CE

Oplossingen voor milieu, economie en technologie

Oude Delft 180
2611 HH Delft
tel: 015 2 150 150
fax: 015 2 150 151
e-mail: ce@ce.nl
website: www.ce.nl
Besloten Vennootschap
KvK 27251086

The benefits of cycling and how to assess them

Paper

Delft, September 26, 2003

Author(s): Joost Vermeulen

Contents

1 Introduction

Although most of us are aware of the benefits of cycling many people are not. When we want to develop and implement a bicycle plan it is useful when we can show them the economic benefits of cycling. It will enhance the chance that we find support and financial contributions for our plan. This paper is meant to give you some support on the methodology when setting up a cost-benefit analysis.

In the highly developed western economies cycling is often considered to be an odd and old-fashioned mode of transport with low status. With the exception of a few countries that are known for their relatively high share of cycling (in Europe: Denmark, Germany, the Netherlands) the cyclist is a rare species on the road even when bicycle possession rates are high. Recently, the attitude towards cycling has started to change somewhat. As the negative effects of motorised transport become increasingly visible (poor air quality, congestion, noise nuisance) the benefits of the alternatives also become more prominent and the benefits of the bicycle are rediscovered. Especially in the urban areas cycling is considered to be a good alternative for the car.

In relatively rich developing countries cycling generally has a low status and is considered to be a transport mode for the poor, or inappropriate for women and people of high status. In this respect there is a danger that the transport system develops along the same lines as it has done in the western countries and that the benefits of cycling, but also of walking, as a mode of transport are not used to the fullest. An example of this is Bangkok, Thailand that suffers from congestion problems and air pollution as a result of a transport investment policy that was focussed on the car.

In poor developing countries for many people cycling has another status than in the Western world: it would be an aide for their economic prosperity if they could afford one. Here, the bicycle is an alternative for walking and matters of environmental pollution or congestion are less important.

It is this contrast that we return to at the end of this paper to illustrate the economic benefits of cycling. In both situations (as an alternative to the car and for walking) the bicycle offers economic benefits to society, although these benefits are different in kind. This paper will try to give handles for a systematic analysis of the benefits (and costs) of cycling.

2 Assessing mobility effects

When we want to make a cost benefit analysis of a bicycle project the first step we need to take is to estimate the effects on mobility.
This contains:

- estimating the normal traffic, i.e. the traffic that would have taken place on the facility in any case, even without the new investment;
- estimating the amount of newly generated traffic;
- estimating the amount of diverted traffic between transport modes.

It is important that these three categories are determined and compared to a proper reference scenario. In order to appreciate the exact effects of the project this reference scenario should also take into account the expected mobility developments were the project not been carried out at all.

For the objective of this paper we assume that the transport effects of the project are known, i.e. the changes in bicycle use, car use, walking et cetera are ex-ante determined. We can than continue with the second step: establishing the costs and benefits arising from these changes in mobility.

We approach the cost benefit analysis from a socio-economic point of view: we consider the costs and benefits of cycling to society as a whole. We do this because we assume that the main use of this paper will be to provide some support setting up a cost benefit analysis for transport (infrastructure) projects that are meant for the public benefit. It is such a project that we have in the back of our mind when we write this paper.

3 Assessing costs and benefits

In this section we briefly discuss the various costs and benefits of cycling. At the end of this section we will focus on the costs and benefits from two perspectives and identify the most important costs and benefits that one should determine in order to estimate the benefits of cycling:

1. From the perspective of the bicycle as an alternative for walking (most likely in poor developing countries), and
2. The bicycle as an alternative for the car (most common situation in western countries and richer developing countries).

We will see that from both perspectives cycling offers significant benefits to both the private users and society as a whole. In the following sections we will further address these benefits and costs.

3.1 Private costs and benefits

Under private costs and benefits we consider the costs and benefits that the private user experiences. These comprise:

- costs of purchasing, driving and maintaining a bicycle (or car);
- costs of traffic accidents;
- costs of travel time and increased economic opportunities;
- benefits of an improved health condition.

Hereafter we address these issues in more detail.

Costs of purchasing, driving and maintaining a bicycle (or car)
In general the costs of purchasing a bicycle or car are relatively easy to determine by comparing market prices. As a rough estimate one can assume that the purchasing and operational costs (maintenance and fuel) per kilometre of a bicycle are about 10 times cheaper than that of a car, but large deviations exist (see the table below).

