URBAN TRANSPORT, PERFORMANCE AND COST MATRICES

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Abstract

Assessment of the cost-effectiveness and total costs of an urban transport system is the indispensable base for the key urban transport policy choices: (a) target modal split; (b) city expansion policy, i.e. segregated or with integrated sub-centers; and (c) traffic demand management and traffic calming policies.

It is desirable to have a robust assessment method, that also provides a tool for monitoring the development over time. The paper outlines such a macro model. In the past, lack of understanding of the total costs of the transport system has often lead to transport policies, that with the wisdom of hindsight might not have been implemented.

BACKGROUND

Urban transport crisis in developing cities

Transport in many cities in Africa, but similarly in Asia and Latin America, is in a state of permanent crisis, triggered by the combined effects of the rapid city growth, increased car use for urban trips and failure to manage and calm the traffic properly. Examples of degrading accessibility are much easier to find than examples where the performance of the urban transport system is improving.

The combined impacts of very day-to-day policies, special group interests and financing opportunities have in many cities created transport "solutions" that can no longer just be seen as the unpleasant effects of city expansion, growth in personal incomes and failure to control land use. The conclusion cannot be escaped that the transport crisis is itself a key cause of the main urban development problems, such as malfunctioning of the city economy, a very low environmental quality, and the virtual exclusion of large masses of people in economically stagnant slums (very low mobility, no access to work or services).

Comprehensible and reliable transport system information

This paper proposes an elementary aggregated model, quantified on the basis of observations only, and meant to investigate the consequences, in terms of travel time and cost, that different policy scenarios will have if they materialize. The feedback loop on feasibility (can effective instruments to make the preferred policy work be found and applied successfully) between the second steps and the first step -the macro assessment- is of course extremely important, but should be functioning primarily through annual monitoring at the macro level, rather than be a theoretical modelling exercise. The second step can probably be attempted best as a series of separate cause-effect studies to identify the best policy instruments to achieve the desired goals. The usual complete, network-based, traffic forecasting model probably has its most important virtue in allowing a consistency check between different partial analyses, rather than as a forecasting tool. This is because such a model puts the uncertainty margins of a large number of components in series, and is as such of limited relevance for cause- effect considerations.

To find out whether more promising urban transport scenarios would be possible than the locally existing one, one must only be able to answer a few questions first:

- what does the current situation cost, and what does one get in return i.e. performance, measured in terms of mobility, travel time and comfort, accessibility?
- how do the existing system parameters (trips made per day, average travel speed, unit cost per passenger kilometer and per ton-km, accidents) compare to those in other places, where different urban transport scenarios were developed?
    - what explains the differences?
    - can a transition to more satisfactory urban transport system scenarios be created?

THEORETICAL FRAMEWORK

Urban trip distances

The first basic dimension of an urban transport system is the number of trips made and the distances involved. The trip pattern as it exists at a certain moment in time is not the "demand for transport", but the actual equilibrium at that moment between demand and supply. The trip pattern can best be measured by means of a household interview, asking respondents to specify their actual trips on the previous day. Unfortunately, the number of observations required to obtain a statistically reliable estimate of the trip pattern between zones of origin and destination at a certain moment is quite large (depending on the required detail in terms of zones, a sample size in the order of 1% of the population may be required). This is a reason to translate the data from substantially smaller surveys into trip generation and trip distribution models that estimate trip patterns. In their simplest form these are coefficients per market segments. Additional information from traffic counts can also be used to improve the estimates, but in many urban areas -in particular when most trips are made on foot or by public transport rather than by private car- traffic count data deviate strongly from travel survey data. Common causes for the misfit between the two being that: (i) the traffic counts miss all trips that do not use the main road system; while (ii) in situations where cars are very expensive relative to average incomes and many car owners have a driver, the travel survey underestimates the extra trips made with the car by the driver during the day, on top of the ones made and reported by the owner (respondent).

