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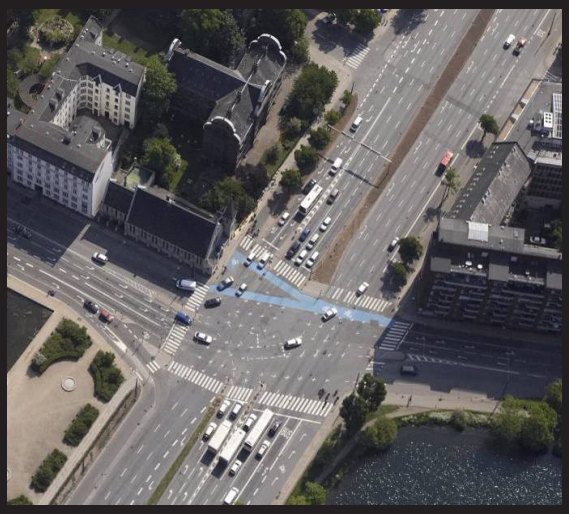
Working paper

# Economic evaluation of cycle projects - methodology and unit prices

## Summary



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Summary

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## 1 Introduction

This note comprises a combined English summary of the report "Samfundsøkonomiske analyser af cykeltiltag - metode og cases" and the accompanying note "Enhedsværdier for cykeltrafik", prepared by COWI for the City of Copenhagen (www.kk.dk/cyklernesby).

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| | |
|---|---|
| Document no. | P-68593-A-6 |
| Version | Final |
| Date of issue | 09 December 2009 |
| Prepared | JOHR |
| Checked | EWI |
| Approved | EWI |

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# 2 Summary

## 2.1 Background

It is the ambition of the City of Copenhagen to be the best cycling city of the world. From 2006 to 2010 the city has devoted approximately 200 million DKK (app. 27 million EUR) to specific bicycle projects. So far the funds have among other things been used for new cycle paths, cycle parking, redesign of intersections and big campaigns to promote cycling. Moreover, the city has set up a range of goals for cycling in Copenhagen to be achieved by 2015. These include making more Copenhageners cycle and increase perceived safety for the cyclists.

There is no established methodology for evaluating the economic costs and benefits of cycle projects in Denmark. For instance, the official manual for economic cost-benefit analyses from the Ministry of Transportation does not contain recommendations with regard to cycling, and there is no official methodology and no unit prices for cost-benefit analysis of bicycle projects.

In order to evaluate cycling on equal terms with other modes of transport and improve the foundation for prioritization of resources for transportation, it is necessary to establish a methodological basis as well as unit prices for cycle transport. The City of Copenhagen asked COWI to take the first steps in this direction by carrying out a project for evaluation of cycle initiatives.

The purpose of the project was to:

1 Establish an initial methodological foundation for economic cost-benefit analyses (CBA) of cycle initiatives in the form of unit prices.

2 Carry out cost-benefit analyses of two cases (Bryggebroen and the intersection in Gyldenløvsgade) on the basis of these unit prices.

