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International review of the significance of rail in developing more sustainable urban transport systems in higher income cities

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Editorial Introduction

If a residential area in the full sense of the word (a collection of men, women, children, teenagers, parents with babies, those over the age of 70, healthy, not healthy, worried, over-confident) could select the level of probability of death and serious injury would they go for a high risk or a low risk?

On June 17th 2008 a group of 20 elected representatives in Lancashire (UK) encouraged by a self-selected group of local residents chose the high risk option. The committee was asked to determine a proposal to introduce a 20mph zone in Silverdale in North Lancashire. Those opposing the idea expressed a strong dislike of humps and bumps that would be introduced to slow traffic. They also expressed concerns about losing car parking places. The opposite argument was put about the benefits of a 20mph speed limit (even one without humps and bumps) but the committee dismissed the whole idea of 20mph in Silverdale and the scheme was scrapped.

The committee of elected representatives chose to impose a higher degree of risk of death and injury on the streets of Silverdale.

The evidence on risks and probability could not be clearer and the World Health Organisation has reinforced the importance of speed limitation to 20mph/30kph, as a major part of the global effort to reduce the 3000 deaths each day in road crashes. Figure 1 shows a very clear relationship between pedestrian fatality risk and the impact speed of a car.

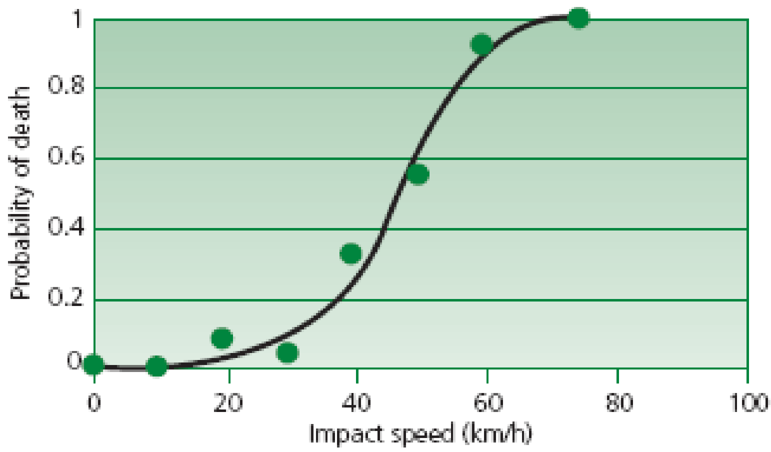

Figure 1: Pedestrian fatality risk as a function of the impact speed of a car
Source: World report on traffic injury prevention
http://www.who.int/violence_injury_prevention/publications/road_traffic/world_report/chapter3.pdf

The decision of elected representatives to increase the chances of death and injury in this community tells us a great deal about transport policy and the enormous barriers we have to overcome to achieve progress. This has been a recurrent theme of the material in this journal for 14 years and if anything the last 14 years have seen a decline in intelligence and ethics in the road traffic environment alongside an increase in fine policies and fine language that is never translated into improvements on the ground. The decline in intelligence is patchy. It is particularly severe in the UK where traffic growth and economic development have been elevated into high level theological objectives with no grasp of alternative scenarios and alternative ways of creating sustainable economies at lower levels of carbon output and lower levels of demand for transport and fewer deaths and injuries in road crashes. Sweden is at the opposite end of the spectrum with high level policy objectives that have been captured in the road safety policy known as "Vision Zero" (there will be zero deaths and serious injuries in the road traffic environment) and it's oil-free by 2020 policy.

So what do we do next?

First of all we have to acknowledge that the problem is a mindset problem. Large amounts of science and research and even best practice will not persuade policy makers who live in their cars and enjoy a high carbon/high mobility life style to visualise a different world. Science and rationality does not work. Secondly we have to find ways to work from the bottom up. Every street and every community should be empowered to articulate its own view of a desirable future and then have the capacity to deliver it. If this means inventing Utopia then so be it. Thirdly we could all become politicians. I don't recommend this for health reasons but someone once said in a UK political broadcast when speaking about how to sort out "the environment":

Don't change your light bulbs, change your politicians…

History is full of major shifts in mindsets and policy including:

- The abolition of slavery
- Stopping children working down coal mines and in factories
- Providing clean drinking water to working class homes in cities in the 1850s and 1860s in the UK
- Introducing the National Health Service (UK)
- Clean air legislation in the 1950s that got rid of yellow smog

The task for all of us in transport is to identify the virtuous DNA or virus that brought about these enormous changes and infect the body politic with the same and do it now.

Are we up to the task?

Note:

The decision of elected representatives to abandon a 20mph scheme in Silverdale in North Lancashire (UK) can be followed through the minutes of the relevant committee. The committee is "Lancashire Locals, Lancaster" and it met at the Midland Hotel in Morecambe on 17th June 2008. The 20mph item is Agenda item 6 "Emesgate Lane Area, Silverdale Proposed 20mph Zone". Minutes and agendas for this committee can be found on:

http://www3.lancashire.gov.uk/council/meetings/committees/locals/committee.asp?cid=1278&sysredir=y

Abstracts & Keywords

Sustainable intermediate transport in West Africa: Quality before quantity

Bryan Dorsey

This research provides a brief review of the scant previous studies of non-motorised modes of sustainable transportation in Sub-Saharan Africa urban and peri-urban areas. Particular attention is given to the need to encourage bicycle transit in West African secondary cities. Although the Institute for Transportation and Development Policy (ITDP) has made considerable progress in developing improved bicycle transportation, much work remains. In their outstanding effort at decentralised cooperation, ITDP has identified key countries for development of the market for quality bicycles, yet some important secondary cities have been thus far, overlooked. This study identifies the potential market for ITDP's quality, yet affordable, "California Bike" in Togo's second largest city, Sokodé. It is argued that ITDP's strategy to focus on quality rather quantity of bicycles is well founded, but significant marketing obstacles have yet to be overcome.

Keywords: Sustainable transportation in Sub-Saharan Africa, ITDP, bicycle transit.

An International Review of The Significance of Rail in Developing More Sustainable Urban Transport Systems in Higher Income Cities

Jeffrey Kenworthy

The significance of urban rail systems in cities, especially in comparison to buses, is a widely discussed topic. This study examines 60 high-income cities in North America, Australia, Europe and Asia, dividing the sample into strong rail, weak rail and no rail cities using three criteria related to the significance of rail within the public transport system of each city and the rail system's speed competitiveness with cars. Trams, LRT, metro and suburban rail are all considered. It then looks systematically at key comparative urban form, public transport operational features, transport infrastructure and performance, private transport patterns, economic features of the transport systems and environmental factors in each of the three groups of cities. It examines whether there are any statistically significant differences in these factors between the three groups of cities and discusses the findings. The study finds generally that cities with more strongly rail-oriented public transport systems experience a wide range of positive impacts at an urban system level in all of the above important areas. Explanations are offered for these observations and the overall results are found to be in line with other comparative research on this topic that has focussed on European and US cities. The paper suggests that urban rail systems are a critical element in building effective multi-modal public transport systems that create a 'virtuous circle' in public transport and compete more successfully with the car.

Key words: Urban rail systems, urban form, public transport operation, infrastructure and performance, economic and environmental factors.

Bicycle Ambulances in rural Uganda: Analysis of factors influencing its usage

Corinna Wallrapp and Heiko Faust

Since 1997 about 400 bicycle ambulances were distributed to villages in rural Uganda to improve their accessibility of health centres. For general understanding, a bicycle ambulance is a bicycle with an attached trailer especially to transport seriously sick patients to the nearest health centre. This paper presents the main results of a study carried out to analyse the usage of the bicycle ambulances in Uganda. The research was undertaken mainly through guided interviews with receivers and the distributors of bicycle ambulances in selected villages. In referring to the technology, the bicycle ambulance can be described as an appropriate technology within the circumstances. However, factors were defined influencing its usage, such as the situation in the villages, the features of the bicycle ambulance, the system of distribution and the organisation of the groups. The only significant influence on the frequency of usage could be observed between the different organisational structures of the bicycle ambulance groups. Furthermore, high distances, costs of repairs and other barriers could be overcome through the positive attitude of group members.

Keywords: Bicycle ambulance, Uganda, access to health centres, intermediate means of transport, rural development, Sub-Saharan Africa.

Simplified travel demand modelling for developing cities: the case of Addis Ababa

Binyam Bedelu & Marius de Langen

This paper presents a simplified travel demand model. The model was developed as a tool to support long-term strategic transport system planning, specifically for low-income cities with limited data availability and the need for a transparent planning tool that can be used easily and at a low cost. A study was carried out to test the applicability of the model for strategic and sustainable transport planning in Addis Ababa (Ethiopia). The model consists of interlinked spreadsheets with open-source codes. It requires no specialized licensed software, and is available free of costs, upon request. In case GIS software is available this can be used to facilitate working with maps and for showing traffic flows on road network maps, but the model can equally be used without.

The key difference between this simplified model and the standard current travel demand model is that the modal-split is dealt with by means of so-called mobility matrices. These mobility matrices show the shares of each mode of travel per distinct trip-distance category, with a further segmentation by trip purpose and income of the trip maker. The mobility matrices can be estimated from a household travel survey of a limited size (1400-2000 respondents).

The test-study divides the Addis Ababa urban area into 35 traffic zones and defines an arterial road network of 137 km. Data required for the model were obtained from the municipality, largely from an earlier urban transport study, which included a household travel survey. Mobility matrices were estimated from this household travel survey. The model applies the traditional four travel-demand forecasting steps: trip generation, trip distribution, modal split, and traffic assignment.

In the test, the simplified model estimates the observed average daily traffic flows on the main arterial road network of the city in a very satisfactory manner (correlation coefficient 0.95, RMSE 14%). The test shows that this simplified model is likely to be a valuable, manageable and low-cost tool in support of strategic and sustainable transport policy and network planning for low-income cities.

Keywords: simplified travel demand model, mobility matrix, urban transport planning.

Sustainable intermediate transport in West Africa: Quality before quantity

Bryan Dorsey

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Introduction

Non-motorised transport (NMT) is central to the issue of sustainable transportation. Among the more arguably important aspects of NMT that are sometimes overlooked are bicycle transportation development and accompanying policy reform. Given the fact that the majority of the world's poor do not have access to motorised transport, it has been well noted that this should not be the only mode considered for development in Africa, the world's poorest region (Leinbach, 2000; Mozer, 2000; World Bank, 2002). Indeed, the last of ten major urban NMT strategy elements that the World Bank reviews in *Cities on the Move* provides some impetus for this study: "development of small-scale credit mechanisms for finance of bicycles in poor countries" (World Bank, 2002, 134). Although the emphasis herein lies not on internal credit mechanisms in particular, the market conditions for bicycle sales and promotion in two very different, yet neighboring countries, Ghana and Togo, are analysed and compared.

The World Bank has made some studies regarding non-motorised transport in the urban periphery in Sub-Saharan Africa (Starkey et al, 2002), yet scant academic research has focused on the intermediate technology of bicycles and bike trailers. World Bank researchers note that a wide variety of factors influence differences in rural transportation: "population density, culture, income, topography, climate, or crops and animals" (Starkey et al, 2002, 22). Some of these same factors, particularly demographics and income, influence choices in urban transport. Just as secondary African cities are often economically linked to primary cities, there is close interdependence with peripheral rural areas that supply agricultural goods, thereby ensuring regional food security. Combined with the general weakness of rural transportation systems in Sub-Saharan Africa, it would therefore seem essential to consider peri-urban NMT when discussing urban transit. Indeed, World Bank reports show a clear link between NMT and the reduction of poverty in both rural and urban settings (Starkey et al, 2002; World Bank 2002).

Among the more successful decentralised, cooperative projects focused on bicycle transport is the recent work conducted by the Institute for Transportation and Development Policy (ITDP). ITDP has been active in Africa for over twenty years, with particular success in Ghana (Gauthier, 2005; Gauthier and Hook, 2005). Gauthier and Hook (2005) present compelling evidence that the market for durable, yet affordable, quality bikes in Africa is primed for development. Based on bicycle marketing studies by ITDP, there may be similar success in developing and marketing bicycle trailers in selected countries, thereby expanding transit mode shares in secondary cities where bicycle use for the movement of agricultural goods is significant. In countries where the transport of agricultural goods is critical to national economic prosperity and food security, the need for alternative mode development becomes even more acute. Given the fact that approximately 42 percent of Togo's gross domestic product comes from agriculture (Bureau of African Affairs, 2005), the country provides an appropriate case study for improving intermediate transport.

Bicycle mode shares and transit oriented development

Before discussing the details of bicycle transport development in Africa, it may be of assistance to note changes occurring in other world regions. Data analysed by the World Watch Institute (2001) show that bicycle production increased from about 10 million units in 1950 to 100 million units in 2000, whereas automobile production increased from about 8 million units to only 40 million units during the same time period. Although Holland has lead the world in per capita bike sales with almost 90 bicycles sold per 1000 people, China has the greatest total bicycle ridership and production in the world (Gauthier and Hook, 2005). While only 20 bikes per 1000 people are sold in China (op. cit.), approximately 52 percent of the estimated 100 million bikes produced worldwide in 2000 were manufactured in China (World Watch Institute, 2001). In terms of urban NMT, Chinese cities have the greatest percentage of cyclists per total transportation mode shares. It has been estimated that Tianjin has among the highest bicycle mode share of any city in the world, with an estimated 77 percent. Close behind Tianjin is the city of Shenyang with a 65 percent bicycle mode share (International Bicycle Fund, 2005). However, bicycle ridership has begun to rapidly decline in some Chinese cities as China moves toward free enterprise. In some cities, bicycles are no longer allowed on major roadways that are increasingly dominated by vehicles. The cycling mode share in Shanghai for example, has declined from an estimated 70 percent in 1990 to only 17 percent in 2003 (Summerville, 2005).

The decrease in ridership within China has signalled a shift in production trends. As the Chinese buy fewer bikes, bicycle exports from China are expected to continue to increase. In fact, the European Union recently endorsed an anti-dumping duty of 48.5 percent on all Chinese built bicycles (begun in July, 2005) (European Union Council, 2005). The rippling effect of depressed demand in China also led the Economist magazine to report that streamlined production in China has led to a significant decrease in the cost of low-end mountain bikes in Ghana where the price dropped from $67 in 2001 to $25 in 2003 (author unknown, 2003).

Despite some decline in ridership in primary cities such as Shanghai, growing world wide bicycle production and sales noted above give proof to the viability of bike transport. In cities where safe bicycle transportation is encouraged, and where bicycle sales are high, it comes as no surprise that a significant percentage of the mode share is in bicycles. The city of Groningen in the Netherlands, for example, has a bicycle mode share of about 50 percent, which is just ahead of Beijing at 48 percent (International Bicycle Fund, 2005). In addition to strong markets for bikes, Holland has some of the most well developed bicycle transportation master planning and supporting transit oriented development (TOD) in the world.

Certainly the prevailing transportation ethics of a community, its level of economic development, and local cultural characteristics will influence the popularity of cycling and trailer use. Even though these cultural characteristics, as well as socioeconomic conditions vary dramatically from Europe, to North America, to Africa, there is one commonality: regardless of dependency on the singly occupied vehicle (SOV), many people are re-evaluating their transportation choices, seeking alternatives that may be counter to the expanding status quo. The European Commission (2003) estimates that the total kilometres travelled in the European Union by SOV will increase by 40 percent between 1995 and 2030. American SOV use has far outpaced bicycle transportation with less than one percent of the mode share occupied by cyclists (American Public Transportation Administration, 2002; US Census Bureau, 2000). Nevertheless, in some American secondary cities where traffic conditions allow, bicycles are being used as a viable alternative mode of transport.

In American primary and secondary cities where TOD has integrated infrastructural development to support bicyclists and pedestrians (e.g., Portland, Oregon and Boulder, Colorado), some of the better developed bicycle pathway systems in the world are emerging. Frustrated by traffic congestion, degrading air quality, and the lack of government initiatives to reduce carbon dioxide emissions, local community planners and commuters are turning to the bicycle and, or mass transit. Cyclists are increasingly prevalent in the Front Range communities of Colorado where TOD includes cycling, whereas Wasatch Front communities in Utah have many recreational cyclists, but far less development to support bicycle commuting. If a revival of bike use is to occur that ensures safe movement, community planning involving "walkable" and "cycleable," or "new urbanist" design elements must be integral to TOD. We cannot assume that where motorised transportation infrastructure has been developed, non-motorised transit will follow. In fact, some "autocentric" planning undermines the safety and encouragement of non-motorised transportation. The lack of cyclist and pedestrian safety is endemic not only to more economically developed countries, but developing countries in Africa face similar challenges of modernisation. For further reading on best practices for pedestrian and bicycle planning, see Litman, Demopolous, Eddy, Fritzel, Laidlaw and Maddox (2000) with the Victoria Transportation Policy Institute in British Columbia (www.vtpi.org). Velo Mondiale is another key decentralised cooperative organization that provides valuable information on bicycle master planning (www.velo.info). While countries like China and the Netherlands have significant percentages of their population moving by bicycle, how do Sub-Saharan African countries compare?

Bicycle promotion in Africa

While attitudes toward bicycling in African cities vary from country to country, many view bikes as an antiquated form of transport, and far prefer motorised vehicles; yet the reality is that bicycles are a sustainable form of transport, particularly for those of low income (Howe, 1997; Mozer, 2000; ITDP, 2005). Researchers have found that bicycle users in Accra and Ouagadougou preferred motorised two-wheeled vehicles (mopeds, scooters, or motorcycles) to bikes. Nevertheless, some found bicycles more appealing than buses due to low cost, speed, reliability, and more flexible routing (World Bank, 2002). In an effort to improve non-motorised transportation, non-government donor agencies and individuals have generously donated used bicycles from the U.S. and Europe to Africa. Although well meaning, donations are problematic in that used bikes are often of low quality, and are therefore prone to mechanical failure. When these foreign bicycles are introduced without proper marketing, there are few services developed for repairs and parts made available to African cyclists. Gauthier and Hook bluntly state the problem: "it was 'a race to the bottom' in terms of the quality [of bicycles], and this undermined cycling as a legitimate form of transport" (2005, 9).

Having experienced the drawbacks to relying on used bikes, ITDP staff then decided to take a new approach to the bicycle commuting problem. ITDP technical team members worked with bicycle manufacturers, Trek and Sram to develop the California Bike. The California Bike, a six-speed, low end mountain bike is being produced by Giant Inc. (ironically, in Shanghai) and made available to consumers in Senegal, Ghana, Tanzania and South Africa at an average price of $100 (Gauthier and Hook, 2005). Once ITDP identified bike dealers and formed the California Bike Coalition (CBC), the bikes were sold at a rate many would not have anticipated.

In spite of low average per capita incomes in most African countries, consumers in Ghana, Kenya and Tanzania are buying bikes at unprecedented rates. Indeed, bicycle sales in Ghana in 2002 were estimated at almost 29 per thousand people, higher than bicycle consumption in China (Gauthier and Hook, 2005). Kenya had the second highest bike sales per 1000 people in Africa in 2002 (16.4 bikes/1000 population). It is important to note that sales in Kenya increased from 9.5 bikes/1000 people in 2001 following a reduction in bicycle import tariffs. As a result, the CBC has identified a bicycle marketing strategy targeting those countries with low import duties such as Ghana and Kenya (op. cit.).

While devising a strategy for the Coalition, ITDP also considered annual growth rates in gross domestic product (GDP), as well as the level of existing bike use and sales in selected African countries. The CBC strategy to target countries with low tariffs seems logical; however, the reliance on GDP growth rates as an indicator of success for the development of the California Bike market may be constraining. Kenya provides a strong example with an annual growth in GDP from 2000-2004 of less than 1 percent, yet as previously noted, bicycle sales almost doubled from 2001 to 2002. Indeed, the use of per capita GDP estimates and fluctuating growth rates as indicators of actual prosperity is flawed. GDP figures mask differences in wealth within countries, and do not account for the informal sector. Even the casual observer in Sub-Saharan Africa can attest to the significance of the informal sector of these economies where much commerce goes undocumented and untaxed.

Though the correlation between GDP growth rate and per capita GDP is weak, bicycle ownership appears to be closely correlated with per capita income (Hook, 1995; Gauthier and Hook, 2005). However, bicycle sales and ownership do not necessarily equate with bicycle use. Hook (1995) showed that the relationship between per capita income and bicycle commuting, or the total number of work trips by bike, is not statistically significant. Table 1 shows relationships between GDP and the prevalence of bicycle ownership and sales for selected countries, yet no definite conclusions can be drawn for actual bicycle use. Clearly, there is positive correlation between Ghana's GDP and the number of bikes per thousand people (Table 1). One would expect to see low bicycle ownership and sales in Togo given the country's low GDP/capita. Unfortunately no data on bicycle ownership or sales are currently available for Togo. Regarding Togo's low GDP growth rate, it should be noted that Togolese face considerable constraints given political unrest and economic decline since the early 1990s.