However, the most difficult aspect of travel demand is not the current pattern, but its development over time. Traffic demand models try to predict future travel demand, by predicting the values of the so-called explanatory (or independent) variables (such as age composition of the population, employment, household incomes, future land use, future travel costs) and calculating the expected travel demand with the model. But in many cases, looking at them when the year that was forecasted has come, the quality of the forecasts turns out to be modest. This is most of all true in situations where urban areas grow strongly, and undergo substantial shifts in modal shares, processes that cannot be predicted with static travel demand models.

In most of the cities in the developing world, the strongest forces that influence future trip patterns are: (a) private vehicle ownership (car or moped or bicycle) and (b) locational choices (residential, business). Daily ("momentary") trip making and mode choices depend strongly on the preceding "permanent" vehicle ownership choice; trip destination choices depend strongly on the much more permanent locational choices. A similar process, locational choices determining the urban transport development, triggered by changes in accessibility (new roads), characterized urban developments in Western Europe during the 1960-90 period (de Langen and Verster, 1979). It is interesting to note that in state-of-the-art transportation engineering traffic forecasting models the first aspect, that of the car ownership choice being a very strong force, coming first in the model hierarchy, has now been made operational. However, surprisingly, the second aspect, that of locational choices, commonly is still left out of consideration, despite the fact that for long-term forecasts it has turned out to be the one creating most changes, e.g. (Algers *et al*, 1995).

In this process the tendency has been a *strong increase in trip distances*, with a marginal increase or even a decrease in the number of trips. The increase in trip distance at the same time means a *strong increase in costs*, particularly where the change involves transition from a cheaper to a more expensive (private car) mode of transport. In Europe, first many -newly- car owning households moved to remote suburbs and peri-urban villages, in a second wave many firms relocated from concentrated inner cities to much more dispersed locations along the main urban and inter-urban highway corridors, which were very accessible by car or truck, but almost inaccessible by traditional public transport networks and were for most people too far from their homes to walk or cycle to (or without Non Motorized Transpot (NMT) infrastructure).

In Africa, Asia and Latin America the process the urban expansion process is very different from that in Europe or the US, but there is also the striking similarity of being very dynamic and *strongly influenced by the opportunities created by the available transport infrastructure and means of transport*. Large differences between urban growth patterns in different developing cities exist. For example, in much of Asia urban densities are very high, mega cities many and inner city parts labyrinths that are almost inaccessible for motor vehicles, while in e.g. Sub Saharan Africa, many large cities have relatively low density/high income central parts and dense low income townships (compounds, slums) at remote locations. However, the big difference between all rapidly developing urban areas in Africa, Asia and Latin America on the one side and European and North American cities is that the former are the home of very large masses of low income and very low income inhabitants (in most cases the large majority of all inhabitants) (Vasconcellos, 1997). They have no access, and will not get substantial access, to private motor vehicles and can only afford to live in high density settlements, which are nevertheless often increasingly remote from job opportunities and services. In developing cities, available money and time are (in that sequence) by far the strongest determinants of the trip patterns that develop; contrary to e.g. Western Europe, where trip costs and travel time only have a limited (and diminishing) influence on urban travel behaviour.

The most appropriate response of urban managers that want to provide their city with a more cost-effective and efficient urban transport system appears to be to shift the attention from forecasting of travel demand to:
(a) assessing the cost-effectiveness that different future scenarios can be expected to have;
(b) monitoring the actual development of the trip patterns at a "macro" level;
(c) checking whether the changes that one observes are heading towards or away from more desirable -cost effective- patterns, and
(d) analysing the reasons why, with special emphasis on the role that new roads and new public transport or NMT infrastructure play in locational choices.

This paper describes a framework that can be used to do (a), the macro cost-effectiveness assessment, and (b), the monitoring -by an annual update of that assessment. In a standard application, environmental costs should be included in the total cost matrix by including them in the unit cost per mode. However, in cases where they are in fact the most critical concern, the environmental costs can better be shown explicitly, in a separate cost matrix. In that case there are two cost matrices, one for environmental and one for all other costs.

