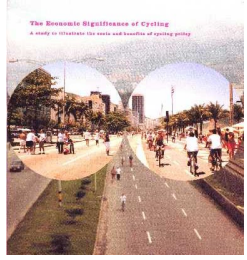
The results of four cost-benefit calculations: Amsterdam, Bogotá, Delhi, Morogoro

Annex of:

The Economic Significance of Cycling

A study to illustrate the costs and benefits of cycling policy



Case studies in four continents

Amsterdam

Bogotá

Delhi

Morogoro

Evaluation

I-Ce Interface for Cycling Expertise

Postbus 30435, 2500 GK Den Haag Fax 070 346 92 01 Internet : www.vnguitgeverij.nl

Case studies in four continents

To investigate the variety of economic benefits of cycling in different continents, four case-studies about different cities have been carried out[1]. The concerning cities are: Amsterdam in The Netherlands, Bogota in Colombia, Delhi in India and Morogoro in Tanzania. The main objective of the case-studies was not to execute four completely comparable studies, using the same methodology, but to give insight in how local differences result into different benefits of bicycle policies.

Starting point are available studies and data about the cities and their traffic situations and policies. This means that the themes included in the case-studies are determined by the available or easy accessible data. Which leads to different studies with different emphasizes.

The common question in each study is: 'What economic benefits can be attributed to an increase in bicycle use due to local bicycle policies?

The investments in Amsterdam regard a strong improvement of the 'core bicycle network' and citywide supply of high quality bicycle parking facilities. For Bogota, the plans that the municipality is implementing for cycling routes were the starting point. For Morogoro and Delhi, scenario's were developed to stop a decline of bicycle use and even increase it by building cycling routes. For Delhi the calculations regards only one corridor and for Morogoro a few roads.

The four selected cities are located on four different continents and are very different. There is one rich city (Amsterdam) two poor cities (Delhi and Morogoro) and one medium-income city (Bogota). There are two big cities (Delhi and Bogota) and two relatively small cities (Morogoro and Amsterdam). Underneath an overview of the case-cities is presented:

	Amsterdam	**Bogota**	**Delhi**	**Morogoro**
Inhabitants	800,000	6,000,000	13,200,000	200,000
Length/diameter of urban area	15 km.	50 km.	30 km.	< 10 km.
income per capita per a.	US$ 19000	US$ 6600	US$ 300	US$ 275
trips per person per day	3.7	2.5	1.8 (est.)	1.7
share bicycle trips	28%	0.5%	7%* (1994)	20%
share walking	26%	22%	32%	65%
share public transport	15%	56%	42%	11%
share motorised two wheelers	1%	0.5%	12%	
share car+taxi	30%	19%	5%	4%
Other	1%	2%	2%	-
share of short trips	60 % < 5 km.	52% < 7 km.	57% < 5 km.	74% < 5 km.

* including rickshaw

We will present the results per city and conclude with an evaluation.

1 I-ce worked in close co-operation with several institutes that delivered data and calculations. The municipality of Amsterdam, Goudappel Coffeng consultancy and Mu Consult contributed to the study of Amsterdam, TRIPP/IIT in Delhi did the same for Delhi and IBC Utrecht for Bogota. Michael Abbey and Marius de Langen from IHE Delft performed the calculation of Morogoro.

Amsterdam

'An obvious need for more parking facilities '

Amsterdam, the capital of the Netherlands, has 727,000 inhabitants. Amsterdam covers an area of 219 km2, of which 165 km2 concerns land. This means 4400 persons per km2. The average household consists of 2 persons.

The average income per capita is about 21,000 US dollar. 30% of the people own a car, 60% a bicycle and 20% has a season-ticket for public transport.

The inhabitants of Amsterdam make on average 3.9 trips per day. The average trip distance is 6 kilometre and 4 kilometres for bicycle trips. 60% of all trips is shorter than 5 kilometre. Of all trips, 30% is by car, 28% by bicycle, 26% on foot and 15% by public transport. The area involved in this study regards the Amsterdam metropolitan area, called ROA, where twice as much people live as in the municipality of Amsterdam. Here, of all trips 39% is by car, 27% by bicycle, 21% on foot and 11% by public transport.

In the inner city of Amsterdam the share of cycling is more than 50% and this share is still increasing. Outside the ring road the share of cycling is lower and decreasing due to longer trip distances.

The Amsterdam traffic and transport policy aims to control car use by parking regulations and by making alternative modes, like the bicycle, more attractive. Amsterdam has an extensive public transport network with 21 bus lines, 17 tram lines and 4 lines for underground and light rail. 15% of all train passengers come by bike to the railway station.

Potential of cycling

Bicycle ownership and bicycle use in Amsterdam are high compared to international standards, although bicycle ownership has a tendency to decrease. Reasons for not using a bicycle are road safety problems and the high risk on bicycle theft. Every year, in this city where about 450,000 people own a bike, 150,000 bikes are stolen. This means that on average every inhabitant gets his bike stolen every 3 years. High-quality bicycle infrastructure and far more safe bicycle parking facilities are expected to increase bicycle use, although most of the potential has already resulted in actual usage.

Bicycle policy

The bicycle policy of the city is aimed at the completion of the network of main routes, the so called "core bicycle network", a big extension of bicycle parking facilities and policies aimed at a mode shift from other modes (in particular the car) to the bicycle. Reconstruction of crossings and routes will improve road safety for all modes of transport. The cyclists will experience the results by a higher average speed, more comfort, increased traffic safety and less risk on bicycle theft. During the last decades, the policy to control car use, especially by parking regulations, has been most effective to increase bicycle use. This kind of policy has not been included in the calculations of this study.