Table 1: Economic Indicators and Bicycle Prevalence, 2005 Estimates

	Population (million)	GDP/capita (PPP$)	GDP growth (% increase)	# of bikes/ 1000 people*	# bikes sold*
Ghana	20.9	2500	4.3	28.7	588,048
Kenya	33.8	1200	5.0	16.4	517,302
Senegal	11.1	1800	6.1	2.0	20,253
Togo	5.7	1600	2.8	N.A.	N.A.
Uganda	26.9	1700	9.0	2.4	60,675

GDP = Gross Domestic Product

N.A. = Not Available

PPP = Purchasing Power Parity

Sources: Bureau of African Affairs, US Dept. of State, 2005; *Gauthier and Hook, 2005.

Economic factors alone do not explain the lack of cycling in Africa, where most trips are made on foot, yet the bicycle is underutilised (Howe, 1997; Mozer, 2000; World Bank, 2002). Although extensive pedestrian movement and some bicycle use are widespread in most West African cities, little attention is given to safe movement. Indeed some villages and cores of secondary cities are divided by major roadway corridors, e.g., Togo's Route Nationale runs through the centre of towns where pedestrians and cyclists are at risk. Drawing again from World Bank policy outlined in *Cities on the Move,* emphasis must be placed on infrastructural development for "safe movement" of non-motorised transport (World Bank, 2002, 134). Although some African city governments are embracing TOD with safe bike route development, the issue is generally neglected.

Road safety and bicyclists in Sub-Saharan Africa: reality and policy

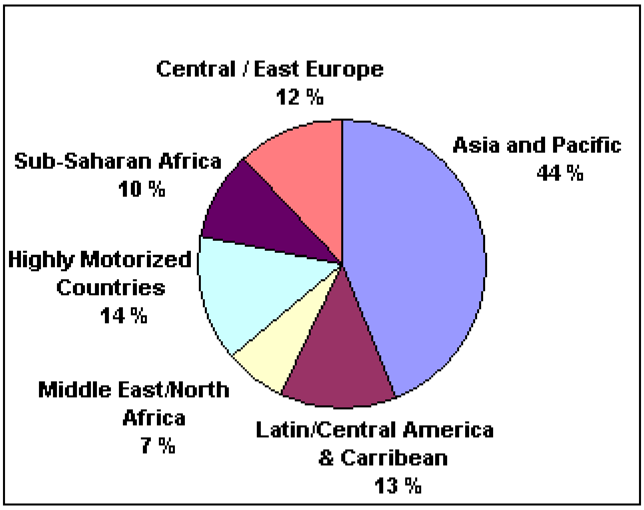
The danger of promoting greater reliance on bicycles in West Africa, and Sub-Saharan Africa in general is inherent in the risks of death and injury of cyclists in the region. Although statistics can be misleading, and in some cases contradictory from one source to another, it is important to consider safety issues and related policies that could assist to reduce death and injury amongst this vulnerable group. To gain some perspective on the safety issues that cyclists face in Africa, it may be helpful to consider overall road-related traffic dangers, both world-wide and in particular African countries.

According to the World Health Organisation (WHO), 23 percent of all injury related deaths world wide can be attributed to road traffic accidents. In

1999, the African region had the highest road traffic injury mortality rate in the world with 28.3 deaths per 100,000 population (Jacobs and Thomas, 2000). The WHO forecasts that by 2020, road crashes will be the third most common cause of premature death globally. According to some estimates, more children died in Africa in 1998 from road crashes than from the HIV/AIDS virus (Dhliwayo, 2007). More recent WHO estimates place road deaths second to AIDS related deaths. Equally compelling is the statistic that more young adults in Africa aged 15 to 44 years died from road accidents in 1998 than malaria. Although Togo's roadways appear to be fairly hazardous, where 132 fatalities per 10,000 vehicles were estimated in 1999 (Jacobs and Thomas, 2000), Nigerian roads have a reputation for being some of the most dangerous in the West African region.

In many Asian, African, and Middle Eastern countries between 40 and 50 percent of people killed as a result of a road accidents are pedestrians. Data from 1995 indicate that 33 percent of all road casualties in Kumasi, Ghana involved pedestrians (Jacobs and Thomas, 2000). In 2002, it was estimated that between 40 and 45 percent of road user fatalities in Ghana were pedestrians (Dhliwayo, 2007) (see Figure 2). Although unsubstantiated here, it would stand to reason that if the trend in pedestrian fatalities exhibits an overall increase, bicycle related fatalities would likely be increasing in Ghana and neighbouring West African countries as well. The validity of road safety statistics is subject to question.

Figure 1: Global distribution of road deaths in 1999

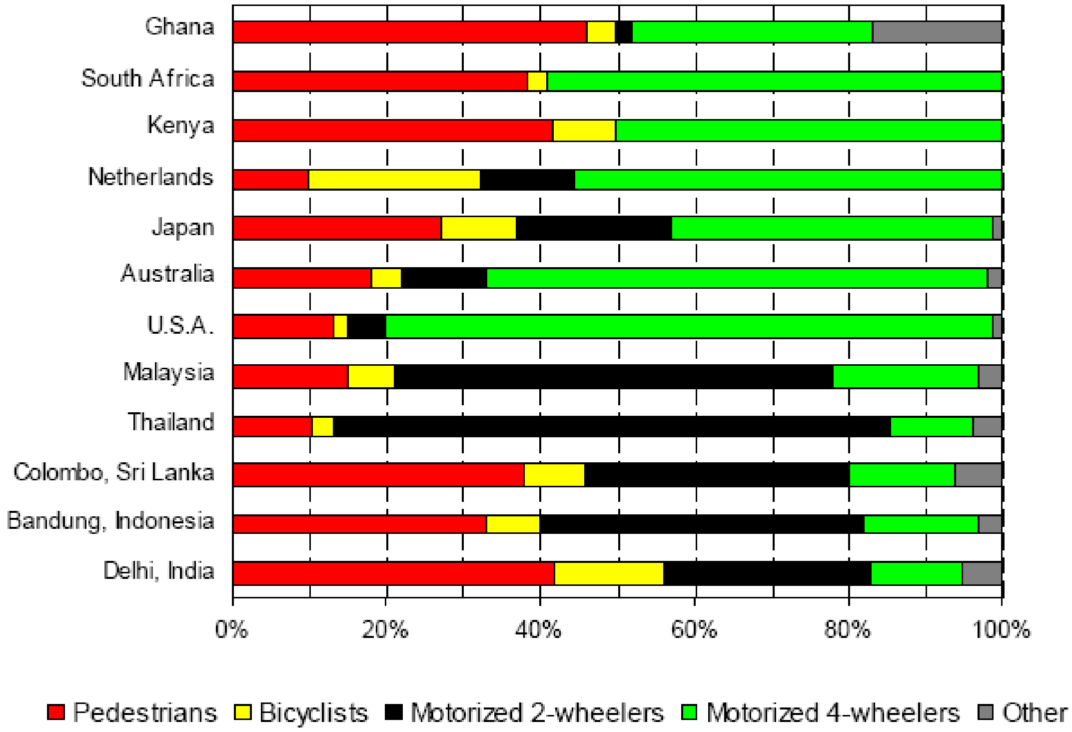


Source: U.S. Dept. of Transportation, Federal Highway Administration (Jacobs and Thomas, 2000)

Results from the Africa Road Safety Review by the U.S. Dept. of Transportation, Federal Highway Administration (supported by the World Bank) reveal that the total 35,394 deaths in 42 Sub-Saharan African countries and the individual national totals are "significant underestimates of the true totals" due to under-reporting and non-reporting of fatalities in transportation related accidents (Jacobs and Thomas 2000, Section 3.1). Figure 1 shows that Sub-Saharan Africa accounts for 10 percent of the estimated total 750,000 road deaths world wide in 1999 (low end of 750,000-880,000 fatalities). Of the 10 percent, a fraction were bicyclists, but data were not available for all Sub-Saharan countries, therefore no meaningful estimates of the numbers or percentages of road deaths that were cyclists could be extrapolated. However, some statistics for selected countries can give an indication of how hazardous the roads are for bicyclists in Africa.

In 1998, there were 303 reported bicyclist deaths in Uganda accounting for 19 percent of total road casualties, while Kenya reported 285 bicyclist fatalities (14 percent of total casualties) for the same year. For the same year in Ghana, an estimated 4 percent of road user fatalities were cyclists (Jacobs and Thomas, 2000). As one might expect, those countries that have a larger urban population and more vehicles/10,000 population tend to have greater risks for bicycle riders. Similarly, countries where a significant percentage of the population relies on bicycle transport as the primary form of mobility, such as the Netherlands, tend to have higher bicyclist fatalities than pedestrian fatalities. Figure 2 shows the number of bicyclist fatalities in selected countries indicating that relative to other countries, cyclist fatality rates may not be abnormally high in West Africa. The high percentages of pedestrian fatalities in African countries are a clear indication that walking is still the most widely used method of mobility. One might expect to find that less urbanised areas in Africa would have lower pedestrian and bicyclist risks, but again, the research is inconclusive on this point.

Figure 2: Percentages of Bicyclist, Pedestrian and Motorist Fatalities in Selected Countries (2002)



Source: World Health Organisation (Krug, 2007)

In an effort to address road safety issues, the World Health Organisation (WHO) and the United Nations (UN) Economic Commission for Africa held the African Road Safety Conference during February 2007 in Accra, Ghana. The overall conference theme was road safety and the millennium development goals, one of which is to reduce road traffic fatalities in Africa by half by 2015. Among the key strategies identified by the WHO to improve safety for cyclists in Africa is the encouragement of helmet use. Although the use of helmets may receive policy support, the very real economic challenge of distributing affordable helmets for purchase is certain to be an issue in most Sub-Saharan African countries. The use of reflectors and headlights is another safety concern. Traffic calming measures such as the installation of speed bumps or even reduced speed limits can have an impact on cyclist safety as well. Speed bumps reduced crashes by 35 percent at a high-risk accident site in Ghana (Krug 2007). Another factor indirectly related to bicycle safety is the development and enforcement of laws that prohibit driving while under the influence of alcohol or drugs (currently, South Africa is the only African country with such law enforcement).

Ideally, cities such as Sokodé in Togo will some day designate bicycle routes, but the recent addition of a traffic light at the main intersection in the centre of town along the exceedingly dangerous Route Nationale, or main national highway bisecting the country, marks a step in the right direction. If distribution and sales of bicycles in Togo and other Sub-Saharan countries are to be promoted, bicycle (and vehicular) safety must be addressed. While the UN and WHO policy goal to reduce traffic fatalities by half may be an important first step, there must be assurance that bicycle safety issues will be an integral part of any policy framework. An equally important solution to the bicycle safety issue is to work through local civic groups, village organisations, schools, sports and fitness and other groups to educate motorists and cyclists, particularly younger people, regarding road safety concerns noted above.

Demographic- and gender-based barriers

Closely related to economic growth factors and market conditions are demographic differences between urban, peri-urban and rural areas that are essential to take into consideration when evaluating bicycle transport systems. Most secondary cities in Africa are tightly bound to surrounding rural settlements and marketing activity, hence the need to discuss subsistence, or smallholder farming communities and their dependence on bicycles and, possibly, bike trailers. Smallholder farmers in Sub-Saharan Africa experience unique challenges in the only world region where per capita food production has declined over the past fifteen years. As farmland holdings are subdivided into smaller plots to accommodate new family members or land sales, and fallow periods decline in closer proximity to village settlements, household members and labourers are forced to travel greater distances between the village and farm, then village to urban market. Transport of goods between the farm and village is most often made on single-track by foot, or occasionally by bicycle (when affordable and available). Smallholders with farms of four or more acres that are more diversified in terms of their production, compared to farms of one to two acres, are often more financially successful (Dorsey, 1999), and may therefore be more likely to have the financial flexibility to purchase a bicycle and, though less likely, an accompanying trailer.

A similar demographic pattern related to economies of scale occurs among urban households. Commuters living in African primary cities often have better access to public transit, typically diesel buses, than those in secondary cities. While ITDP estimates that less than 2% of commuting trips in major African cities are made by bicycle, it is possible that the figure for secondary cities is as high as 45 percent (Gauthier and Hook, 2005). ITDP members also note that many of the bikes sold in major cities are actually used in secondary cities and, or villages (op. cit.). Based on the previous discussion of tariffs on imported bicycles, it would also be expected that bikes bought in major cities where there are low to no tariffs may be taken into adjoining countries with higher tariffs, e.g., from Ghana to Togo.

Perhaps one of the more challenging demographic issues influencing the use of bicycles is that of gender. Women in many Sub-Saharan communities often carry the majority of goods (farm products, tools, fuel wood, etc.) between the village and larger urban markets (Leinbach, 2000; Mozer, 2000). Development of policy and support for bicycles and bike trailers offers a critically needed alternative to the burden of moving loads by foot, yet few African women ride bikes. Due to cultural differences in western Burkina Faso, women's bicycles do not sell as well as in other regions (Sifa, 2001). One aspect of culture and gender effecting bicycle use is dress. The traditional wrap of cloth, a "pagne" or sarong, worn by women in much of Africa is not conducive to bicycle riding. An effort to break down the norm of gender division in cycling was pursued during the "Tour des Femmes" in Senegal and the "HIV/AIDS Education Bike Ride" in Ghana. Both bike tours, initiated in 2002, were bold attempts by local men and mostly women, US Peace Corps volunteers, and various non-government organizations to raise awareness about girl's education and health issues. The tours lasted from four days to three weeks and inspired many Africa women to try cycling even where traditionally only men cycle (ITDP, 2005).

Bicycles and trailers in Ghana and Togo

So as not to put the cart before the bike, it should be noted that Togo has little to no investment or policy support for bicycle transport, nor has ITDP attempted to introduce the California Bike (CA Bike) in Togo (Figure 3). Discouraged by high tariffs in Togo, ITDP staff members are working to establish a bicycle manufacturing facility in Senegal. Since Togo is a member of the West African Economic and Monetary Union, or Union économique et monétaire oust-africaine (UEMOA), bicycles manufactured in Senegal could then be imported in Togo without exceedingly high tariffs. ITDP representatives have been working with an independent bike dealer in the secondary city of Tamale (Ghana's third largest city) to distribute the CA Bike in Ghana. Tamale has a population of about 270,000 people, and is centrally located in a region where bicycle use is expected to be high (Figure 4). If the CA Bike were to be introduced in a secondary city in Togo, the most closely comparable city would be Sokodé, Togo's second largest city with a population of roughly 75,000. Although Tamale is larger than Sokodé, both cities are characterised by large, sprawling residential areas with relatively weak infrastructural development. Connections to surrounding rural villages are strong, and intensified agricultural production is prevalent in both peri-urban areas.

Figure 3: ITDP's California Bike (shown by captain of the Ghanaian cycling team)
Photo by author

Figure 4: Locator map for Tamale and Sokodé

Given the obvious need to have quality, affordable bikes, with readily available replacement parts and repairs, before bicycle trailers can be used, the first stage of the bicycle sale and support project discussed below was to survey the market for quality bikes. Cooperation with the Togo Ministries of Transportation and Agriculture will be requisite to the long term promotion of intermediate transport policy, but more immediately important will be cooperation with localized groups such as "Jeunesse et Sports," or Youth and Sports advocates, as well as local retailers who may wish to sell the CA Bike. Such decentralised cooperation is now viewed as essential to the success of transportation projects. Indeed, the development of bicycle and bike trailer projects in Africa has been largely the result of cooperation between organisations such as ITDP, the Swedish International Development Agency (SIDA) and others.

Bicycle trailers are being used in many world regions to broaden the mode share for transit. Trailer use may be most pragmatically applied in secondary urban areas and the urban periphery where access to transportation is more constrained than in capitol cities such as Accra or Lomé. The development of prototype bicycle trailers has a history of mixed success in Ghana, but the extent to which trailers are being used in Togo is unclear. Development of trailers as bicycle powered "ambulances" has been undertaken to assist in urgent medical care where vehicle access is limited. Bike ambulances produced in Ghana are now being used in Uganda with considerable success (Gauthier 2005).

One of the few critiques of bicycle trailer projects comes from Ghanaian researcher, M. Salifu (1994). In the Transport Rehabilitation pilot project in Northern Ghana, supported by the World Bank, the bicycle and trailer combination was often unaffordable. Salifu concludes that although the trailer was a reasonable technology, it was inappropriate given the failures of the pilot project. Several key findings are worthy of note: the trailers lacked the structural integrity to haul heavy loads, the trailers were cost prohibitive, and as noted above, generally, women do not use bikes (Salifu, 1994). Furthermore, the trailers did not perform well on village footpaths (Starkey et al, 2001). As a result, the Togo pilot project discussed below will target two different trailers. First, an affordable, locally produced, two-wheel trailer will be designed for urban areas, and at a later date, a single-wheel trailer designed for use on single-track footpaths will be developed in hopes that diversified smallholders will be able to afford a light-weight, simply constructed vehicle.

Where bicycle use is high, and/or markets offer promise, it would follow that the use and sales of bicycle trailers might also accelerate. Hence, the objectives of the pilot project are two-fold: to identify urban and urban periphery transport challenges related to the movement of goods between villages, farms and urban centers; and to develop a sustainable bicycle trailer construction program for improved rural to urban transport. Administration of a brief survey of urban household members, smallholders, and cyclists in the Sokodé urban and peri-urban area of Central Togo in June of 2006 identified the following:

- the most common means by which household members travel to work is still by foot, followed by bicycles, but use of motor scooters is increasing rapidly;
- average distances and travel times for travel to work vary widely according to rural versus urban or peri-urban settings;
- average cost of travel to work remains low, while increasing fuel prices favor cycling;
- if travel is made by bike, cost of bicycles remains an impediment for subsistence farmers, but remains affordable for many urban residents;
- availability of "quality" bicycle repairs, parts and accessories, including trailers remains problematic in the region;
- average income of bicycle owners varies from low to high (wide range, but fewer in upper income range use bicycles as primary form of transport).

Currently, avenues for funding of a shipment of the California Bikes is being explored jointly with ITDP and other interested organisations. It is hypothesised that not only urban household members, but also diversified smallholder farmers with more than 3 hectares under production could benefit from affordable bikes and trailers. As prototype two-wheel and single-wheel bicycle trailers are developed, tested and introduced in Central Togo, attention can be shifted to larger scale production and marketing of trailers in Togo, or perhaps Senegal where CA Bikes are produced. By surveying women and developing a trailer that may be converted to a hand cart, the Bicycle Trailer Pilot Project (BTPP) in Togo will take issues of gender into consideration in the testing and introduction of this appropriate technology program. The BTPP will attempt to form a partnership between researchers, smallholders, the Togo Ministries of Agriculture and Transportation, ITDP, and perhaps the U.S. Agency for International Development.

Conclusions

Urban transportation planning is often focused on mass transit and roadway improvements that inadvertently perpetuate dependence on the singly occupied vehicle. As transit oriented development becomes more widespread, alternative modes of walking and bicycling may be revitalised despite trends in primary cities such as Shanghai where bicycle ridership has begun to decline. Direct cooperation between organisations such as the Institute for Transportation and Development (ITDP) and cycling advocates in secondary cities, such as Tamale in north central Ghana and Sokodé in central Togo, are critical to providing reliable intermediate transport to those who cannot afford private vehicles. While some transportation specialists and many elite in Sub-Saharan Africa anxiously embrace motorised vehicles, some are realizing the value of less polluting, more dependable, efficient, quality bicycles for commuting to work, school, the market place or other destinations.

Development of the market for quality bicycles such as the California Bike may be key to promoting non-motorised transport in Africa. Currently, those countries with growing GDP per capita are being targeted for bicycle sales, yet countries plagued by political unrest and faltering economies may miss these marketing opportunities. In fact, countries such as Togo may be in greatest need of bicycles and trailers to perpetuate food security in the urban periphery. As less expensive, but adequate quality bicycles from Chinese manufacturers saturate the market outside of China, countries with low import tariffs will capitalise on intermediate transport. Ghana's recent per capita bicycle sales that exceed those of China indicate that the African market should not be ignored as it has been for decades. However, given that actual bicycle ridership is not necessarily correlated with bike sales, bicycle use in countries such as Togo could also expand rapidly. If bicycle manufacturing within the West African Monetary and Economic Union can be achieved, perhaps marketing of quality, affordable bike trailers will follow. Transportation survey data from West African urban and peri-urban areas, as well as the development of trailer prototypes will undoubtedly assist us in meeting the demand for improved movement of both agricultural goods and commuters.

References

American Public Transportation Administration. 2002. APTA Transit Ridership Report. www.apta.org

Author unknown. 2003. Is the wakening giant a monster? *Economist* magazine Feb. 13, 2003

Bureau of African Affairs, US Department of State. 2005. Togo Profile. www.state.gov

Dhliwayo, M. E. 2007. Road Safety Development in Africa. Presentation at the Economic Commission for Africa, African Road Safety Conference in Accra, Ghana, February 5-7, 2007.

Dorsey, B. 1999. Agricultural intensification, diversification, and commercial production among smallholder coffee growers in central Kenya. *Economic Geography* 75(2): 178-195.

European Commission. 2003. Clean Urban Transport. www.europa.eu.int

European Union Council. 2005. Records from the Council of the EU. *Official Journal of the European Union* no. L 183.

Gauthier, A. & Hook, W. 2005. Tapping the market for quality bicycles in Africa. *Sustainable Transport* 19: 8-11, 30.

