Using GIS to analyze the influence of public transport availability on the choice of health service: a case study of Dar es Salaam, Tanzania

T. de Jong
Department of Human Geography and Planning, Faculty of Geographical Sciences, Utrecht University, Utrecht, the Netherlands

S. Amer
Division of Urban Planning and Management, International Institute for Geo-Information Science and Earth Observation, Enschede, the Netherlands

ABSTRACT: This paper investigates in how far ease of access to public transport influences the spatial choice behavior of patients seeking care at governmental health care facilities in Dar es Salaam, Tanzania. It describes a GIS-based approach that compares differences in travel time by means of public transport as an alternative to walking. The analysis is based upon advanced analytical GIS functionality which is capable of calculating generalized public transport travel time that includes waiting and transfer time. On the basis of calculated travel time, an accessibility analysis is performed to identify under-serviced areas and investigates how extensions of the public transport network can reduce the size of currently under-serviced areas.

RESUME:

Cet exposé étudie dans quelle mesure le fait de faciliter l'accès au transport public influence les choix "spatiaux" de malades qui veulent recourir au système de santé publique à Dar Es Salaam (Tanzanie). Il décrit une approche basée sur la comparaison des divers temps de trajet dans un mode de transport public, en tant qu'alternative à la marche à pied. L'analyse est fondée sur des fonctionnalités avancées du SIG, qui permettent la généralisation du calcul du temps de transport (en transport public), en incluant les temps d'attente et de transfert. Sur la base du temps de parcours calculé, on effectue une analyse d'accessibilité, pour identifier les zones mal desservies et rechercher comment l'extension du réseau de transport public peut réduire la taille des zones actuellement mal desservies.

1 INTRODUCTION

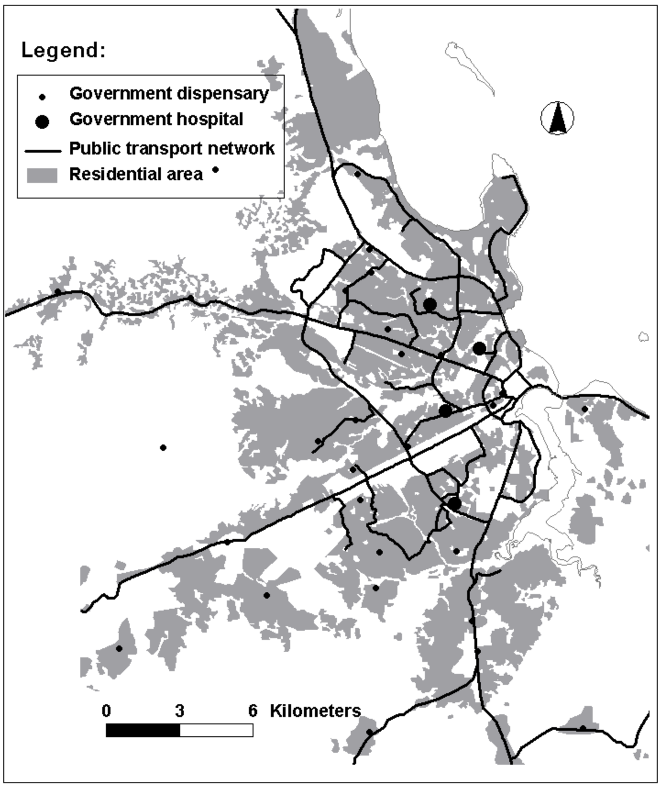
1.1 *Structure*

This paper investigates in how far ease of access to public transport influences the spatial choice behavior of patients seeking care at governmental health care facilities in Dar Es Salaam, Tanzania. It does so by comparing differences in travel time by means of public transport versus walking time. On the basis of observed regularities in utilization behavior, a GIS-based model is developed which is used to identify areas currently under serviced by public transport. The analysis proceeds with a short investigation of how the public transport network can best be extended or modified to reduce both the size and number of under-serviced areas.

The analysis is based upon empirical data collected during sample-based surveys at governmental health care facilities in Dar es Salaam in 1996 and 2000. The survey was restricted to outpatient services only. For a detailed description of the data collection procedures and sampling strategy see Amer (1998).