Costs and benefits of bicycle policy

To calculate the results of different policy measures, the GENMOD-model of the municipality of Amsterdam has been used. Starting point has been a powerful bicycle policy reaching ahead of existing plans. Forecasts of changes in modal split emanating from the proposed bicycle policy have been used to calculate economic benefits. However, changes in public transport use have not been included. Two scenario's are used:

- Scenario 1: improvement of bicycle parking facilities, with the aim to meet the demand in the whole city.
- Scenario 2: improvement of the bicycle network, according to the proposals in the Core Bicycle Network Plan, resulting in high quality bicycle facilities on 7 important routes and quality improvements of all other routes of the core bicycle network.

Calculations are based on data from 1998. The results in table 1 describe how many more trips and kilometres would have been done by bicycle if the improvements would already have been finished before 1998.

The improvement of the core network will result in an increase of the average speed, on the network routes, of 3 kilometres per hour. It is difficult to give a value to the comfort and convenience of the parking facilities in such a manner that this can be used in the transport model. In this study it is estimated that cyclists value the parking facilities equal to time savings of 4 minutes per trip.

The outcome of the model calculation is that the proposed bicycle policy will result into a mode shift from car and public transport to the bicycle. This means 44,000 extra bicycle trips per day and a reduction of 131,000 car kilometres per day or 30 million car kilometres per year. The parking facilities contribute the most, they cause a 7% increase in bicycle use. The improvements of the network result in 2% more bicycle use. We only discuss the results of scenario 3.

	Trips (x1000)						Kilometres (x1000)					
	Bicycle		Car		Public transp.		Bicycle		Car		Public transp.	
Actual situation 1998	102		219		138		335		4216		2471	
Scenario 1 – parking	109	+7%	216	-1,4%	135	-2,2%	367	+10%	4200	-0,4%	2451	-0,8%
Scenario 2 – network	104	+2%	218	-0,5%	137	-0,7%	345	+3%	4212	-0,1%	2464	-0,3%
Scenario 3 – scen. 1+2	219	+9%	215	-1,9%	133	-3,6%	379	+13%	4195	-0,5%	2446	-1,0%

Table 1: changes in the total amount of trips and kilometres during evening peak hours (16.00 - 18.00 h.) due to bicycle policy, in 1998.

Investments in bicycle facilities

Taking into account the average parking time and the bicycle parking demand at home, the total bicycle parking demand is 250,000 places. The costs per place are about 1500 guilders, which leads to a total investment of 375 million guilders.

The investments in the network are estimated to be 150 million guilders. By experience, a saving of 20% can be reached by planning the improvement together with other reconstructions. The total investments are therefore 120 million guilders.

Accessibility and the use of space

The total amount of car kilometres decreases only by 0.5%. This will not result in a substantial reduction of the congestion.

Regarding space the assumption is that 1.9 % less car trips make it possible to decrease the total amount of parking places also by 1.9%. In 1998 Amsterdam had 85,500 parking places for which a fee had to be paid. For 24,000 places someone had a parking permission. The difference of 61,500 has been taken as a basis to calculate the decrease of the total amount of parking places and this results in a reduction of 1685. Particularly in the inner city where land is very expensive, the benefits are substantial. If we calculate that one parking place needs 10m2 and the price is 1000 guilders per square metre, this will result in savings of 10,000 guilders per place. The total benefits are one-off savings of 16.8 million guilders.

Health

As a consequence of an increase of bicycle use, the health of people who take too little exercise will improve. Using calculations of the Dutch "Stichting voor Economisch Onderzoek", a 9% increase of the amount of kilometres cycled in Amsterdam results in savings on absenteeism and medical treatment of 7 million guilders per year.

Pollution

The benefits of less pollution are based on the average emissions per car passenger kilometre within built up areas in the Netherlands in 1998 and the external costs of the emissions. The following table presents the cost savings per year of the five most important emissions, due to a replacement of 30 million car kilometres per year. The most important are CO2, VOC (volatile organic compounds) and PM10 (particulate matter). Regarding CO2 the costs to prevent or as a result of the greenhouse effect are important. Regarding particulate matter, the medical costs are important. Regarding VOC the greenhouse effect, smog and medical costs are relevant.

The savings as a consequence of less pollution are 1.3 million guilders per year.

To calculate the savings resulting from a reduction of noise nuisance, the starting point was a total number of 51.628 houses with a noise levels above 65 dB(A), which is the maximum to tolerate. There is a linear cor-

Emission	Emissions per Pass. km. (gram/km.)	Total Prevented Emissions (kg.)	External costs Per pass. km. (fl./kg)	Costs per 1000 km.	Total costs
CO^2	156	4,680,000	fl 0,10	fl 15,60	fl 468,000 per year
NOx	0,44	13,200	fl 15,00	fl 6,60	fl 198,000 per year
VOS	0,70	21,000	fl 15,00	fl 10,50	fl 315,000 per year
PM_{10}	0,031	930	fl 325,00	fl 10,08	fl 302,250 per year
SO^2	0,015	450	fl 6,50	fl 0,10	fl 2,925 per year
					fl 1,286,175 per year

Table 2: Emissions per car passenger kilometre and external costs of these emissions (sources: CBS, 1998 and Centrum voor Energiebesparing en Schone Technologie, 1999)

relation between a decrease in car kilometres and the level of noise nuisance. The decrease in car kilometres result in a decrease of 309 houses that are affected by noise nuisance above 65 dB(A). The costs per dwelling to take other preventive measures are 6000 guilders. This result in one-off savings of 1.8 million guilders.

Road Safety

Every year, 3000 people are injured because of a traffic accidents in Amsterdam, of which 25% are cyclists. On average, during the last years, 25 people were killed and 400 hospitalised. In 1998 4 cyclists were killed and 427 injured.