Modes of transport

The second basic dimension of an urban transport system is the modes by which the trips are made. In each distance class, what is the share of the main modes of transport (walk, cycle, public transport (bus), private car, in some cases moped, tri-cycle)? The combination of trip generation, trip distance distribution and modal split provides a complete specification of the trip pattern in the urban transport system. Urban freight is left out of consideration in this paper, but should in real applications be included.

The various modes of urban travel have very different characteristics with respect to efficiency, cost, operating speed, flexibility, comfort, image, road space requirements, nuisance or danger to other road users (noise, traffic accidents, air quality). The characteristics of the different modes of urban travel (walk, cycle, bus, rail, car) that are taken into account in the assessment method described in this paper are their costs (investment, operational costs, indirect costs) and their overall journey speed. Other aspects, which may be very important for their actual use, are left out of consideration here, in particular their perceived comfort and the perceived image of their users.

Intangible aspects such as the urban atmosphere and beauty (is it a pleasant town? is it the town we want?) are very important. Quantitative assessment of trip patterns and modes of transport is not the only way to observe transport system qualities. Urban transport characteristics are also sensed intuitively by everybody, reflected as they are in the structure, environment and atmosphere of an urban area. Parts of cities dominated by metro/underground or light rail systems, or cars, bicycles, mini-buses or pedestrians are all valued distinctly different by both inhabitants and visitors. And although large differences in judgement and preferences exist between individuals, it is interesting to note that many cities that have inefficient and very cost-ineffective transport systems are perceived by most people as unpleasant and/or ugly.

Cost of the different modes of urban transport

It is difficult to present a simple overview of the unit costs per passenger km of the various modes of urban transport, since these are quite different in different countries, depending on the type and age of vehicles, utilization levels, infrastructure stock, driving behaviour,and taxation or subsidy (the last two affecting private financial costs to users, but not affecting national economic costs). (Replogle, 1992) and (de Langen *et al*, 1993) have attempted to give an overview, which is summarized in table 1 below (averaged and adapted to the same base year).

Table 1 - Unit costs of various modes of urban transport

	# passengers estimated average	**unit cost per passenger-km** USD cents, 1993
Individual modes		
Walking		-
Cycling in mixed traffic		0.4 - 0.9
Cycling on cycle track network		0.3 - 0.6
Moped/scooter		4 - 8
Private car		15 - 30
Collective modes		
cycle rickshaw	1	3
shared taxi	4	3
mini bus	9	3
midi bus	25	2.5
stage bus	80	2.5
stage bus on bus lane network	80	2.0
urban light rail	na.	3.0

Note: the collective modes are calculated for the most basic comfort level, operated in efficient systems with a high load factor (see average number of passengers per trip).

Since most of the cost components of motor traffic (vehicle, spares, fuel) are roughly the same world-wide (leaving taxes apart) and have to be paid in strong international currencies, there is a huge difference in the *relative* costs of an urban passenger-km as a percentage of per capita income between rich, intermediate and poor countries. In this respect the transport sector is different from education, or health care, or a significant part of the construction sector, where the local labour costs component is so important that the *relative* costs of these services -as a percentage of the available local income- are more similar between countries with very different income levels. In the transport sector (as is increasingly the case in many industrial production sectors), *absolute* costs -in foreign currency equivalents- are fairly similar internationally. This dictates that urban transport systems in developing cities can never be analogies to those in Europe, North America or Japan, because the money for them is not, and will never in the foreseeable future, be available. If superficially it seems that they are similar, this error of judgement is because the portion of the system that one is aware of and looking at at the moment that this thought occurs is only a small part of the total system, and carries a similarly small part of the total population (typically the middle and high income fraction).

Speed of the different modes of urban transport

In urban transport the common sense notion that walking is slow, cycling a bit faster but also slow, a bus is in-between, and metro and car are fast *does not apply*. For the vehicles themselves it is true, but for their operation in urban transport systems it is not. There, the network dictates the performance, not the vehicle. Door-to-door travel times in urban networks depend strongly on intersection efficiency and delays, the directness of the connection (particularly for pedestrian and cycle trips), the number of interchanges between buses/metro lines, walking distances to/from parking points and public transport stops, and traffic jams. The incidental top speed that the vehicle in use (car, bus or metro) can reach during the trip at a certain section of the network is almost irrelevant to the overall average speed that is achieved. Table 2. gives a few data on observed average urban travel door-to-door speeds.