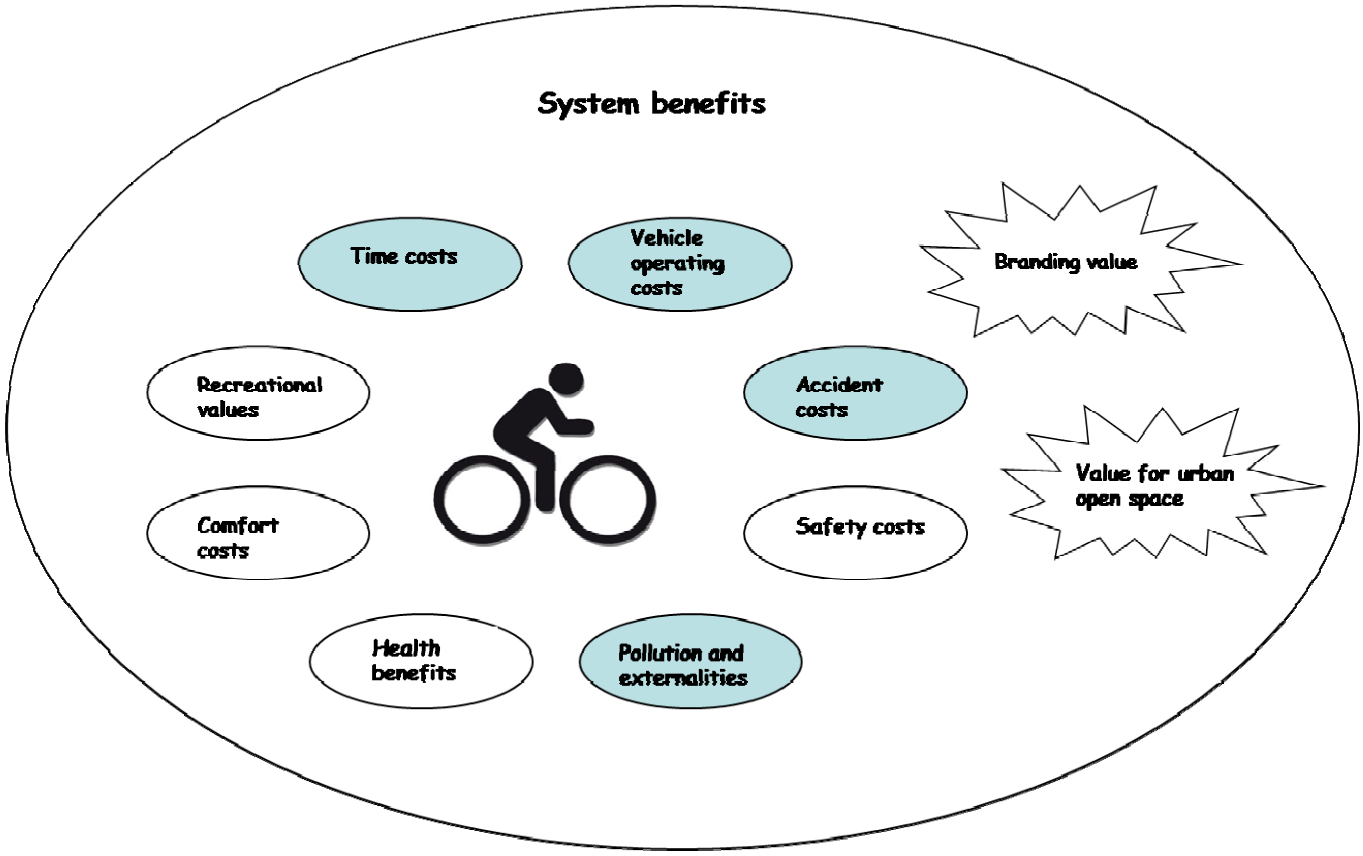
3 Evaluate potential network effects arising from cycle projects.

The established unit prices are evaluated on a general term based on existing material and - in the cases where the existing material was limited - best guess assumptions. Hence, the results should be perceived as a first rough estimate of the unit prices for cycle economics.

**Framework**
There are two main purposes of cycle projects in Copenhagen: to improve the conditions for existing cyclists and to encourage more people to cycle.

The below figure illustrates effects potentially caused by a cycle project, which involve economic costs and benefits.

*Figure 2.1 Economic effects of cycling*




Each of these elements is evaluated in the project and, when possible, unit prices have been estimated.

Besides the unit prices, another important aspect of the economic CBA is the assessment of the traffic effects, i.e. changes in the number of cycle kilometres, changes in use of time and indirect changes in traffic patterns.

The table below illustrates how the traffic effects can be assessed.

*Table 2.1 Assessing the traffic effects of cycle initiatives*

| Effect for the economic CBA | Methodology to quantify traffic effects | Data requirement |
|---|---|---|
| Vehicle operating costs | Change in vehicle kilometre by mode, i.e. for different motorized vehicles, public transportation and bicycles. | Traffic counts and/or modelling. |
| Time costs | Change in transport time by transport mode. | Traffic counts and/or modelling. |
| Accident costs | Change in the number of accidents with and without bicycles involved. | Accident registrations, traffic counts and/or modelling. |
| Pollution and externalities | Change in vehicle kilometres for each mode of transportation. | Traffic counts and/or modelling. |
| Recreational value | Change in cycle kilometres and cyclists' statements. | Interviews and traffic counts and/or modelling. |
| Health benefits | Change in cycle kilometres. | Traffic counts and/or modelling. |
| Safety | Change in the number of accidents, cyclist statements and change in cycle kilometres. | Accident registrations, interviews and traffic counts and/or modelling |
| Discomfort | Change in cycle kilometres. | Traffic counts and/or modelling. |
| Branding value | Not a traffic effect. | - |
| Value for urban open spaces | Not a traffic effect. | - |
| System benefits | Change in cycle kilometres. | Traffic counts and/or modelling. |

At present no real traffic models for cycling exist. In a longer perspective it will be desirable to develop a model in order to quantify traffic effects for the CBA in a structured way.