Gauthier, A. 2005. Scaling up for healthcare mobility in Africa. *Sustainable Transport* 19: 20-23, 25.

Hook, W. 1995. Economic Importance of

Non-motorised Transportation. Transportation Research Record #1487. Washington, DC: Transportation Research Board, National Research Council.

Howe, J. 1997. *Transport for the Poor or Poor Transport? A General Review of Rural Transport Policy in Developing Countries with Emphasis on Low-Income Areas.* Geneva: International Labour Office. ISBN 92-2-110473-7.

Institute for Transportation and Development Policy (ITDP). 2005. Non-motorised transport in Africa. www.itdp.org

International Bicycle Fund. 2005. Bicycle Statistics. www.ibike.org

Jacobs, G. and A. Aeron-Thomas. 2000. Africa Road Safety Review Final Report. Published by the U.S. Department of Transportation / Federal Highway Administration.

Krug, E. 2007. Preventing Road Traffic Injuries. World Health Organization, Department of Injuries and Violence Prevention.

Leinbach, T. R. 2000. Mobility in development context: changing perspectives, new interpretations, and the real issues. *Journal of Transport Geography* 8: 1-9.

Litman, T., Blair, R., Demopolous, W., Eddy, N., Fritzel, A., Laidlaw, D., & Maddox, H. 2000. Pedestrian and Bicycle Planning: A Guide to Best Practices. Victoria Transportation Policy Institute, Victoria BC, Canada. <www.vpti.org>.

Mozer, D. 2000. *Transportation, Bicycles and Development in Africa*. International Bicycle Fund: Seattle, WA.

Salifu, M. 1994. The cycle trailer in Ghana: A reasonable but inappropriate technology. *African Technology Forum* 7(3): 37-40.

Sifa (Société Industrielle du Faso). 2001. Production et distribution de vélos en milieu rural cas de la Sifa (Société Industrielle du Faso). Paper presented at a Group Forum National du Burkina seminar on gender and transport, 3-5 April, Ouagadougou, Burkina Faso.

Summerville, P. 2005. *A Bicycle Built for Two.* Report on Canadian International Trade Tribunal. http://paulsummerville.ca/node/126

Starkey, P., Ellis, S., Hine, J., & Ternell, A. 2002. Improving Rural Mobility: Options for Developing Motorised and Non-motorised Transport in Rural Areas. World Bank Technical Paper No. 525.

US Census Bureau. 2000. Census. www.census.gov

World Bank. 2002. *Cities on the Move: A World Bank Urban Transport Strategy Review*. Washington D.C.: World Bank Publications.

World Watch Institute. 2001. *State of the World 2001*. World Watch Institute: Washington DC.

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An International Review of The Significance of Rail in Developing More Sustainable Urban Transport Systems in Higher Income Cities

Jeff Kenworthy

Introduction

With growing attention being paid to sustainability issues, most cities are making efforts to restrain the growth in automobile dependence. Many avenues are available to cities in the pursuit of this goal. Physical planning policies can aim to make development more compact with mixed land uses, thus building in less auto-dependence at the start (Cervero 1998, Newman and Kenworthy 1999a). Economic policies towards the automobile can seek to minimise car ownership and use through higher prices that perhaps better reflect the car's true social cost, as has happened in Singapore for example (Ang 1990, 1993). Amongst these efforts, there is a general recognition that the role of public transport needs to be enhanced, along with its companion modes, walking and cycling, and the latter for reasons of health, not just transport (Pucher 2002, Pucher and Dijkstra 2003).

Within this general recognition that public transport can play a much greater role in most cities, arguments exist about the most appropriate modes to install to achieve enhanced public transport use and other desirable qualities, such as cost-effectiveness, integration with land uses and ability to shift people out of cars. In particular, there is considerable debate about buses versus rail (e.g. Henry 1989, Pickrell 1990). Some argue that rail is very capital intensive and that well-conceived bus systems can achieve the same results at a fraction of the cost (Bonsall 1985, Kain and Liu 1999). This argument is strongly used in lower income cities where there appears to be less financial capacity to afford the extra capital costs of rail systems (Badami 2005). Others argue that rail systems in general have greater intrinsic passenger appeal and that they compete better with cars (Newman and Kenworthy 1991). Hass-Klau et al (2003) have made extensive studies of European cities with and without light rail systems and have concluded strongly that those cities that develop LRT systems consistently outperform, across many criteria, those cities that attempt to run their public transport systems only using buses.

Likewise, a report from Litman (2004) of the Victoria Transport Policy Institute called 'Rail Transit In America: Comprehensive Evaluation of Benefits' evaluates rail's benefits in terms of transport system performance in 130 U.S. cities. It finds that cities with large, well-established rail systems have a wide range of system-wide benefits relative to those that have no urban rail (see later).

It is further argued that rail stations are natural sites for dense residential and mixed-use development which can help to reshape the city into a more sustainable urban form (Cervero 1995, Kenworthy 1995, Cervero 1998, Newman and Kenworthy 1999a, Hass-Klau, et al 2004).

In order to contribute a more international perspective on the issue of the merits of rail in cities, this paper will explore a wide range of transport, economic and environmental features in

60 higher income metropolitan areas that have strong urban rail systems compared to those that have weak rail systems or no rail systems at all. The term 'cities' in relation to data in this paper refers generally to whole metropolitan regions, not the smaller administrative unit at the heart of the region, which often bears the same name (e.g. City of New York etc.). Higher income cities were defined for the purposes of this research as those with annual GDPs per capita of $US10 000 or more (i.e. it embraced those cities that are generally perceived as being part of the 'developed world', as opposed to cities that are clearly in developing nations). It will examine the evidence for whether urban rail in a city's public transport system appears to make any observable, statistically significant difference to the broad patterns of transport and related factors at a metropolitan scale.

Method

This paper draws upon the Millennium Cities Database for Sustainable Transport developed by Kenworthy and Laube (2001), which in turn built on and extended earlier work by Newman and Kenworthy (1989) and Kenworthy and Laube (1999). Some details about items in the Millennium database, including definitions of indicators and methodologies behind the research can be found in Kenworthy and Laube (1999), Kenworthy and Laube et al (1999) and Newman and Kenworthy (1999a). More specific details about other variables in the Millennium database are available from the author.

The list of 24 'strong rail', 28 'weak rail' and 8 'no rail' cities involved in the research in this paper, together with their 1995/6 populations, appears in table 1. Rail in this study is defined as the combined modes of trams, LRT, metro and suburban rail. The strong rail cities (SRCs) have been defined using three criteria:

- To be classed as a SRC, cities were required to have more than 50% of their total public transport task (public transport passenger travel measured as passenger kilometres) on rail, the weak rail cities (WRCs) have rail systems that account for less than 50% of their total public transport passenger kilometres and no rail cities (NRCs) have either no rail systems or rail systems that are so negligible in terms of extent and usage as to be tantamount to having no rail. Cities in table 1 that fulfill this last criterion are Tel Aviv, Denver, Los Angeles and Taipei where rail usage in 1995 is negligible due to the existence of only very small rail systems.

- SRCs also had to have no less than 40% of total public transport boardings by rail modes.

- Finally, for classification as a SRC, cities were required to have rail systems that are competitive with the car in speed terms. The overall average speed of all rail modes in each city was calculated, weighted by passenger hours, and expressed as a ratio of the average road traffic speed. Only those cities with an average rail speed that was equal to or greater than 0.90 of the road speed were classed as SRCs. Most SRCs exceeded this criterion, often by a considerable margin.

STRONG RAIL CITIES	POPULATION (1995/6)	WEAK RAIL CITIES	POPULATION (1995/6)	NO RAIL CITIES	POPULATION (1995/6)
Washington	3,739,330	Calgary	767,059	Ottawa	972,456
New York	19,227,361	Atlanta	2,897,178	Denver	1,984,578
Brisbane	1,488,883	Chicago	7,523,328	Houston	3,918,061
Sydney	3,741,290	S. Francisco	3,837,896	L. Angeles	9,077,853
Wellington	366,411	Montreal	3,224,130	Phoenix	2,526,113
Barcelona	2,780,342	San Diego	2,626,714	Bologna	448,744
Berlin	3,471,418	Toronto	4,628,883	Taipei	5,960,673
Berne	295,837	Vancouver	1,898,687	Tel Aviv	2,458,155
Brussels	948,122	Melbourne	3,138,147		
Frankfurt	653,241	Perth	1,244,320		
Hamburg	1,707,901	Amsterdam	831,499		
London	7,007,100	Athens	3,464,866		
Madrid	5,181,659	Copenhagen	1,739,458		
Munich	1,324,208	Dusseldorf	571,064		
Oslo	917,852	Graz	240,066		
Paris	11,004,254	Helsinki	891,056		
Ruhr	7,356,500	Lyon	1,152,259		
Stockholm	1,725,756	Marseille	798,430		
Stuttgart	585,604	Nantes	534,000		
Vienna	1,592,596	Rome	2,654,187		
Zürich	785,655	Geneva	399,081		
Osaka	16,828,737	Glasgow	2,177,400		
Sapporo	1,757,025	Newcastle	1,131,000		
Tokyo	32,342,698	Manchester	2,578,300		
		Milan	2,460,000		
		Hong Kong	6,311,000		
		Singapore	2,986,500		
		Seoul	20,576,272		

Table 1: Strong rail, weak rail and no rail cities in the study

The Millennium Cities Database contains complete data for 84 metropolitan areas worldwide, of which 24 can be considered as lower income (i.e. with a GDP per capita of less than $US10 000 per annum). All of these cities, apart from those in Eastern Europe and South Africa, are clearly located in 'developing nations'. However, Eastern European cities such as Prague in 1995 had low GDPs per capita but cannot be considered as 'developing cities', whilst South African cities present a starkly mixed picture whose GDPs per capita are low because of the huge majority poorer populations. Attempts were made to conduct the analysis of the role of urban rail in all these lower income cities as well, but by the criteria just described, only three of these 24 cities could be considered as having strong rail systems. A larger sample of lower income cities worldwide for which comprehensive and reliable data were available would yield more SRCs so that the analysis could be meaningfully conducted, but this was not possible for this paper. The focus of this paper is therefore on cities in the 'developed world', as shown in table 1 whose GDPs per capita range from $US10 305 up to $US54 692 per annum.

Tables 2 to 7 systematically examine how the strong rail, weak rail and no rail cities perform on a wide range of factors using 1995/6 data. The values for each variable in the tables are the medians for the three groups of cities, since the data in each case are generally skewed distributions where the median value is a better representation than the mean. In order to test the statistical significance of the difference amongst the medians, the nonparametric Kruskal-Wallis test from SPSS was used. The Kruskal-Wallis test is used for simultaneously testing multiple cases and eliminates the increased probability of significant results that occurs where, in this case, three separate pair-wise tests could have been undertaken for each variable. Since the samples are relatively small and the asymptotic significance value is not accurate enough, the Monte Carlo simulation of the Kruskal-Wallis test was employed using 100 000 iterations, which gives a 99% confidence level for the p-value (significance of the difference in the medians for each variable). P-values of 0.05 or less (95% confidence level) were considered statistically significant and these are shown in the last column of each table, with significant results marked with an asterisk*.

Urban form and GDP

Table 2 shows the differences in urban form between the groups of cities, as reflected by density and centralisation of jobs, as well as economic differences in the cities expressed through the GDP per capita of the urban regions.

Although urban densities are systematically higher in the cities with rail and lowest in the no rail cities, the result is not statistically significant. Since density is a powerful determinant of transport patterns, especially private car use (e.g. Kenworthy and Laube et al 1999, Newman and Kenworthy 1999), it is useful for the purpose of this research that differences in densities between the three groups of cities are not significant. On the other hand centralisation of the city, as measured by the proportion of metropolitan jobs in the CBD, is clearly highest in the SRCs (18.2%) and lowest in the NRCs (10.2%) and the differences are statistically significant. This might be expected, given the link between radial urban rail systems and the development of strong city centres, through rail's capacity to deliver large numbers of people into small areas (Thomson 1978).

Amongst these high-income cities, the SRCs are clearly wealthier than both other groups of cities in a statistically significant way, and as the next section shows, they are also more public transport-oriented. This undermines the idea that cities inevitably become more auto-dependent and move inexorably away from public transport as they become wealthier. In this significant international sample of higher income cities, the reverse would appear to be true. We have argued elsewhere that excessive automobile dependence drains the economy of cities and there is some tacit support for this in the results in table 2 (e.g. see Kenworthy et al 1997).

The additional relevance of some of these data to the arguments made in this paper will become more apparent in later discussions.

Urban form and GDP	**Strong Rail Cities**	**Weak Rail Cities**	**No Rail Cities**	**p-value**
Urban density (persons per ha)	47.6	36.6	27.7	0.453
Job density (jobs per ha)	27.4	16.1	13.4	0.293
Proportion of jobs in the CBD (%)	18.2%	14.6%	10.2%	0.008*
Metropolitan GDP per capita (US$1995)	$35,747	$26,151	$27,247	0.014*

Table 2: Median values and statistical significance for urban form and GDP in strong, weak and no rail cities (1995)

Operational performance of public transport

Table 3 examines differences in public transport operational performance (service and use). The first item reveals a key basis for the formation of the groups of cities. It shows how the SRCs clearly rely much more heavily on rail systems to deliver public transport mobility, with a median value of 74% of passenger kilometers on rail modes, compared to 43% and 0.4% respectively for the other two groups of cities.

Looking more broadly at the public transport operational measures, table 3 shows that the supply of public transport service rises systematically from NRCs to SRCs for both vehicle and seat kilometres of service per capita. SRCs have over four times higher seat kilometres of service per capita than the NRCs. In usage, there is the same ascending pattern from NRCs to SRCs for boardings, passenger kilometres and the proportion of total motorised passenger kilometres on public transport. Public transport use is some three to four times higher in the SRCs than in the NRCs, depending on the measurement used. This is especially interesting in the light of the urban density data in table 2, which show that there is no statistically significant difference in the median population and job densities between the three groups of cities.

Interestingly, however, despite these big differences in the supply and use of public transport, per capita use of public transport energy is only some 1.6 times higher in the SRCs than in the NRCs, though the difference amongst the medians on this factor is statistically significant. This demonstrates the intrinsically high energy efficiency of public transport systems in providing mobility (i.e. service and use are four times higher in the SRCs compared to the NRCs, while energy use to run the systems is only 1.6 times higher).

Public transport operational performance indicators	Strong Rail Cities	Weak Rail Cities	No Rail Cities	p - value
Percentage of pubic transport passenger kms on rail	74%	43%	0.4%	0.000*
Annual public transport vehicle kilometres of service per capita	77	50	29	0.000*
Annual public transport seat kilometres of service per capita	4,086	2,704	969	0.000*
Annual public transport passenger trips per capita	275	188	77	0.002*
Annual public transport passenger kms per capita	1,628	975	496	0.000*
Percentage of total motorised passenger km on public transport	21.8%	12.3%	5.3%	0.004*
Annual public transport energy use per capita (megajoules: MJ)	1,107	880	675	0.019*

Table 3: Median values and statistical significance for operational performance of public transport in strong, weak and no rail cities

Overall, each of the factors in table 3 varies in a strong, statistically significant way in favour of greater rail-orientation of the city. This suggests that for public transport to maximise its role within the passenger transport systems of cities in the developed world, it would appear necessary to move increasingly towards urban rail as the backbone and mainstay of those systems.

Transport infrastructure and infrastructure performance

Table 4 presents a range of public and private transport infrastructure parameters for the three groups of cities.

The data on the extent of transport infrastructure and infrastructure performance reveal, not unexpectedly, that the SRCs have very significantly higher reserved public transport route on a spatial and per capita basis. The vast majority of reserved right-of-way (ROW) in cities is rail; physically segregated busways are very rare (which can be inferred from the fact that in the NRCs, which have either no or negligible amounts of rail ROW, the quantity of reserved public transport route in total is indeed very small).

The SRCs have the lowest total per capita road supply and lowest per capita freeway provision of all three groups of cities and the NRCs have the highest. For example, the NRCs have 71% greater per capita supply of freeways than the SRCs and 65% greater road provision. Although in both cases the differences amongst the median values between the groups are not significant, the consistent direction of the results suggests that higher income cities with more significant rail systems appear to be able to function with fewer roads and freeways.

Perhaps not surprisingly, the data show that SRCs have very much reduced parking supply in their CBDs (68% less than the NRCs), as do WRCs (48% less than NRCs). This is due to rail's capacity for effectively delivering high volumes of people into constrained sites such as CBDs and sub-centres, which eliminates the need for the extensive CBD parking areas found in cities that have no rail systems. Thomson (1978) found similar results in his 'strong-centre' cities.

Transport infrastructure and performance indicators	Strong Rail Cities	Weak Rail Cities	No Rail Cities	p-value
Total length of reserved public trans. routes per 1000 persons	172	78	7	0.000*
Total length of reserved public transport routes per urban ha	9.0	3.0	0.4	0.000*
Length of road per capita (metres)	3.0	4.1	5.8	0.398
Length of freeway per capita (metres)	0.070	0.098	0.120	0.282
Parking spaces per 1000 CBD jobs	186	303	585	0.002*
Total private and collective passenger VKT per km of road	2,026,433	1,461,402	1,615,749	0.708
Overall public transport system speed (km/h)	31.3	23.8	22.6	0.000*
Ratio of public transport system speed to road traffic speed	0.86	0.70	0.49	0.000*

Table 4: Median values and statistical significance for transport infrastructure and infrastructure performance in strong, weak and no rail cities

Finally, the data in table 4 show that in the high-income cities, the intensity of road usage or congestion, as measured by the total private and collective passenger VKT per kilometre of road, is highest in the SRCs, but the differences in the medians are statistically very insignificant. The more important point here, however, is not so much the level of congestion as the competitiveness between private and public transport. In this respect it is very clear that the more rail-oriented the city, the higher the overall average public transport speed for all modes (39% higher in SRCs compared to NRCs) and the higher the ratio between the overall speed of the public transport system and the speed of general road traffic. The median value of this ratio for SRCs is 0.86, while for the NRCs it is only 0.49, which suggests that in speed terms public transport will generally struggle against the car in wealthier cities with no rail systems, while in cities with strong rail systems, public transport speed competitiveness will be much better.

The results for both the overall speed of public transport and the speed ratio between public transport and general road traffic are statistically very significant with p-values of 0.000 in each case. It has been suggested elsewhere that it is this relative speed between public and private transport that is a critical factor in giving public transport a competitive edge over private transport (Laube 1998, Newman and Kenworthy 1999a, b).

Overall, it can be suggested that rail systems help in minimising the amount of road, freeway and parking infrastructure required in cities and are a central ingredient in developing public transport systems that can successfully compete with cars in the critical area of travel speed.

Private transport patterns

Table 5 provides a core set of data related to patterns of private transport and broader modal split in the three groups of cities.

The data reveal that in terms of modal split, there is a systematic pattern in these high-income cities of enhanced use of both non-motorised modes and public transport and reduced use of private modes the more rail-oriented are the cities, and the results have a high level of statistical significance. For example, in the SRCs, the median value for the percentage of total daily trips by private transport is 47%, whilst in the NRCs, it is 84%. The WRCs also have only 56% of daily trips by private transport. Likewise, the median value for non-motorised mode use is almost three times greater in the SRCs than the NRCs, while public transport use for daily trip making is some four times higher.

Despite this modal split pattern, table 5 reveals that there is very little difference between the car ownership and actual car travel (VKT and passenger kms per capita in cars and motor cycles) in SRCs and WRCs. However, there is a considerable difference between these more rail-oriented cities and the cities with no rail, though overall the differences amongst the medians are not statistically significant. Despite this lack of overall statistical significance amongst the medians, the NRCs do have about 70% higher median car use than both the SRCs and WRCs.

Private transport indicators	**Strong Rail Cities**	**Weak Rail Cities**	**No Rail Cities**	**p-value**
Total cars and motor cycles per 1000 people	463	476	544	0.256
Private passenger vehicle VKT per capita (cars + mc)	5,133	5,151	8,732	0.276
Private vehicle passenger kilometres per capita (cars + mc)	6,981	7,014	11,736	0.252
Percentage of all trips by non-motorised modes	31.2%	20.8%	11.3%	0.001*
Percentage of all trips by public transport	19.3%	13.8%	4.7%	0.007*
Percentage of all trips by private transport	47.5%	56.3%	83.8%	0.000*

Table 5: Median values and statistical significance for private transport indicators in strong, weak and no rail cities

What is quite interesting about this pattern of private transport use is its relationship to the density and GDP data presented earlier. First, there is a very strong and statistically significant negative relationship found between urban density and private transport use per capita in the higher income cities in this study (R^2 of 0.8392); it is virtually the strongest correlation found between all the variables in the entire database. As such it could be expected that the NRCs, with a lower median value of urban density (27.7 per ha) than the SRCs (47.6 per ha), would tend to have higher car use per capita, just based purely on their more sprawling land use patterns. Based on the equation of the regression curve between urban density and car passenger kilometres per capita, the NRCs could be expected to have approximately 2 700 more car passenger km per capita than the SRCs. In fact, the difference in Table 5 is 4 700, perhaps suggesting that without the superior public transport systems of the SRCs, the NRCs struggle to substitute car use with public transport use. There is some support for this suggestion in the literature in what is known as the 'transit leverage effect' where one passenger km of public transport travel replaces multiple kilometres of travel in cars (Neff 1996, Newman and Kenworthy 1999).