Table 1 Purchase costs and average yearly operational costs (use and maintenance) in relation to income per capita in 1992 (in US$)

City	Country	Bicycle		Motor cycle		Car		Income per capita
		purchase costs	operational costs	purchase costs	operational costs	purchase costs	operational costs	
Phnom Penh	Cambodia	0.053	0.004	0.338	0.035	2.510	0.060	200
Kampur	India	0.071	0.020	0.240	0.070	0.640	0.010	200
Surabaya	Indonesia	0.184	0.027	0.296	0.037	2.460	0.082	610
Manila	Philippines	0.235	0.021	0.352	0.029	3.130	0.113	740
Chiang Mai	Thailand	0.237	0.021	0.304	0.048	1.980	0.128	1580
George Town	Malaysia	0.240	0.027	0.400	0.076	1.600	0.223	2490
Tokyo	Japan	0.213	0.031	0.360	0.080	1.200	0.260	26920

After: VNG, 2000, assuming 750, 5000 and 10000 kilometres per year for bicycle, motorcycle and car respectively.

The private costs of walking are very low. Probably only the wear and tear of shoes could be considered in a cost-benefit analysis. For the case of Morogoro, Tanzania, the travel costs of the various modes are summarised below.

Table 2 Travel costs per kilometre in US$ for the year 2000

Walking	0.002
Bicycle	0.010
Bus	0.033
Car	0.3

After: VNG, 2000

When we want to compare the purchasing and operational costs it is important that they are calculated on the same basis. Most commonly, these costs are expressed as yearly costs by using depreciation functions that calculate the average yearly costs on the basis of purchase price, residual value, lifetime and interest rate.

Costs of traffic accidents

Road accident rates in developing countries are typically an order of magnitude higher than that in industrialised countries (Adler, 1987). This is due to a number of reasons among which:

- poor road design and pavement quality;
- limited training of drivers;
- motorised vehicles and slow vehicles, pedestrians and animals are not spatially separated;
- poor condition and overloading of vehicles.

Traffic accidents generally impose costs on both the involved victims and the society. The costs for the user comprise primarily the material damage and medical costs. These costs can in principle be derived from the costs of insurance. In the Netherlands the costs of accident insurance are on average about 500 Euro per year. Insurance for damage to bicycles is not common, as the owner can generally raise these costs with relative ease. Although in developing countries many vehicles are not covered by insurance we can derive the

The costs of medical insurance are generally not dependent on the transport mode that is used and is therefore not important for our cost-benefit analysis.

Cost of travel time
In the industrialised world the phrase “time is money” certainly applies in transport. As people have a remarkable similar daily time budget for travelling (about 1 hour), the faster one can travel the more destinations you can reach (see below).

In order to establish the costs and benefits of (saved) travel time we need to start with some theoretical background on their determination. If a bicycle project leads to changes in travel time, generally three categories of users will benefit (as mentioned in chapter 2):

1 The people that continue to use the bicycle.
2 The new users.
3 The people that switch from another mode to the bicycle.

Suppose the building of a free-lying dedicated bicycle path leads to reductions in travel time for cyclists on that route. The people that continue to use the route will experience the full benefits of the travel time reduction (which we can express in financial terms, as we will see later).

The new users however, will experience a lower benefit: The first newcomer that in the situation without the bicycle path was almost willing to make the trip by bicycle will experience benefits that are almost as large as that for the cyclists who continue to use the route. On the other end there will be new users that are only just willing (and thus gaining just more than zero benefits) to use the new bicycle path. On average the benefits for these new users are therefore half that of the existing users. This principle is called the rule of half in cost-benefit analyses.

Finally, the people that switch from another mode (e.g. the car) to the bicycle will gain at least the benefits of that of the people that continue to use the car. But, because they switch from the car to the bicycle there must be extra benefits or they would not do that. On average these extra benefits equal half of the difference between the level of benefits of the bicycle and that of the car in the situation with the new bicycle path[1].

