‘CYCLE THROUGH’

A methodology for the identification of (potential) major cycle routes, case study for Dar as Salaam, Tanzania

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Contribution from I-CE Locomotives program

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ABSTRACT

The objective of the research that has led to this paper was to develop a method for identifying (potential) major cycle routes in cities where the role of cycling and available data on travel behaviour is limited. Furthermore, the method should be made applicable to the case of Dar es Salaam (DSM), Tanzania, where AALOCOM (Association for Advancing Low Cost Mobility) is working on a cycle master plan for the city. This paper elaborates on the method developed and the process of defining a bicycle network for DSM in which the method plays a part.

It first describes the potential of cycling for the people and the transport system of DSM and points out the relevance of infrastructural facilities for cycling. From a comprehensive study on Non Motorized Transport (NMT) in 2004, it can be concluded that cycle infrastructure can really stimulate people to cycle and help cycling to become a substantial mode in the local transport system.

One of the next steps following the NMT study was the development of a strategic outline for a bicycle network, initiated by experts of the Interface for Cycling Expertise (I-CE). In the process of checking and refining the strategic outline the primary subject of the paper comes in, i.e. the application of 'Cycle Through', a new method for defining cycle routes. The method confirmed the already identified routes and added a couple of missing links to the map.

'Cycle Through' only provides information on the principal attractiveness of roads for cycling. Insight in practical feasibility and local demand can only be obtained with the help of experts with local knowledge. The paper ends with some ideas on how to study feasibility and prioritize roads for adopting them as part of a bicycle network.

INTRODUCTION

In many countries, regions and cities in the world the bicycle has proven to be a successful mode of transport, both with regards to individual goals as with regards to the local society and the transport system. For the local society, cycling has economical, social and environmental benefits: among other things, it can alleviate poverty, air and noise pollution and fuel dependency and can contribute to equity, accessibility, liveability, social participation and economic well-being. For an individual bicycle use can have at least three direct advantages, namely time savings, money-savings and/or more earnings, and therefore gives more opportunities to enhance the standard of living.

In Tanzania the advantages of cycling are advocated by AALOCOM (Association for Advancing Low Cost Mobility), partner in the LOCOMOTIVES program, initiated and coordinated by I-CE (Interface for Cycling Expertise). They promote cycling among the public and support planners, designers, decision makers and alike to raise funds and to fully acknowledge cycling as an important means of transport in their plans, designs and decisions. For this reason, they are making a cycle master plan for Dar es Salaam (DSM), the economic capital of Tanzania. This paper describes some work that has been done to contribute to the cycle master plan.

Despite the many advantages mentioned there can be many reasons why the local modal share of cycling is marginal or diminishing. Part of the reasons can be related to cultural and social constraints, e.g. the fact that the bicycle is sometimes regarded as a mode only for special purposes, like leisure and sports, or for a certain group, defined by age, gender, lifecycle, income etcetera. Other reasons may have to do with personal constraints e.g. concerning availability and usage. In most situations there are also spatial constraints, related to "car-based" spatial development and the availability of proper infrastructure for cycling. In this paper an overview will be given of research outcomes with respect to constraints and possibilities for cycling in DSM. Furthermore, a method will be presented to help overcome some of the constraints related to the transport system.

First the transport system and the role of cycling in the city of DSM will be discussed. The second part of the paper describes the method 'Cycle Through' with which cycle routes can be identified. The third part deals with the ways to assess the feasibility of facilitating cyclists on the routes that were identified and to prioritize these routes for incorporating them in a bicycle network. The paper ends with a discussion of the usefulness and practicability of the method.

DAR ES SALAAM

In the city of Morogoro cycling is a predominant mode of transport (20% market share, Sambali et al. 1998). About 200 kilometers down the road, in Dar es Salaam, the modal share of cycling in all vehicles on major routes is less than 5% (maximum ca 150 cyclists per hour, both directions; DDI 2004). At first sight however, one cannot see an obvious reason for this low share, like the existence of hills or the lack of road pavement.

Dar es Salaam is located on the plain area between the Indian Ocean and the Pugu hills at the east coast of Sub-Saharan Africa. In 1973 the Tanzanian government decided to move the capital city from Dar es Salaam to Dodoma (for political reasons). However, economic activities stayed in DSM and at present the city is developing very fast. DSM is the largest city in the country and still the economic capital. The city of DSM has about 3 million inhabitants in both planned and unplanned residential areas. Most citizens are using the DSM transport network on a daily basis and with an annual population growth of nearly 5% the demand for mobility is rapidly increasing. The two transportation modes with the largest share are walking and the daladala (micro- and mini-vans). The daladala has been a success story with nearly half of the city's residents depending now on them for longer distances. However, the current transportation network in DSM is not designed for the huge number of daladala's, cars and trucks. The enormous amount of traffic causes severe congestion, traffic casualties and other traffic related problems. The traffic situation in the city gets worse every month.

In order to cope with the transport problems the City Council of DSM started in 2002 with the development of a Bus Rapid Transit system; the DART (Dar es Salaam Rapid Transit system). DART aims at providing quality and accessible mass transport for the residents of DSM, which will enable them to improve their standard of living, achieve a high sustainable economic growth and which will act as a pioneer of private and public investment partnership in the transport sector in the city. The system will consist of high capacity, environmentally friendly buses that meet international service standards and will operate on exclusive lanes in the middle of major roads. In 2006 the implementation phase will commence, starting with Morogoro road, one of the main roads in the city. In order to make DART possible, the many daladala's will be banned from the main routes.