Furthermore, it is clear that the SRCs in this study have significantly higher GDP per capita than either the WRCs or the NRCs (37% and 31% respectively: see table 2). It is thought by some commentators that greater wealth in a city tends inevitably towards higher automobile dependence and therefore that the SRCs would be unlikely to have equal or lower car use than the WRCs and NRCs with their considerably lower GDP per capita (Gomez-Ibañez 1991, Lave 1992). Again, it would appear that the NRCs are experiencing considerably higher dependence on the car than either their urban form or wealth characteristics would point towards.

The data on private transport and overall modal split strongly suggest that rail is a significant factor in minimising automobile dependence in cities in the developed world. Strong rail systems apparently help in developing urban characteristics that together favour less private transport use (though not necessarily statistically significant lower car + motor cycle ownership), and greater capacity to exploit both public transport and non-motorised modes.

Economic factors

Table 6 summarises some important indicators of the economic performance of urban systems in relation to transport.

Many discussions on the overall effectiveness of urban public transport systems focus on the 'subsidy' afforded to public transport, particularly as reflected in the operating cost recovery of the system. Whilst it can be argued that this focus constitutes a very limited view of the significance of public transport systems in keeping a city operating effectively and minimising environmental impacts (e.g. none of public transport's benefits to non-users such as congestion minimisation appear on the credit side of the balance sheet), and that the word 'subsidy' is something of a misnoma, it is nevertheless important to examine this factor. The data show that it is the SRCs that have the best recovery of operating costs (60%) with WRCs at 51%, while the NRCs recover a much lower figure of 35% and these differences in the medians are statistically significant. Although the differences in average public transport vehicle occupancy in table 6 are not statistically significant, the SRCs do have 16% higher occupancy than the NRCs, which would partly explain the better cost recovery result. Rail cities tend to concentrate public transport services into more focussed corridors with more transit-supportive land uses, which generally deliver higher patronage per unit of service supplied. On the other hand, cities with no rail or those relying solely or almost solely on buses, tend to have public transport systems that have to 'chase' fewer patrons through lower density settings, which inevitably detracts from higher rates of cost recovery.

Economic indicators	Strong Rail Cities	Weak Rail Cities	No Rail Cities	p-value
Public transport operating cost recovery (%)	60%	51%	35%	0.037*
Overall public transport vehicle occupancy	19.8	17.8	17.0	0.192
Percentage of metro GDP spent on public transport investment	0.42%	0.20%	0.10%	0.000*
Percentage of metro GDP spent on road investment	0.73%	0.72%	0.88%	0.774
Total passenger transport cost as percentage of metro GDP	9.03%	9.27%	11.78%	0.018*

Table 6: Median values and statistical significance for economic indicators in strong, weak and no rail cities

The other three economic items in table 6 refer to how much of the GDP of the cities is spent on investing in their public transport and road systems and how much of their GDP they spend on passenger transport as a whole (both public and private transport operating and investment costs from all sources). The patterns are quite clear and statistically significant: the more rail-oriented the cities, the greater proportion of their GDP goes back into investment in their public transport systems, and the lower is the overall cost to the society of running the entire passenger transport system (9.0% of metro GDP in SRCs compared to 11.8% in NRCs). The cities with rail also spend less of their GDP on road investment, but the overall differences in the median values between the groups of cities is not statistically significant on this factor because of the virtually identical result between the SRCs and WRCs.

In summary, the economic data suggest that in this sample of developed world cities, those where rail is a strong feature have greater wealth and more cost-effective urban transport systems overall. They are also investing more in the quality of their public transport systems. Such cities would appear to be wasting less economic resources on passenger transport functions and on this factor are therefore likely to be more competitive economically than cities which sink a higher proportion of their wealth into transport functions.

Environmental factors

Transport systems produce a range of environmental impacts, taken here to include energy use and deaths attributable to transport accidents. Table 7 highlights the relatively favourable position of the more strongly rail-based cities in minimising these impacts.

Per capita use of energy in private passenger transport increases as cities become less rail-oriented, with the NRCs being 144% higher in this factor than the SRCs. Because the SRCs and the WRCs do not vary very much in their median values, the overall differences in the medians are not statistically significant, even though there is this clear difference in private transport energy use between cities that have rail and those that don't (as there was with car use in table 5).

Per capita generation of local smog producing emissions from transport (nitrogen oxides, carbon monoxide, sulfur dioxide and volatile hydrocarbons) is also much higher in the NRCs than in the SRCs (100% higher). The pattern of decreasing per capita transport emissions is quite systematic as the strength of rail increases, though the result falls a fraction short of statistical significance at the 90% confidence level. The spatial intensity of smog emissions also rises slightly the less rail-oriented the cities become, but the results fall far short of any statistical significance (the median value for the NRCs is only 6% higher than the SRCs).

Finally, the costs incurred through transport-related accidents in cities are significant, especially the loss of life. The data in table 7 reveal a consistent and statistically significant pattern of increasing transport deaths as the cities become less rail-oriented and of course less public transport-oriented as a whole. This is true both for per capita transport deaths, which are 129% higher in the NRCs than in the SRCs, and also deaths per billion passenger kilometres, which are 58% higher. It would appear that the more rail-oriented cities become, the less exposure there is to the risk of death from transport causes, even though the use of the riskier non-motorised modes also increases with greater rail orientation.

Environmental indicators	**Strong Rail Cities**	**Weak Rail Cities**	**No Rail Cities**	**p-value**
Private passenger transport energy use per capita (MJ)	16,381	17,197	39,951	0.317
Total transport emissions per capita (NOx, CO, SO2, VHC: kg)	96	114	195	0.105
Total transport emissions per urban hectare (kg)	3,538	3,663	3,753	0.692
Total transport deaths per 100,000 people	5.8	7.8	13.3	0.000*
Total transport deaths per billion passenger kms	6.4	8.0	10.1	0.017*

Table 7: Median values and statistical significance for environmental indicators in strong, weak and no rail cities

In summary rail systems, through their capacity to reduce car use and enhance public transport and non-motorised mode use, are associated with cities that use lower energy for passenger transport and generate lower local emission loads and transport deaths, both on a per capita and per passenger kilometre basis.

Discussion

The findings in this study are in line with extensive and detailed work by Hass-Klau et al (2003), Hass-Klau et al (2004) and Hass-Klau and Crampton (2002), which has demonstrated the many system-wide benefits in European cities of having Light Rail Transit (LRT) systems compared to only having bus systems, including busways. These benefits include higher public transport patronage, which was also found in this international study, but also a wide range of benefits in other factors, which were not examined in this study, but which help perhaps to understand the favourable results found for rail modes in this international comparison. Even though their work refers specifically to LRT systems, some of the findings are likely to be extendable to rail systems in general. Some of their key findings were:

- LRT requires the least width of corridors – busways require most width.
- LRT normally transports more

passengers per hour than standard buses.

- Noise and pollution are lowest with LRT
- Running comfort is best with LRT
- LRT is better in overall urban design terms
- LRT and busways are very similar in cost
- LRT vehicles cost much more but have the longest life expectancy
- LRT is slightly cheaper than buses, on a whole-life basis for similar levels of service.
- Complementary measures are critical to the success of public transport (parking cost and availability, land use policies, pedestrianisation, urban design)
- Buses need stronger complementary measures in order to reach their maximum potential.
- Complementary measures are easier to implement with LRT and important to do in all transport projects to maximise the benefits of the investment.
- Political and psychological factors related to different transport modes modify financial considerations e.g. successful pedestrianisation schemes are strongly linked to implementation of LRT systems.
- Under equal conditions people prefer to use LRT than to use buses.
- There are a higher percentage of higher income groups using light rail than buses (e.g. in Calgary, Canada).
- LRT has a strong potential following among car users, even in cities with no recent experiences of LRT or trams.

The study by Litman (2004) comparing 130 US cities with and without rail concluded that those with significant rail systems have:

- Lower per-capita traffic congestion costs.
- Lower per-capita traffic fatalities.
- Lower per capita consumer transport expenditures.
- Higher per capita public transport ridership.
- Higher public transport commute mode split.
- Lower public transport operating costs per passenger-mile.
- Higher public transport service cost recovery.

Of the above factors that were examined in this international study, the results were similar. The Litman study found that residents in cities with large, well-established rail systems enjoy about half the per capita traffic congestion delay as people who live in comparable size cities that lack rail. The reason for this is in line with the findings in this international study that people in cities with rail systems enjoy lower per capita annual vehicle kilometres whilst also having an effective alternative when travelling on the most congested corridors. Litman (2004) also found that US cities with large rail systems have about a third lower per capita traffic fatality rates. Residents of the strong rail cities also save approximately $US450 annually per capita in transport costs compared with residents of cities that have no rail systems. The study concluded that rail system service costs are repaid several times over by reduced congestion, road and parking facility costs, reduced traffic accident costs, and consumer cost savings. Such findings are in line with the observed comparative differences in this sample of high-income cities around the world that have rail systems (e.g. lower CBD parking, lower transport deaths, a lower proportion of metropolitan GDP being spent on passenger transport, better cost recovery for public transport, higher public transport use).

Rail also has important impacts on urban form in terms of its capacity to increase densities and consolidate both residential and mixed use development around centres or nodes or along corridors. The positive land use impacts of urban rail and their transport flow-on effects are partly responsible for the urban system benefits outlined in this paper. Nodes of development are easier to service with public transport (including bus systems), walking and cycling are more viable for more trips and a polycentric city based around rail stations can help to minimise urban sprawl. These aspects of urban rail and its city-shaping capacity are discussed in detail in other works (Vuchic 1981, Bernick and Cervero 1997, Cervero 1998, Laube, Kenworthy and Zeibots 1999, Newman and Kenworthy 1999a).

Conclusions

Any developed city wishing to build a better public transport system, to curb or reduce its automobile dependence and to become more environmentally and economically sustainable, should not ignore the potential benefits of building a strong rail backbone as the mainstay of the city's public transport system. The data in this paper point strongly to the idea that public transport systems based on buses alone cannot achieve the same positive urban system results across a wide range of factors as when rail systems assume a more significant role within the public transport system.

The mechanisms for the advantages of urban rail are complex. However, they appear to relate at least in part to the legibility of rail systems and the greater permanence of rail services, the positive image of rail in the mind of the public and business community and people's willingness to use rail systems over buses for a variety of reasons, including more competitive travel speed and greater reliability and quality of service.

None of this, however, diminishes the critical role that buses play in public transport systems. Buses are essential public transport providers to areas that simply cannot be served by rail and there are many such areas in most cities, and buses provide critical feeder systems into major sub-centres and into rail systems. Well-patronised urban rail systems are usually associated with strong and healthy levels of bus use (Kenworthy and Laube 2001). Where network structures are well devised and services well coordinated, rail and bus are highly complementary and are not in competition with each other, but rather form an integrated, multi-modal public transport system that provides competition with the car.

Finally, the arguments and research put forward in this paper should not be read or construed in terms putting one mode of public transport above another merely for the sake of it. This is clearly not productive since the best public transport systems emerge out of choosing the right mode for the right task for the multitude of situations in any city. Public transport should be seen as a multi-modal system whose chief aim is to compete with and reduce dependence on the car, building a 'virtuous circle' rather than a cycle of decline, which has tended to be the story of public transport in so many cities over the last decade (Kaufmann 2000). Rather, what the paper has shown is that urban systems, whether in auto-dependent North America or Australia, more transit-oriented Europe, or the wealthier parts of Asia, do seem to gain multiple benefits from developing public transport systems that are anchored and shaped primarily by fixed-track modes, the vast majority of which are rail systems, in one form or another. This then forms the basis for a superior overall public transport system, utilising rail modes, buses and in some cases ferries, which fills a much greater role in the city's transport system.

Finally, it needs to be said that although the analysis in this paper is based on data from 1995 or 1996, the overall conclusions and patterns between the three groups of cities are unlikely to be altered were the analysis to be conducted using later data. In other words, the systematic differences in the various factors found between strong rail, weak rail and no rail cities are not ephemeral observations, but are based on strong structural differences between the cities, which reveal themselves repeatedly over long periods of time. A similar analysis was carried out with 1990 data on a more limited set of cities listed in Newman and Kenworthy (1999a). The same systematic patterns of variation between the rail cities and no rail cities emerged on the same variables.

In addition, the author has begun the update of data on some cities, especially in the USA and the completed transit data for 2005 shows that the US cities with no rail, such as Phoenix, continue to stagnate in transit use with only an 11% increase in annual boardings per capita from an extremely low level of 15.1 trips per capita up to 16.8 (virtually the lowest in the world). Phoenix is building a LRT system at this moment. Likewise Houston declined slightly in transit use over the 10 year period and has finally voted to build an extensive LRT system. Los Angeles in the mean time has been aggressively growing its rail system (light rail, metro and commuter rail) and has achieved the highest growth rate in transit use of all the US cities studied (39%, up from 49.1 boardings per capita in 1995 to 68.3 in 2005). New York, the most rail-oriented of the US cities, was the other big transit winner with a 28% increase in transit use from 131.5 boardings per capita to 167.7 per capita, the bulk of which came from the NY underground. Thus more recent data are tending in the direction of reinforcing the patterns observed in this paper, so that the ageing nature of the data used do not undermine the policy value of the results and conclusions.

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References

Ang, B.W., 1990, Reducing traffic congestion and its impact on transport energy use in Singapore. *Energy Policy*, 18 (9), 871-874.

Ang, B.W., 1993, An energy and environmentally sound urban transport system: the case of Singapore. *International Journal of Vehicle Design*, 14 (4).

Badami, M.G., 2005, The urban transport challenge in India: Considerations, implications and strategies. *International Development Planning Review*. 27 (2), 169-194.

Bernick, M. and Cervero, R., 1997, *Transit villages in the 21st century* (New York, U.S.A.: McGraw Hill).

Bonsall, J., 1985, A bus for all seasons. Presented to Seminar on The Canadian Experience: Making Transit Work in the Golden Gate Corridor, San Rafael, California, U.S.A., October 3.

Cervero, R., 1995, Sustainable new towns: Stockholm's rail served satellites. *Cities*, 12 (1), 41-51.

Cervero, R., 1998, *The transit metropolis: A global inquiry* (Washington DC, U.S.A.: Island Press).

Gomez-Ibañez, J. A., 1991, A global view of automobile dependence. *Journal of the American Planning Association,* 57 (3), 376-379.

Hass-Klau, C. and Crampton, G. (2002) *Future of urban transport learning from success and weakness: Light rail* (Brighton, U.K.: Environmental and Transport Planning).

Hass-Klau, C., Crampton, G. and Benjari, R., 2004, *Economic impact of light rail: The results of 15 urban areas in France, Germany, UK and North America* (Brighton, U.K.: Environmental and Transport Planning).

Hass-Klau, C., Crampton, G., Biereth, C. and Deutsch, V., 2003, *Bus or light rail: Making the right choice - A financial, operational and demand comparison of light rail, guided buses, busways and bus lanes* (Brighton, U.K.: Environmental and Transport Planning).
Henry, L., 1989, Ridership forecasting considerations in comparisons of light rail and motor bus modes. In: *Light Rail Transit: New system successes at affordable prices*, Transportation Research Board, Special Report 221, (Washington DC, U.S.A.: Transportation Research Board), pp. 163-189.

Kain, J. and Liu, Z., 1999, Secrets of success: Assessing the large increases in transit ridership achieved by Houston and San Diego transit providers. *Transportation Research A* 33, 601-624.

Kaufmann, V., 2000, Modal practices: From the rationales behind car and public transport use, to coherent transport policies. Case studies in France and Switzerland. *World Transport Policy and Practice*, 6 (4), 8-17.

Kenworthy, J.R., 1995, Automobile dependence in Bangkok: An international comparison with implications for planning policies. *World Transport Policy and Practice* 1 (3), 31-41.

Kenworthy, J.R. and Laube, F.B., 1999, Patterns of automobile dependence in cities: An international overview of key physical and economic dimensions with some implications for urban policy. *Transportation Research A* 33, 691-723.

Kenworthy J, and Laube F., 2001, *The Millennium Cities Database for Sustainable Transport*. (Brussels, Belgium: International Union of Public Transport, UITP and Perth, Australia: Institute for Sustainability and Technology Policy, ISTP), CD ROM database.

Kenworthy, J., Laube, F., Newman, P. and Barter, P.,1997, *Indicators of transport efficiency in 37 cities*. Report to World Bank, Institute for Science and Technology Policy, Murdoch University, Western Australia.

Kenworthy, J. and Laube, F. [with Newman, P., Barter, P., Raad, T., Poboon, C. and Guia, B. (Jr)], 1999 *An international sourcebook of automobile dependence in cities 1960-1990* (Boulder, U.S.A.: University Press of Colorado).

Laube, F. B., 1998, Optimising urban passenger transport: Developing a least-cost model based on international comparison of urban transport cost, transport patterns, land use, infrastructure, environmental and best practice in public transport. PhD thesis, Murdoch University, Perth, Western Australia.

Laube, F.B., Kenworthy, J.R. and Zeibots, M.E., 1999, Towards a city science: City observation and formulation of a city theory. In: *Siedlungsstrukturen, räumliche Mobilität and Verkehr: Auf dem Weg zur nachhaltigkeit in Stadtregionen,* edited by M. Hesse (Berlin, Germany: Institut für Regionalentwicklung und Strukturplanung), pp. 99-118.

Lave, C., 1992, Cars and demographics. *Access,* 1, 4-11.

Litman, T.A., 2004, Rail transit in America: Comprehensive evaluation of benefits. http://www.vtpi.org/railben.pdf

Neff, J.W., 1996, Substitution rates between transit and automobile travel. Paper presented at the Association of American Geographers' Annual Meeting, Charlotte, North Carolina, April.

Newman, P. and Kenworthy, J., 1989, *Cities and automobile dependence: An international sourcebook* (Aldershot, U.K.: Gower).

Newman, P. and Kenworthy, J., 1991, *Towards a more sustainable Canberra: An assessment of Canberra's transport, energy and land use*. Institute for Science and Technology Policy, Murdoch University, Perth.

Newman, P. and Kenworthy, J., 1999a, *Sustainability and cities: Overcoming automobile dependence* (Washington DC, U.S.A.: Island Press).

Newman, P. and Kenworthy, J., 1999b, 'Relative speed' not 'time savings': A new indicator for sustainable transport. *Papers of the 23rd Australasian Transport Research Forum*, Perth, Western Australia, 29 September – 1 October, Volume 23, Part 1. pp. 425-440.

Pickrell, D. H., 1990, *Urban rail transit projects: Forecasts versus actual ridership costs* (Cambridge, U.S.A.: US Department of Transportation).

Pucher, J., 2002, Renaissance of public transport in the United States? *Transportation Quarterly* 56 (1), 33-49.

Pucher, J. and Dijkstra, L., 2003, Promoting safe walking and cycling to improve public health: Lessons from The Netherlands and Germany. *American Journal of Public Health*, 93, (9), 1509-1516.

Thomson, J.M., 1978, *Great cities and their traffic* (Harmondsworth, U.K.: Penguin).

Vuchic, V. R., 1981, *Urban public transportation: Systems and technology* (Englewood Cliffs, New Jersey, U.S.A.: Prentice-Hall).

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Bicycle Ambulances in rural Uganda:
Analysis of factors influencing its usage

Corinna Wallrapp and Heiko Faust

Introduction

This paper is concerned with the potential of bicycle ambulances to improve the accessibility to health centres in rural Uganda. The bicycle ambulance is a bicycle with an attached trailer to transport especially seriously sick patients a maximum distance of 15km to the nearest health centre.

Figure 1: Photo of a bicycle ambulance

These bicycle ambulances were distributed to villages or health centres in rural areas of Uganda by the non-governmental organisations FABIO (First African Bicycle Information Office & Workshop) and BSPW (Bicycle Sponsorship Project & Workshop) from Jinja and by the governmental institution Directorate of Health Services (DDHS) of District Kabale. This paper describes the main results of a study carried out in Uganda by the author herself. It aimed to analyse the usage of the bicycle ambulances in selected villages. Furthermore factors that promote or limit its frequency of usage were defined. The results are used to improve the projects of FABIO/BSPW and the DDHS and to provide further recommendations.

The paper is structured as follows: The first section briefly reviews the range of difficulties accessing health centres commonly faced by men, women and children living in rural areas in developing countries as a result of scarce means of transport and limited financial resources.
The second section of the paper focuses on the case study in Uganda with the analysis of the potential of bicycle ambulances to improve the accessibility to health centres for the rural population. Thereby factors related to the bicycle ambulance are examined and presented. Two research areas with different circumstances – the area around Jinja in the central region and the area of District Kabale – are compared with each other.