In summary, the total travel time benefits B of this project equal

$$B = 0.5\left(Q_a^0 - Q_a^1\right)\left(P_a^0 - P_a^1\right) + 0.5\left(Q_b^0 - Q_b^1\right)\left(P_b^0 - P_b^1\right)$$

With
Q_a = demand for cycling
Q_b = demand for car
P_a = costs of travel time for cycling
P_b = costs of travel time for car
Without (0) and with (1) the new bicycle path.

1 If the new bicycle path does not influence the travel by car, the benefits of the car with or without the bicycle path will be equal. If the new path e.g. alleviates the congestion on the road there will be benefits for the car as well. The extra benefits for those who switch from the car the bicycle will then be somewhat smaller. If, on the other hand the bicycle path is combined with a narrowing or closure of the road the benefits of the car will decrease. The extra benefits for those who switch from the car the bicycle will then be larger.

In the example above the demand and costs can be calculated on the basis of the number of people or vehicle-kilometres etc. It is of course important that all costs and benefits share the same basis so that they can be added and compared. For the purpose of this paper we will not worry about the basis when we identify the various costs and benefits of cycling and indicate how we can determine and value them.

The valuation of travel time depends on the motive of travel. Business trips are generally valued highest and the valuation is mostly derived from wage rates. The travel time value of commuting trips and leisure or holiday trips is generally lower. An example of these differences for the value of time (VOT) is given in the table below. A value of time for cycling of 4 euro (9 Dutch guilders) is mentioned for a case study for Amsterdam in VNG, 2000. This value is in line with that for leisure trips with motorised modes.

Table 3 Values of time (in euro of 1998 per hour) for Europe, based on state of the art studies

Mode > Motive v	Car /motorcycle	Coach (inter-urban	Urban bus /tramway	Inter-urban rail	Air travel
Business	21	21	21	21	28,5
Commut-ing/private	6	6	6	6,4	10
Lei-sure/holiday	4	4	3,2	4,7	10

Source: Unite, 2001

Values of time in the developing countries are significantly lower. An example is the case study for Morogoro, Tanzania from VNG, 2000. In this case the time costs per hour are estimated to be somewhere between 0.17 US$ and 0.68 US$[2]. However, with a purchasing power parity per capita that is about 40 times lower than that of the EU (CIA, 2003) the valuations of time in real terms are comparable.
As a last remark we note that the value of time can be very dependent on the local circumstances. In many poor developing countries the rate of unemployment is high. Therefore wages do not properly reflect the economic costs of labour. A derivation of the value of time from wage rates should therefore be carried out with care (Adler, 1987).

As one of the benefits of a faster mode of transport is that it makes more destinations accessible, it is likely that the economic opportunities of the user will increase. On average, a person that walks will cover about 4 kilometres per hour. In rural areas of development countries this will allow him to get a round his own village on maybe reach some neighbouring settlements. If however such a person would use a bicycle his radius would increase to about 10 kilometres. In that case he will be able to reach many more destinations and economic activities. In our example he would be able to reach the market in a regional town in 1.5 hours and sell his products instead of in over 4 hours (and probably not making the journey at all).

[2] In principle the valuation of time is independent on the transport mode, as it is the one unique value of time that can make a person choose between one mode or the other.

Two examples of these increased economic opportunities are given in VNG, 2000:

1 In Midrand, South Africa bicycles are used to collect used paper for recycling in a paper mill. This raises an income for the collector that is 3 times that of his colleagues who collect and transport paper by foot.
2 Near Accra, Ghana women sell their oranges for very low prices at the local market because local supply exceeds demand. However, only 15 km down the road in Accra supply is relatively low and prices are high. Had these women possessed bicycles they could have offered their oranges in Accra and raise their income substantially.

There is great discussion about these increased economic benefits. Many argue that they represent no new benefits other than those of travel time gains and should therefore not be added to the other benefits.
In addition to an increase in economic opportunities, new economic activities can arise. A flourishing bicycle culture will bring about bicycle rental, sale and repair shops. When attributing these benefits one should be very careful and take into account the economic development that would have taken place without the bicycle project as well as the economic activities that are lost in other sectors as a consequence of the project.

Benefits of an improved health condition
In the developed countries cycling is often seen as a means of physical exercise. Where many people suffer from health conditions due to lack of physical labour and a lavish diet, cycling can indeed contribute to health improvements. However, in most developing countries conditions are different. The benefits of extra physical exercise from cycling are likely to be negligible.