In March 2004 the Lord Mayor of Dar es Salaam City, Hon. Kleist Sykes, presented a vision of Dar es Salaam on Cycling and signed the Charter on Non-Motorized mobility as part of the initiatives of building sustainable communities in the city. The Charter is a joint initiative of the World Bank, American Bicyclist and Velo Mondial. The aim is to improve the role of NMT (and cycling) as a way to improve the transport system, livability, traffic safety as well as individual mobility. In DSM the special aim is to incorporate cycling in the DART plans in order to make a new, sustainable transport system. AALOCOM, member of the DART steering committee, is steering, supporting and monitoring this process.

INFRASTRUCTURE FOR CYCLING

At present cycling is not facilitated on the major routes in DSM, apart from a stretch of Nyerere road where a cycle lane is present. Inside the city centre cyclists are cycling in front of and behind motorised traffic. Outside the city centre the cyclists make use of the space for pedestrians alongside the road and of the road surface in case the pedestrian routes are blocked or overcrowded. Especially nearby daladala stops and markets this leads to dangerous situations. Traffic casualties are suffered frequently and mostly cyclists or pedestrians are involved. Between 1985 and 1994 65% of the fatal casualties were pedestrians and 4% were cyclists (Sambali et al. 1998). Dangerous traffic conditions and the lack of facilities for cyclists appear to be explanations for the low market share of cycling (Howe and Dennis 1993).

Because of the development of DART there is now a great chance to substantially improve the infrastructure for cycling. In the plans for DART non-motorized transport and cycling play an important role. As mentioned in the introduction cycling can lead to time and money savings. For short distances cycling can be a mode for people wanting to save time. This can be the case for trips between the DART stations and the feeder areas, so the designs will allow for safe and quick access to the stations.

NMT crossing facilities and bicycle parking facilities will be incorporated. In the feeder areas provisions need to be made to facilitate bicycle usage, e.g. by providing safe parking, simplifying the rider's task and minimizing body energy use. The latter provisions are not yet part of the DART plans. For long distances cycling can be a mode for people without means to pay for travel, wanting to save on travel expenses or suffering from a lack of public transport accessibility. These people will be facilitated by cycle lanes on the major routes in and out of the city, which are incorporated in the road reconstructions for DART. In this way the reconstructions will further help in reducing congestion, CO2 emission and pollution and in improving livability and safety.

For AALOCOM the cycle infrastructure in the DART project is just a starting point for creating a comprehensive bicycle network. With the help of the cycle master plan they will pursue their ambition.

THE NMT STUDY

To be able to support the DART development process and to provide a solid basis for a cycle master plan AALOCOM commissioned a comprehensive NMT inventory study. The study has been carried out by DDI consultancy in 2004 and focuses on Morogoro road. This corridor has been selected for the first phase DART implementation. The study has delivered numerous findings characterizing the demand and supply side of NMT in particular and transport in general. Here we sum up some major findings from the NMT survey, aimed at describing characteristics of the demand profile and the opinion on cycling. In this survey 1010 cyclists and 4275 pedestrians (walking the whole trip) were interviewed along Morogoro road.

For cyclists the following was found:

- 74% of the cyclists are between 15-30 years old, 51% between 20-30 years. 94% of the cyclists are male. 34% of the cyclists use their bicycle for business, 23% for sports/leisure and 22% for going to work. 64% of the households of the cyclists earn less than Tsh 45.000 (~ € 35) per month;
- 77% of the cyclists own their bicycle. Most of the owners have one bicycle and use it on a daily basis. The most important reasons for not owning a bicycle are the cost (too expensive), the unsafe traffic situation and the lack of parking facilities;
- 67% of the cyclists are reluctant to use the bicycle more often, due to unsafe parking, insecurity in riding and unsafe traffic situations. 85% say they would use the bicycle more often if specific lanes and parking sites were developed;
- 55% express ignorance of the relevant traffic regulations for cyclists;
- 92% of the cyclists have been involved in an accident while cycling, which was a collision with other NMT users in most cases (65%);
- The three most given advices to increase bicycle usage are: implementation of safe bicycle paths, implementation of safe parking facilities and price decrease.

For pedestrians the following was found:

- The age, occupation and income distribution among pedestrians looks quite similar to those of cyclists. There is a difference in the gender distribution though: 67% of the pedestrians are male instead of 94% among cyclists;
- 75% of the pedestrians indicate they would be willing to walk to work daily if safe paths for pedestrians were developed;
- 60% of the pedestrians state that they experience difficulties while walking with carts and bicycles using the same paths. 57% see exclusive paths and widening

of these paths as a major improvement, a minority (43%) recommends safety improvements related to encountering motorized traffic;
- 47% of the pedestrians say they do not opt for the bicycle, because this mode is too expensive. 31% of the pedestrians prefer walking, because of safety reasons.

The NMT study 2004 shows results that are in line with results from earlier travel studies concerning DSM, like the cross-case analysis in which Temeke, a ward in Dar es Salaam, was compared to the city of Morogoro (Sambali et al. 1998). For the latter study a household survey was conducted in 1994 and 1995 which yielded answers of around 1000 respondents in both areas.