State of the art:
Access to health centres in Uganda

The authors Thaddeus et al. (1994) constructed a model to categorise barriers for the rural population in developing countries to seek health care. According to this model, barriers or delays to seek health care can appear on three different levels. Firstly, there is the process to decide that medical treatment is needed. Secondly, there is the means to reach health facilities. Finally, there is the issue of attaining sufficient medical care in the health centre itself. Socio-economic factors, culture, knowledge about facilities, availability and affordability of transport, road infrastructure conditions, opportunity costs and availability of drugs and medical staff are all examples that determine access to health services for patients. Different case studies in developing countries provide different results and factors which mainly influence the rural population in seeking medical treatment. For example, Ensor et al. (2004) focus on the side of the health seekers rather than on the providers. In their study they conclude that an improvement in the quality of health care would not necessarily increase the number of health seekers, because of their burdens to have access to them. Other case studies in developing countries tone down the distance to the health centre (Noorali et al., 1998; Akin et al., 1999) or emphasise the cultural constraints, such as the vulnerability of women or disadvantaged groups (Katahoire et al., 2004; Amooti-Kaguna et al., 2000). Therefore, they arrive at different results referring to the factors influencing the behaviour of patients when seeking health care. However, in almost every study about health-seeking behaviour and its barriers, the aspect of distance to the health facility is a described factor.

The term 'distance' is related to the factors of 'road infrastructure conditions', 'availability' and 'affordability of transport'. In the rural areas of Uganda, where nearly 90 % of the population live, most trips are made by foot. Private motorised transport is mostly not available, and public transport, such as minibuses are rare and for many people not affordable (Barwell et al., 1985; Barwell, 1996; Howe, 2001). In Uganda, animal carts are not common in most regions, yet it is a country with a culture of bicycles. Therefore, the means of transport that is both available and affordable in most villages is the bicycle. With regard to an emergency transport service however, the bicycle cannot be used in all situations. In the hilly areas of southwest Uganda the patients are traditionally carried on stretchers to the health centre. In the central region of Uganda they put a chair on the carrier of the bicycle to enable the patient to sit a little more comfortably and stable.

Figure 2: Stretcher in Kabale District carried by at least four persons

Figure 3: Bicycle with a chair on the carrier to transport patients

Both methods have disadvantages; transportation is slow and exhausting for the people who help to push or carry. Additionally, the poor road infrastructure deteriorates the transport situation. Rural roads are dirt roads, mostly in a fair condition yet riddled with potholes. In the rainy seasons they are often impassable.

Consequently, people in rural areas in Uganda lack access to social institutions and in particular to health centres. Referring to the health sector, the services are mainly centralised in the capital city Kampala, while other smaller cities and especially the remote areas are undersupplied with adequate health facilities and staff. This contributes to a low life expectancy, high mortality rates and a high percentage of self-treatment or visits to traditional healers. According to a study from the Ugandan Bureau of Statistic in 2006, the main reason given for not seeking medical attention from a health provider was that the illness was mild, followed by statements such as the health facility is too costly or is too far. Approximately 20% of the population of Uganda have to travel more than 5km to receive primary health care (UBOS, 2006). Yet even the aspired distance by the government of a maximum 5km for every household is a significant distance for someone ill to travel without appropriate transport.

According to the study in rural Uganda, the most challenging factors affecting the people are availability of transport to the health centres and the necessary money to meet the costs of transport and treatment. It can be assumed that some people, who lack the means to go to the health centres, treat themselves or do not seek any treatment at all. Thus, the introduction of the bicycle ambulance provides an acceptable, alternative form of transport which overcomes the barriers of availability and affordability of transport, and improves the accessibility to health centres.

Analysis of bicycle ambulances in rural Uganda

Background of the study

The first bicycle ambulance was designed and distributed by the non-governmental organisation BSPW in Jinja, Uganda in 1997. Since then, over 400 units have been distributed to different districts. BSPW promotes non-motorised transport, especially the bicycle. Bicycle ambulances are mainly sponsored by international donors. They are distributed to community groups or social institutions in the rural areas to overcome their problems of transport in emergencies. The criteria for the community groups to receive a bicycle ambulance are their relatively high distance to the nearest health centre and the existing poor road and transport infrastructure. Since 1999, the Directorate of Health Services (DDHS) for the Kabale District has taken up the idea of bicycle ambulances and also distributes them.

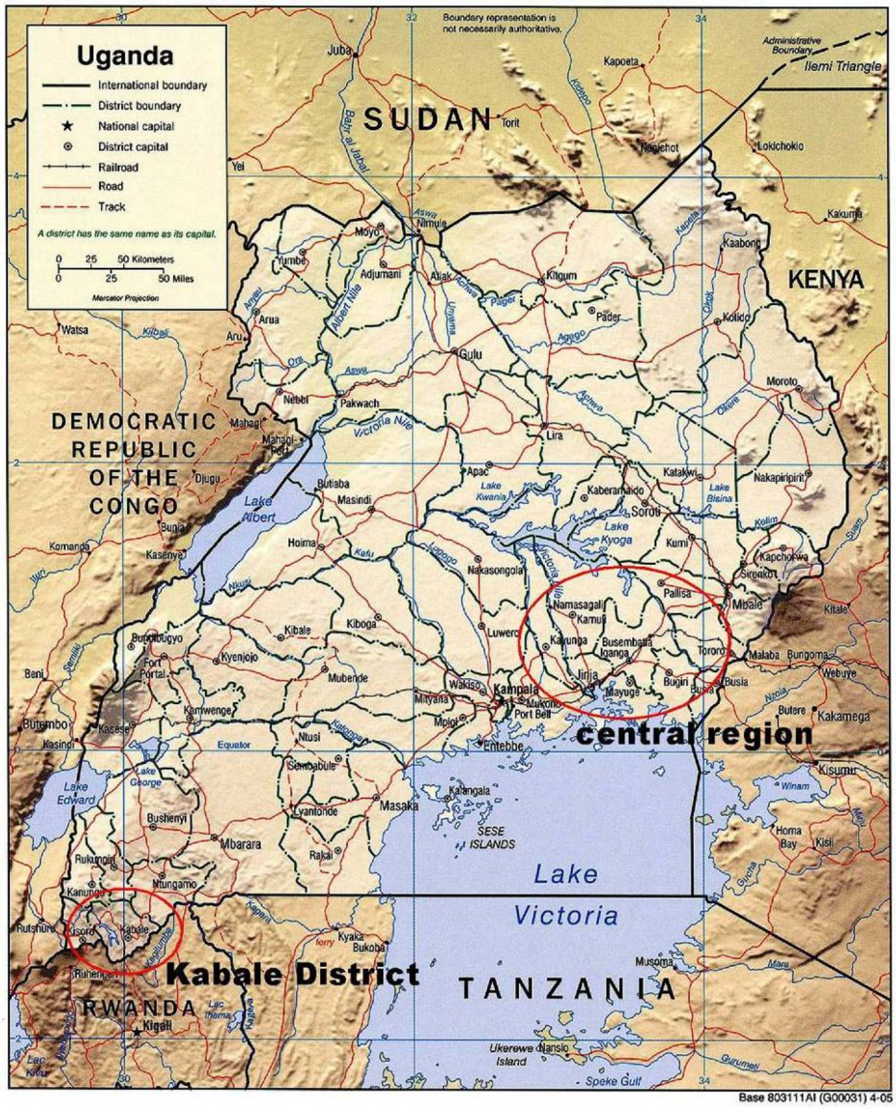

Figure 4: Map of Uganda with the two research areas, www.lib.utexas.edu

Aims and methods

The objective of the study was to explain and understand the usage of bicycle ambulances and their problems. The key questions were as follows:

- Which factors and conditions influence the usage of the bicycle ambulance and;
- Can the bicycle ambulance be described as an appropriate technology in Uganda?

Data collection took place between March and June 2007 and involved qualitative interviews with the distributors and the recipient groups of the bicycle ambulances. A total number of 37 villages were selected, whereby in each village, different community members were interviewed independently. Another method was the distribution of record books to write down details about the usage of the bicycle ambulance in order to provide information and to control the answers in the interviews. In order to compare the villages, the frequency of the usage of the bicycle ambulance was used as the indicator to get an overview of the group's performance.

Research areas

Two research areas with quite homogenous circumstances and a high quantity of bicycle ambulances were identified:

Research area one included the districts of Jinja, Bugiri and Kamuli in the central region of Uganda. The terrain is flat with scattered settlement structures. The selected villages were a mixture of those with peri-urban or very remote characters and those with good or poor road infrastructure access. Research area two represents District Kabale in the southwest of Uganda. There, the terrain is very hilly with a more concentrated settlement structure than in the flatlands, although road and transport conditions are also often poor. The main differences between the two areas were the community groups and the distributors. In area one, the bicycle ambulances were distributed mainly to women's groups by the non-governmental organisation BSPW. In contrast, the bicycle ambulances in area two were distributed to so-called stretcher/engozi groups, established in almost every village to organise the transport of patients to hospital with a stretcher. The local government of Kabale were the distributor of the bicycle ambulances through the DDHS in this area.

Performance of the groups

Before analysing the factors influencing the usage of the bicycle ambulance, the performance of the groups had to be determined. This was achieved by means of a 'frequency of usage' indicator. The frequency of usage depended on the frequency of sick persons. However, it was assumed that on average, there were more cases of sick persons in a village in comparison to those making use of the bicycle ambulance. As demonstrated in Table 1, only one group (Buwaiswa, Kitayunjwa Sub-county, District Kamuli) out of 37 observed villages made use of the bicycle ambulance on average more than two times per month. Approximately two-thirds of the groups used the bicycle ambulance less than one time or on one occasion per month. Eight did not use it at all.

Table 1: Performance of groups in the observed villages

Performance		*No. of villages (total 37)*	*Village names (central region: total 14, Kabale: total 23)*
1 –	More than 2 times per month	1	*Central region:* Buwaiswa
2 –	2 times per month	3	*Central region:* Bwase, Kitengesa *Kabale:* Kyasano
3 –	1 time/month	11	*Central region:* Buwala, Nawaguma, Mafubira *Kabale:* Mpalo 2, Nyakashebeya, Mpungo, Kabere, Nyaruhanga vill, Kagunga, Mugyera, Kicumbi
4 –	less than 1 time per month	11	*Central region:* Kalogoyi, Kasuku A, Kigingi, Nsekaseka, Iringa HC *Kabale:* Mpalo 1, Katokye 1, Katokye 2, Nyaruhanga TC, Buranga, Kasheregyenyi
5 –	Not used	8	*Central region:* Kasangoile, Nakasita, Namuganza *Kabale:* Kibanda vill, Kibanda TC, Bwindi, Nyamabare, Mwendo
Doubtful answers		3	*Kabale:* Rutegye, Muhanga, Kisaasa

Results: Presenting the factors influencing the usage of the bicycle ambulance

Subsequently, the factors influencing the usage of the bicycle ambulance, as determined through interviews, were categorised into different categories: external factors, describing the situation in the villages, and internal factors, describing the features of the bicycle ambulance, the distributors and the organisation of the groups. The following demonstrates the outcomes:

External factors

The different circumstances in the villages, such as distance to infrastructure, availability and costs of means of transport, did not provide a clear picture of how, and to what extent these factors influence the usage of the bicycle ambulances. Neither the distance to the health centre, nor the distance to the main road and quality of the road itself, significantly influenced the usage of the bicycle ambulance. The only factor that significantly limited the usage of the bicycle ambulance was the availability of motorised transport in the villages. However, motorised transport is scarce and, most likely, not affordable to the rural population in the near future.

Features of the bicycle ambulance

The frequency of the usage of the bicycle ambulances was limited to a few cases in a month or year, and the features and the construction of it were predominantly described as positive by the interviewees. Although some people have negative attitudes towards it, such as ‘the patient looks like a dead body lying down in the bicycle ambulance’ or that ‘the costs of maintenance are too high because repairs are needed too often and spare parts are too expensive’, the majority of people in the villages appreciated the bicycle with the trailer in emergencies. The bicycle ambulance construction is easy to maintain, with common spare parts. Additionally, almost every man can ride the bicycle due to the bicycle culture. Furthermore, it is available at any time with little cost, and in comparison to the stretcher, it is more comfortable and less people are needed to transport it. Out of the eight villages that did not use the ambulance, only three of them reported that it had broken down and could not be repaired. Therefore, non-usage of the bicycle ambulance in the other five villages depended on factors other than repairs.

Perspective of distributors

The system of bicycle ambulance distribution differed in the two research areas. In research area one, as access to the villages is difficult and distances are far, BSPW worked with partner-organisations in the areas of work, these organisations having local knowledge of the area and direct contact to the villages. Before the distribution of the bicycle ambulance took place, BSPW carried out 'capacity building' workshops in the villages to facilitate knowledge of management and maintenance of the bicycle ambulance to the community and group members. BSPW saw it as their responsibility to monitor and control the performance of their distributed bicycle ambulances, but funds were limited. Access to the areas is difficult and visits were rare due to financial and time constraints. The direct monitoring process was therefore carried out by the partner-organisations who forwarded the information to BSPW. In Kabale, research area two, the DDHS played a more passive role. They neither carried out specific monitoring of the groups, nor provided specific 'capacity building' workshops. However, their passive role did not influence the usage negatively. Whether 'capacity building' and/or continuous and frequent monitoring influenced the usage can only be assumed, but could not be observed in the villages.

Organisation of the groups

Bicycle ambulances in both areas were always distributed to community groups or social institutions that were responsible for the management and maintenance.

In almost every community in area two, there exists a stretcher/engozi group that is responsible in the community for the transport of patients to health centres on a stretcher and to give additional support in funeral functions. They groups are long-established and at least one person from each household is a member of the group. The bicycle ambulance provided an additional activity. Maintenance of the group is financed through membership fees. Every household is therefore aware of the activities of the group and the bicycle ambulance and makes a contribution towards its maintenance. As a consequence, each member has a strong feeling of ownership and responsibility to the bicycle ambulance.
In area one, most of the groups that received bicycle ambulances were recently established women's groups working across several villages. Since the members are spread over different villages, the organisation and activities of the group depend a lot on the motivation and efforts of the leader. In other villages, specific bicycle ambulance committees were founded to manage the ambulance. However, neither the women's groups nor the committees were as integrated into community life as the stretcher/engozi groups in Kabale, due to the fact that only a few members live in the same village and/or the fact that the groups were only recently established. Consequently, only a few community members were involved with the management and maintenance of the bicycle ambulance and had knowledge about it.

Another important point to consider is the necessity of the bicycle ambulance. Vulnerable people have a proportionally higher need for an affordable means of transport, such as the bicycle ambulance, than other community members. Additionally, they may not have the self-esteem to ask for the facility. Therefore, targeting and informing these vulnerable people is essential in the community and an important task for the group. Consequently, this has a positive influence on the usage of the bicycle ambulance. For example, the children's home in Buwaiswa, District Kamuli, has direct contact to vulnerable people in the neighbouring villages and, at the same time, the most frequent usage of the bicycle ambulance of all observed villages.

Nevertheless, each location and region has its particular difficulties when transporting the bicycle ambulances. In Kabale, steep climbs make usage difficult, and in the central region, area one, the scattered settlement structures make access difficult. Therefore, the attitudes of people either supporting or hindering its usage are essential for the decision to use it.

Conclusion

This paper presents results from the study in Uganda about the usage of bicycle ambulances. The study was based on a qualitative research analysis involving guided interviews with distributors and beneficiaries of the bicycle ambulance. External and internal factors influencing the usage of the bicycle ambulances were defined.

As listed in Table 1, the bicycle ambulance was only used more than two times in a month in one out of 37 selected villages. In eight villages the facility was not used at all. The reasons for using the bicycle ambulance or not are based on different factors. On the one hand, the technology itself may be in/appropriate to the local conditions and on the other hand, the attitudes of the people may either promote the technology or refuse it.

With regard to the bicycle ambulance's technology, it is appropriate to the circumstances in the rural areas of Uganda when compared to the available and affordable alternatives such as motorised transport, stretchers and bicycles.

As a consequence, usage or non-usage of the bicycle ambulance depends on factors other than the technology:

- Firstly, the situation of the villages and location has little or no influence on the usage.
- Secondly, the influence of the distributor – BSPW or DDHS – can be assumed, but could not be observed.
- Thirdly, the organisation of a group determines the usage of a bicycle ambulance significantly. Awareness of the group and their activities from within the community, as well as the group's integration into the village community itself positively influence the usage of the bicycle ambulance.

The principal problems encountered in usage of the bicycle ambulance in the observed villages were the awareness of the bicycle ambulance and the support of the community members to make use of it. Possible solutions to these problems would be changes in the organisational structure of the groups and the distributors.

In the author's opinion, the situation of the majority of rural people in developing countries will not improve significantly in the near future in terms of income and transport opportunities. Therefore, intermediate means of transport like the bicycle are important facilities in order to access social and economic institutions. The bicycle ambulance is an example of an appropriate mode of transport in emergencies in order to improve access to health centres.

References

AKIN, J.S. and HUTCHINSON, P. (1999) 'Health-care facility choice and the phenomenon of bypassing' *Health Policy and Planning* Vol 14, No 2, pp 135-151.

AMOOTI-KAGUNA, B. and NUWAHA, F. (2000) 'Factors influencing choice of delivery sites in Rakai district of Uganda' *Social Science and Medicine* Vol 50, pp 203-213.

BARWELL, I. (1996) 'Transport and the Village, Findings from African Village-Level Travel and Transport Surveys and Related Studies' *World Bank Discussion Paper* No 344, Washington.

BARWELL, I., EDMONDS, G., HOWE, J. and DE VEEN, J. (1985): *Rural Transport in Developing Countries* London, Intermediate Technology Publications.

ENSOR, T. and COOPER, St. (2004) 'Overcoming barriers to health service access: influencing the demand side' *Health Policy and Planning* Vol 19, No 2, pp 69-79.

HOWE, J. (2001) 'Village Level Transport' *Rural Transport Knowledge Base, of the Rural Travel and Transport Programme 2001,* Sub-Saharan Africa Transport Policy Programme (SSATP), http://www4.worldbank.org/afr/ssatp/Resources/HTML/rural_transport/knowledge_base/English/Module%201%5C1_1a%20Village%20level%20travel.pdf (14/04/08).

KATAHOIRE, A., SCHEUTZ, F., SABROE, S. and WHYTE, S. (2004) 'The importance of maternal schooling for child morbidity and mortality and maternal health behaviour in southeastern Uganda' *Journal of Health & Population in Developing Countries*.

NOORALL, R., LUBY, S. and RAHBAR, M.H. (1999) 'Does use of a government service depend on distance from the health facility?' *Health Policy and Planning* Vol 14, No 4, pp 191-197.

THADDEUS, S. and MAINE, D. (1994) 'Too Far To Walk: Maternal Mortality in Context' *Social Science and Medicine* Vol 38, No 8, pp 1091-1110.

UBOS UGANDA BUREAU OF STATISTIC (2006) *Uganda National Household Survey 2005/2006 Report on the socio-economic module*, Kampala.

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Simplified travel demand modelling for developing cities: The case of Addis Ababa

Binyam Bedelu & Marius de Langen

1. Introduction

Low-income cities in developing countries lack sustainable transport network planning tools. Their networks are often planned and implemented with pure speculation. No rational explanation can be given to policy decisions affecting the transport system, nor is there a rational basis for urban transport network plans. To transform this common practice into a more systematic approach, there is a need for strategic planning. It is the most neglected planning dimension in low-income cities. Strategic plans deal with the overall structure and capacity of the main transport network, and also deal with the relationship between transport and land-use.

Travel demand modelling can be used as a strategic planning tool. However, application of the conventional modelling system, as practiced in developed countries, produced unsatisfactory results. Thomson (1983) has explained in detail the apparent weaknesses of the conventional method for developing countries. The focus should, then, be on applying simplified modelling techniques to developing cities.

The main objective of this study was to asses the applicability of one specific simplified travel demand model as a tool for strategic transport network planning. In addition, an answer was sought to the question: 'can a simplified model be developed not requiring the use of licensed software, that can be utilised by competent municipal engineers in developing cities as a forecasting tool to assist transport network planning?' A special concern was that the model must, in a transparent way, include all modes of travel (walking, where relevant two-wheelers, public transport modes and private motor vehicles), and allow to investigate the implications of different modal split scenario's that include pedestrian and bicycle traffic. The reason for this concern is that these modes, and pedestrian traffic in particular, serve the majority of travellers in many low-income cities, and that therefore the use of the standard travel demand model with a focus on private car travel or the car/public transport modal choice is less suitable.

The four steps – trip generation, distribution, modal split and traffic assignment - were modelled within a spreadsheet environment. The study addressed only passenger transport. Urban freight transport was not included in the modelling. The observed traffic flows, derived from traffic counts specifying the share of freight vehicles, were corrected for freight traffic.

2. Literature review

According to Fischer (1987), the main objective of travel demand analysis is to provide an understanding of why people travel, to identify the essential factors influencing their travel decisions and to provide information for the evaluation of alternative transportation policies by predicting the travel consequences of alternative policies or planning. In practical terms, the ultimate purpose of urban travel demand modelling is to provide a tool with which one may predict, or forecast, urban travel patterns under various conditions. These conditions may represent the state of the transportation network or, generally, that of the urban area at a future time. The conditions could also be policy alternatives under which different travel patterns can be analysed.