Without taking measures, a shift from car to bicycle will not change the total amount of traffic victims in the Netherlands, taking into account the injuries of the road users and the injuries caused to others and not including kilometres on freeways. Road safety countermeasures, however, can be effective, sometimes even resulting in 70% less injuries (reconstruction of a crossing into a roundabout). For the calculation a 15% reduction of the amount of injured people are assumed when the right measures are taken at crossings and on stretches. We only calculate the results for cyclists on the core network and estimate that 20% of all bicycle kilometres will be the network will attract 20% of all cyclists kilometres. The results for other modes are more difficult to estimate but this will not say they are very marginal. On the basis of other calculations saying that a fatality on average costs 1,346,000 Euro in economic terms and other traffic injuries on average 109,000 Euro, the economic benefits of the improvements for more road safety are 5.6 million per year.

Theft prevention

Per year 150,000 bicycles are stolen in Amsterdam. The huge investments in parking facilities will decrease bicycle theft with an estimated 100,000 bicycles per year. A new bicycle costs between 500 and 1500 guilders, but the bikes that are stolen and the second hand bikes that are being buoyed, have a low value, that is estimated to be on average 75 guilders. The benefits of less bicycle theft are therefore 7.5 million guilders per year.

Time savings

It is assumed that the average speed on the core network will increase by 3 km per hour. If we assume that the actual speed on average is 15 km per hour, the average speed will become 18 km per hour. We only involve the city of Amsterdam and not the region in this calculation, because the major part of the core network is located in the city. The total amount of bicycle kilometres in Amsterdam is 770 million kilometres per year, of which 20% is estimated to take place on the core network, which is 154 million kilometres. The total time savings therefore are 1.7 million hours. One hour travel time has an economic value of 9 guilders. So the benefits are 15.3 million guilders per year.

The comparison of costs and benefits

The analyses of costs and benefits of investments in the core bicycle network and the bicycle parking facilities, results in higher benefits than costs. The investments are 495 million guilders or 476 million after distraction of the savings as a consequence of less space consumption and less noise nuisance. The facilities will last for at least 20 years. Therefore, we can sum the annual benefits of 36.7 million guilders over this period, taking into account an interest rate of 4%. This results in the following total costs and benefits

Costs	**Benefits**
323 million guilders	**499 million guilders**

So the ratio between costs and benefits is 1 : 1.5.

For this study, the city of Amsterdam and Goudappel Coffeng collected data and made calculations. Mu Consult gave advises on the approach.

Conclusions

The investments in high-quality bicycle facilities have a significant return for society. This result will be achieved notwithstanding the high bicycle use in Amsterdam. The cost benefits ratio will improve, the more the Amsterdam bicycle policy will be integrated in the overall traffic and transport policy like parking regulations.

Bogotà

Cycle path under construction in Bogotá

Bogotá, the capital city of Colombia, has a population of 6 million. The city is situated 2600 metres above sea level and is flat. Because of the high altitude, the city has a moderate climate. Bogotá covers an area of 490km2 and has an elongated shape. The entire urban area is around 50 kilometres long and 15 kilometres wide. The annual income per head of population in Colombia amounts to US$ 6,600. However, there are enormous differences between rich and poor people.

On working days, Bogotá's residents make an average of 2.5 journeys a day. The bus is the most important means of transport, with a 56% share of all journeys, while 22% of journeys are made on foot, 15% by car, 4% by taxi, 0,4% by motorbike, 2% by truck and 0.6% by bicycle.

Of all journeys in Bogotá, 52% are shorter than 7 kilometres and 77% are shorter than 11 kilometres. The average bus journey is 9 kilometres long and takes 50 minutes.

The city suffers from serious traffic congestion. To combat this, a number plate quota has been introduced that permits just a certain number of the city's cars to drive during the rush hour.

Bogotá has an extensive road network, laid out according to a grid system. Due to inadequate maintenance, however, the quality of the road surface leaves a lot to be desired.

The potential of the bicycle in Bogotá

There are good prospects for the bicycle because the climate is moderate, the city is flat and a large number of the journeys are short. Partly due to the congestion, the average speeds of cars and buses are low, especially during the rush hour, which means that the bicycle can potentially compete with these means of transport on longer journeys too (of up to around 10 kilometres) with regard to travelling time. Added to this, Colombia has a cycle racing culture and many of Bogotá's residents have bicycles. The potential of the bicycle in Bogotá is particularly borne out by the city's 'Sunday bicycle route'. Every Sunday morning in Bogotá, a track of around 70 kilometres of road is cordoned off for cyclists, skaters and pedestrians. In good weather, up to a million cyclists use this route.

Bicycle policy

The current mayor, who campaigned as a bicycle supporter during his 1997 election campaign, has decided on the following order of priorities for traffic policy in his political programme: walking, cycling, public transport, the car. This programme has now been converted into a number of large projects. The Master Plan for Cycle paths (PMC) is one of those projects, and includes the construction of a bicycle route network 300 kilometres long. The network will consist of a primary network of separate cycle paths of 150 kilometres and an equally long secondary network of less high-quality bicycle amenities. In addition to cycle paths, the project also includes designs for junctions, traffic signals, parking amenities at public transport stops and stations, numerous improvements for pedestrians, and information and education to promote cycling.

Costs and benefits

Calculation of the costs and benefits of the bicycle policy in Bogotá is based on the following assumptions. In the city's Bicycle Master Plan it is assumed that an increase in bicycle use between 1999 and 2009 from 0.58% to 3 to 5% is a realistic target. This study calculates the costs and benefits of the bicycle policy that has been introduced, assuming that this leads to a 5% level of bicycle use in 2009. It is assumed that bicycle use will gradually increase by around 0.5 percent per year. It is also assumed that total mobility will continue to grow by 2.5% per year. All of this will result in 953,000 bicycle journeys per day in 2009, while autonomous growth would only increase the number of journeys from 86,000 per day in 1999 to 110,000 in 2009. Thanks to the Bicycle Master Plan, therefore, 843,000 extra bicycle journeys will be made per day in 2009.
The following method was used to estimate the benefits resulting from avoided motorized journeys.