3.2 Infrastructure and external costs

After we have addressed the costs for the private user we will here discuss the costs that are not carried directly by the users but are covered by the government or by society as a whole. These costs comprise:

- costs of infrastructure building and maintenance;
- traffic accidents;
- emissions;
- noise nuisance;
- congestion.

With the exception of the costs of infrastructure all the above costs can be referred to as external costs of transport. External costs are the external effects of mobility that are judged to be financially negative. External effects are taken to mean those which the originator does not taken into consideration in his or her decision on mobility (CE, 1999). Hereafter we address these issues in more detail. At the end we shortly discuss the benefits of welfare sharing for which the bicycle can act as a facilitator.

Costs of infrastructure building and maintenance
The costs for construction and maintenance of infrastructure are relatively easy to assess. If we assume the same high quality of asphalt to be used as pavement the costs of a square metre of bicycle lane does not differ substantially from that of a road for cars. And although wear of the pavement is much smaller for bicycle lanes as for car lanes, cyclists are more sensitive to the quality of the pavement than motorists, meaning more regular maintenance.

However, the cost of bicycle infrastructure will be lower per user since its capacity per metre is larger: bicycles need less space, so the lane can accommodate more cyclists per metre. In the Netherlands an urban road (with 1 lane of 3-4 metres wide for each direction) has a capacity of 2000 cars per hour at most for each direction. With an average occupancy rate of 1.6 that equals 3200 persons per hour. A one-way bicycle lane of 2.5 metres wide can accommodate 6500 persons per hour, which is double that of the car.

In reality the costs of infrastructure will greatly depend on its design and the addition of facilities as tunnels, bridges and traffic lights. As an illustration of the cost of bicycle infrastructure serve that of Morogoro, Tanzania where on average the costs amount 35,000 US$ per km and Bogotá, Colombia where costs amount 360,000 US$ per km. When we know that the ratio of the purchasing power parity per capita equals 10, the costs become similar[3].

Emissions and noise nuisance
In contrast to the car a bicycle does not produce noise, polluting emissions or contribute to global warming. As an illustration, the emissions of a cars and buses in the Netherlands are given in the table below.

Table 4 Emission factors (in gram per km) for urban and rural trips of the average vehicle built in 1993 and 2002

Vehicle type	Year	CO_2		NO_X		PM_{10}		HC	
		urban	rural	urban	rural	urban	rural	urban	rural
Petrol car	1993	264	164	1.1	1.0	0.018	0.011	5.75	0.85
	2002	262	164	0.1	0.05	0.001	0.001	0.44	0.03
Diesel car	1993	229	151	0.7	0.6	0.24	0.13	0.23	0.12
	2002	228	152	0.7	0.4	0.06	0.03	0.09	0.01
Bus	1993	1002	849	16.5	12.9	1.03	0.58	2.21	1.01
	2002	1080	916	10.6	7.6	0.31	0.17	0.65	0.35
Moped	1993	59	59	0.1	0.1	0.04	0.04	12.39	12.39
	2002	59	59	0.1	0.1	0.04	0.04	7.82	7.82

Source: CBS, 2003

The polluting emissions of vehicles in developing countries are typically and order of magnitude larger because they are older (newer vehicles are generally cleaner due to ongoing tighter emission standards in the industrialised countries, see the table) and their condition is worse due to lack of proper maintenance. As a result the air quality in many cities in developing countries is poor.

Monetary valuation of environmental effects is relatively well established during the last decade and will be based ideally on an estimate of the damage (reduction in welfare) caused by the environmental effect. This method is to be preferred for environmental problems that are closely related to quality of life, because a good estimate of the loss of welfare can be made in this type of problem.
In the case of noise nuisance, a satisfactory estimate of the loss can be effected by means of the loss of house values as a result of noise. Allowances

3 This is a rough approach as the design of the bicycle lanes and the facilities that are included in its costs per km are not exactly the same.

must be made in this case for the fact that such a loss represents a total sum, which must be subsequently allocated to the various types of vehicle.