**Unit prices**

Table 2.2 illustrates the estimated average cost per kilometre for cycling. In the cases where it has not been possible to estimate a unit price at this point, the expected sign of the unit price is indicated with either plus (+) or a minus (-).

The costs of cycling are split into internal and external costs. The internal costs are the only costs, which the cyclist (in theory) responds to when deciding transport mode and route (the costs are internalized in the cyclist's choice function). The external costs are the costs for third party caused by the cyclist's choices and behaviour that do not (in theory) affect the cyclist's choices.

*Table 2.2 Average costs per kilometre for cycling, DKK, 2008 prices*

| | Cycling (16 km/h) | | | For reference: Car (50 km/h) in city | | | |
|---|---|---|---|---|---|---|---|
| | Inter-nalized | External | Total | Inter-nalized | External | Duties | Total |
| Time costs (travel time, non-work) | 5.00 | 0 | 5.00 | 1.60 | 0 | 0 | 1.60 |
| Vehicle operating costs | 0.33 | 0 | 0.33 | 2.20 | 0 | -1.18 | 1.02 |
| Prolonged life | -2.66 | 0.06 | -2.59 | 0 | 0 | 0 | 0 |
| Health | -1.11 | -1.80 | -2.91 | 0 | 0 | 0 | 0 |
| Accidents | 0.25 | 0.54 | 0.78 | 0 | 0.22 | 0 | 0.22 |
| Perceived safety | *+ (?)* | *0* | *+ (?)* | ? | ? | 0 | ? |
| Discomfort | *?* | *0* | *?* | ? | ? | 0 | ? |
| Branding/tourism | 0 | -0.02 | -0.02 | ? | ? | 0 | ? |
| Air pollution | 0 | 0 | 0 | 0 | 0.03 | 0 | 0.03 |
| Climate changes | 0 | 0 | 0 | 0 | 0.04 | 0 | 0.04 |
| Noise | 0 | 0 | 0 | 0 | 0.36 | 0 | 0.36 |
| Road deterioration | 0 | 0 | 0 | 0 | 0.01 | 0 | 0.01 |
| Congestion | 0 | 0 | 0 | 0 | 0.46 | 0 | 0.46 |
| **Total** | 1.81 | -1.22 | 0.60 | 3.80 | 1.13 | -1.18 | 3.74 |

Source: The unit prices for cars are from the Ministry of Transportation's official unit price catalogue (Transportøkonomiske Enhedspriser). The external values for cars are reported for gasoline cars in the city during off-peak hours.

Note: Note that the table displays the cost of cycling. A negative number can thus be interpreted as being a benefit of cycling. When splitting the health benefits into internal and external benefits, it is assumed that 50% of the production gain is own consumption and thus internalized. The rest is taxes etc.

The above table illustrates that a kilometre on cycle involves time costs, vehicle operating costs and accidents. Moreover, there is also a “cost” connected to perceived safety as the cyclist may feel unsafe when cycling. On the other hand, cycling also has health benefits, such as less illness and longer life-expectancy as well as having a marginal benefit on branding/tourism. In total, a kilometre on cycle is estimated to cost 0.60 DKK, when all estimated effects are included.

Apart from the above mentioned costs and benefits of cycling, some projects will affect the *perceived magnificence* of the cyclist, i.e. how much the cyclist values her/his surrounding environment. This effect can vary significantly from project to project, which is why it is recommended that this effect is evaluated for each cycle project specifically, rather than including it in the average costs per kilometre in Table 2.2..The total internalized average cost is 1.81 DKK per kilometre. This means that a 3 kilometre cycle trip from the national stadium, Parken, at Øster Allé to Nørrebro Station costs app. 5.40 DKK. According to numbers from the Ministry of Transportation's unit cost catalogue (time and

vehicle operating costs) the same trip by car costs 16 DKK, if the driver is alone in the car. By bus the trip costs almost 29 DKK in time and ticket costs[1].

The external costs, which in theory do not affect the behaviour and choices of the cyclist, are estimated to -3.65 DKK and are thus actually a benefit to the society. The primary reason is the reduced risk of lifestyle diseases and consequently lower costs to the society for treatment and lower tax losses - if people cannot work due to illness etc., then obviously their tax contribution is lower. For cars the external costs are 3.38 DKK and thus a cost for the society. These costs are counterbalanced by duties of 3.54 DKK for the trip. Note, however, that congestion costs in peak hours are significantly higher than during off-peak hours, which is why the external costs in peak hours are not fully matched by duties. During peak hours the congestion costs are 1.53 DKK per km according to the Ministry of Transportation's official unit price catalogue (Transportøkonomiske Enhedspriser). This means that in peak hours the total external costs for a trip by car would be 6.59 DKK and thus significantly higher than the duties of 3.54 DKK.