It is assumed that of the extra bicycle journeys resulting from the bicycle policy, 56% will replace the bus, 20% will replace the car, taxi and motorbike and the rest will replace pedestrian journeys.
Of the 843,000 extra bicycle journeys per day in 2009, 472,000 will therefore be instead of the bus and 168,000 instead of the car. Based on an average number of 1.66 persons per car and 21.46 persons per bus, in 2009 this will result in total 'savings' of 22,000 bus journeys and 102,000 car journeys per day. Based on 250 working days per year, this means that in 2009 5.5 million bus journeys and 25.5 million car journeys will be replaced. In the years 2000 up to and including 2008, this will obviously involve smaller numbers.

In the period from 2000 up to and including 2009, the bicycle plan will save a total of 32 million vehicle journeys made by bus and 151 million journeys made by car. For the sake of uniformity, 1 bus journey is considered to be the equivalent of 4 car journeys. The total number of car-equivalent journeys to be replaced will then be: 282 million in 10 years.

Investments in infrastructure

A number of large projects have been developed within the framework of the current mayor's traffic policy. To improve the flow of car traffic, a project worth US$ 638m. was developed for a ring road in the city (IRE). In addition, a sum of US$ 1356m. is to be spent on the construction of a core bus network with individual bus lanes, the Transmillenio project. The total costs of the Bicycle Master plan amount to US$ 178m. These three projects are complementary and are not meant to replace each other. This certainly indicates that investments in the bicycle are relatively inexpensive.

The following costs have been calculated for the entire Master plan:

Costs of bicycle infrastructure

	Total	Per km. bicycle path
Construction costs incl. design	US$ 108,462,000	US$ 360,000
Costs of promotion and education	US$ 33,350,000	
Running costs	US$ 10,863,000	
Maintenance costs	US$ 25,196,000	
Total	**US$ 186,000,000**	

These costs are very high in Colombian terms. It must be remembered, however, that these are high-quality bicycle amenities and that the price per kilometre also includes bicycle bridges, junctions and parking amenities.

Benefits from saved motorized journeys

The costs saved by a reduction in the number of motorized journeys have been calculated in the following way.

In 1996, Todd Litmann put a value on the costs associated with a vehicle kilometre using different means of transport. In this study, these values have been converted to values per replaced motorized journey. It is assumed that such a journey is an average of 4 kilometres long and that 60% of the replaced journeys are made during the rush hour. This means that US$ 1.75 is saved with each replaced car journey. For the total number of car-equivalent journeys of 282 million, the saved costs as a result of the 'effects' specified in the table for the period 2000-2009 come to US$ 493m.

These consist of the following:

less road maintenance:	US$ 0.05 per journey:	in total, US$ 14.1m.
fewer parking spaces:	US$ 1.00 per journey:	in total, US$ 282m.
less congestion:	US$ 0.256 per journey:	in total, US$ 72m.
less pollution:	US $ 0.44 per journey:	in total, US$ 124m.

Due to insufficient information, any benefits from the bicycle policy due to improved health (as a result increased physical exercise) and benefits due to time saved have not been calculated in this study. However, it does include a calculation of the benefits of traffic safety and travel costs saved by the new cyclists because they now cycle the journey they would have made by car or bus.

Traffic safety

In a study carried out by I-ce as part of a commission from the municipality of Bogotá to design of cycle paths along Calle 80, it has been estimated that the number of traffic accidents will drop by 50% once the road has been reconstructed.

This comes to around 600,000 US$ per kilometre. Because only half of the bicycle network has the quality of Calle 80, and because Calle 80 is also a very dangerous road, for the sake of simplicity it is assumed that on average for the entire network the savings on traffic accidents come to US$ 300,000 per kilometre. Based on the schedule for the construction of cycle paths per year, this brings the total benefits to US$ 643m.

Savings on running costs for vehicles

Because cycling is cheap and uses no fuel and the depreciation costs of a bicycle are negligible compared to those of a car, cyclists who do not take the bus or car save a lot of money. With regard to the running costs, in Bogotá the figures are based on US$ 0.13 for well-maintained cars and US$ 0.20 for badly maintained cars. This is calculated using a high average of US$ 0.175 per kilometre, or US$ 0.70 per vehicle journey. For 151 million saved car journeys, this results in savings of US$ 105m. in 10 years.

In the same way, total savings of US$ 62m. have been calculated for buses, based on US$ 1.95 running costs for every bus journey of 4 kilometres. It must be remembered, however, that this involves the running costs of the means of transport itself, and infrastructure costs or salary costs for drivers have not been included in the calculations.

The total savings for users through an increase of bicycle use therefore comes to US$ 167m.

Conclusions

In total, the following benefits have been calculated for the bicycle policy in Bogotá for the period 1999 to 2009:

Cost item	Saved costs in millions of US$
Road maintenance	14
Parking amenities	282
Congestion	72
Environment	124
Traffic safety	643
User costs	167
Total benefits	1302

A total investment of US$ 178m. produces US$ 1302m. worth of benefits. The cost-benefit ratio therefore comes to 1:7.3. It should also be remembered here that benefits from time saved by cyclists who switch from the bus or car to the bicycle have not been included.

It can be concluded that investing in a bicycle policy in Bogotá is very cost-effective. What is remarkable in this calculation is that around half of the benefits are in increased traffic safety.

This text is created by I-ce and based on the publication, "The economic Benefits of Cycling in Santa Fe de Bogota, Colombia", by Ton Daggers, IBC, May 2000.

Morogoro

Old Dar-es-Salaam road, Morogoro, immediately after reconstruction in 1999

Morogoro is a city in central Tanzania with a population of 200,000. The city is situated at an altitude of 400 metres, the climate is somewhat cooler than on the coast and the city's many trees make it very green. The urban area is flat and covers 70 km2.