1.2 *Context*

Dar Es Salaam, the former capital and largest economic and population center of Tanzania, has experienced high rates of population growth over the past decades. Robertshaw et al. (1999) report that the city has an estimated population growth rate of 4.8 % per annum and population of over 3 million. The magnitude of urban development is such that the local government has not been able to manage a controlled spatial development of the city. As a result, over 75% of the population currently lives in unplanned settlements which are generally characterized by high rates of unemployment, substandard housing, limited access to piped water, sanitation, drainage, electricity, basic social services and public transport. Much of the informal development occurs at the outskirts of the city, which adds considerably to the horizontal spatial expansion of the urban area. Dar es Salaam, in short, is a rapidly expanding urban agglomeration where a large proportion of the population is faced with poverty and unhealthy living conditions. This combination results in high levels



Map 1 Overview of Dar es Salaam residential area, transport network and government health care facilities.

of morbidity and mortality and has caused a massive increase in the need for urban health care.

At the same time, the ability of the government to allocate sufficient public resources for the provision of health services has diminished. This is mainly caused by a prolonged period of economic stagnation and the introduction of structural adjustment programs which lead to cuts in public sector spending (Turshen, 1999). The outcome of the restructuring process for the Tanzanian health sector is a shift away from pure state provision of health care towards a situation with greater reliance on market forces. This takes the form of the emergence of market driven private health care provision and the introduction of cost-recovery measures in the public health care sector.

The essence of the above description is that it illustrates that health care, which until recently was seen as a basic human right for all, is becoming a commodity for those who can pay, while the have-nots must rely on charity or opt out of using health care altogether. As a result of these developments, social and spatial inequalities in health status and in accessibility to health care are increasing in recent years.

Map 1 presents a global overview of the residential area of Dar es Salaam, the public transport network and of the spatial distribution of all governmental health facilities.

2 OBSERVED SOCIO-SPATIAL BEHAVIOR

2.1 *Socio-economic characteristics*

Despite the changes that are occurring in the Tanzanian health system, the results of the survey clearly show that governmental health care provision remains of vital importance to the functioning of the health care system in general: almost half of the respondents usually visits a governmental facility. A welfare index was constructed to see if governmental facilities serve particular segments of the population. The index is a relative measure that describes the degree of prosperity or deprivation of respondents. It was constructed using criteria such as income, housing conditions, the availability of basic infrastructure (water, electricity) and possession of transportation and consumer goods. The results strongly support the general assumption that governmental facilities have a very important role in serving the health needs of the poorer population groups. Almost three-quarters of the people visiting a governmental health care facility can be considered as (very) deprived.

In demographic terms, the main clients of governmental health care are females in the reproductive age groups (35%), very often young mothers accompanied by children under 5 years old (another 40%). It is evident that, given the high fertility rate, very high percentages of women seek health care because of health problems associated with pregnancy, and with infant and early childhood morbidity. It is important to note here that private sector dispensaries normally do not provide his type of services.

2.2 *Spatial interaction patterns*

Respondents indicate that the prime motivations for visiting the governmental facility of their choice are related to travel distance or time (37%), affordability (28% and perceived quality (23%). Travel distance or time is thus a fundamentally important consideration for patients when seeking health care. In the following, we present a number of measures that allow us to explore in how far patients actually exhibit spatial rationality in selecting health facilities.

When turning to the mode of transport, the survey shows that overall around 75% of all health care seeking movements in Dar es Salaam involves walking to the clinic. In around 21% of all cases public transportation is used. Other means of transportation (car, taxi, bicycle) together cater for the remaining 4%. Since the latter category is of very limited importance it is excluded here from further analysis.

Using GIS the travel time for every trip was estimated for each of the two modes of transport. Travel time calculations were made from the place of residence to the chosen facility along the street network. If transportation mode is then broken down according to the hierarchical level of provision (dispensary or hospital) and average travel time, a more diverse picture emerges. Table 1 shows that the overwhelming majority of patients -over 90%- travel to the dispensary of their choice on foot.

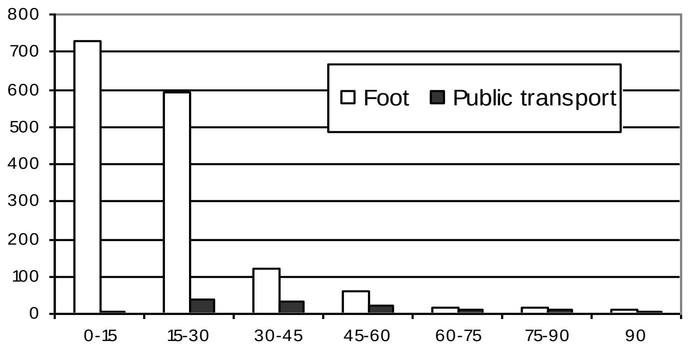


Figure 1. Actual transport mode for government dispensaries per 15-minute walk time interval.