However, for more complex environmental problems and those related to sustainability, it is often impossible to make an appropriate damage cost estimate. A good example is CO_2 emissions in connection with climate change; moreover direct valuation of damages soon proves to be inadequate for acidification, too. Society has nevertheless established implicit damage valuation for these emissions, usually on the basis of the precautionary principle, having decided that it wants to achieve certain objectives for reductions. By analysing the costs of measures that are necessary to achieve objectives, it can be ascertained how much society implicitly wants to reduce the environmental effect. In this case the evaluation is based on what are known as prevention costs. Prevention costs represent a kind of social willingness to pay, in which all uncertainties regarding the actual environmental effect are included. Valuation of environmental effects relating to sustainability, based on the prevention cost method, also results in a much smaller spread than evaluation based on estimation of direct damage. Because the prevention cost method is based on marginal prevention costs (the costs of the most expensive measures required to meet the objectives), the costs of prevention represent the marginal costs of emissions. Since the prevention costs are expressed in ε per kg of emissions and emission factors in gram per km are known, the external costs of emissions can be calculated directly ('bottom up'). This is in contrast with for instance to the costs of infrastructure and noise nuisance where an indirect method ('top down' with allocation factors) must be applied.
From the valuation efforts a set of so called shadow prices is established for the major pollutants (see the table below).

Table 5 Environmental effects and their financial valuation (in euros of 2001 per kg) for the EU

Type of emission	Type of effect	Valuation method	Financial valuation Urban areas	Financial valuation Rural areas
CO_2	Climate change	Prevention costs	0.02	0.02
NO_X	Acidification and eutrophication, smog formation (forced greenhouse effect), health effects	Prevention / damage costs	12	7
HC	Smog formation (forced greenhouse effect), health effects	Prevention costs	6	3
Particulates (PM_{10})	Health effects	Prevention / damage costs	300	70
Noise nuisance (in euroct/km)	Stress, sleep problems and psychological problems	Willingness to pay (damage)	Passenger car 1.3 Bus 8.0 Moped 5.4	Passenger car 0.2 Bus 1.2 Moped 0.8

Source: CE, 2001

These shadow prices however are not readily applicable to developing countries as the valuation depends on the national welfare level. A good approximation of the shadow prices in a particular country is therefore to correct the prices in the table with ratio of the purchasing power parity (PPP) of that country with that of the EU. An exemption is in place for the shadow price of CO_2. As this is a pollutant with global effects its shadow price is derived from the expected level when a global CO_2-emissions trade scheme were in place.

Traffic accidents

The external costs of road traffic accidents can be divided into four categories:

1 Processing and prevention costs: these are police, fire brigade, court, insurer, investigation, information and congestion costs (congestion due to accidents).
2 The costs of medical care, convalescence and replacement, if applicable: the proportion not covered by insurance is external.
3 The costs of productivity losses due to accident victims being off work.
4 The costs of human suffering. This last item is very significant in the total external effects of road traffic accidents.

The allocation of external costs to vehicle categories in one-party accidents (e.g. a car driving into a tree) is simple. With these, 100% of external costs are allocated to the party concerned.
For multi-party accidents allocation is more complex. In their driving behaviour, every road user attends to his or her own safety. A good measure of the external costs of road accidents is therefore the extent to which the various road users expose others to danger.
Cyclists are vulnerable but harmless. For motorised vehicles the heavier and the faster a vehicle, the more likely it is that they impose risk to others. This intrinsic risk is reflected in road accident statistics. In a crash between a cyclist and a lorry it is less likely for the cyclist to survive than it is for the other party. In a certain sense, then, the mere presence of the lorry is also responsible for the occurrence and seriousness of the accident, even if the drivers of these vehicles are not to blame for the cause of the accident. The so-called 'conflict tables' used in accident statistics show how casualties in multi-party accidents are divided over the various means of transport.

As a consequence of allocating responsibility for multi-party accidents on the basis of *intrinsic risk* only an insignificant part of the external costs of road traffic accidents is to be allocated to cyclists (and pedestrians). Moreover, on the basis of study results it is believed that when the number of pedestrians and cyclists increases the risk for all vulnerable road users will fall (HLG, 1999). The expert advisors to the high level group on infrastructure charging (an advisory board to the European Commission) even mark in their final report on the calculation of transport accident costs that "*Consequently, the remaining external component (of accidents costs) is negative, i.e. they should be subsidised because more pedestrians and cyclist reduce the risk for existing vulnerable road users*".