Table 2 - Typical urban travel speeds

	operating speed average (km/hr)	**door-to-door speed** average (km/hr)
Individual modes		
Walking	4	4
Cycling in mixed traffic	10-12	10
Cycling on cycle track network	10-18	13
Moped/scooter	15-30	20
Private car	15-30	15
Collective modes		
cycle rickshaw	6-10	6
shared taxi	12-20	10
mini bus	12-20	10
midi bus	12-20	10
stage bus	12-20	8
stage bus on bus lane network	30	12
urban light rail	35	12

The data are derived from (Replogle, 1992) and (de Langen, 1993).

For an objective assessment of the actual performance (efficiency and cost-effectiveness) of the various components of an urban transport system it is important to use actual average door to door travel speeds achieved by the various modes of transport. It is interesting to note that this average speed is in many cases very different from the so-called design speeds that are used when the road networks are constructed or reconstructed. These design speeds are usually far higher than the actual average speeds. This discrepancy between technically possible maximum speeds -from a vehicle and road specifications point of view- and urban network and traffic-mix dictated limitations is one of the common causes of unsafe urban traffic conditions, in particular during off-peak periods.

Performance matrices

The three of the four dimensions of an urban transport system described in the previous paragraphs, trips/distances travelled, modes of transport and travel speed jointly allow a comprehensive assessment of the technical performance (the output) of an urban transport system. By adding the fourth dimension, costs, the "value for money" aspect can be assessed. First it is useful to give a summary of the technical performance.

The mobility matrix and the travel-time matrix

The mobility matrix is defined as

X(i,j) whereby one cell of the matrix, $x_{i,j}$ counts the observed (estimated) number of trips by mode of transport *i*, in distance-class *j*, $\sum_{i,j} x_{i,j}$ = the total number of trips made in the system (per observation period, week or year)

The travel-time matrix is defined as:

T(i,j) whereby each cell, $t_{i,j}=x_{i,j}*d_j/v_i$, and d_j is the average trip distance in distance class *j*
v_i is the average door-to-door travel speed using mode of transport *i*, $\sum_{i,j} t_{i,j}$ = the total travel time in the system (per observation period, week, or year)

To judge the output of the transport system both the mobility matrix and the travel time matrix must be known with reasonable accuracy. T(i,j) can be estimated from the mobility matrix using average door-to-door travel speed measurements (speed averages per distance class should be taken, since average door to door speed increases with trip distance for most modes of transport). Jointly, the mobility matrix and the travel time matrix specify the performance of the transport system.

There is one important performance, or rather adequacy, aspect of the transport system that has not yet been quantified through the mobility matrix and the travel time matrix: *accessibility*. Accessibility and mobility are two sides of the same coin. Mobility describing the trip making of the travellers in the system, accessibility describing the ease of reaching activity locations (residential, employment, services). Two simple indicators for accessibility that can be used to supplement the mobility and travel time matrices are the *average cost radius* (total travel cost to an activity location) and the *average travel time radius* (travel time to an activity location) within which a fixed number of potential customers for that activity can be found. For example: what is the travel cost radius surrounding a certain residential area within which a fixed number of job locations can be found. Are 50,000 job locations within reach with a travel budget of 1 US$, or 3?, 10? 20? Or, expressed in travel time: within what maximum (door-to-door) travel time can 100,000 potential clients for a certain market be found? 20 minutes, 30, 90? The lower the cost radius of the important activity locations and/or the lower their travel time radius, the higher the performance of the transport system in providing good accessibility. This measure of the quality of accessibility clearly includes the effect of urban land use density and activity integration, so it describes the combined quality -with respect to accessibility only- of the existing land use plus the transport system. No accessibility indicators as defined here have been calculated yet for the case study that is presented in this paper, they will be the subject of further research.