LESSONS FROM THE NMT STUDY

From the results of the NMT study it seems that cycling could become a substantial mode if constraints were addressed regarding:

Availability and usage

* affordability of riding a bike. Since the income distribution of pedestrians and cyclists is quite similar, it is possible that affordability has also to do with setting priorities, (mis)perception and preferences. This suggestion is strengthened by results from the cross-case analysis mentioned before. Although the incomes in Morogoro were lower, the percentage of adults that cannot afford a bicycle was found to be lower as well (75% compared to 85% for Temeke; Sambali et al. 1998). Hence, launching promotion campaigns and arranging education and training can be part of the program. The figures also show that solutions need to be found in the field of providing loan schemes, subsidizing bicycles, bicycle hire businesses etcetera. In the cross-case analysis it was found that 71% of the respondents in Temeke would consider buying a bicycle if it were possible to borrow money (Sambali et al. 1998);
* operating a bike. Part of the problems related to the operation of a bicycle can be dealt with by providing education and training. Also, separate cycle lanes and clear road signs and regulations will simplify the rider’s task and reduce the risks involved with cycling;
* gender issues. As far as the constraints are related to the operation of a bicycle, solutions can be found in the provision of separate lanes, non-stop routes, bike repair shops, ladies bikes with child’s saddle, education and training. It might prove quite difficult to lift constraints related to culture or religion.

NMT trip making

* lack of traffic safety. Together with affordability and gender this constraint seems to play a major role. In the cross-case analysis mentioned earlier almost 70% of the respondents in Temeke DSM not owning a bicycle stated the risk of having traffic accidents as reason, let aside the problem of affordability. In Morogoro only 10% gave this reason (Sambali et al. 1998). From the NMT study in 2004 it seems that the feeling of traffic safety is more related to encounters among NMT than between NMT and motorized vehicles. By making separate lanes the traffic safety for both cyclists and pedestrians will improve. Traffic safety can further improve by implementing traffic calming measures and providing safe crossing facilities;
* lack of cycle infrastructure. This constraint is related to the lack of traffic safety, but also seems to have its own meaning with regards to accessibility. The competition of space with pedestrians and motorized vehicles can be enlightened

by downgrading infrastructure for motorized vehicles, widening NMT paths and/or separating cyclists from pedestrians. In order to further increase accessibility the cycle lanes should become part of a coherent, direct and obstacle free network, connecting dwellings with markets, schools, bus stops, clinics etcetera;

* lack of parking facilities. Although the lack of parking space at home might be a reason for not owning a bicycle, the parking problem in general seems to be more a second-order constraint reducing the utilization of the bicycle. In the cross-case analysis it was found that the actual utilisation of a privately owned bicycle during the day is rather low (Sambali et al. 1998), possibly indicating unsafe parking at destinations. Problems related to parking and theft can be tackled by the provision of safe parking facilities, at the origins as well as the destinations, and the interchange points (e.g. DART stops).

TOWARDS A CYCLE MASTER PLAN

From the NMT study it shows that improving the infrastructure could really help cycling in claiming a vast share in the modal split. With the implementation of DART separate cycle lanes will be constructed on all DART routes. In order to really boost cycling the cycle infrastructure should further combine to a network where all major origins and destinations are interlinked in a direct way. AALOCOM is working on a cycle master plan to be able to make further steps in this direction.

As a means to consultation of and communication with the several stakeholders experts of I-CE prepared a strategic outline for a bicycle network in DSM. Figure 1 shows a draft version of this outline. On the basis of expert knowledge the major existing (green lines) and potential cycle routes (blue lines) have been identified, together with some missing links (red dashed lines) connecting the cycle routes to each other and to the CBD. Some routes run through major corridors and are therefore shared with motorized traffic. Some others are more or less exclusive shortcuts through residential areas.

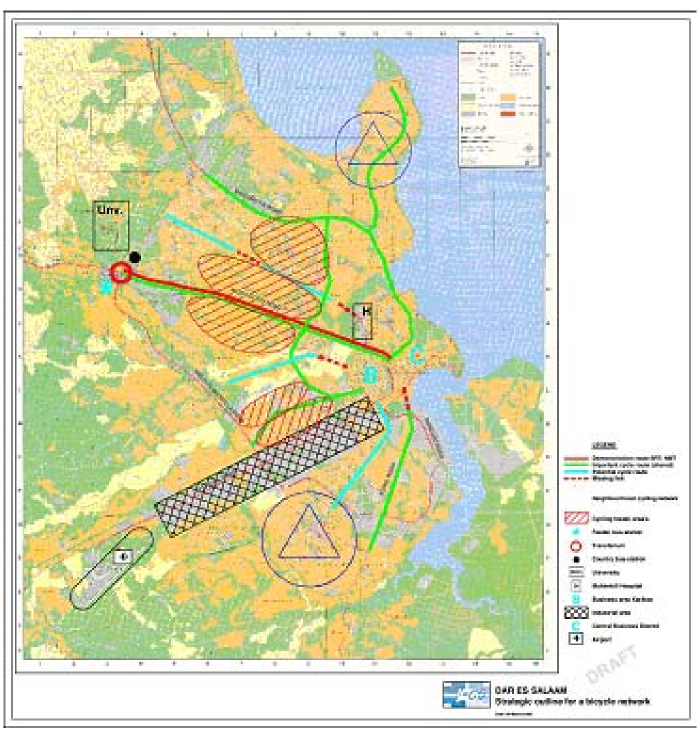

FIGURE 1. DRAFT STRATEGIC OUTLINE BICYCLE NETWORK DSM (I-CE 2005)

AALOCOM has used this strategic outline as the starting point for discussion with the various stakeholders. The map has been further elaborated upon and foundations for the map have been developed in a workshop at the AALOCOM office in June 2005. Separately, at the University of Twente, an analysis of origins and destinations has been carried out, in order to check and to supplement the strategic outline. This analysis has led to the development of a more general scientific method called 'Cycle Through'.

INTRODUCTION TO THE METHOD

'Cycle Through' can be used to investigate the need for NMT infrastructure, both along existing roads in current networks as in terms of missing links in the network. The method is based on the well-known gravity model and inspired by the so-called star analysis (Bach et al. 1988) and the old rubber band method for constructing routes. With the help of the gravity model OD (Origin-Destination) matrices for NMT are produced. With the help of a GIS tool the estimated NMT trips are then assigned either to the network (for existing routes) or to the areas (for missing links) between origins and destinations. The method differs from traditional methods in the way the OD matrices are produced and visualized.

