levels with potential speed levels in a situation of free vehicle flow. It is shown, how the combined use of free web-based map data from OpenStreetMap and network analysis functionality in GIS can enhance the general knowledge of accessibility levels in areas and regions, where official road map data may be inadequate or difficult to access. The information that is generated in this process may increase the level of knowledge among urban planners, NGOs and other stake holders as well as accentuate, how cities such as Dar es Salaam are negatively affected by poor accessibility and mobility due to inadequate transport infrastructure. The proposed methods are novel in the sense that they take advantage of the recent global increase in the availability of digital map data up-loaded by ordinary travelers in possession of a Global Positioning Unit (GPS) or a smart-phone with similar capabilities. These data provides new opportunities but they also necessitate a number of methodological considerations due to their specific nature. The combination of the new and constantly improving digital datasets of road locations and the availability of advanced network analysis tools in standard GIS software provide an analysis setup that can be applied regularly in urban planning organizations. This will provide new and unique opportunities for city-wide mapping and visualization of current conditions as well as for scenario analysis.

Congestion and free flow

Central to the analysis is the delays caused by the congested traffic and how this influences the accessibility. The concept of *accessibility* refers to how good the access is to a given location, or how easy (or difficult) it is to reach a certain geographical point. Within the framework of GIS-based network analysis accessibility is often measured in terms of network drive times (km/h) between origin and destinations, and, therefore, as a function of distance and speed levels (Møller-Jensen et al., 2012). Speed levels and, hence, accessibility will depend on the level of congestion.

Bertini (2005) identifies two general methods of measuring *congestion*. One method calculates congestion by point measurement, e.g. by counting the number of cars that pass a specific road point or by measuring the specific speed level at a certain location. The other approach perceives congestion by its spatial extension e.g. as travel time between destinations, as the density of vehicles at a given road segment, or as the length of queues on the road network (Bertini, 2005). The current study uses speed levels (km/h) as a measure of congestion. The speed levels are deduced from a range of empirical travel time measurements that have been conducted in Dar es Salaam. Thus the concept of congestion, used in this study, predominantly reflects the second approach, in which congestion is perceived by its spatial extension and calculated as travel time differences between reduced flow periods (normally associated with peak-hour situations) and free flow conditions. It is however noteworthy that the congestion in Dar es Salaam currently constitutes an almost permanent problem as congestion is not limited to the morning and afternoon periods, but may sometimes occur during the whole day.

Within the current study *free flow* is calculated as the average speed in a situation where the density of vehicles is low and the