In Tanzania, the average income per head of population is around US$ 165 per year. In Morogoro, however, the average income has been estimated to be around 50% to 80% higher: between US$ 250 and US$ 300. Industrial activity in the city has diminished in recent years. Although the economy is currently enjoying something of a recovery, most residents say that before 1990 many more people had permanent jobs and more of them were able to buy bicycles with their salaries at that time.

Morogoro has 20 kilometres of paved roads, of which 15 kilometres are national highway along the edge of the city. Up to 2001, around 15 kilometres of road will be paved in the city. Public transport consists of minibuses, the so-called daladalas, and these cover the urban area very well.

Mobility in Morogoro is low. On average, adults travel just 1.7 trips per day. Cyclists and car owners travel an average of 2.5 trips per day, and people without a vehicle travel 1.5 trips. In Morogoro, walking is the most important means of transport, and has a 65% share of trips. The bicycle has a 20% share in the number of trips, the daladala 11% and the car and moped together 4%.

The potential of the bicycle in Morogoro

Morogoro is well positioned for bicycle use. It is a medium-sized city, and 74% of all trips within the city are shorter than 5 kilometres.

If it was easier for women, schoolchildren and students to own bicycles, the bicycle's share of trips could increase from 20% to 30%. Among the higher incomes – around 5% of the population – the bicycle has a low status. The main reason that people with lower incomes do not cycle is because they cannot afford a bicycle. 52% of households have a bicycle. This usually involves just one bicycle, however, which is generally used by the man of the house. As a consequence, men make 33% of their trips by bicycle, while women make just 2% of their trips by bicycle and 83% on foot. The average household size is 5.5 persons. One remarkable piece of information is that over a quarter of bicycle trips are made using a hired bicycle. There are 200 bicycle hire companies in the city, each with around ten bicycles.

The State government could stimulate bicycle use by removing the import and sales tax on bicycles. This reduces the cost price of a bicycle by 30%. A switch to the bicycle as a means of transport will not stem from the few motorists, and can be expected more from users of public transport and pedestrians. The costs of bicycle use are 1 dollar cent per kilometre, against 3 cents per kilometre for public transport. For bus trips over short distances, the bicycle is therefore an attractive alternative. In addition, the bicycle provides people who now travel on foot with increased mobility.

Bicycle policy

Morogoro has 15 kilometres of national highway running through the city. Speeds are high on the national highway, and this is therefore where almost all fatal traffic accidents occur. The bad surfaces on the other roads do not allow people to drive at high speeds, so that cycling among motorized vehicles is relatively safe here. The plans to improve existing roads and construct new asphalt roads could lead to higher driving speeds. As a consequence, cycling will become less safe, and bicycle use could drop. It is therefore necessary to introduce traffic calming facilities on paved roads and bicycle facilities on trunk roads. The municipal council has proposed this to the road managers in the State government. However, there is always the risk that these plans will again be scrapped in favour of more car lanes – to save costs, for example.

Costs and benefits

A number of different scenarios for the period 2000 to 2010 have been considered in order to determine the costs and benefits of a bicycle policy in Morogoro. The two most probable scenarios are described and compared below.

The scenario in which nothing extra is done for the bicycle, the 'do-nothing scenario', looks as follows:

- Around 15 kilometres of road in the city will be paved as trunk roads; therefore without traffic calming or facilities for cyclists and pedestrians.
- The number of trips made by adults in 2000 is estimated at 200,000 per day (120,000 persons above the age of 15 years making 1.7 trips per day). Due to the growth in population, this will have increased to 360,000 in 2010.
- The journey distances are assumed to be constant (74% < 5 km).
- Reduced traffic safety causes bicycle use to drop from 20% to 10% of all trips.
- Bus use increases from 11% to 21% of trips.

The 'bicycle policy scenario' looks as follows:

- Investing in traffic safety for cycling as described below.
- The number of trips by adults between 2000 and 2010 increases from 200,000 to 360,000.
- The journey distances are assumed to be constant (74% < 5 km).
- The bicycle's share of trips increases from 20% to 25%.
- The bus's share of trips decreases by 3%, walking's share by 2%.

In Morogoro, the potential of the bicycle would theoretically seem to facilitate even greater growth of bicycle use than was assumed in the ' bicycle policy scenario'. This is limited because of low incomes, however, and an increase to 25% would seem to be realistic.

Investment in safe traffic facilities for cyclists and pedestrians

To make bicycle use safer and to stimulate it, it is assumed that the following investments are necessary:

- cycle paths 2.5 metres wide, on both sides of the 20-kilometre road where motorists regularly drive faster than 50 kph, and safe pedestrian crossings. The costs come to US$ 40,000 per kilometre.
- 7.5 kilometres of bicycle lane 1.5 metres wide alongside roads in the

city centre, and traffic calming. Costs include junctions, and come to US$ 20,000 per kilometre

- 8 kilometres of separate cycle path 4 metres wide in 2 directions, costing US$ 40,000 per kilometre.

These cycle paths cost a total of US$ 1.26m. The annual capital costs amount to US$190,000, based on real interest of 10% and a depreciation period of 10 years. Maintenance costs are based on 3% of the investment: US$ 40,000 per year, therefore. The total annual costs of the new bicycle infrastructure are therefore US$ 230,000, or US$ 2.3m. in 10 years.

In addition to these infrastructure measures, a policy is required to promote bicycle ownership and rental. This might include lifting import and sales taxes and introducing credit facilities.

Costs for users

In Morogoro, travel costs are an important part of total spending. The average adult resident of Morogoro spends around US$ 100 per year on transport, roughly 20% of annual income. These costs include the purchase of shoes, depreciation of the bicycle or car, maintenance and fuel, cost of bus tickets, etc. To obtain an accurate picture of the personal costs, the time taken to complete the journey must also be calculated. The costs of that time are evaluated in relation to income. Because motorists have a higher income, car trips are given a higher time value. The calculation is therefore based on the following costs and average speeds:

The table shows that the total journey costs of the car are by far the highest, while walking, due to its low speed, is scarcely 'cheaper' than the bus. The bicycle is the most economical of all.