Application of the method consists of four phases:
1. Data collection
2. Data processing
3. Processing of results
4. Interpretation of results

In the next paragraphs the different phases will be explained. More detailed information on the method and the results derived for DSM can be found in the report "Planning for NMT" (Rouwette 2005). In the case of DSM we used the method for finding cycling and pedestrian routes. The reason for considering both modes was the thought that routes for pedestrians should also be routes for cyclists and vice versa. Hence, we used the pedestrian routes for completing the picture.

DATA COLLECTION

In the first phase the data input for the method is gathered. The study area is divided into zones, zonal productions and attractions are estimated and data is gathered for the distribution values that are needed for the OD matrix estimation. Furthermore, skim matrices are derived with distances between zones, both for network and Euclidian distances.

Zones

A first requirement is a zoning of the study area. A smaller size of the zones results in a more detailed OD matrix and can lead to more accurate results. However, with smaller zones there is also an increasing need for detailed (scarce) data. When choosing for a certain division in zones there are several points of consideration:

- Homogeneity of the zones: It is important to be sure that the most important characteristics explaining travel behavior (like density and income levels) are approximately equal over the complete zone area. The larger the zones, the less chance that they are homogeneous for the characteristics.

- Borders: In order to avoid practical problems it is best to comply with natural and administrational boundaries. Examples of such borders are ward limits, primary roads or rivers.
- Data requirements: The data requirements are partly determined by the zonal structure chosen. For each zone productions and attractions have to be determined based on socio-economic data. If very specific data are available, it is possible to choose for a fine zoning. However, more often it will prove difficult to gather the necessary data for each part of the study area. If the availability of data is restricted, larger zones have to be defined.

In the Dar es Salaam case the data availability is restricted and a rather coarse zoning system consisting of 50 areas was chosen. Figure 2 show the zones that were used for DSM. The zones are based on the division of the city in wards.

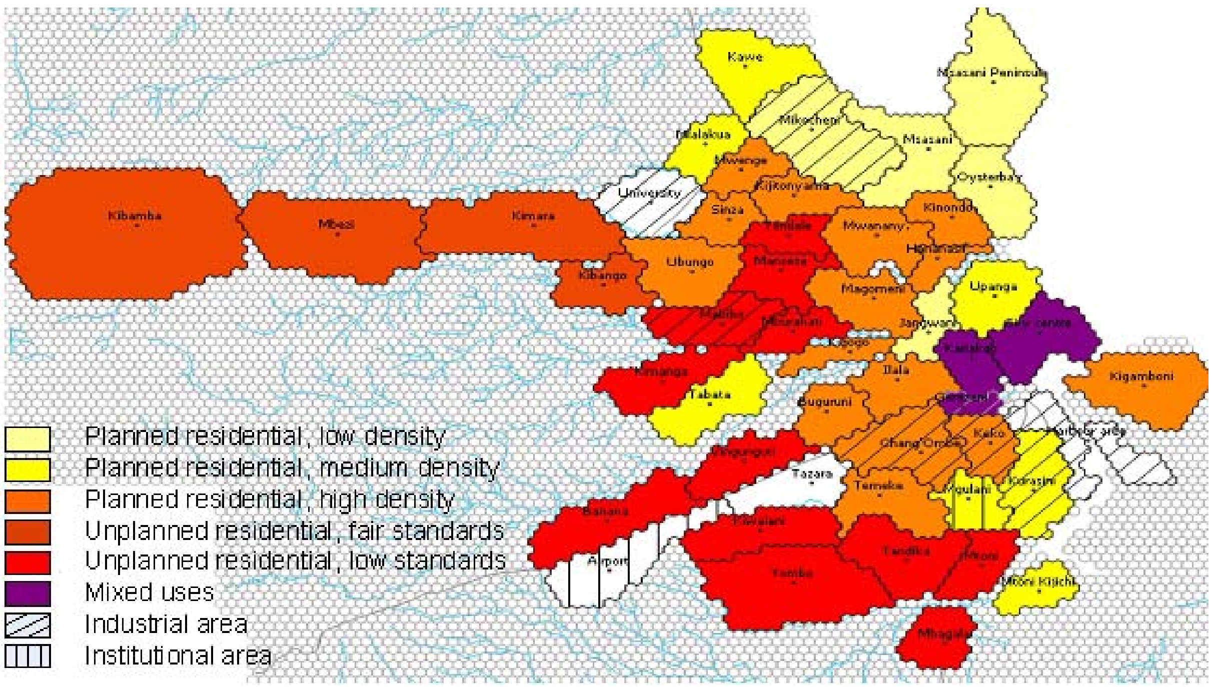

FIGURE 2. ZONES FOR THE OD ANALYSIS DAR ES SALAAM (ITC, JICA)

The GIS map was developed at the International Institute for Geo-Information Science and Earth Observation (ITC) in Enschede, The Netherlands by Mr. Sherif Amer (Amer 2005). The land use data were taken from the interim report for the Dar es Salaam road development plan (JICA 1994).

Production and attraction of NMT trips
In the absence of a comprehensive household survey over the study area NMT trip production and attraction of zones have to be calculated differently. In the DSM case the production of a zone has been estimated with the use of the population number and NMT trip rates. A trip rate is the average number of trips made by a person per day. With a rather small questionnaire trip rates can be estimated. If cycling is a marginal mode, as in the case of DSM, it can best not be treated separately.