The costs matrix

The remaining factor is travel costs. These can also be estimated from the mobility matrix, using the unit costs per km of each mode of transport and average trip distances per distance class. The measure can be direct financial costs, or include secondary effects of transport (economic costs), as appropriate for the purpose of analysis. The matrix of total travel costs per distance class and mode of transport is referred to as the travel cost matrix. The total travel cost matrix is defined as:

C(i,j) whereby each cell, $c_{i,j}= x_{i,j}*d_j*cm_i + t_{i,j}*c_t$, and d_j is the average trip distance in distance class *j*, cm_i is the unit cost per km using mode of transport *i*, c_t is the average value of travel time, $\sum_{i,j} c_{i,j}$ = the total travel costs in the system (per observation period, week or year)

The total travel cost matrix as defined here does not include the costs of the transport infrastructure (roads, tracks) used by the traffic. The method of calculating the unit costs of each mode of transport can be chosen depending on the purpose of the analysis: financial or economic analysis. For financial analysis the current market prices must be used, corrected for yearly inflation in case of monitoring the development of the transport system over time. For economic analysis the usual corrections to financial costs should be made to estimate the economic cost, most importantly: elimination of transfer payments, the use of shadow costs for foreign currency costs and for labour costs, and inclusion of indirect costs that the transport system is not financially charged for (mainly costs of accidents and environmental costs).

Measurement and accuracy

Measurement of the data needed to calculate the three above mentioned mobility, travel time and cost matrices is comparatively easy. The measurement of the mobility matrix is the most complicated task, measurement of the additionally needed unit cost data (sample of commercial data of operators and private vehicle financing and operating costs) and door -to-door speed data (sufficient sample of door-to-door trip measurements) is straight forward and can be done quickly. The most important aspect of the quantification is to pay enough attention to the accuracy of the measurements and consistency checks to trace and eliminate measurement errors. As already mentioned in paragraph 2.1. a key element is to use data from different sources to countercheck each other rather than in a sequential manner. For example, while comparison of traffic counts on road sections with travel flows estimated from a limited household survey is difficult because route choice is unknown, a cordon count in a certain area is much more reliable as a consistency check, provided that all unofficial walking tracks are included in the cordon. The number of public transport users can be checked between road traffic counts and household survey data after public transport vehicle types and average occupancy are estimated, etc. The subject of optimizing the reliability of the required information with a minimum of data is an interesting area of further research.

Necessary and sufficient information

For the providers of public services such as road and track infrastructure, traffic by-laws and regulations and their enforcement, traffic management schemes etc. -usually the municipal government and, partly, the national-, it is important to reflect on two aspects of the information that is used to manage an urban transport system: what pieces of information are necessary, and what overall package of information is *sufficient*. If important pieces of information are overlooked and not available, reaching good day-to-day management decisions as well as good long term strategies will, to an unnecessarily high degree, be a matter of luck. But if, on the other hand, out of a feeling of uncertainty and lack of understanding of the most important driving forces of an urban traffic system, a very large number of data are collected indiscriminately, the overdose of data will obscure the understanding of the main aspects. Analysts will indulge in technical detail studies without policy guidance, and will subsequently market their solutions to policy makers. Those in turn lack the information on the bottom lines, and take decisions based on their individual perceptions.

A typical example of a mixture of too much information on details and too little information on overall system performance and cost can be found in the report Cities and Transport (OECD, 1988), which describes the transport system status, problems and intended policies in ten important cities in OECD countries (a.o. Athens, Los Angeles, London, Paris, Singapore). For none of the ten cities has the actual performance of the transport system been reported clearly and in a comprehensive manner. Information on travel times, distances and costs is limited for most cities and completely lacking for some others. Long term strategies are not discussed systematically in terms of the desired performance of the transport system in future, and a large part of the report consists of proposed policies focussing on problems of one particular mode of transport, most of all environmental degradation caused by car traffic and the operational and financial problems of public transport.

Many of the examples are very interesting, but scattered and without a comprehensive policy framework.