Travel demand models have been in use since the late 1960's and a lot of criticism is thrown at them. This is mostly aimed at the standard four stage aggregate model. Different authors express their views relating to the weaknesses of the conventional method. It is worthwhile to mention that the criticism sometimes doesn't concentrate only on the model as such, but on the planning and decision making aspects as well. Bruton (1988) expressed that the conventional four step model is criticised on the grounds that it is concerned more with simulating or reproducing known situations, than predicting the way travellers behave now or will behave in the future. The main weakness of the conventional model is generally understood to be its failure to allow for consequences of change. Trip rates are assumed to be independent of the transport changes being considered. Land uses are assumed to remain equal in the analysis of alternative transportation improvements. Forecasting future travel demand by using base-year correlations makes the process non-causal, in the sense that it is not based on any logical or behavioural responses of travellers to new conditions.

Looking at many of these criticisms, one wonders why developing cities should go through such travel demand analysis procedures. Even, there are some who argue that developing countries should only work on better traffic management and concentrate more on low-cost, short-term improvements (Thomson 1983).

Even if it is true that low cost measures and traffic management works are essential to address some of the existing problems, Ortúzar and Willumsen (1998) point out that weak transport planning, emphasis on the short term and mistrust in strategic transport planning in the past had brought its own lessons. It was learnt that 'problems do not fade away under the pressure of mild attempts to reduce them through better traffic management; old problems reappear with even greater vigour, pervading wider areas, and in their new forms they seem more complex and difficult to handle.'

Furthermore, no adequate replacement has been proposed to the transport planning model and practitioners still extensively use it in part or in its entirety. The logic of the modelling process, and the representation of the ways in which decisions are made has remained to be its strength (Banister 1994). From the perspective of the state of the practice, the choice of this approach is not because it is the best available but because it is often the only approach available, given current institutional requirements and financial limitations (McNally 2000). Therefore, as the proponents of modelling theory argue, some guide as to what the future might hold in terms of travel patterns is better than pure speculation. Yet, the conventional travel demand models appear to be less suitable for the developing world, and hence the emphasis should be on simplified models geared to the urban travel conditions and planning needs of developing countries (Bayliss 1992).

An important question that needs to be addressed at this juncture is: 'what is simplified modelling'. Is there an accepted definition and procedure as to what the term 'simplified modelling' encompasses? After all, there are a whole range of modelling approaches in between the extremes of using no formal models at all and employing the most advanced and complex simulation techniques. Literature reviewed doesn't seem to offer a specific global definition. Nevertheless, different authors have put forth the idea and reported about the application of simplified modelling to different cases.

The repeating theme that comes when dealing with simplified modelling is *data requirement*. Collecting and processing enormous amounts of data has been seen as a main setback to utilising conventional transport modelling methods in developing country cities. Hence a simplified modelling approach is desirable that requires minimum data input, which can be obtained in a reliable manner, and that utilises available data. Another important aspect of simplification is the need for a simple model structure. A procedure that is transparent and has a simple analytical processes, i.e. without 'black-box effects', is confirmed to be the basis for simplified modelling.

3. Zonal and network definition

3.1 Addis Ababa profile

Addis Ababa is the capital city of Ethiopia. The city administration territory extends over 540 km^2. The 2004 population of the city is estimated to be 3 million. A household survey, conducted as part of an Urban Transport Study during 2004 has revealed many socio-economic characteristics of the people of Addis Ababa. The average household size is 5.08. The people are young in age with the median value being 18-40 years. Income is low, nearly 50% of the people are below poverty line and about 23% are in absolute poverty (ERA 2005).

ERA's (2005) Findings Report provided the salient characteristics of the trip making behaviour of the people of Addis Ababa. A total of 3.4 million trips per day are generated, on average, in the city. The overall Per Capita Trip Rate (PCTR), including persons of all age groups is 1.08. Excluding the population in the age group 0-5, the PCTR is reported to be 1.14. Walking is the predominant mode, accounting for a share of 60.5% of all trips. The Minibus comes next with a share of 20.6%, followed by City Bus with a 10.9% share. The average trip length including walking is 3.3km. According to the study, the total travel demand generated in Addis Ababa, on an average day, is 11.05 million-passenger-km. The Minibus takes the highest share of travel demand with 34%, while the walking share drops to 27.3%.

It is important to note that the modal share of car trips is very low, with 4.7%. Vehicle ownership in Addis Ababa is very low. Nearly 90% of households do not own a vehicle. Another important finding of the study is the very low interaction between city households and the external region. Of the total trips produced, almost 99.75% are intra city, i.e. they have their points of origin and destination within the study area. However, it is also reported that the outer cordon survey revealed a reasonable movement of people and goods into/out of the city from external regions.

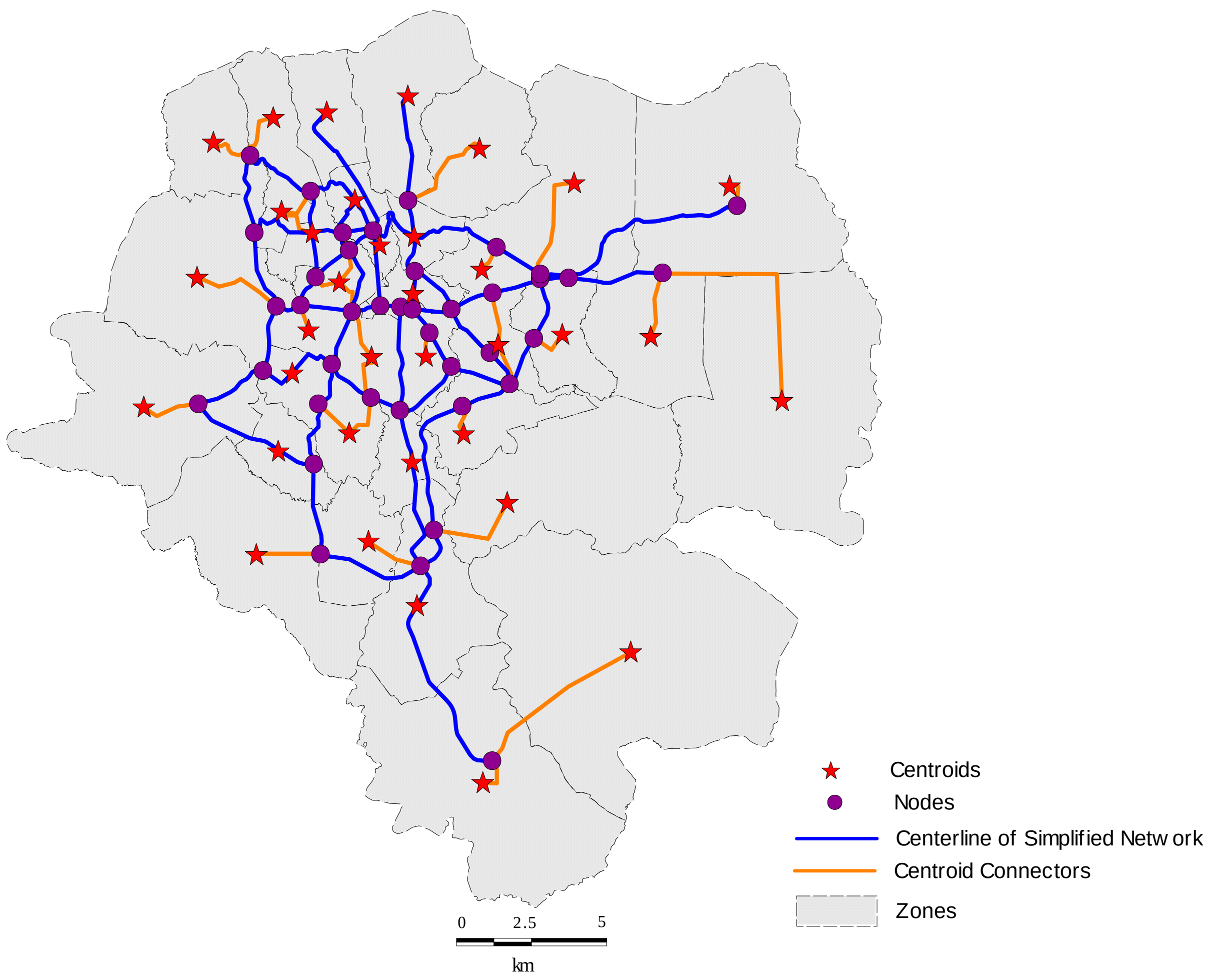
3.2 Demarcating traffic analysis zones and simplified network

Addis was divided into 35 traffic zones under this study. The zoning was carried out to ensure that each demarcated zone falls within the formal administrative zone of sub cities. Hence the traffic zones are made of clusters of *kebele* administrations, which is the smallest administrative unit of the city. Moreover effort was made to ensure that zones are as homogeneous as possible. The aim of this simplified modelling exercise was to use as low divisions as possible and test the results of the model. Generally, the lower the number of zone divisions, the less data collection requirement.

Figure 3.1: Zones and network presentation

Addis has 472km of paved road network. Out of the total paved roads, 25% are arterial 14% are sub arterial 27% are collector and 35% are local roads. For this simplified modelling work, arterial roads are chosen. The choice is done in order that all zones are possibly connected with the road network. The total length of selected roads is 137km (of 2x1, 2x2 or 2x3 lanes).

A total of 65 links, 40 nodes, 35 connectors, and 35 centroids were identified for the model. Figure 3.1 shows the final map that was used as a base for modelling.



4. Data

The purpose of this simplified travel demand modelling is to provide a model for estimation of traffic numbers on main road corridors for scenario analysis of the urban transport system that can be applied with a limited set of input data, for which the collection and analysis is manageable. The required key input data grouped into source and type are presented below:

a) *Administrative (Census or other)*

Data under this group are sourced from offices where records of data are kept for administrative purposes. Relevant offices keep track of statistical data as part of their main work activities. The municipality and local administrations keep track of population figures. Education bureaus keep records of students. Labour and statistics offices keep records of employment data. These data are basically reflections of land use and the economic activities of the area. Hence, zonal data that were made available for this study are: population, employment, and student enrolment.

b) *Household survey (inventory)*

Data under this group need to be collected by means of a household (HH) travel survey. This study used the HH survey data obtained from the ERA's (2005) Findings Report. The ERA transport study carried out 5,500 household interviews during 2004.

For this simplified modelling, the HH survey data are classified into two: zonal data, and city trip characteristic data. The specific zonal data and the city trip characteristics data used in the model are presented below:

Zonal data:

Resident workers; Resident students; Work trip productions and attractions; education trip productions and attractions; other purpose trip productions and attractions.

City trip characteristic data:

Table 4.1: Modal share of trips

Mode	Share of trips
Walk	60.5 %
Car	4.7 %
City Bus	10.9 %
Mini Bus Taxi	20.6 %
Others	3.3 %

Table 4.2: Average trip length for each mode of travel

Mode	Average Distance (km)
Walk	1.4
Car	7.4
City Bus	7.5
Mini Bus Taxi	5.4
Others	8.1

Table 4.3: Share of trips by distance group

Distance	Share of trips
0-2 km	53%
2-4 km	21%
4-8 km	15%
8-12 km	7%
>12 km	4%

Table 4.4: Income versus modal share of main modes of travel

HH income Birr/Month	**Up to 300**	**300 - 500**	**500 - 800**	**800 - 1000**	**1000 - 2000**	**2000 - 4000**	**>4000**
Walk	12.4%	16.6%	14.0%	6.6%	9.4%	1.4%	0.2%
Car	0.1%	0.3%	0.5%	1.1%	1.8%	0.8%	0.3%
Minibus	1.5%	2.9%	3.0%	1.2%	1.9%	0.3%	0.1%
Bus	1.3%	3.3%	4.6%	3.2%	6.0%	1.9%	0.4%
Others	0.1%	0.2%	0.9%	0.6%	1.0%	0.4%	0.0%

A distinction should be clarified between the variables "Resident workers" and "Employment". The workers variable is the total number of employed persons residing in a zone, while the employment variable represents the number of employees whose place of work is within a zone. It should be noted that while these variables are mentioned here under the HH survey data, because the estimates of labour participation and of work place location distribution were based on the HH survey, the scaling of these variables was based on census data.

c) Network and Traffic data

Road network inventory: In this study, inputs for the model were: topology of the network (map), and road section length, number of lanes and observed average traffic flow speed. The availability of a digital map of the network expedited the network definition exercise. Network data and a digital map of the road network for this study were made available by the Addis Ababa City Roads Authority.

Traffic counts: Independent data regarding the actual traffic volume on selected links on the network is necessary to validate the model output. These should be of the same year as the household survey. As the model is limited to passenger traffic, ADT without freight traffic is taken for comparison.

It should be noted that while traffic count data are used to compare the model's traffic volume estimates with observed traffic flows, the key calibration of the model is carried out at the distribution and modal split stage (average O/D trip distances equal to observed average trip distances, and modal split equal to observed one – observed in both cases: by means of household survey).

Table 4.6 summarises the data requirements.

Table 4.6: Summary of data requirement

Data	**Generation**	**Distribution**	**Modal Split**	**Assignment**	**Remark**
City travel characteristics data - household survey					
Modal share of trips			X		For development of base matrices
Average trip lengths for each mode		X	X		
Share of trip distances		X	X		
Income versus mode of travel			X		
Zonal data - Household survey					
Trip production	X				
% work, education and other trips	X				
Resident workers	X				
Resident students	X				
Trip attraction	X				
Share of trips by income		X			
Zonal data - Census					
Population	X				
Employment	X				
Student enrolment	X				
Network data					
Road length (per section)				X	
Number of lanes ..				X	
Traffic flow speed ..				X	

5. Development of mobility matrices

This simplified model uses aggregate modal choice data. To obtain the best accuracy in predictions for future years, modal-split market segmentation is carried out. This means that the aggregate modal split is considered for market segments that can be expected to be, in themselves, more constant over time than the market as a whole, shifts in modal choice being, to a considerable extent, caused by the transition of travellers from one market segment to another. For example in the Addis case: getting to a higher income level allowing the use of public transport for more trips, or, in the highest income class, obtaining a private motor vehicle.

The segmentation variables used are: trip distance, trip purpose and income of the traveller. An alternative for this last one would be vehicle ownership of the traveller, but insufficient data were available in this case study to use it.

Since market-segmented modal choice matrices provide a detailed insight into the actual mobility of the urban population, they are referred to as *Mobility Matrices.* They show over what distances and in what modal shares per distance class people travel, and how the pattern differs by trip purpose and income group.

The basic matrices used in the simplified model as specified in this paper for trip distribution and modal split modelling stages are listed below. The complete - desirable market segmentation mentioned above could not be applied in the current test, because the basic records of the 2004 Addis household travel survey were not available for this study, only the report presenting the aggregate survey findings. This findings report didn't include the cross-tabulations providing immediate estimates of the different mobility matrices by market segment. This made it necessary to derive best estimates indirectly (as explained below), and to omit the segmentation by trip purpose. For validation of the model's traffic volume calculations on the arterial road network against observed ADT flows, leaving out the differences in modal choice per trip purpose isn't problematic (the average over all purposes *is* the current overall pattern). However, for forecasting it is desirable to include representing shifts in size between trip purpose segments, the modal split pattern differing significantly between trip purposes.

The basic matrices used in this study are:

- Overall Mobility matrix (mode versus distance; total urban travel market)
- Income versus distance matrix
- Mobility matrices for different income groups

5.1 Develop mobility matrix

The data available to develop the mobility matrix for Addis Ababa are:

- Modal share of trips (Table 4.1)
- Average trip lengths for each mode of travel(Table 4.2)
- Share of trip distances (Table 4.3)

The problem to derive the matrix has the following form:

Trip Distance	**0-2 km**	**2-4 km**	**4-8 km**	**8-12 km**	**>12 km**		**Average**
Mode	**(1 km)**	**(3 km)**	**(6 km)**	**(10 km)**	**(18 km)**	**Total**	**Distance (km)**
Walk	?	?	?	?	?	*60.5 %*	*1.4*
Car	?	?	?	?	?	*4.7 %*	*7.4*
City Bus	?	?	?	?	?	*10.9 %*	*7.5*
Mini Bus Taxi	?	?	?	?	?	*20.6 %*	*5.4*
Others	?	?	?	?	?	*3.3 %*	*8.1*
Total	*53%*	*21%*	*15%*	*7%*	*4%*		

As can be referred from the formulated problem, there are 25 unknowns and 15 independent constraints. The problem is solved through the tri-proportional fit method. The procedure starts with initial estimates of matrix-cell values, by applying the direct percentage on the daily number of trips. Then the matrix is further improved to reflect the absolute deviation of distance group from the average distance of each mode. This is done by multiplying the values in the matrix by a factor: $\frac{1}{(/d_i - d_{avg}/)^f}$

where d_i is the average distance of class, d_{avg} is the average distance of modes, and f is a factor which is initially set to 2.

Then, iteration similar to Furness is applied, which involves successive corrections by rows and columns to satisfy row and column summation constraints. The iteration stops when corrections are 100% satisfied. Finally a value for the factor *f* is searched such that the average distance of modes coincides with the target average distances. The final result is given in Table 5.1 below.

Table 5.1: Mobility Matrix for Addis Ababa

Trip Distance ***Mode***	**0-2 km (1 km)**	**2-4 km (3 km)**	**4-8 km (6 km)**	**8-12 km (10 km)**	**>12 km (18 km)**	**Total**	**Average Distance (km)**
Walk	50.2%	9.7%	0.3%	0.3%	0.0%	*60.5%*	1.4
Car	0.4%	1.2%	1.2%	1.2%	0.6%	*4.7%*	7.4
City Bus	0.9%	2.8%	2.7%	3.0%	1.5%	*10.9%*	7.5
Mini Bus Taxi	1.5%	6.8%	10.2%	1.0%	1.0%	*20.6%*	5.4
Others	0.2%	0.7%	0.4%	1.5%	0.5%	*3.3%*	8.6
Total	*53%*	*21%*	*15%*	*7%*	*4%*		

5.2 Develop income versus distance matrix

The data available to develop income versus distance matrix are:

- Average trip lengths for each mode (Table 4.2)
- Share of trip distances (Table 4.3)
- Income versus mode of travel (Table 4.4)

First, average distance of each income group is calculated, and then the problem is formulated similar to the one shown above as follows:

Distance ***Income (Birr/Mon)***	**0-2 km (1km)**	**2-4 km (3 km)**	**4-8 km (6 km)**	**8-12 km (10 km)**	**>12 km (18 km)**	**Total**	**Average Distance (km)**
Up to 300	?	?	?	?	?	*16%*	2.5
300 - 500	?	?	?	?	?	*24%*	2.9
500 - 800	?	?	?	?	?	*23%*	3.4
800 - 1000	?	?	?	?	?	*12%*	3.8
1000 - 2000	?	?	?	?	?	*19%*	4.1
2000 - 4000	?	?	?	?	?	*4%*	5.2
>4000	?	?	?	?	?	*1%*	5.6
Total	*52.85%*	*21.25%*	*14.90%*	*7.00%*	*4.00%*		

Using a similar iteration procedure mentioned under the foregoing section the solution is given in Table 5.2 below:

Table 5.2: Income Vs Distance Matrix

Distance ***Income***	**0-2 km (1km)**	**2-4 km (3 km)**	**4-8 km (6 km)**	**8-12 km (10 km)**	**>12 km (18 km)**	**Total**	**Average Distance (km)**
Up to 300	12.0%	1.8%	1.1%	0.8%	0.5%	*16%*	2.5
300 - 500	10.1%	11.3%	1.4%	0.9%	0.6%	*24%*	2.9
500 - 800	12.8%	5.1%	2.9%	1.7%	1.0%	*23%*	3.4
800 - 1000	6.7%	1.3%	2.3%	1.2%	0.7%	*12%*	3.9
1000 - 2000	9.9%	1.6%	4.5%	2.0%	1.1%	*19%*	4.3
2000 - 4000	1.2%	0.1%	2.1%	0.5%	0.2%	*4%*	5.5
>4000	0.1%	0.0%	0.6%	0.1%	0.0%	*1%*	5.8
Total	*53%*	*21%*	*15%*	*7%*	*4%*		

5.3 Develop mobility matrices for different income groups

The first step will be determining the income classification. It is recommended that the income class be divided in to three groups: low income, medium income, and high income. The income threshold is proposed to coincide with those having similar trip making characteristics. To figure out those having similar trip characteristics, the income versus mode of travel matrix is recalculated in such a way that share of mode for each income group is known. Table 5.3 below shows the converted income versus mode matrix. It should be noted that the income classification tables presented herewith are based on number of trips not number of population.

Table 5.3: Income versus mode

Birr/Month	**unto 300**	**300 - 500**	**500 - 800**	**800 - 1000**	**1000 - 2000**	**2000 - 4000**	**>4000**
Walk	80%	71%	61%	52%	47%	30%	22%
Car	1%	1%	2%	8%	9%	17%	29%
Minibus	10%	12%	13%	10%	10%	6%	8%
Bus	8%	14%	20%	25%	30%	40%	40%
Others	1%	2%	4%	4%	5%	7%	1%
	100%	100%	100%	100%	100%	100%	100%

From the table above it can be concluded that, based on modal choice characteristics, it makes sense to simplify to three distinct income groups, as shown in Table 5.4.