In the case of DSM the following method was used to estimate the zone NMT production:

- For high density, unplanned residential areas and for the business areas production was set to three times the population number

- For medium density the production was computed as twice the population number
- For low density the production was set to one time the population number.

This method is based on two assumptions: the median income level in high density areas is lower than in low density areas and people with a low income level will be more inclined to use NMT.

Zone attraction is more difficult to estimate. Several factors affect the number of trips attracted by a zone, like land use, activity centers, population number and accessibility. In the DSM case zone attraction values were based on population numbers as well as land use.

The following assumptions were made:
- The total NMT trip attraction is the same as the total of production over all zones (this implies that only trips with both trip ends in the study area are taken into account)
- Zone attraction is calculated as one time the population number plus a rating for the major activity centers
- The total population over all zones is the same as 36% of the NMT trip attraction, which means that 64% of the attraction has to be spread over the zones based on major activity centers. This 64% was assigned as follows, on the basis of personal experience by the authors: CBD/Kariakoo 16%, Industry 12%, Institution/education 11%, Markets 11%, Minor centers 12% and bus stations 2%.

For the estimation of the pedestrian and the cyclist OD matrix the same production and attraction values were used; difference for both modes was made in the distribution values. The final production and attraction values are not very realistic, especially not for cyclists. Since the method's aim is to identify the strongest NMT routes this is not regarded as problematic. If the data are well enough to be able to calculate meaningful absolute values, 'Cycle Through' could be applied to single OD relations, without the need of a computer.

Distribution values
The distribution values represent the attractiveness to make a trip with a certain resistance (time, distance, cost) between an origin and destination. In the DSM case distance was used as resistance, since it is easy to calculate and equal for all NMT modes. Per distance class and mode a distribution value is derived. Normally, distribution values tend to become smaller as distance increases. The order of values as a function of distance is called the decay function, although in this case no mathematical formula has been used. Instead we have chosen for a direct approach, in line with the quality of the input data.

Necessary for a direct calculation is an empirical OD matrix of cycle trips and walking, for at least a part of the study area. The matrices can be derived from a representative household survey or from a survey at preferably different types of destinations. The matrices can also be deduced from interviews at one or more screen lines in the network. For DSM we have tried several data sources of which the OD information from the NMT study seemed to be best. In this study several screen lines on Morogoro road were used, so we needed the NMT counts from the study as well to weigh the screen line data for the total OD matrices. In the case of just one screen line NMT counts are not even necessary. There are, however, three things that should be kept in mind, while deriving the decay function:

- only OD pairs need to be taken into account that will pass the screen line for 100%, i.e. there is no major alternative route.
- in the case of one screen line or large distances between screen lines OD pairs over short distance will be under-represented in the sample. This is not so much a problem for the validation of the distribution values, but could mean that for some distance classes values cannot be derived.
- the distribution values are supposed to be valid for the whole study area, while in fact they could be different in other parts of the study area, e.g. due to other neighborhood characteristics.

Skim matrices

In order to derive a decay function matrices of the resistance between the zones are needed. For identifying missing links it is imperative to build two different matrices, one representing the resistances over the network and one representing the situation if there were direct links between all OD pairs. For the latter the Euclidian distance between all zones can be used, based on the coordinates of the zone centroids.

If there is a GIS map of the network available, the network skim matrix can be calculated by GIS software like Flowmap, a freeware package from the University of Utrecht in the Netherlands. In the case of DSM the network matrix was provided by Sherif Amer from ITC in Enschede, the Netherlands. The matrix contains distances between zones over the existing road network.

DATA PROCESSING

The first step in the processing phase is to get a trip length distribution per mode (e.g. in time or in distance) from the available OD data. Here fore the trip lengths from the OD pairs have to be binned in classes, so that each class is filled with a reasonable number of cases (and OD pairs). The next step is to calculate a homogeneous matrix based on the row and column totals of the OD matrix per mode and again to link all cases to the trip length classes (the same classes as in the preceding step). In the third step modal distribution values for the classes are calculated as the ratio of the number of real trips in each class (the "observed" value) and the number of homogeneous trips in each class (the "expected" value).

The above steps are followed for Euclidian distance as well as network distance, based on the two skim matrices. This results in two different decay functions per mode. Now the decay functions are confronted with the zonal attraction and production of trips to derive a priori O-D matrices for the whole of DSM. This step consists of making a homogeneous matrix based on the NMT production and attraction totals and then multiplying the trips in the homogeneous matrix with the modal distribution value that corresponds to the distance class (either Euclidian or network based).

If the decay functions are accurate, the OD matrices will give a good estimation of the zone totals. If the decays are not accurate, but the zonal production and attraction figures are, the Furness method can be used to fit the matrices to the zone totals. The data processing phase results in two OD matrices per mode, for the whole study area:

1. the matrix based on network distance, reflecting the most probable trips
2. the matrix based on Euclidian distance, reflecting the trips if there would be a perfect, direct network.

The trips of the first matrix can be assigned to the network to get an idea of the importance of network links for cycling and pedestrians. The trips of the second matrix can be assigned to desire lines in order to get an idea of the important OD relations. Both matrices can also be confronted in order to find missing links. Relations with a large number of trips in the Euclidian matrix and a small number in the network based matrix indicate the presence of a missing link and the existence of latent demand.