The assessment method proposed in this paper aims at providing the required initial balance between too little and too much information. It defines a package of information and analysis that is considered "necessary and sufficient" as a first step to keep urban transport systems under control and guide them in the most desirable direction. It is hoped that further discussions within the transportation profession in forums such as the WCTR, where this paper is presented, will contribute to the development of an improved and generally applicable macro assessment method. It is hoped that this will provide much of the ongoing detailed work with an overall framework that allows to see better in what direction urban transport systems are heading, whether that is the desired direction or not, and how detailed policies may -or might not- contribute positively to the desired development.

CASE STUDY: DAR ES SALAAM AND MOROGORO

In this paper the mobility, travel time and cost matrices for a part of Dar es Salaam, Temeke, are shown, plus for comparison the mobility matrix of Morogoro, a smaller town in Tanzania. The example shows that the three matrices, (a) can be estimated without too much difficulty; and (b) together provide the type of assessment of the status of the transport system that is wanted as the basis for decisions about long-term traffic policies; and (c) could adequately monitor traffic system improvement or deterioration, if measured over a longer period of time.

The method of describing the urban transport system in this manner clarifies the contribution of each market segment (mode of transport and trip distance category) and the corresponding logical priorities for achieving a better performance/cost ratio for the system as a whole. For example, the data of the Temeke area in Dar es Salaam show that its transport market is an clear case of market failure: a mere 6 percent of all trips, made by private car, require 54 percent of the total system cost, 60% of the money spent on urban transport, and claim more than 70% of the road network and the associated public investment. From the point of view of creating efficient and effective urban mobility and accessibility a worse mis-allocation of funds is difficult to find.

The mobility matrices of Temeke and Morogoro

The mobility matrices (Tables 3 and 4, presented here in percentages because that is easier to understand for a reader not knowing the area) show a number of interesting things:

- In both cases the overall mobility is low, less that two trips per adult per day (going+ going back= 2.0 trips). Based on international comparisons, the target value for an efficient urban area should be 3.0 or more.
- Walking is the dominant mode of transport in both cases,
- Cycling is the second important mode in the medium-size city, Morogoro (from further analysis it appears that the limiting factor on its use is mainly the affordability of bicycles),
- Cycling is almost absent in the big city (the main reason is that poor traffic safety makes cycling almost impossible),
- In Dar es Salaam, bus traffic (mostly informal minibus (dala-dala) services) is the main carrier of trips that are too long to walk (in the absence of the cycle option), but in the much smaller city of Morogoro urban bus traffic is secondary in importance to cycling (in Morogoro longer trips can be cycled),
- Private car traffic is unimportant as a means of personal trip making for the large majority of all travellers, in both cases.

Table 3 – Mobility matrix (Temeke, DSM)

distance (km) mode	0-2	2-5	5-8	>8	Total
WALK	23	20	3	0	46
CYCLE	0	2	0	1	3
BUS (PT)	2	11	4	27	44
CAR	0	2	0	3	6
TOTAL	25	35	7	31	100

(total trips per adult (>=15 years old): 1.9/day)

Table 4 – Mobility matrix (Morogoro)

distance (km) mode	0-2	2-5	5-8	>8	Total
WALK	27	33	7	0	67
CYCLE	2	8	4	3	17
BUS (PT)	1	3	1	7	12
CAR	0	0	2	2	4
TOTAL	30	44	14	12	100

(total trips per adult (>=15 years old): 1.7/day)

Table 5 – Travel time matrix (Temeke, DSM)

distance (km) mode	0-2	2-5	5-8	>8	Total
WALK	10	32	10	1	52
CYCLE	0	1	1	1	3
BUS (PT)	1	5	3	33	42
CAR	0	1	0	2	3
TOTAL	11	39	14	37	100

Road space requirement priorities

To assess priorities with respect to the demand for road space, the modal shares in terms of passenger-km's are the most relevant measure. These passkm shares are approximately:

	walk	cycle	bus	car	total
Temeke	32	3	57	8	100
Morogoro	51	22	19	8	100

These data indicate that the most important road infrastructure requirements are for bus and pedestrian traffic (big city) and pedestrian, cycle and bus traffic (medium city). The pedestrian infrastructure requirements are very important: walkways separated from the motor-carriageway, and safe (frequent , no detours) crossing facilities. It is interesting to note that traffic counts on the main roads often show a modal share for trips on foot that is much lower than the one shown in the mobility matrices which are based on travel surveys, because most trips on foot are on access roads and tracks.