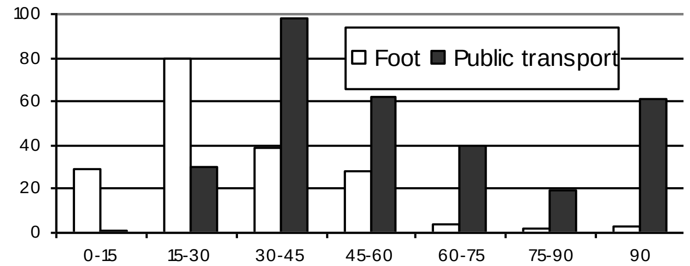


Figure 2. Actual transport mode for government hospitals per 15-minute walk time interval.

Table 1. Breakdown of transportation modes and estimated average travel times.

Transport mode	Walking		Public Transport	
	%	minutes	%	minutes
Government dispensary	92	19	6	29
Government hospital	40	31	52	32

The average walking time is only 19 minutes, which indicates that dispensaries have a strong local function and tend to serve the population in their immediate vicinity. For higher order health care facilities such as hospitals, public transport is much more important. Over half of the patients make use of public transport and travel on average 32 minutes. The importance of public transport in combination with longer average walking time indicates that the service area of hospitals is larger than that of dispensaries. We can obtain further insight in the spatial pattern of health care utilization by decomposing all trips into 15-minute intervals of estimated walking time and compare this with the actual mode of transport. Figure 1 and 2 respectively illustrate this for governmental dispensaries and hospitals

Figures 1 and 2 further confirm our earlier observations: the large majority of dispensary patients are normally not willing to walk more than approximately 30 minutes to reach the facility of their choice. Although the description in this paper is restricted to governmental dispensaries, this travel behavior applies strongly and equally to private as well as voluntary dispensaries (Amer and Thorborg, 1996).

The observed travel behavior of hospital patients shows similarity as well as difference. The similarity is that, again, a considerable group of patients walk short distances to reach the hospital of their choice. The distance decay curve, however, is less steep than that of dispensaries. Around 35% of patients are willing to walk between 30 and 60 minutes to reach the hospital of their choice. The main difference nevertheless is that a much larger proportion of patients make use of public transport,

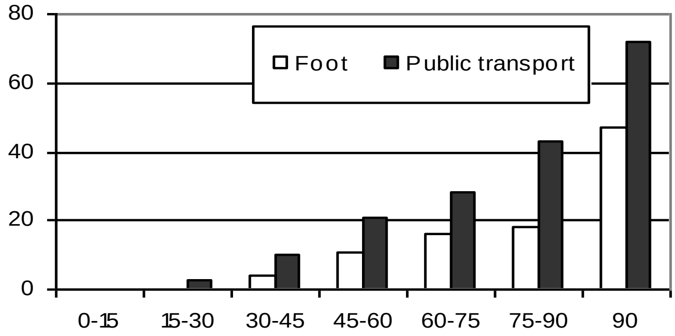


Figure 3. Travel time gain (in minutes) between estimated walk time and estimated bus time (for government hospitals).

and that those patients are willing to overcome considerable distances. The more extensive spatial reach of hospitals, of which there are only few, is caused by the fact that hospitals deliver the complete spectrum of medical services.

Overall, it can be noted that patients exhibit a certain degree of spatial rationality in terms of travel time: they walk on the short distance and increasingly use public transport as distances become larger. We can also observe that some patients make use of public transport on short distances but this can be traced back to the main user groups of governmental health care. Pregnant women with infants have limited mobility when it comes to walking longer distances. Furthermore, people may opt for public transport just because they feel too ill to walk even if the distance to the hospital is short.

Another way of viewing spatial rationality is to look at the possible gain in travel time if we compare walking time with travel time by bus.

Figure 3 shows that there is hardly any gain in travel time for trips of less than 30 minutes. This outcome is very much in accordance with Figure 2, which, shows that public transport only becomes the dominant transport mode when walking time exceeds 30 minutes.

Further analysis of figures 2 and 3 shows that more respondents choose the bus rather than walking only when the gain is more then 10 minutes or thirty percent of travel time. A second conclusion that can be drawn from Figure 3 is that the time gain obtained by respondents that actually choose to use the bus is substantially larger than the gain that could have been reached by respondents choosing to walk. In other words, ease of access to public transport does influence the spatial choice behavior of patients.