Table 5.4: Income classification of trips

Birr/Month	*Class*	*Percentage*
Up to 800	Low-income	62%
800 - 2000	Medium-income	33%
> 2000	High-income	6%

Hence Table 5.4 above can be converted into class versus distance matrix as shown in Table 5.5 below:

Table 5.5: Income class versus distance group

Trip Distance ***Income Class***	**0-2 km**	**2-4 km**	**4-8 km**	**8-12 km**	**>12 km**	**Total**
Low	33%	18%	5%	3%	2%	*62%*
Medium	18%	3%	7%	3%	2%	*33%*
High	2%	0.2%	2%	1%	0.3%	*6%*
Total	*53%*	*21%*	*15%*	*7%*	*4%*	

Again, Table 5.5 above can be recalculated as presented in Table 5.6 below:

Table 5.6: Income class versus distance converted

Trip Distance ***Income Class***	**0-2 km**	**2-4 km**	**4-8 km**	**8-12 km**	**>12 km**	**Total**
Low	54%	29%	9%	5%	3%	*100%*
Medium	54%	9%	22%	10%	5%	*100%*
High	36%	4%	44%	11%	5%	*100%*

Likewise, Table 4.3 can be converted as class versus mode matrix as presented in Table 5.7 below.

Table 5.7: Class versus mode

	Low	**Medium**	**High**	**Total**
Walk	43%	16%	1.6%	*60%*
Car	1%	3%	1.0%	*5%*
Minibus	7%	3%	0.4%	*11%*
Bus	9%	9%	2.2%	*21%*
Others	1%	1%	0.4%	*3%*
	62%	*33%*	*6%*	

And Table 5.7 can be recalculated and presented as Table 5.8:

Table 5.8: Class versus mode converted

	Low	Medium	High
Walk	69%	49%	29%
Car	1%	9%	19%
Minibus	12%	10%	6%
Bus	15%	28%	40%
Others	2%	4%	6%
Total	100%	100%	100%

Once the necessary matrices are derived, mobility matrices for the three income groups can be derived using a similar iteration procedure mentioned before.

Mobility matrix for low-income group

The daily number of trips by the low income group needs to be established first. Hence, the daily number of trips by low income group can be calculated by as follows:

$$T \times LIT$$

Where T is the total number of trips per day and LIT is the share of trips made by low income group, which is 62%, 3,352,732 x 0.62

Daily trip by low income group is: 2,072,762

After the total number of trips by the low income group is calculated, the problem for the matrix can be formulated by taking the low income modal share and distance share from Table 5.6 and Table 5.8 as follows:

Trip Distance ***Mode***	**0-2 km (1km)**	**2-4 km (3 km)**	**4-8 km (6 km)**	**8-12 km (10 km)**	**>12 km (18 km)**	**Total**	**Average Distance (km)**
Walk	?	?	?	?	?	*69.4%*	*1.4*
Car	?	?	?	?	?	*1.3%*	*7.4*
City Bus	?	?	?	?	?	*12.0%*	*7.5*
Mini Bus	?	?	?	?	?	*14.9%*	*5.4*
Others	?	?	?	?	?	*2.4%*	*8.1*
Total	*54%*	*29%*	*9%*	*5%*	*3%*		

The final matrix after solving the problem is shown in Table 5.9:

Table 5.9: Mobility matrix of low-income group

Trip Distance ***Mode***	**0-2 km (1 km)**	**2-4 km (3 km)**	**4-8 km (6 km)**	**8-12 km (10 km)**	**>12 km (18 km)**	**Total**	**Average Distance (km)**
Walk	53.1%	16.1%	0.1%	0.1%	0.0%	*69.4%*	1.4
Car	0.1%	0.5%	0.3%	0.3%	0.2%	*1.3%*	7.4
City Bus	0.5%	4.6%	2.1%	3.1%	1.7%	*12.0%*	7.5
Mini Bus Taxi	0.5%	7.4%	6.1%	0.5%	0.6%	*14.9%*	5.0
Others	0.1%	0.7%	0.2%	1.1%	0.4%	*2.4%*	8.6
Total	*54%*	*29%*	*9%*	*5%*	*3%*		

The average trip distance of the low income group is calculated to be 3.0km.

Similar to the procedure employed for the low income group, mobility matrices were developed for medium income group and high income group, whose average distances were calculated to be 4.1km and 5.2km respectively.

Once mobility matrices were estimated using aggregate city trip characteristics data, the simplified travel demand modelling procedure was developed as explained in the next section.

In cases where household travel survey records per respondent are available, the estimation procedure shown above is not needed, since all mobility sub-matrices can then directly be derived from the survey.

6. The Four Modelling Steps

The first stage of the four step model is the *trip generation* model which predicts the number of trips produced and attracted per day to a traffic zone. The output of the trip generation model is total person trips productions and attractions. The second step is the *trip distribution* model which distributes all trips produced in a zone to all possible attraction zones. The output of the trip generation model is input for this model. The output of the trip distribution model is nine total person OD matrices stratified by purpose (3) and income class (3). The third step is the *modal split* model which separates the total person trip matrices into alternative modes. The outputs of trip distribution model, all person OD matrices, are the inputs for this model. The final output of the modal split model is a traffic matrix expressed in passenger car equivalent units (pce). The fourth and the last step is *traffic assignment* model that loads vehicle trips on the road network. The final output of the model was average daily traffic or peak hour traffic on each link.

6.1 Trip generation modelling

Trips are, at the generation stage, stratified by three trip purposes. These are: work trips, education, and other purposes. All three are home-based trips. None-home based trips are left out as a separate group in this study, because their share is very small (2%, compared to home-based trips). To assess the effect of this, the model was run once with inclusion of the non-home based trips, but the final output (traffic on the arterial roads) didn’t differ from the result obtained without.

Regression equations were applied to estimate trip productions and attractions per zone. The equations were tested with and without a constant term. In this study, all constant terms in the trip generation equations were insignificant (very low values for the t-statistic), so equations without a constant term were used (i.e. the average percentage of resident workers in a zone was used as an estimator of the number of work trips generated per day, etc.)

Trip productions

Total number of trips generated per day per zone in 2004 was available as input data, from the household survey. For trip purposes, only the share of each trip purpose in the ten sub-cities was available. These shares were applied to traffic zones according to the sub-city they belong, to get productions per purpose for each zone (should raw survey data have been available, these values could have been derived directly from the survey).

The explanatory variables for work, education and other purpose trip productions respectively are the number of *resident workers, resident students (incl. primary school)* and *population* in the zone. Estimates of resident workers and students were available from the household survey.

Trip attractions

The method used for estimating trip attraction is similar to that used for trip production. Regression models were used for the three purpose groups. The explanatory variables for work, education and other purpose trip attractions are, respectively, *employment number, student enrolment* and *employment* in the zone.

6.2 Trip distribution modelling

In this study, the trip distribution model has been applied separately for three trip purpose groups: work, education, and other trips. The reason for doing this is that the average trip distance differs strongly between these trip purposes (for example, work trip being on average much longer). Each trip purpose group is in turn subdivided into three income groups: low, medium, and high. Hence, the model estimates nine (3x3) origin-destination matrices.

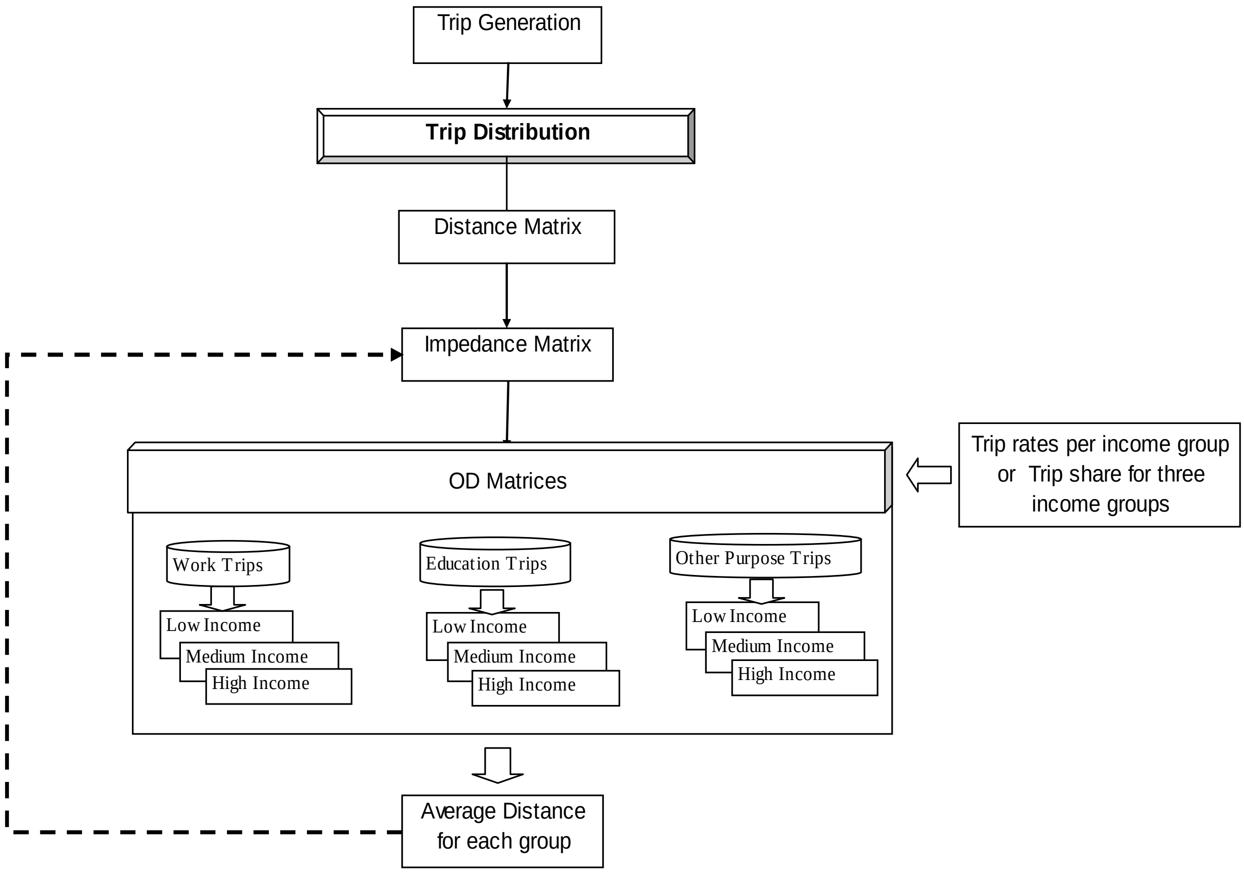
A Gravity Model -the most widely used trip distribution technique- is used. The gravity model assumes that flows between zones decrease as a function of distance separating them, just as the gravitational pull between two objects decreases as a function of the distance between them. The procedure employed for each purpose and income group is shown below.

Trip Distance Matrix

In the simplified model, it isn't immediately obvious how the distance between two traffic zones can best be quantified in order to get the best fit between the estimated O/D matrix and observed average trip distances and key O/D flows. Initially, in the model test, distances were estimated as shortest paths along the simplified (main arterial) road network, and the O/D matrix estimated with this measure of inter-zone distance. However, with this approximation of inter-zone distance no satisfactory fit can be achieved. The explanation is that the simplified network (consisting of the main arterial roads only) is a too rough approximation of the much denser actual network of roads and tracks that travellers use to provide realistic inter-zone distances. This is in particular true for short trips and trips on foot (at the distribution stage trips by all modes are included in the same manner, and hence in the Addis case, as in many low-income cities, a high percentage of the trips is on foot). It turns out that by simply using straight-line distance between zone centroids a much better and in fact satisfactory fit is obtained.

predicted for new situations, while there would also be no ground for assuming it is an invariant zone characteristic constant. This is the underlying overall logic of the simplified model: not to use unclear model-fitting parameters.

Figure 6.1: Diagram of trip distribution modelling



Trip distance of trips within one traffic zone was approximated by 0.5 the average radius of the built-up area of the zone. Higher and lower values of the intra zonal trip distance were tested (0.25, 0.75 r), but produced a less good fit between the estimated and observed intra/inter zonal trip ratio. The use of intra-zonal trip distance per separate traffic zone as a parameter that can be adapted (per zone) to achieve a perfect fit was not considered. For the base-case this could be done, but, in the absence of an underlying explanation, it could not be

Impedance matrix

The impedance of travel from zone *i* to *j* is usually defined as a function of generalized cost of travel between the two zones. One common form is $F_{ij}=C_{ij}^{-\alpha}$. For this study, the generalised cost is assumed to be the distance between zones. Hence the impedance function is calculated as $1/d_{ij}^{\alpha}$, where d_{ij} is distance between zones and α is model parameter to be determined by calibration. The calibration iterations start with α=2, by analogy to the law of gravitation – hence the name gravity model. The impedance matrix is calculated by applying the impedance function on the distance matrix.

Trip productions and attractions

The trip productions and attractions for each zone, sub-divided by purpose of the trip, calculated in the generation model are taken as input for the distribution model. Productions and attractions by trip purpose are then further sub-divided into low, medium, and high income groups according to the trip rate per each income class (more trips per day by higher-income).

Doubly constrained iteration

Furness iteration is carried out separately for the nine income group (3) and trip purpose (3) combinations. The iteration involves consecutive correction of columns and rows till the summations are satisfactorily balanced.

At each iteration of the gravity model, the total trips attracted to each zone is adjusted so that the next iteration of the gravity model will send more or fewer trips to that attraction zone, depending on whether the immediately previous total trips attracted to that zone was lower or higher, respectively, than the trip attractions estimated by the trip generation model. After several iterations a final Origin-Destination (OD) matrix for the particular purpose and income class is produced.

Calibrate matrix

A simplified calibration procedure is employed in this study. First, the average distance of the O/D matrix is calculated to compare it with the target (observed) average trip distance of the income class concerned (calculated from the base mobility matrices). Second, the value of *a* is sought such that the average distance value of the matrix coincides with that of the actual average trip distance of the income group (/purpose). As shown during the development of base matrices, the average trip distances of low, medium and high income groups are 3.0 km, 4.1 km, and 5.2 km respectively. The average distance of a matrix is calculated with the following equation:

$$d_{avg} = \frac{\sum_{i}^{n}\sum_{j}^{n} d_{ij}T_{ij}}{\sum_{i}^{n}\sum_{j}^{n} T_{ij}}$$

where T_{ij} is number of trips between zone *i* and zone *j* and d_{ij} is the distance between the two zones and *n* is the number of zones.

6.3 Modal split modelling

The simplified modal split procedure applied in this study deviates significantly from the conventional model. The now commonly used travel demand forecasting models uses disaggregate modal split models, often on separate choice-based samples, and reflecting choice probabilities of individual trip-makers (McNally 2000), and often use combined modal split/ traffic assignment or combined modal split/distribution.

In contrast, the simplified model presented here uses mobility matrices of different travel market segments, as explained earlier. Hence the data requirement for the modal split model is in fact the data required to develop mobility matrices.

The modal split model is undertaken by taking into consideration income classes and trip distances. The modal split matrices are calculated based on mobility matrices of each income class, and the distance group of each mode. For each OD matrix table, modal split matrices are derived. The modes considered are: walk, minibus, bus, car, and other types. From the nine OD matrices, a total of 45 OD passenger travel matrices per travel mode are calculated first (measure in passenger trips). Per mode nine matrices are added up, resulting in five matrices, one for each mode, as shown in Figure 6.2. Finally, after leaving out the pedestrian traffic matrix, the four remaining mode-specific traveller OD matrices are transformed into a single "passenger car equivalent" (pce) OD traffic matrix, by applying occupancy and equivalency factors per modes of transport. Note that the choice for five modes of travel is specific for the Addis case, and should be made in each city on the basis of the actual traffic composition (for example requiring inclusion of motorised two-wheelers or of bicycles categories; the simplified model can be adapted easily by using more or less rows in the mobility matrices).

An example showing the procedure followed is presented below. Data from low income group is chosen for the purpose of explanation.

- **OD Matrix**

  The OD matrix for low-income group under work trip is taken as a case for explanation.

- **Mobility matrix**

  The mobility matrix of the low-income group will be used for this calculation, as the group under investigation is low-income. Table 6.1 below presents the mobility matrix of the low income group.

Table 6.1: Mobility matrix of low income group, example

Trip Distance	***0-2 km***	***2-4 km***	***4-8 km***	***8-12 km***	***>12 km***	
Mode						***Total***
Walk	*53.0%*	*13.9%*	*0.1%*	*0.1%*	*0.0%*	*67.2%*
Car	*0.1%*	*0.5%*	*0.2%*	*0.4%*	*0.2%*	*1.3%*
City Bus	*0.5%*	*2.7%*	*1.0%*	*2.3%*	*1.1%*	*7.7%*
Mini Bus Taxi	*1.5%*	*11.0%*	*7.0%*	*1.3%*	*1.2%*	*21.8%*
Others	*0.1%*	*0.5%*	*0.1%*	*1.0%*	*0.3%*	*2.0%*
Total	*55.2%*	*28.5%*	*8.5%*	*5.1%*	*2.7%*	

The above mobility matrix is converted into the following matrix where modal shares are given per trip-distance class:

Table 6.2: Converted mobility matrix, example

Trip Distance ***Mode***	**0-2 km**	**2-4 km**	**4-8 km**	**8-12 km**	**>12 km**
Walk	96.0%	48.8%	1.6%	2.7%	0.0%
Car	0.2%	1.6%	2.3%	7.5%	6.7%
City Bus	1.0%	9.3%	12.3%	46.2%	39.7%
Mini Bus Taxi	2.7%	38.4%	82.3%	24.7%	42.8%
Others	0.2%	1.8%	1.6%	18.9%	10.8%
Total	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*

- **Calculate modal split matrices**
  Trips in each cell of the OD matrix will be checked for the distance group they belong. Then the trip values in each cell will be split into modes in accordance to the share of mode by using the proportion calculated in Table 6.2. The calculation is carried out using the following conditional clauses:

  If 0 km < d_{ij} < 2 km, then *walk* = $0.96*T_{ij}$, *car* = $0.002*T_{ij}$, *city bus* =$0.01*T_{ij}$, *minibus* = $0.027*T_{ij}$, *others* = $0.002*T_{ij}$

  If 2 km < d_{ij} < 4 km, then *walk* = $0.49*T_{ij}$, *car* = $0.016*T_{ij}$, *city bus* =$0.093*T_{ij}$, *minibus* = $0.38*T_{ij}$, *others* = $0.018*T_{ij}$

  If 4 km < d_{ij} < 8 km, then *walk* = $0.016*T_{ij}$, *car* = $0.023*T_{ij}$, *city bus* =$0.123*T_{ij}$, *minibus* = $0.82*T_{ij}$, *others* = $0.016*T_{ij}$

  If 8 km < d_{ij} < 12 km, then *walk* = $0.027*T_{ij}$, *car* = $0.075*T_{ij}$, *city bus* =$0.46*T_{ij}$, *minibus* = $0.247*T_{ij}$, *others* = $0.19*T_{ij}$.

  If d_{ij} > 12 km, then *walk* = $0*T_{ij}$, *car* = $0.067*T_{ij}$, *city bus* =$0.397*T_{ij}$, *minibus* = $0.428*T_{ij}$, *others* = $0.108*T_{ij}$

  where d_{ij} is the distance from zone *i* to zone *j* which would be picked from the distance matrix, and T_{ij} is number of person trips between zone *i* and zone *j* which would be picked from the OD matrices.

Hence at the end of the calculation, five origin-destination matrices for the five modes are produced for the low-income group, for the work purpose trips. To check the accuracy of the result, average distance of each mode and modal share are calculated and checked against the observed average distances of modes. The average mode distances and modal shares are used to calibrate the mode split matrices to get satisfactory result. If the modal shares and distances are not replicated well, an iterative procedure is employed by slightly varying the distance groupings. For example, for low income trips, a d_{ij} between 0 and 2km did not give good result. Thus trials are made by varying group margins with values of 2.1km, 2.2km etc. till the model result converges with the observed values. These adjustments are needed because the mobility matrices are prepared with discrete distance classes, while the impedance function in the gravity model is continuous.

The generalised form of the methodology applied for the modal split model can be represented as follows:

Table 6.3: A general form of mobility matrix

Trip Distance Mode	G_1	G_2	... G_k	... G_m
m_1	S_{11}	S_{12}	...S_{1k}	... S_{1m}
m_2	S_{21}	S_{22}	... S_{2k}	... S_{2m}
$\vdots$				
m_f	S_{f1}	S_{f2}	... S_{fk}	... S_{fm}
$\vdots$				
m_n	S_{n1}	S_{n2}	... S_{nk}	... S_{nm}
Total	100%	100%	100%	100%

For $d_{ij} \in G_k$, *then* $M_f = S_{fk} \times T_{ij}$

where d_{ij} is distance between zone i and j, G_k is the distance group, M_f is the number of trips using mode m_f, S_{fk} is share of mode m_f in distance group G_k , and T_{ij} is the number of person trips between zone i and zone j .

Table 6.4 shows results of the model output against observed values after calibration of final matrices.