The total cost of a trip by bicycle may seem unrealistically low compared to the cost associated with a car trip. However, it should be noted that costs do not include everything, e.g. discomfort is not currently included in the cost functions. It should also be noted that the unit prices do not include duty corrections following changed consumption patterns nor tax distortion costs. These factors must of course be included in a full scale economic cost-benefit analysis.

On the basis of the estimated unit prices for cycling above, two economic cost-benefit analyses have been carried out. The two analyses are presented below.

## 2.2 Economic cost benefit analysis of Bryggebroen

In September 2006 the City of Copenhagen opened a 200 metre long pedestrian and cyclist bridge, Bryggebroen, across the harbour of Copenhagen from Kalvebod Brygge at Zealand to Islands Brygge on Amager.

The bridge supplements the existing connections, which are all intended for motorized vehicles with cycle lanes along the carriageways. North of Bryggebroen is Langebro in a distance of 1 kilometre and Knippelsbro in a distance of 2 kilometres. App. 3 kilometres south of Bryggebroen is Sjællandsbroen.

In the fall 2008 COWI carried out a survey of the cyclists using Bryggebroen with a following evaluation of the traffic effects of the bridge. The economic CBA is based on the results from this survey.

The result of the CBA is illustrated in the table below.

[1] According to Google Maps the trip takes 8 minutes by car, while the trip by bus takes 12 minutes and costs 12.50 DKK with a 10-trip ticket according to www.rejseplanen.dk (2008-prices).

*Table 2.3 Results from the economic cost benefit analysis of Bryggebroen*

| million DKK | Net present value 2008 |
|---|---|
| Construction costs and maintenance incl. scrap-value | -77 |
| Effects for cyclists | 222 |
| External effects of cycling | -84 |
| Traffic diverted to cycling from other modes | 8 |
| Taxes, tickets and operating costs for public transportation | 0 |
| Tax distortion loss | -34 |
| **Net present value (NPV)** | **36** |
| **Internal rate of return (IRR)** | **7.7%** |

The result of the CBA shows that the construction of Bryggebroen was a good investment for the society from an economic point of view. The bridge has resulted in large benefits for the cyclists, primarily in the form of time savings, which are estimated to outweigh the cost of the project. The central estimate is that the bridge has yielded a good economic return with a net present value of 36 million DKK and an internal rate of return at 7.7%. This does not include benefits for pedestrians. Also note that since the 2008 survey the number of cyclists using the bridge has increased from around 5,500 per day to almost 7,200 per day in 2009 which means that the above benefits may be underestimated.

As a reference, the economic analysis of the future bridge across Fehmarnbelt resulted in an internal rate of return at 6.8%. Likewise, the newest economic CBA of the upgrade of the railway between Copenhagen and Ringsted estimates an internal rate of return at 5.8% for the best alternative analyzed. An IRR of 7.7% for Bryggebroen is thus comparable to the return of other actual public capital investments.

The sensitivity analyses show that the result is relatively robust to changes in central input parameters and assumptions. Of the sensitivity analyses carried out, the society will experience an economic loss only when the gain for each cyclist as well as the number of cyclists is reduced by 25%.

In addition to the main CBA, another four "what if"-calculations have been carried out where benefits in the form of *perceived magnificence, perceived* safety and discomfort were included on a very general basis. The calculations show that the total result may be significantly better than the 33 million DKK when these effects are included. It should be noted, however, that these "what if"-calculations are based on assumed unit prices and hence can not be used as actual results.

## 2.3 Economic cost benefit analysis of the intersection in Gyldenløvesgade

In 2005 the City of Copenhagen decided to rebuild the intersection Gyldenløvsgade-Nørre Søgade-Vester Søgade. The rebuilt intersection was ready by October 8, 2006.

The decision to rebuild the intersection grew out of the fact that the intersection was identified as the most accident loaded intersection in the city. Assessing the accidents registered by the police in the period September 2000 to September 2006 shows that 46 persons, of which 26 were cyclists, were injured in the intersection in this period.

The rebuilding included a change of the design and signals in order to minimize conflicts between road users from different directions. This was done by establishing more phases in the traffic light signals, prioritizing turning traffic to straight ahead traffic, and closing the possibility of making some specific turns.

For the handling of the cycle traffic the rebuilding solved a conflict between right turning cars and cycles by letting them through the intersection in two separate light phases. A major change is the design of the access via Nørre Søgade, which means that cyclists now risk waiting for green light twice, rather than crossing a right turn lane for cars.