In a limited number of cases, we can observe that patients appear to walk long distances (one hour or more) to reach a hospital while they could have made a very substantial time gain if they would have used the bus. This behavior is not necessarily irrational and (apart from coding mistakes made during the survey and data entry) can be attributed to the way in which travel time was calculated. Further scrutiny of the survey shows that in some of cases, the observed disparity is caused by patients that visit a hospital because it is close to the place of work whereas our travel time calculations are based upon the residential location. The survey shows no indication that the monetary costs of using public transport is a discouraging factor in this respect.

Using GIS we can also determine for each individual trip whether or not the chosen facility was the nearest (in terms of travel time) from the place of residence, the second nearest or the third nearest and so on. Calculations are based upon walking time for those patients that actually walk, and on estimated public transport time for those that made use of the bus. Table 2 illustrates the nearness ranking and the cumulative percentage of visiting respondents for governmental dispensaries and hospitals.

Table 2. Nearness ranking of chosen facilities (cumulative percentage).

Nearness rank	Dispensaries		Hospitals	
	%	Cum%	%	Cum%
1	85	85	93	93
2	10	95	3	96
3	2	97	2	98
4	2	99	2	100
5 and over	1	100	-	-

The results are indeed very striking: a very large majority (85%) of respondents actually travels to the governmental dispensary, which is nearest to their home. Only a limited percentage bypass the most nearby clinic and seek medical care at alternative government dispensaries located further away. The spatial behavior of patients visiting government hospitals is very similar, spatial rationality prevails.

Although the nearness rank shows that a very large proportion of all respondents exhibit spatial rationality, it does not indicate the degree of 'spatial irrationality' of those patients that bypass the nearest facility. In principle, it is possible that the second nearest facility involves considerable additional travel time. Concurrently, the extra travel time to reach, for example, the fifth nearest facility could be limited. The nearness ranking measure gives no clarity in this respect.

Table 3. Nearness ratio of chosen government dispensaries and hospitals.

Nearness ratio	Dispensaries		Hospitals	
	%	Cum%	%	Cum%
1	85	85	93	93
< 1.5	9	94	3	96
< 2	2	96	2	98
< 2.5	1	97	1	99
< 3	1	98	1	100
< 3.5	1	99	-	-
< 11.5	1	100	-	-

To obtain an insight in the amount of extra time that the 'spatially sub-rational' patients travel, we use GIS to determine what we can describe as the nearness ratio. This ratio is a straightforward measure, which is obtained by dividing the distance to the visited facility by the distance to the closest facility (see Table 3). Measurement is from the place of residence and calculated on the basis of the actual mode of transport used.

It will be obvious that the values of the first category of Tables 2 and 3 are the same: those patients that visit the closest facility incur no additional travel time. The added value of the nearness ratio, however, becomes apparent when we look at the subsequent categories. From table 3 we can clearly see that most dispensary and hospital patients (9% and 3% respectively) that do not visit the closest facility have a travel time factor of at most 1.5 more than strictly required. The fact that only a very limited proportion of patients opt to visit clinics which are further away from their homes, can (again apart from coding errors in the dataset) be caused by a variety of factors. In this respect, one might think of patients that go to a clinic, which is recommended to them by friends or relatives, which they have known for a long time or which is close to their place of work and so forth.

Although not all patients visit the closest facility they do make a choice on the basis of the available options known to them, in most cases in the vicinity of their homes. Only few patients make choices that seem independent of the location of their residence. The overall conclusion therefore remains firm: there is abundant indication of spatial rationality in health seeking behavior when it comes to the users of governmental health care facilities.

3 ACCESS TO PUBLIC TRANSPORT

3.1 *From health care to public transport*

Before orienting the discussion more explicitly to the subject of public transport accessibility, we briefly need to take another look at Figure 3 from which we can discern a group of respondents that walk for more than one hour although it would clearly be advantageous for them to use public transport. Apart from the reasons mentioned previously in section 2.2, it could be possible that some of them did not consider taking the bus simply because they live far away from the nearest public transport access point. In table 4 the travel time from the residence to the nearest bus stop is shown. Although the results in the table are not uniform, it is very apparent that, respondents that walk for 60 to 90 minutes do indeed live much further away from bus stops than the users of public transport. Once again, this can be seen as an indication that ease of access to public transport impacts on the travel behavior of patients.