Table 6.4: Comparison of model output and target

	Low Income				**Medium Income**				**High Income**			
	Percentage		Average Distance		Percentage		Average Distance		Percentage		Average Distance	
	Observed	Model	Observed	Model	Observed	Model	Observed	Model	Observed	Model	Observed	Model
Walk	67.2%	68.5%	1.41	1.31	51.2%	49.5%	1.4	1.65	32.6%	31.9%	1.4	1.63
Car	1.3%	1.3%	7.38	8.00	9.0%	9.3%	7.4	7.01	21.0%	21.1%	7.4	7.27
City Bus	7.7%	7.5%	7.45	8.11	15.5%	16.0%	7.5	7.08	23.8%	24.5%	7.5	7.45
Mini Bus Taxi	21.8%	20.7%	5.41	5.84	19.2%	19.9%	5.4	5.66	13.8%	11.1%	5.4	5.30
Others	2.0%	2.1%	8.12	9.00	5.1%	5.2%	8.1	7.85	8.9%	11.4%	8.1	9.03
	Average		3.00	3.00			4.14	4.14			5.49	5.50

It can be seen that the modal split methodology captures all significant modes of transport in the city. An origin-destination matrix specifically for the walk mode is generated. Likewise an origin-destination matrix for public transport modes is generated. Had there been significant usage of bicycles in the city, cycling would have been included as well.

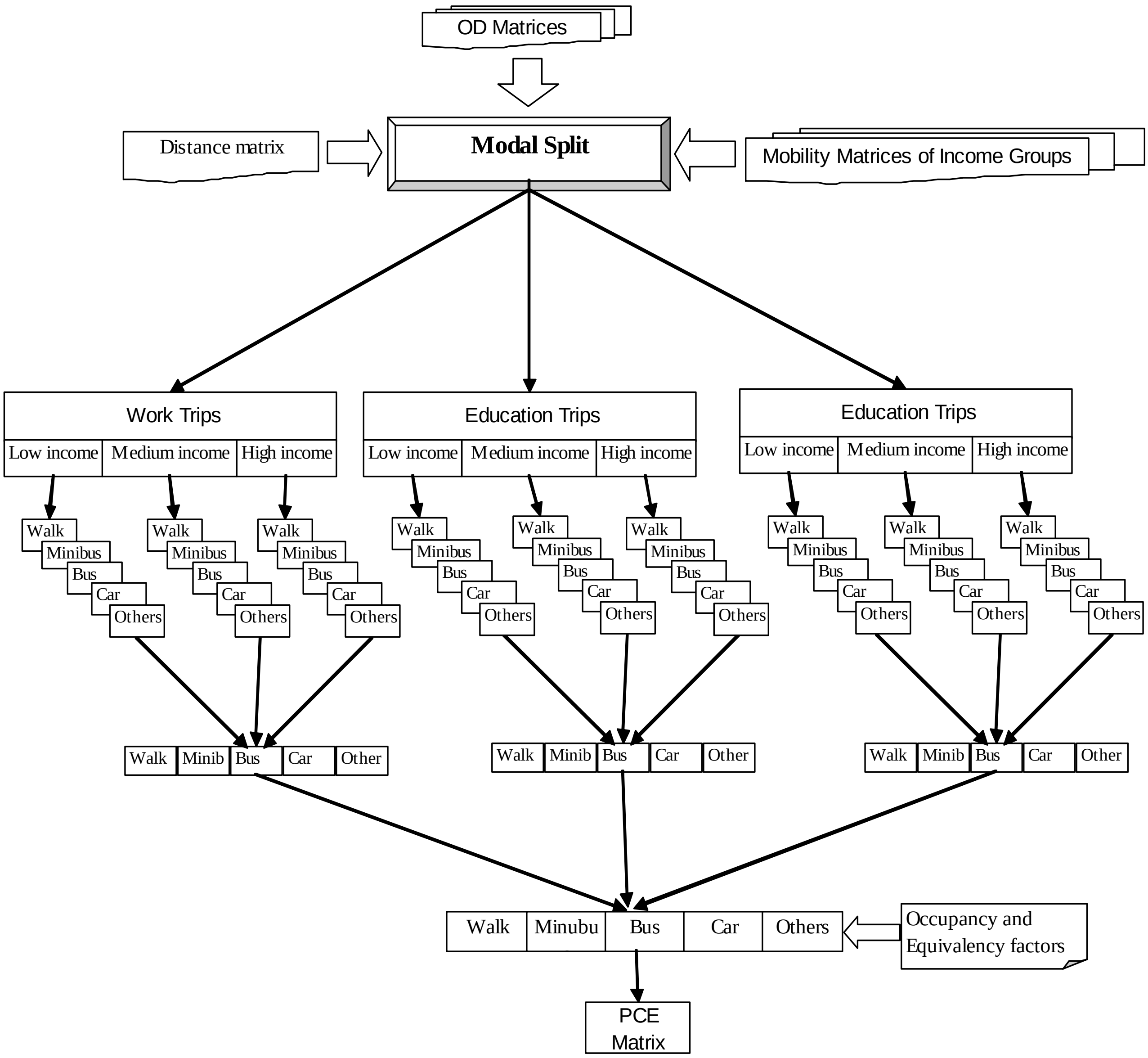


Figure 6.2: Diagrammatic presentation of modal split model

6.4 Traffic assignment modelling

Two assignment methods were employed: all-or-nothing assignment and capacity restraint assignment. A computer program using VBA language was developed to do both assignment models within the spreadsheet set-up of the model.

All-or-nothing assignment

The "all-or-nothing" assignment procedure (AoN) loads the trips between each origin and destination pair on the shortest travel time path in the simplified network connecting this pair. The problem is thus that of finding the minimum travel time paths connecting each OD pair for a given set of link travel times (Sheffi 1985).

Box 4.1: *Floyd's all-pairs shortest path algorithm (Foster 1995)*

procedure sequential floyed
begin
$I_{ij}(o) = 0$ if $i = j$
$I_{ij}(o) = \text{length}((v_i, v_j))$ if edge exists and $i \neq j$
$I_{ij}(o) = \infty$ otherwise
for $k = 0$ to N - 1
    for $i = 0$ to N - 1
        for $j = 0$ to N - 1
            $I_{ij}(k+1) = \min(I_{ij}(k), I_{ik}(k) + I_{kj}(k))$
        endfor
    endfor
endfor
$S = I(N)$
end

Two algorithms are popular for the identification of shortest paths in a network: Floyd's, and Dijkstra's. Floyd's algorithm calculates the shortest path from all nodes to *all other* nodes in a given directed or undirected graph. In comparison, the algorithm of Dijkstra only calculates the shortest path from *one* node to all others (Foster 1995). Floyd's algorithm was chosen for this study (Box 4.1).

The output of the all-or-nothing assignment is Average Daily Traffic (ADT) on the road network. The input data for the model are the traffic (PCE) matrix and the attributes of links in the network. The link attributes used for the model are: length, number of lanes and speed.

The ADT's estimated for Addis by the AoN assignment model show a good fit with available traffic volume (ADT) counts. The correlation coefficient between the counted volume and the assigned volume is 0.95. The percent RMSE is 14%. It should be underlined that this fit is satisfactory indeed, since the estimates derived from the four step model are based on data that are completely independent of the traffic count data. The fit with observed traffic flows thus is a real validation of the simplified model's capability to predict traffic volumes on the main arterial road network well.

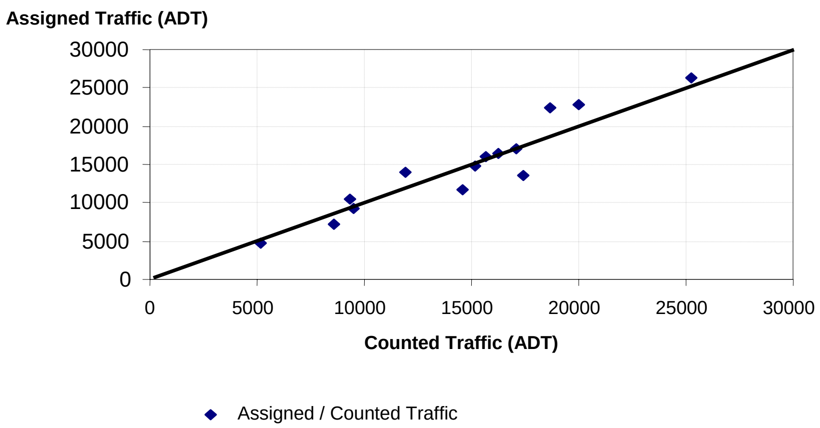
Table 6.1 shows the percent differences in volume; the volumes are two-way average daily traffic. According to Wegmann and Everett (2005) the proposed standard correlation coefficient is greater than 0.88 and a suggested appropriate value of Percent RMSE is less than 30%. And a desirable error range for daily link volumes is 20% to 25% for an ADT range of 10,000 to 25,000. However, while commonly it is advised that the comparison is made for at least around 60% of the network links, in the current study traffic count data were only available for 14 links (23%, quite evenly spread though).

Table 6.1: Comparison of counted traffic and assigned traffic

Link	Counted Traffic without freight (ADT)	Model Output (ADT)	Deviation of model
7-38	19991	22905	15%
9-48	17082	17099	0%
12-38	17445	13524	-22%
27-70	15646	15951	2%
36-37	16209	16531	2%
36-49	9472	9230	-3%
40-41	14581	11758	-19%
41-74	15189	14726	-3%
47-53	9293	10383	12%
51-52	11904	13962	17%
57-60	25250	26317	4%
59-60	18635	22448	20%
64-66	8544	7163	-16%
68-69	5135	4793	-7%
	204376	206790	1.2%

Figure 6.3 shows the comparison between the assigned traffic and the counted traffic. The AoN traffic assignment can also be carried out separately for specific modes of transport. For public transport modes this allows the use of the network consisting of the actual routes only (and the assignment to use the number of buses rather than pce). The AoN assignment for public transport reflects its normal practice of serving fixed routes.

Figure 6.3: Comparison of assigned and counted traffic volumes



Applying the assignment procedure to bicycle traffic on the simplified road network cannot be expected to be very useful, since the actual routes used by cyclists are likely to differ significantly from the ones included in the simplified network. Pedestrian traffic cannot be described at all with the simplified road network. In both cases, the output of the mode split model step (OD matrices for pedestrian and for bicycle traffic – including the estimated intra-zonal volume) can best be used as the starting point for route infrastructure planning for these modes per city district, in combination with the actual detailed road network.

Capacity restraint assignment

An alternative to the AoN traffic assignment procedure that is often used is the so-called capacity restraint assignment. Among the various assignment approaches that take into consideration the effect of congestion, *incremental* assignment is generally considered a realistic approach (Ortúzar and Willumsen 1998). This procedure has also been incorporated in the model presented in this paper. In it, step by step a certain percentage (e.g. 25%) of the total traffic O/D matrix is assigned to the network in batches, and in each step the link travel time is recalculated as a function of the traffic volume on the link already assigned (cumulatively) in preceding steps.

Different relationships can still be assumed for the increase in travel time with increasing traffic density. For example the following BPR (US Bureau of Public Roads) formula presented by both Bruton (1988) and Caliper (2001):

$$t = t_f \left[1 + \alpha \left(\frac{v}{c} \right)^{\beta} \right]$$

where t is congested link travel time, t_f is link free flow travel time, v is link volume, c is link capacity, and α and β are calibration parameters with 0.15 and 4 commonly used values respectively. However, it is questionable whether this relationship is realistic for an urban road network such as Addis. A speed-flow curve derived by ERA (2005) shows a much stronger increase of travel times with increasing congestion (V/C ratio), as is shown in Figure 6.3 below. For a sensible application of the capacity restraint traffic assignment, the best approach appears to be to measure the actual average speed/flow relationship on a number of important routes in the city (longer routes along the same type of road, including several intersections).

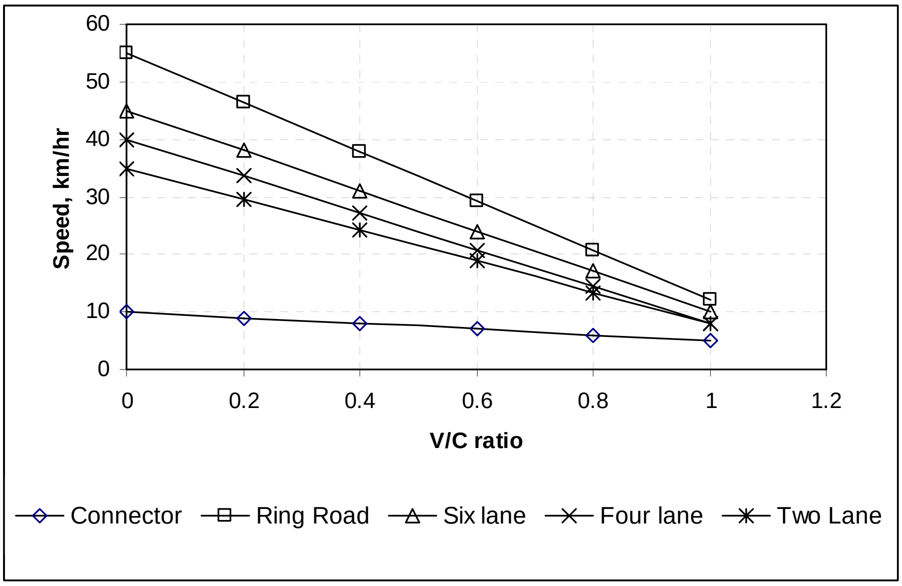


Figure 6.3: Speed flow relationship

For the incremental capacity restraint approach, peak hour traffic per traffic direction of course has to be considered. Unfortunately, reliable peak hour traffic counts for Addis were not available to us to check the accuracy of the capacity restraint assignment. Assuming a constant peak-hour/ADT ratio, the fit between the capacity restraint model estimates and the "observed" peak flows turned out to be considerably worse than that of the AoN. However, this cannot be considered a conclusive test, since according to ERA studies the peak/ADT ratio in Addis appears to vary between 7.5% and 13%. An application to a case where such counts are available is required to pass a judgement on the usefulness of applying this procedure in the simplified model.

One should bear in mind that the simplified travel demand model presented here is not meant for traffic flow analysis or a study of traffic management options. The strength of the model lies in its capability to investigate the likely future traffic flows along the main arterial corridors in a city depending on the type of urban development scenario that materializes (in terms of activity locations/land use, trip rate development and modal choice) , as a tool to support long-term strategic urban transport planning.

7. Conclusions

- In the travel demand model presented in this paper, the simplification has two main dimensions. The first is the use of a limited amount of data, a combination of administrative data (such as population numbers) and data that can be obtained relatively easy with a modest scale and size household travel survey (questionnaires and surveying procedures and instructions are available from the authors in addition to the simplified model code). Zonal data requirement is reduced by using a minimum number of zones. Calibration is carried out by a simple procedure using average trip distance as the key parameter.

- The second dimension is the use of a simple and transparent model structure and calculation procedure, modelled within a spreadsheet structure, with all calculus and algorithms (and source codes) accessible –and adaptable- to the model user. It is expected that competent staff of a municipality in a developing city can utilise the model independently.

- It is demonstrated by the application to Addis Ababa that the simplified model can predict passenger traffic on the main arterial urban road network with satisfactory accuracy. Hence, it can be utilised for strategic transport network planning.

- The simplified model presented in this paper provides an overview of the entire urban passenger transport system, covering all modes of travel: for car and public transport traffic it provides estimates of the traffic flows on the main arterial road network, for pedestrian traffic (and where applicable bicycle traffic) it provides estimates of OD flows between traffic zones. This is particularly important for low-income cities where a high percentage of all trips are pedestrian and two-wheeler traffic.

- The simplified model can be used for strategic planning at corridor level. It will help in identifying future main urban route corridor capacity requirements. The model also allows analysing the consistency of different network improvement alternatives with future activity locations/ land-use patterns. Not only is the model useful for future planning, but is also useful for the present. It can be applied for prioritising current road investment proposals on the main network.

- The simplified model is unable to predict precise future traffic volumes on specific road sections (and intersections) that could serve as an input to detailed road designs. However, in this respect there is no fundamental difference with the more complex standard travel demand model, which is equally unable to provide such accurate detailed forecasts, given the error margins in the input data and the uncertainty about the stability of the model parameters over time.

- The simplifications used increase the transparency of the forecasts and facilitate a clear comparison of long-term urban transport scenarios. The mobility matrices have the added advantage of allowing a direct robust estimate of the total annual operational costs and travel time cost of the transport system for all modes of travel, including walking, likely to result in future from specific development scenarios –combinations of land-use scenarios and transport policy choices.

- The test of the simplified model on Addis Ababa indicates that the final fit between the predicted and the measured traffic flows most of all depended on utilising accurate trip production and attraction values (the estimates of average trip distance per trip purpose and income group and of the mobility matrices being rather robust). Hence, giving detailed attention to the trip generation model is recommended.

- The model test on Addis Ababa showed that the use of straight-line distances between traffic zones gave the best output in the OD step (rather than using shortest distances along the simplified arterial road network). However, by introducing a detour factor on the arterial routes (based on fitting estimated model OD flows to large OD flows of which estimates can be derived from the travel survey), a comparably good OD matrix estimate can be achieved (not shown in this paper). In view of the advantage of reflecting the impact of creating a new arterial route (e.g. a new ring road) at trip distribution stage it is recommended to calibrate the OD model with a factored arterial road distance.

- It is expected that in cities with (unlike Addis Ababa) significant physical barriers, such as rivers, the use of factored simplified road network distances will be required anyway to arrive at correct OD matrix estimates (to be tested in further applications of the simplified model).

- By using aggregate mobility matrices per travel market segment the simplified model sacrifices the analysis of underlying determinants of modal choice such as travel time and cost differences, fear for traffic accidents or violence affecting the use of certain modes, comfort and status considerations, etc. However, for strategic long-term planning the sacrifice is considered to be small, in view of the likelihood that the elasticity's (parameters) concerned will change over time in a non-predictable manner, and the fact that reliable forecasts of some of the determining factors (the attitudinal ones in particular) cannot be made.

- This argument doesn't imply that the analysis of modal choice determinants is unimportant. On the contrary: it provides very useful indications of the effectiveness that different policies to influence modal choice are likely to have. Yet, such analysis can more successfully and efficiently be carried out in its own right, without being incorporated in the travel demand model meant for long-term strategic planning.

References

Banister, D. (1994). Transport Planning. first edition, London, UK, E & FN Spon.

Bayliss, B. (1992). Transport Policy and Planning: *An Integrated Analytical Approach*. Washington, D.C., U.S.A., The International Bank for Reconstruction and Development / THE WORLD BANK.

Bruton, M. J. (1988). Introduction to Transportation Planning. Great Britain, Hutchinson & Co. (Publishers) Ltd.

Caliper (2001). Travel Demand Modelling with TransCAD. U.S.A., Caliper Corporation.

ERA (2005). Urban Transport Study and Preparation of Pilot Projects for Addis Ababa. Addis Ababa, Ethiopian Roads Authority.

Fischer, M. M. (1987). Travel Demand Modelling: A State-of-the Art Review. Transportation Planning in a Changing World. P. Nijkamp and S. Reichman. England, Gower Publishing Company.

Foster, I. (1995). Designing and Building Parallel Programs : Case Study of Shortest-Path Algorithms [Online]. *http://www-unix.mcs.anl.gov/dbpp/text/node35.html* [Accessed Oct 3 2007].

McNally, M. G. (2000). The Four-Step Model. Handbook of Transport Modelling. D. A. Hensher and K. J. Button. New York, Elsevier Science Ltd.

Ortúzar, J. d. D. and L. G. Willumsen (1998). Modeling Transport. ,second edition, West Sussex, England, John Wiley & Sons Ltd.

Sheffi, Y. (1985). Urban Transportation Networks: Equilibrium Analysis with Mathematical Programming Method. U.S.A., Prentice-Hall, Inc.

Thomson, J. M. (1983). Toward Better Urban Transport Planning in Developing Countries. Staff Working Paper No. 600. Washington DC, USA, The World Bank.

Wegmann, F. and J. Everett (2005). Minimum travel demand model calibraton and validation guidelines for State of Tennessee [Online]. *http://ctr.utk.edu/TNMUG/misc/valid.pdf* . [Acessed Mar 20 2007].

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Corrections to WTPP Number 14.1 May 2008

Article: Sustainable happiness and the journey to school
Author: Catherine O'Brien

Pg 19: Indentation to indicate quote:

… Sunday. He writes about this in the context of sustainable happiness.

> *Ciclovia* attracted over 1.5 million people every week to walk, run, bike or skate. Despite the multiple issues happening in the country, this was the safest and most enjoyable place. On average, people were doing 50 minutes of physical activity but stayed on the *Ciclovia* for over 4 hours, enjoying other people's company. Obviously this is very respectful of people, the environment and future generations (G. Peñalosa, 2007).

Pg 16: "As adults, those journeys…" – "ours" should be "our"

Pg 20: Indentation to indicate quote:

… happiness and reinforce the 'virtuous circle' described by Martin (2005).

> Happiness and sociability go hand in hand…research has also shown that we have a higher quantity and quality of social interactions when we are happy…Happy people find social encounters more satisfying, they adopt a less cautious social style, and they are more inclined to be cooperative and generous. What is more, this link between sociability and happiness works both ways; sociable people, become happier and happy people become more sociable, creating a virtuous circle (p 30).

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