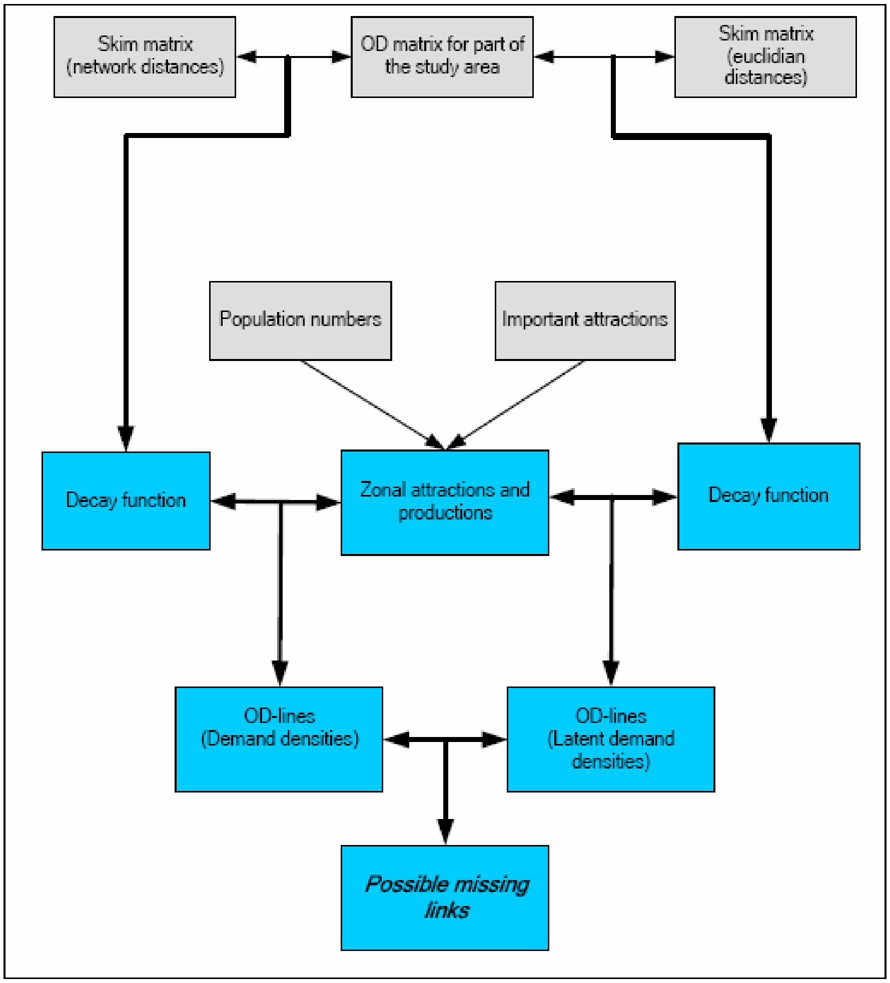

FIGURE 3. OUTLINE OF CYCLE THROUGH

Figure 3 outlines the 'Cycle Through' method with emphasis on the first two phases. The light grey boxes contain the necessary input in the data collection phase. The products in the blue boxes are mainly derived in the data processing phase. In the next phases results will be presented and interpretated.

PROCESSING OF RESULTS

The results of the data processing, the OD matrices, can be used for several purposes, e.g. for demand density, flow and missing link figures.

Demand density figures:
The OD matrices can be translated to direct OD lines on a map, with a certain flow value between each couple of zones. Through summation of the flow lines for each

(small) area, a distribution of flows over the city can be found. These so-called flow heights can be translated into a contour map, which shows areas with a propensity for high flows: a demand density figure. The figure shows stretches where a lot of NMT movements might happen and indicate the locations where NMT infrastructure is desired. Figure 4 shows the figure for cycling, based on network distance. A great flow height corresponds to a red color. If demand density figures are produced based on the Euclidian distance, they show possible flow densities if there would be a perfect network ("latent demand" density figures).

FIGURE 4. DEMAND DENSITY CYCLING DAR ES SALAAM

Flow figures:
The network based OD matrices can be assigned to the current network. This assignment will show which roads are heavily used by NMT at the moment. The assignment can be used in deciding on the need for NMT facilities along existing roads.

Missing links figures:
If both demand density figures and latent demand density figures are produced, these can be used to come to conclusions on missing links in the network. If the network is perfect (direct connections between every couple of zones) both figures will be equal. However, because the connection between certain zones is better than between other zones there will be differences in the figures. Through comparison of the flow heights in the demand and the latent demand density figures, the locations can be found where the latent demand density figures show a larger flow. These locations indicate missing links in the network. If the comparison is done automatically, missing link figures can be derived. These figures show that some connections would be used more if there would be appropriate infrastructure.
Establishing a missing link could actually lead to even higher NMT volumes than predicted, since the trips from the Euclidian matrix are based on direct routes between all zones, thus involving maximum competition.

INTERPRETATION OF RESULTS

The last phase in the application of 'Cycle Through' concerns the interpretation of the results. Important in this phase is to keep in mind that the quality of the results is largely dependent on the quality of the input. If the input data are quite certain, the method should deliver results that are not just valuable in a relative sense. Often the reality will be that the quality of the input data is dubious or that zonal production and attraction values cannot be based on cycle trips. Then the method should be merely seen as an instrument for prioritizing likely NMT routes that must be further assessed by other criteria. In any case, the results should always be used in combination with knowledge on the actual situation.

Another important issue is related to the loss of information while summing up flows through areas. The question is whether the resulting contour lines really relate to the direction of the flows. For Dar es Salaam this appears to be the case (Rouwette 2005). One should, however, use the method with caution in other cities.

The value of the method can greatly improve if better information is available on:

- zonal production and attraction values. It is especially important to estimate more precisely the relative attraction of different activity centers;
- OD relations, preferably based on a household survey covering the whole study area.