The total current journey costs in Morogoro amount to US$ 14m. per year. Of this, 25% are the result of the time needed to make the journey. This calculation is based on an average journey distance of 2.5 kilometres for trips up to 5 kilometres and an average of 7 kilometres for trips longer than 5 kilometres

In the 'do-nothing scenario' the total journey costs increase to US$ 27.1m. in 2010, while in the bicycle scenario the total journey costs are US$ 24.9m. in 2010. It is assumed that the shift in the modal split between 2000 and 2010 will be linear. In the bicycle scenario, for example, the share of the bicycle increases by 0.5% per year. The benefits of the bicycle policy as a result of a drop in user costs then go from 0 dollars in the year 2000 to US$ 2.2m. in 2009. The total benefits over 10 years then amount to US$ 11m.

The other benefits of the bicycle policy in Morogoro have not been calculated. The following can be said on this subject:

- Costs of motorized traffic:

Savings on investments in motorized transport due to increased bicycle use are not to be expected in Morogoro. Bicycle trips are not made at the expense of car trips, and bus trips in Morogoro are cost-effective.

- Accessibility, quality of life and environmental pollution:

Because of the small number of motor vehicles in Morogoro, congestion is an unknown phenomenon in the city and there are also very few environmental problems as a consequence of traffic.

- Traffic safety:

As already mentioned, there are currently few traffic accidents in Morogoro, except on the national highways. When road surfaces in the city are improved, however, this situation may change. The paving of roads should therefore be accompanied by bicycle and pedestrian facilities (for example, pedestrian crossings) and speed-restrictive ('traffic calming') measures. The benefits of these have not been included in the cost-benefit calculation, but they are expected to be considerable.

The road in the photograph is an example of a very badly designed urban road. It was designed without any serious attention being paid pedestrians and cyclists who use and cross the road. Three fatalities had already occurred in the first four months after the road was reopened; 65% of the vehicles are bicycles and just 35% are motorized.

- Employment:

Increased bicycle use as a result of bicycle policy will create employment in the bicycle sector. In Morogoro, that particularly refers to bicycle rental, sale and repair. A modal shift from minibus to bicycle can, however, cost jobs.

- Income development and increased mobility:

One of the most important arguments for a bicycle policy is the resulting increase in mobility, particularly for women. Such benefits of the bicycle policy have not been examined here. The benefits through savings in journey time and travel costs are described under the header 'Costs for users'.

Means of transport	Travel costs per kilometre US$	Time costs per hour US$	Average speed (door to door) kph	Time costs per kilometre US$	Total journey costs per kilometre US$
Walking	0.002	0.17	4.0	0.042	0.044
Bicycle	0.010	0.17	10.0	0.017	0.027
Bus	0.033	0.17	10.0	0.017	0.050
Car	0.300	0.68	15.0	0.045	0.345

Conclusions

Two scenarios are compared in the cost-benefit calculation. The first involves an increase from 20% to 25% in the share of bicycle trips between 2000 and 2010 as a result of bicycle policy for the same journey distances. The second sees bicycle use being halved to 10% of all trips as a result of completely ignoring the bicycle and traffic safety policy.

In a period of 10 years, the total benefits of the bicycle policy as a result of replaced journey costs (travel costs and time costs) have been calculated at US$ 11m., as opposed to a total of US$ 2.3 million in investment and maintenance costs. On the basis of only the user costs, the cost-benefit ratio of the proposed bicycle policy is therefore around 1:5.

When other benefits of the bicycle policy – such as prevented traffic accidents – are also calculated, the ratio between costs and benefits are even more favourable.

The above text is a summary, created by I-ce, of the report: "Economic costs and benefits of Cycling in Morogoro, Tanzania.", by Michael A. Abbey and Marius de Langen. IHE Delft, April 2000.

Delhi

Delhi, the capital city of India, has a population of around 13 million. Like most Indian cities, Delhi has mixed land use and a relatively high population density. This combination means that a large proportion of the population make their daily trips within a relatively small area. The average household income in Delhi is around 4400 Rupees* per month (1997). The average household in Delhi consists of 5 to 6 persons. When these figures are converted, the average income per head amounts to around US$ 250. However, almost 30% of households have a monthly income of less than Rs. 2000, which means that they depend, to a large extent, on walking or cycling for their daily mobility. According to the Municipal Corporation of Delhi, between 1991 and 1999 the percentage of poor people in the total population of Delhi increased from 14.5% to 44%. mainly due to the fact that the migrants coming to Delhi are in general very poor. For every 1000 households in Delhi, there are 320 bicycles, 430 scooters and motorbikes, and 170 cars.

It is extremely difficult to find reliable and recent modal shares for Delhi. The latest official data result from the Household Travel Survey of 1994 (ORG 1994). This survey, however, is hardly representative for the population of Delhi because 70% of all interviewed belong to the higher income group which only represent a minor part of the Delhi population. Additional to this comes the fact that the population of very poor increased substantially between 1994 and 1999. Therefor the mode share of the bicycle in 1999 will be much larger than indicated in the ORG 1994. In 1999 IIT performed two household surveys, one among the lower income people and one among the middle and higher incomes.
Assuming that 50% of all trips are made by the poorest part of the population (between 50 and 60% of the population) and 50% by the richer part an estimate has been made for the whole Delhi population. Underneath, both results are shown:

	ORG 1994	ITT 1999
Bicycle and rickshaw	10%	25%
Bus	62%	38%
Car	7%	16%
Motorised two-wheelers	17%	18%
Others	4%	3%

Table 1. Modal split in Delhi according to different studies, excluding walking.