Of all the costs from accidents that of human suffering are generally most important. A common quantity in which to express these costs is that of the value of a statistical life (VOSL). This is the value of a 'random' human life that is derived from the expressed willingness to pay for risk reduction. IN Europe a value of 1.5 million euro is commonly used. For use in developing countries this value should be adjusted according to the ratio of PPP's. The costs of processing and prevention, medical care and the costs of productivity losses can, as a rough estimate, be valued as 10% of that of a VOSL (Unite, 2001).

Congestion
A bicycle takes less space than a car. On (urban) roads intensive car use will lead to congestion.
As opposed to the costs of infrastructure, noise and emissions, in the case of congestion costs we take ‘external’ to mean not so much that the transport system *as a whole* generates delay costs for society, more that road users generate delay costs for *one another*. A road user has it within his power to decide to travel at a time which is susceptible to queues, allowing in any case for his own (anticipated) delay (as a result of which it is internalised), but not for the delay he causes other road users through this decision.
Congestion costs can amount to great sums as the valuation of lost productive time is relatively high. It is estimated that Bangkok, Thailand misses out on a third of its economic growth due to congestion. In this city the congestion due to a policy of facilitating the car has lead to an average speed for cars of 8 km per hour. As a contrast, in Singapore where space has been given to public transport and the bicycle the average speed of cars is about 30 km per hour (VNG, 2000).

Benefits from welfare sharing: the bicycle as a bridge
Now that we have addressed the most important external costs and benefits we would like to add one more benefit of cycling that is often forgotten. In many countries the welfare distribution over the population is not even. For example only the small rich class experiences the benefits of the car. The bicycle could help to change this situation, and offer opportunities to many people who now have very little chances. In the long term this will contribute to a larger economic participation and stability of the country as a whole. Although it is hard to quantify this effect it is believed that benefits can be potentially large.

4 Conclusion: the main benefits of cycling

As an alternative for walking the major benefit of the bicycle in development countries for the user is the reduction in travel time that allows for an enormous increase in the socio-economic opportunities that the owner has. Now he or she can reach more jobs and markets than before and existing destinations can be reached in less time.

As an alternative for the car the bicycle’s main benefits for the user are:
- its much lower purchasing and operational costs;
- in congested urban areas: travel time savings;
- a better physical condition (health effects).

In addition society gains benefits from:
- lower infrastructure costs per user;
- less congestion;
- smaller safety risks, especially to vulnerable groups (pedestrians and cyclists);
- the absence of polluting emissions;
- the absence of noise nuisance;
- larger economic participation.

The size of the benefits of the bicycle over the car will depend on the specific local situation (whether or not a city suffers from congestion), but as time progresses small benefits may grow.

As a conclusion we may therefore say that the bicycle is a relatively fast means of transport with major benefits over walking and without the drawbacks of the car.

Literature

CIA, 2003
Website of the US Central Intelligence Agency:
http://www.cia.gov/cia/publications/factbook/fields/2004.html

CBS, 2003
Website of the Dutch national statistics office:
http://www.cbs.nl/nl/cijfers/statline/index.htm

Adler, 1987
Economic appraisal of transport projects; a manual with case studies
Revised and expanded Edition, published for The World Bank.
Hans A. Adler
1987

CE, 1999
Efficient prices for transport; Estimating the social costs of vehicle use
Dings, J.M.W et al.
Delft, October 1999.

CE, 2001
Benzine, diesel en LPG: balanceren tussen milieu en economie
(Petrol, diesel and LPG: balancing between environment and economy)
Kampman, Bettina et al.
Delft, August 2001

HLG, 1999
Calculating transport accident costs
Final report of the expert advisors to the high level group on infrastructure charging
April 1999

Unite, 2001
Valuation conventions for UNITE, UNITE (UNIfication of accounts and marginal costs for Transport Efficiency)
Nellthorp, J et al.
April 2001

VNG, 2000
De economische betekenis van het fietsen; een onderzoek om kosten en baten van fietsbeleid te illustreren (The economic significance of cycling: a study to illustrate costs and benefits of cycling policy), including the annex: *The results of four cost-benefit calculations: Amsterdam, Bogota, Delhi, Morogoro.*
Stichting Habitat Platform, Interface for Cycling Expertise I-ce , Vereniging van Nederlandse Gemeenten
VNG Uitgeverij, Den Haag, 2000.