IMPLICATIONS FOR THE CYCLE MASTER PLAN

The flow figure from 'Cycle Through', containing the cycle trips assigned to the network, comes up with the same major cycle links as the ones indicated in the draft version of the strategic outline (figure 1). The missing link figure for cycling however, shows four important missing links that are not yet included in the plan.

FIGURE 5. MISSING CYCLE LINKS DAR ES SALAAM

Figure 5 presents these missing links resulted from the 'Cycle Through' method. The missing links not yet identified by the strategic outline are numbered from 1 to 4, namely:

1. a link between Manzese (residential area with a big market) and Buguruni (residential area);
2. a link between Magomeni (residential area with a lot of business) and Buguruni;
3. a link from Magomeni to Kariakoo (largest market of the city);
4. a link from Temeke (residential area) to Kariakoo.

The first two missing links can be clarified when looking at the area which is crossed by these links. The routes cross a valley with several creeks where hardly any infrastructure is available. However, there seem to be a lot of people wanting to use these routes. The other routes are shortcuts to the market of Kariakoo, which is one of the main activity centers in Dar es Salaam. The four missing links can be a useful addition to the strategic outline.

PRIORITIZING THE ACTIVITIES

The strategic outline gives an overview of all the cycle routes that are considered important and feasible. The 'Cycle Through' method confirmed the importance of the routes identified and added some missing links to the map. Ideally, all the routes should be facilitated and they should be further interlinked to form a bicycle network. In reality this is a step-by-step process in which priorities need to be set. In this paragraph we will give some rough guidelines for this process, with special reference to the Dar es Salaam case.

Prioritization can be made with the help of a qualitative cost-benefit analysis. Since all the identified routes are thought to offer great benefits for cycling, the first priority could lie with route stretches where other projects are envisaged and resources can be bundled. A continuing activity should be to look for possibilities to link the design and construction of cycle facilities to existing or planned projects in the different areas. Indeed, the combination with the DART project in DSM is a good example of this. Morogoro road will be the first road in DSM where DART and NMT infrastructure will be integrated. On other DART routes the same integration can be established. Besides bus rapid transit projects like DART links can be made to other projects, like road maintenance and (re)construction, the construction of drainage systems, habitat improvements in feeder areas, pedestrianization etcetera.

If there are no projects envisaged, they can perhaps be initiated by seeking cooperation with stakeholders in the area. In this process it will be important to stress all the possible benefits, also those outside the scope of cycling. A way forward is to identify and analyze specific traffic related problems and try to establish a sense of urgency among the different "problem owners". One of the first things to look for is information on traffic casualties and the places where they occurred (black spots).

There are other route stretches where the outcome of a cost-benefit analysis is less obvious. In these cases one needs to get a better idea of the cycling potential and the costs involved. Here we make a distinction between the routes that coincide with existing roads and the routes that can not yet be facilitated by existing infrastructure.

Existing routes
For the existing routes it is helpful to categorize the different route sections and the junctions in a way that they can be arranged in order of feasibility. An example of such a categorization for route sections, based on an inventory by Rouwette (2004), is given by figure 6.

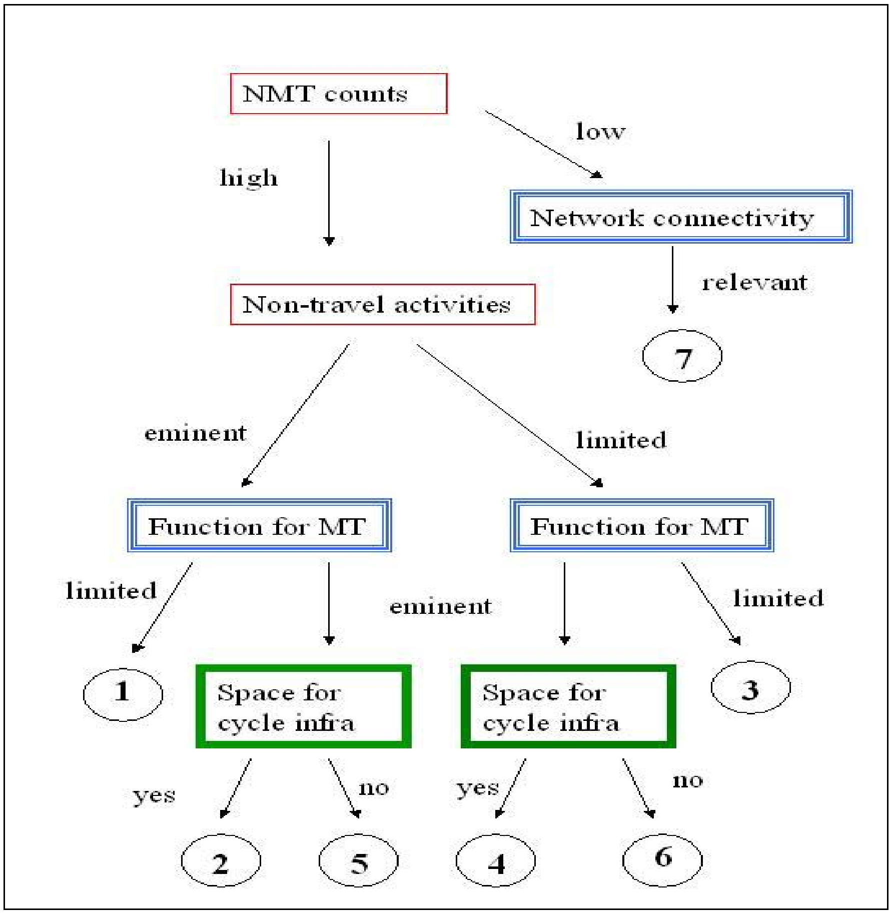

FIGURE 6. EXAMPLE OF CATEGORIZATION METHOD ROUTE SECTIONS

The first question asked in figure 6 is about present road usage by NMT. This is thought as the main criterion regarding possible benefits from cycling infrastructure. One should keep in mind, however, that at some roads the NMT counts could underestimate the desire for people to use the road as a pedestrian or cyclist. This might especially be the case if the road would be connected to an NMT/bicycle network. Therefore a question about possible connectivity is included.