Walking is not included in the presented table because the different studies do not provide matching and reliable figures. The modal share of walking will probably be between 10 and 30% of all trips. Because people living in unauthorised colonies and slums depend largely on the bicycle for their mobility the 25% share of the bicycle for the Delhi population seems credible. The lower bus-use in the IIT-data is surprising but could be explained by mentioning the fact that the larger share of low-income people in the IIT-sample leads to a larger share of people who cannot afford a daily bus ticket. Another explanation can be the fact that the Delhi car park grows even faster than the population and many former bus trips are now made by private car.
A characteristic feature of Indian cities is the high average occupancy rate of the vehicles. In the rush hour, there are an average of 2.68 persons per car and no less than 66 persons per bus. Spread over the whole day, the averages are 2.2 and 37 persons, respectively.
The roads in Delhi have no separate facilities for the different means of transport, as a result of which the roads are used very inefficiently. The left-hand lane (Indians drive on the left) is avoided by motor vehicles because it is used by slow traffic; buses actually make their stops in the middle of the road. The mix of slow and fast traffic also poses significant danger for pedestrians and cyclists.

The potential of the bicycle in Delhi

The enormous growth of the city means that distances are increasing. For some of trips, therefore, bicycle trips have been substituted by bus or motorised two-wheeler trips. The great majority of the population cannot afford a car. According to the ORG Household Surveys bicycle use in Delhi has dropped from 36% of trips in 1957 to 6% in 1994 (not taking trips on foot into account). Because middle income households are over represented in the ORG sample, the figures illustrate the falling bicycle use among this part of the population. In the same period, the bus's share has increased from 22% to 62% and that of motorised two-wheelers from 1% to 18%. This can be explained by the growth of motorised traffic, which has made cycling less safe. In addition, the city grew considerably in that period – from around 2.5 million to more than 10 million residents – making the trip distances greater. On the other hand the percentage of the populations that are so-called 'captive' cyclists who cannot afford any motorised mode of transport is growing as well. The bicycle's enormous potential in Delhi is apparent from the fact that 57% of all trips are still shorter than 5 kilometres. Separate facilities for the bicycle and for the bus can increase the capacity of a road by between 50% and 100%, thanks to an increase in the share of bicycles and the improved flow of all means of transport.

Bicycle policy

Proposals have been developed to construct cycle paths along the 368 kilometres of main roads in the city. The corridors, usually with a 30 or 45 metres right of way, will then be divided into a footpath and service road, a cycle path, a bus lane and two lanes for other motorised traffic, in both directions. Vehicles travelling at different speeds will no longer obstruct each other and as a result, traffic will not come to a standstill as often, and the chance of accidents will decrease.

It is difficult to estimate the level to which bicycle use will increase. However, the reduction in bicycle use owing to the risks would seem to justify the supposition that increased safety will have the opposite effect. The share of short trips is still very high and at least a quarter of the population depends on the bicycle and walking for its mobility. The need for the planned bicycle facilities is therefore very urgent. They will not lead to

a reduction in car use, but they will probably lead to a switch from bus transport and from walking to bicycle use.

Costs and benefits

To gain an impression of the possible effect of pro-bicycle measures in the city, this report includes a study of a representative stretch of the road network in Delhi: Vikas Marg. This 9 km. road is an important, 45 metres right of way corridor between the centre of Delhi where commercial centres and governmental offices are located and East-Delhi where residential areas of all classes are located. The costs and benefits have been calculated for the reconstruction of Vikas Marg. This includes the construction of a cycle path and a bus lane. The new road will be more efficient because the present chaotic mix of different modes, including bicycles, leads to a reduction in capacity and speed. In this report the benefits emanating from this increased efficiency are calculated. A possible increase in bicycle use due to the improved safety and comfort for cyclists only taken into account to calculate the savings on fuel costs and emissions. In this calculation a comparison is made between the situation where the mode share will rise to the Delhi average (ORG 1994) of 7% and a complete disappear of the bicycle. The other calculation have been made assuming a stable mode share for the different modes on this route. The composition of the vehicle flow at Vikas Marg as found in 1999 counts is as follows:

	Veh/h.	Occupancy. rate	Pers. per h.	Modal share
Car	975	1.15	1121	7.6%
Motorised two-wheeler	2565	2.2	5643	38.5%
Bus	180	37	6660	45.4%
Three wheeled scooter rickshaw	430	1.75	753	5.1%
Bicycle	464	1.05	487	3.3%
Total	**4614**		**14664**	**100%**

It is clear that the bus and motorised two-wheelers are by far the most important modes at this stretch of road. The counted pedestrian flows on this route are about 1500 pedestrians per hour.

Investment in bicycle facilities

The costs for reconstruction of Vikas Marg as described above amount to around Rs. 236m, or Rs. 26m. per kilometre. Maintenance costs have been calculated at 10% of the investment costs, or Rs. 23.6m per year.

Accessibility and use of space

The new design of the route will lead to an improved traffic flow and therefore a higher capacity on the route for all means of transport. It is expected that the capacity for car traffic will double and that for bus traffic can increase from 290 to 400 vehicles per hour in each direction. The available space for each mode of transport will actually remain the same, except that they will be separated more. Calculations have shown that the redesign results in time-saving of 50% for bus passengers (from 37 to 18 minutes for 9 kilometres) and of 30% for car and scooter drivers (37 to 26 minutes). After making a distinction between trips that are work-related or not work-related, and taking the occupancy rates of vehicles into account, the economic value of saved time is determined. This is based on the average income per user of different means of transport. For work-related trips, 1 hour of travelling time for a bus passenger is valued at Rs. 24, for a scooter driver at Rs. 35 and for a motorist at Rs. 70.

The average total travelling time for all motorised trips over this route of 9 kilometres will drop by 48%. This leads to savings of Rs. 128m per year.