If one calculates the vehicle-km's in the network rather than the passenger-km's, and omits the bicycle as a vehicle, then the private car comes at the top of the list (car occupancy average 2, bus occupancy average 20). This reflects the well known aspect that in Sub-Saharan Africa (SSA) cities cars, although only carrying a minor fraction of all trips (or for that matter of the passenger-km volume), claim the lions share of the available road space on the core network of urban roads.

Unit cost of urban transport in DSM

Table 6a (below) shows the average direct financial unit costs of transport of the four main modes of transport. Table 6b gives the total costs, including a valuation of the travel time involved. The value of time used is 1/12 of an average daily wage of someone (unskilled) without a permanent job, which is a reasonable approximation of what an average person can manage to earn additionally in their spare time. Both are operational (trip making) costs only, the costs of the infrastructure and of external effects such as accidents are not included in these estimates. The conclusions from tables 6a and b are:

- Walking and cycling (NMT) have much lower costs than either bus(dala-dala) or private car (MT), but the real watershed in cost is between the private car and all other modes of transport.
- Cycling has by far the best performance (lowest total unit cost) of any urban transport option. Taking travel time into account, walking is not all that cheap, it is almost twice as expensive as cycling and not much cheaper than bus transport.

Table 6 - Cost of urban transport in Dar es Salaam (1996)

mode	WALK	CYCLE	BUS	CAR
a. direct cost (Tsh / pass.km)	1	6	20	150
b. direct cost + time costs	20	9	25	154

Total cost of urban transport of Temeke inhabitants

In the total costs matrix for Temeke (DSM) shown below, the mobility matrix and the unit cost data are combined to give the total costs of all daily urban trips made by inhabitants of that area. The cost shown are the direct trip costs plus time costs. Infrastructure costs, both new investment and maintenance, are omitted, as are the costs of accidents, noise and air pollution.

Table 7 – Total travel cost matrix (Temeke, DSM)

distance (km) mode	0-2	2-5	5-8	>8	Total
WALK	4	1	1	0	6
CYCLE	0	0	0	0	1
BUS (PT)	0	5	3	31	39
CAR	1	11	3	40	54
TOTAL	5	17	7	71	100

Average cost per person/day = 210 Tsh (550 Tsh = 1.0 US$). Total area +/- 10km2, adults 100,000 (>= 15 year old, total pop. 150,000). Total cost (trip cost+time cost) per year 7,800 million Tsh=14 mill US$

Performance: mobility versus costs

Table 8 is a summary of the cost matrix and the mobility matrix. It shows the percentage of all urban trips served by each mode of transport and the percentage of total financial + time costs that each mode of transport claims in return.

Table 8 - Modal share and cost share per mode of transport (Temeke, DSM)

mode	WALK	CYCLE	BUS	CAR	TOTAL (USD)
modal share	46	3	44	6	
cost share	6	1	39	54	100% = 14 million

The Temeke area in Dar es Salaam has an estimated population of 150,000, with an estimated total area income of 45-50 million US$. The total amount of money spent directly on transport by inhabitants from Temeke is estimated at 12 million US$ (excluding cost of time), or 25% of the area income. In Morogoro the percentage of income spent on urban transport is a bit lower, because more of the trips are on foot and by bicycle.

The conclusions from table 8 are:
1. The total amount of money spent annually on urban transport is high. If 10% of this amount would be spent as an investment in road infrastructure for both NMT and MT, the road networks of most SSA cities would look very different from what they look like now.
It should be emphasised that this money is now spent from local sources by local parties, so re-allocating the expenditure could be done without any external financial inputs such as "donor aided" projects: all the money is already there, the only challenge is intelligent spending.
2. The contribution of private car transport to urban trip making is small, and disproportional to the costs involved. To carry 6% of all trips (or 8% of all passenger-km's), the cars consume 54% of the total costs (60% of money spent). From an economic point of view this represents a serious misallocation of funds, and transport policies should aim at adjusting that.