The second main question in figure 6 concerns present activities alongside the road, like street hawking, markets, schools, preparing meals, waiting for buses etcetera. Those activities have a strong link with NMT and should rather not be disentangled from NMT. Together with the road function for motorized traffic they define a road as being more for living or traveling.

The third question regarding the function for MT is depicted with a different border (blue, double-lined), indicating the answer is partly a planner's decision. The last question in figure 6 is concerning the available space for cycling infrastructure. In most cases this is related to the present capacity for MT and the desired function for MT, since space should mostly be found within the road profile. In the case that non-travel activities alongside the road are limited space for cycling might be found to the expense of pedestrians.

Figure 6 leads to seven categories, depicted with a number, reflecting the possible priority. The seven categories can be described as:

1. *Activity streets*. MT can perhaps be directed to alternative routes or traffic calming measures can slow down MT traffic. If conflicts between pedestrians and cyclists exist, cyclists could be directed to a sort of dedicated track, enforced by elements like trees, sewers etcetera.
2. *Wide activity corridors*. On these roads cyclists are competing for space with non-travel activities, pedestrians as well as motorized traffic, but there is space to facilitate the cyclists. An option here is to construct a cycle lane away from non-travel activities and/or enforced by elements that can't be overridden by cars (fences etc.).
3. *NMT corridors*. The NMT roads can for instance be optimized by leveling the road surface, providing elements for shade, placing street lights, stimulating some minor roadside activities and perhaps lay special pavement. There will not be many roads in the network of this category. In fact, previous missing links will fall in this category.
4. *Wide mixed corridors*. Just as with the wide activity corridors a cycle lane or road reserve can be considered. On these category roads, however, the cycle lane will not so much be threatened by non-travel activities, which means that less enforcing elements are necessary.
5. *Narrow activity corridors*. On these roads it will prove more difficult to facilitate the cyclists. Here the decision can be made to use the road surface for MT for cyclists as well, in order to minimize dangerous encounters with pedestrians and elements related to non-travel activities. In order to improve traffic safety traffic calming measures should be taken, complemented with a limited number of safe crossing (enforced by fences etc) and a possible ban for lorries.
6. *Narrow mixed corridors*. Possible solutions on these roads are quite similar to those for the previous category. Since non-travel activities are limited, measures for a soft separation of pedestrians and cyclists on the same sidewalks can be considered.
7. *NMT connector roads*. The roads in this category can be quite diverse in their appearance and therefore the relevant measures can be versatile.

Missing links

For assessing the feasibility of realizing a missing link a logical step would be to obtain an expert guess on the costs to overcome the obstacles present. On the benefit side further study needs to be carried out concerning the possible NMT demand. Besides an inventory of origins and destinations on both sides of the missing link a survey can be conducted among households to investigate the possible usage of the link.

CONCLUSIONS

For identifying NMT routes and cycle routes in particular the 'Cycle Through' method has proven to be a valuable tool. The method suggested the same cycle routes as the ones identified by experts of I-CE. Moreover, it came up with a couple of missing links that were not yet identified. Despite these promising results, it should be kept in mind that the method depends heavily on its input, i.e. the production and attraction of zones, an OD matrix and skim matrices for the zones. For Dar es Salaam several assumptions needed to be made on the NMT *production and attraction* of zones.

Especially the NMT attraction proved difficult to estimate, even in a relative sense. If no extensive household survey has been made, a way forward is to derive relative attraction factors from NMT counts or for example the number of bus stops, which might represent attractiveness. For the DSM case we used an *OD matrix* derived from a comprehensive NMT study in 2004. Although the derived distribution values looked quite plausible, we were not able to assess whether these values taken from a part of the city are valid for the whole city. In case there is no OD data available, surveys could be carried out at a couple of representative screen lines on major routes. The *skim matrices* we used for the DSM case were of good quality. A skim matrix containing distances between zones over the network can easily be obtained with the help of GIS maps and software. If this is not available, one could use a road map or measure routes by travelling on them.

Because of the difficulties concerning the input, the method can best be used as a quick scan for NMT routes or as a check for routes identified with other methods. The results might not have an absolute meaning, but are valuable in a relative sense. The question remains whether a yet simpler method would lead to the same results. In the case of Dar es Salaam this might have been true. The answer to this question is related to the coarseness of the zoning. With smaller zones more detailed links can be found and more distinction can be made between cyclists and pedestrians. Indeed, the method could also be used for identifying routes within residential areas instead of just between them. The problem is however that more and better data will be needed to perform such an analysis. Therefore, the usage as a quick scan for major routes seems more appropriate.

With the help of 'Cycle Through' existing and possible cycle routes can be identified. Their feasibility can be further assessed by getting an idea of the necessary measures and the costs involved. For this task a categorization of roads is helpful and we gave an example how this can be done. It is important to note here that infrastructural measures that are undertaken do not give a guaranty that more people will cycle. Indeed, the findings of the NMT study of 2004 showed that the lack of proper infrastructure is one of the main reasons for people not to cycle. We need to realize, though, that as the NMT study shows there can be many other reasons for not cycling and these reasons can be intertwined with each other. The cycle master plan from AALOCOM should acknowledge this and ways need to be found to lift all the barriers concerning cycling.

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