Environmental pollution and energy consumption

Delhi is the fourth most polluted city in the world, and its traffic produces 64% of the air pollution. It is very important, therefore, that this pollution is tackled. In order to calculate the effects of increased bicycle use due to the provision of bicycle facilities, a future 7% modal split of the bicycle on Vikas Marg is compared with the situation where cycling disappears completely of this road due to traffic safety problems. It is assumed that the bicycle trips will be substituted by bus and scooter trips in case no facilities for the bicycle are be provided. The average trip distance by bicycle is assumed 4.9 kilometre.

The internal costs (price of the fuel) and external costs as a consequence of effects on health through environmental pollution are then determined. The following table provides an overview.

	Price per litre	External health costs per consumed litre
Bus (diesel)	Rs. 9.8	Rs. 21.7
Scooter (petrol)	Rs. 23.8	Rs. 2.4

One striking fact is the significant difference in external costs between the bus and scooter. This has to do with the poor quality of the diesel fuel used by buses which has a high sulphur content.

For Vikas Marg, the total savings due to saved fuel use are Rs. 68.1m per year and the saved externality costs of air pollution are Rs. 14.5m per year.

Traffic safety

There were 2123 traffic deaths in Delhi in 1998, of which 1057 were pedestrians, 198 were cyclists and 422 were drivers of motorised two-wheelers. Using the number of injuries and fatalities per passenger kilometre in Delhi the expected injury rate for Vikas Marg is 45.4 per year and the expected fatality rate is 10.4 per year. Because most accidents happened on roads between junctions rather than at junctions themselves, it is reasonable to assume that separating the different traffic flows on Vikas Marg would have a positive effect on traffic safety. It is assumed that the number of casualties will drop by 40% per passenger kilometre and the number of fatalities by 50% per passenger kilometre. As the total traffic flow and mode shares are assumed stable the number of injured people is expected to drop by 18 per year and the number of fatalities by 5 per year. Based on costs of Rs. 67,694 per injury and Rs. 469,475 per fatality (Kadiyali, 1992), the total savings on Vikas Marg amount to Rs. 3.7m per year.

Conclusions

The costs of separating traffic on Vikas Marg are a one-off investment of Rs. 236m. The total annual benefits are presented underneath.

Annual maintenance costs of Rs. 23.6m are deducted from these benefits. Account is taken of a depreciation period of 25 years on the infrastructure and a discount rate of 6% per annum. This brings the total costs in the 25 year period to a net present value of Rs. 121 million and the total net present benefits to Rs. 2444 million. The ratio between costs and benefits therefore is about 1: 20. More than half of the benefits are from the savings in travel time. This calculation displays the gains made by constructing bicycle facilities on a relatively short stretch of thoroughfare. If the construction of separate bicycle routes in larger parts of Delhi were to lead to an increase in bicycle use, which can be expected, the savings in the total number of trips could be considerably greater.

	Benefits per year	Benefits due to ...	% of total benefits
Time savings	Rs. 128.4 million	improved traffic flow	60%
Emission savings	Rs. 14.6 million	mode shift to cycling	7%
Fuel savings	Rs. 68.1 million	mode shift to cycling	31%
Traffic safety	Rs. 3.7 million	safer infrastructure	2%
Total annual benefits	Rs. 214.8 million		100%

***Rs. 1.00 = US $ 0.025 (1997)**

This publication is based on a study executed by the Indian Institute of Technology and written by I-ce, Interface for Cycling Expertise. Due to the fact that there are contradictions in the available data on Delhi additional research is needed in order to calculate the costs and benefits of bicycle policies for the whole city.

Evaluation

The fact that in all four cities more than 50% of all trips concern easy to cycle distances and all cities are (almost) flat, shows the potential of the bicycle. All four cities have some kind of bicycle culture. To what extent this potential results in bicycle use depends on income, the traffic situation, the availability of bicycle infrastructure among others.

In Amsterdam and Morogoro cycling is one of the main means of urban transport. In Amsterdam this share is expected to fall slowly due to an increase in trip-length because of an expanding urban area. In Morogoro a more rapid decrease in bicycle use is expected as a result of improvements in the road-infrastructure leading to higher speeds of motorised traffic.

In Delhi the bicycle still holds a substantial share of all trips, but the conditions, such as safety, have become worse due to an increase in motorised traffic.In Bogota cycling is dangerous and marginal. The use is more or less stable. Hundreds of thousands do use the bicycle during weekends for recreational purposes, which shows that cycling is not at all an uncommon thing in Bogota.

The costs of the city wide investment plans in Amsterdam and Bogota are about 200 million US$. For the few roads of Morogoro and the only corridor for which data in Delhi were available, the costs are only some millions. But in any case, high quality of facilities is assumed to provide direct, quick, safe and comfortable access to destinations. The benefits that have been included in the calculations differ, depending on their relevance or on the availability of data.

The table presents an overview.

	Amsterdam	Bogota	Corridor Delhi	Morogoro
Less investments other modes		X		
Fewer parking space	X	X		
Less congestion		X		
Less pollution	X	X	X	
Improved safety	X	X	X	
Improved health	X			
Less bicycle theft	X			
Less direct users costs		X	X	X
Time savings	X		X	X

For Morogoro, only time savings and less travel costs make investments in facilities for cycling (and walking) already very high beneficial. Since Morogoro is not motorised, external costs of motorisation are of little relevance here.

For Delhi, the benefits of time savings and less travel costs far outweigh the two other factors that have been included. The benefits of less users costs and/or time savings contribute also very much in Bogota and Amsterdam.

In other words, the improvement of the traffic flow of cycling by providing better facilities combined with the fact that cycling is cheap, has in itself a high economic value. Road safety contributes to about 50% of the benefits in Bogota and also significantly in all cities, although this could not be calculated in Morogoro. For Amsterdam in particular, improved health (cycling keeps you fit) and bicycle theft are also important factors.

The final results show that in all cities the benefits exceed the costs. The benefits outweigh the costs much more in the cities that have not invested in cycling facilities.