ECONOMIC IMPORTANCE OF THE URBAN NMT ISSUE

Mobility

The modal shares are expressed in terms of trips, since the main measure of mobility is the trips made between an origin and a destination. The trip distance is not so important as a measure of the effective mobility in a city. What matters is the number of different activities that can be carried out at different places, connected with a trip between two locations. In fact, if many trips involve a long distance because the desired trip destination is far away from the trip origin, this represents a negative feature of the land-use pattern in the urban area, rather than being the reflection of a healthy degree of mobility.

The data reveal a low level of mobility in both places (DSM and Morogoro). Clearly the cost of additional mobility with motorized transport cannot be afforded. To increase the mobility, only strategies involving increased trip making by non motorized means of transport can be expected to have a real impact. Most importantly these are: policies to allow safe and efficient urban cycling, plus strategies to get a better spread of services over the entire urban area, allowing access on foot. One aspect should be thought of when reflecting on the possibilities to increase mobility. A significant aspect of the low mobility is the low level of economic activity (the large unemployment and the low productivity of the existing jobs). A low level of activity and a low mobility are for many people linked in a vicious circle: low mobility because of very low income, very low level of income/activity because of lack of mobility. Increased low-cost mobility can contribute to higher efficiency (productivity) of the urban economy as well as to higher productivity of "self help", i.e. improvement of their houses, local drains etc. by (groups of) households because it facilitates communication (/organization) and the search for inputs. But although proper mobility enhancement policies can play a very useful role, they can only be really successful as a complement to sensible economic policies.

Accessibility

Accessibility indicators as proposed in paragraph 2.3 have not yet been calculated. From the data in the mobility matrices it can already be seen that at this moment in time accessibility of most of the important trip destinations in Morogoro is actually reasonably good. It can be further improved by making the bicycle available for access to a much larger part of the population (particularly the female part). But as important as trying to improve the existing accessibility of the main destinations, is to prevent the accessibility from going down. The most threatening developments in this respect are (i) deterioration of the travel time radius because:
- cycling becomes more dangerous for trips from the outer parts of town to the city center (forcing a shift to walking or buses, which are both slower door-to-door),
- residential expansion continues outward in low densities without a further spread of schools, markets and jobs,
and (ii) deterioration of the average travel cost radius, because of a shift towards higher cost bus traffic.

In Temeke (DSM) the travel time radius is rather low compared to the newest parts of town, because the mixture of urban functions in Temeke is quite intense, land use density high and segregation between different population groups not very strong (still a heritage of the past social and housing policies of the Tanzanian Government in the 1970's and early 80's). The most promising strategies to improve the accessibility indicators, in particular to get the average travel cost radius down, is to implement preferential treatment for buses in the CBD traffic jams (dedicated bus-only routes) and to allow access by dedicated cycle tracks to the CBD.

Economic reality

Combining the different aspects of performance, total costs, unit costs, trip distances and the actual number of trips made, one can conclude:
- The most important challenge that urban transport professionals (and policy makers) in SSA face is to *reduce* the total cost of urban transport, and at the same time *increase* the number of *trips* that the average person can make.
- To achieve this *improved mobility at reduced cost* it will be vital to make the best possible use of the potential of Non Motorized Transport. As much as possible trips should concentrate in the upper left corner of the mobility and cost matrices: over *short to medium distances, and on foot or by bicycle.* On neighbourhood and area level roads (access roads and local collectors) NMT should be prioritized over MT. Concentrated high frequency bus (matatu etc) services should cater for most of the long distances in urban transport and be prioritized over private car traffic on urban corridors.
- The most *threatening urban traffic and mobility development* that can take place is a shift towards ever longer trip distances, growing dependance on fragmented bus route networks and private cars, and even less trips that can be made within the available money and time budgets of the average person.

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