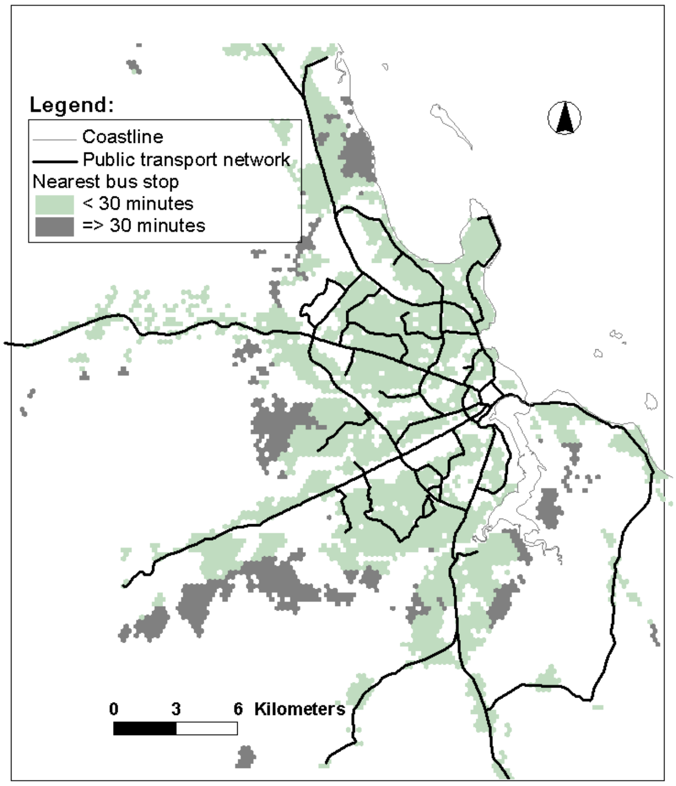
Table 4. Walking time in minutes to nearest bus stop for respondents that walk and for those that use public transport.

Time interval	Travel time to nearest bus stop	
	Using foot	Using bus
0 – 30	8	8
30 – 60	11	7
60 – 90	25	9
90 and over	14	9

We now take this outcome as the starting point of a further analysis, which addresses two major questions. The first is to identity those areas, which are under serviced by public transport. The second is to present an approach that can be used to identify those areas that can be considered for extension of the existing public transport network.

3.2 *Identification of under-serviced areas*

To identify areas under serviced by public transport, the residential area of the Dar es Salaam Metropolitan Area was tessellated into hexagons, with an edge length of 250 meters which amounts to just over halve a square kilometer in area. To approximate actual walking time as good as possible, the existing road network was supplemented with footpaths wherever possible. On the basis of this extended network, travel times on foot were



Map 2. Walking time to the nearest access point of public transport.

calculated for each residential hexagon to the nearest bus stop. It should be noted that this procedure is very similar that the one previously used to estimate the travel time of patients seeking health care.

Map 2 shows the travel time from each hexagon to its nearest bus stop. The light gray value indicates the presence of a bus stop within a walking distance of 30 minutes, whereas the dark gray value indicates a walking time of more then half an hour. The map clearly shows that most under serviced areas are located at the periphery of the city. In most cases these are the more recent unplanned urban extensions.

Although the results of this calculation gives a good insight in the location and extent of the under serviced areas, it only gives a rough estimate of the total number of people that is under serviced. If accurate disaggregated data on the spatial distribution of the population would be available this could easily be incorporated in the calculations. At this moment, however, such information is not available.

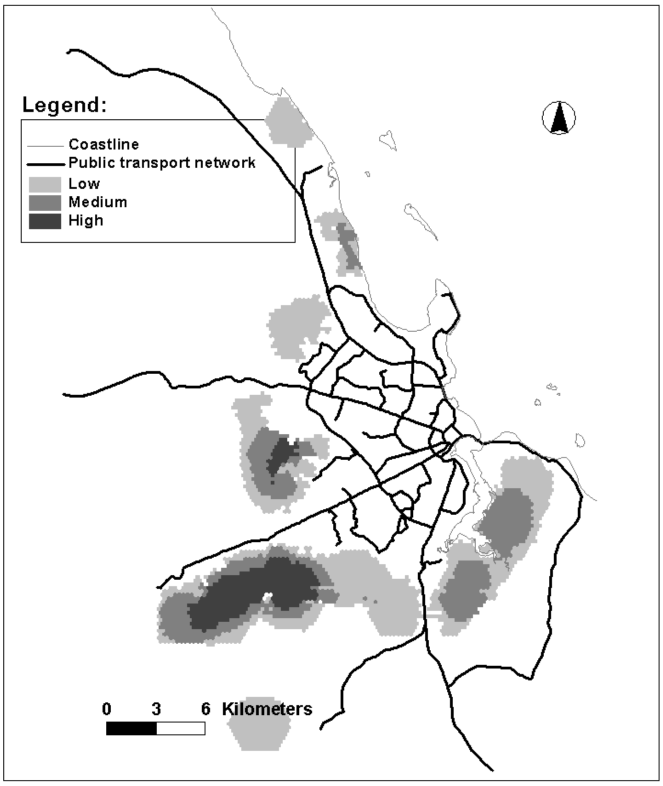
To illustrate the approach we, nevertheless, present our case on the (admittedly unrealistic) assumption that there is a uniform population density throughout the residential areas. If we recall that the estimated population of Dar es Salaam is 3 million living in residential area that covers around 205 square kilometers, we would arrive at about 800 people per hexagon. In all, about 19% of the residential hexagons lie outside this 30 minute walking limit, which (under our working assumption) would amount to over half a million persons being under serviced by public transport. The added value of a population-based measure is that it gives a better insight in the magnitude of the problem.

Although this type of information is very useful for public transport planners, they will also require information that helps them to identify priority areas for extending the public transport network. A measure, which is capable of providing such information, is presented in the next section.

3.3 *Extending the existing public transport network*

To find suitable locations for additional bus stops we use an accessibility measurement called the Proximity Count (de Jong et al., 1991). The Proximity Count simply adds up all potential clients that live within a given distance range from an actual or planned service location. In our case we use the residential hexagons as indicators for the amount of potential clients and set the distance range to a travel time of 30 minutes on foot. Varying the distance range can develop different scenarios.

First we apply this measurement to the already existing bus stops. The proximity count scores vary from 8 to 173 residential hexagons in reach; the average score is 73 hexagons. Translated into people this means that the currently existing bus stops service a potential client population varying from 6000 to 140,000 per bus stop. On average each bus stop services potentially around 59,000 persons. We can use these numbers to determine



Map 3. Priority areas for extending the public transport network.

whether or not other locations qualify as potential new bus stops.

The next step is to reduce the potential client population to only those living in a hexagon that is outside a 30-minute walking distance from any current bus stop. In other words we only take the dark gray value hexagons of Map 2 into account.

To define potential new bus stops, we simply tessellate the entire study area into well over 18,000 hexagons. To each potential bus stop a proximity count is then applied on the under serviced population only. Map 3 shows the result. As the gray tone becomes darker, more and more people would be serviced if a new bus stop would be located in that particular hexagon. Visual interpretation of Map 3 leads to the conclusion that there is a clear need for the extension of the current public transport network with two completely new connections. A frequently stopping high demand east-west connection and a less frequent north-south connection with bigger intervals between stops. In part, the realization of the two public transport extensions can be based upon existing (unpaved) roads; in part new road infrastructure would have to be put in place. Further analysis would be required to identify which parts of the existing road network could be used and where new road infrastructure would be needed.

The visual result of our calculations is particularly interesting as there is considerable resemblance with the outcome of a study carried out by the Dar es Salaam road development plan in 1994. In this study an east west as well as a south-north corridor is foreseen (Tanzania Ministry of Works, Communication and Public Transport, 1994).

4 CONCLUSIONS

The analysis presented in this paper is based upon advanced analytical GIS functionality capable of calculating generalized travel time along the street network for different modes of transport.

Using this analytical functionality, we analyzed the spatial behavior of patients seeking governmental health care in Dar es Salaam. Findings show that most dispensary patients walk relatively short distances of less than 30 minutes. The main difference with hospital patients is that a much larger proportion of these patients make use of public transport and are willing to overcome considerable distances. A number of straightforward analytical measures demonstrate that patients exhibit a remarkably high degree of spatial rationality, regardless of the chosen transport mode (foot or public transport).

From the survey, it was found that a small proportion of respondents walk for more than one hour although is would be advantageous for them to use public transport. Our findings indicate that these respondents live relatively far away form existing bus stops, which demonstrates that ease of access to public transport impacts on the travel behavior of patients.

The observed regularities in travel behavior are subsequently used to identify areas currently under serviced by public transport. Not surprising is that most of the under serviced residential areas are recently developed, unplanned urban extensions located at the periphery of the city.

Finally, on the basis of an accessibility measure called Proximity Count, we illustrate that there is a need to extend the current public transport network with a frequently stopping high demand east-west connection and a less frequent north-south connection with bigger intervals between stops. Realization of these extensions would substantially improve public transport access to governmental hospitals.

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