COWI has assessed the effect on the number of accidents related to the rebuilding of the intersection based on data from "VIS" (The Road Sector's Information System) delivered by the City of Copenhagen. The rebuilding is estimated to have reduced the number of injured by 3 persons per year. As the evaluated post period is only 2 years the results are preliminary, as the post period should usually be at least 3 years.

The estimated change in accidents and traffic effects form the foundation for the economic cost-benefit analysis of the rebuilding of the intersection. The result is presented in the table below.

*Table 2.4 Results from the economic cost benefit analysis of the intersection in Gyldenløvesgade*

| million DKK | Net present value 2008 |
|---|---|
| Construction costs and maintenance incl. scrap-value | -9 |
| Time costs for cyclists | -2 |
| Welfare benefits for cyclists from accident reductions | 32 |
| Saved direct costs for the society from accident reductions | 33 |
| Tax distortion loss | 4 |
| **Net present value (NPV)** | **59** |
| **Internal rate of return (IRR)** | **33%** |

The cost-benefit analysis shows that rebuilding the intersection in Gyldenløvesgade has been a good investment in economic terms. The rebuild has entailed large benefits for the cyclists in the form of welfare benefits from the reduction in accidents and for the society in the form of saved costs and higher tax revenue. In total the benefits of the project are estimated to more than outweigh the costs. The central estimate is that the project has yielded a large economic return with a net present value of 59 million DKK and an internal rate of return at 33%.

The sensitivity analyses show that the result is robust to changes in central parameters and input data. None of the analyses yield a negative economic result, and the reduction in the number of accidents has to be lower than 18.5% of the central result before the project is expected to yield an economic loss.

In addition to the central estimate three "what if"-calculations have been carried out where the economic value of the change in perceived safety has been included in a very general manner. The calculations show that the value of the perceived safety may have a significant effect on the result. If the value of the perceived safety is 0.50 DKK per passage of the intersection, the result will improve by 22 million DKK. It should be noted, however, that these "what if"-calculations are based on assumed unit prices and hence can not be used as actual results.

## 2.4 System effects of cycle lanes

A determining factor for an individual's choice of mean of transportation is the perceived availability for each specific mean. Whether the cycle is perceived as an easily available means of transportation and a real alternative to car and public transport depends, among other things, on peoples' perception of Copenhagen as a cycle friendly city, where getting around on bicycle is easy.

In this regard it is possible to imagine that even projects that do not directly affect a person, may affect his/her preferred means of transportation, as the project may affect his/her perception of how easy it is to get around in Copenhagen on bicycle.

COWI has carried out calculations that show that if 1 kilometre of cycle lane causes 10 new trips per day with an average length of 5 km (i.e. a total of 50 new kilometres by cycle) somewhere else in Copenhagen, then 1 kilometre cycle lane entails an economic benefit of 423,000 DKK in net present value over a 20 year period.

It should be noted that this benefit is solely caused by persons, who are not directly affected by the new cycle lane, but still cycle more as they perceive Copenhagen as more easily available on cycle. Thus, the above mentioned benefit is solely related to system effects. If the benefits for the cyclists, who use the new cycle lane are included, the total benefits would most likely be significantly larger.

## 3 External costs for other modes of transportation

The benefits associated to reduced pollution and other externalities when transferring a road user to bicycle are included in the cost-benefit analysis based on unit prices from the official unit price catalogue of the Ministry of Transportation (Transportøkonomiske Enhedspriser) and information about the change in vehicle kilometres for each mode of transportation.

However, in order to illustrate these benefits the below table shows the saved external costs per road user-kilometre transferred to bicycles when load factors are taken into consideration.

*Table 3.1 Avoided external costs per kilometre transferred to cycle, DKK, 2008 prices*

| Transferred from: | Car off-peak | Car peak | Bus | Electrified trains | Diesel trains |
|---|---|---|---|---|---|
| Air pollution | 0.02 | 0.03 | 0.11 | 0.01 | 0.03 |
| Climate changes | 0.03 | 0.04 | 0.02 | 0.02 | 0.01 |
| Noise | 0.24 | 0.33 | 0.10 | 0.01 | 0.01 |
| Accidents | 0.15 | 0.20 | 0.03 | 0.02 | 0.02 |
| Road deterioration* | 0.01 | 0.01 | 0.04 | 0.07 | 0.12 |
| Congestion** | 0.30 | 1.38 | 0.05 | 0.00 | 0.00 |
| Total avoided externalities | 0.73 | 1.98 | 0.36 | 0.13 | 0.18 |

Notes: The illustrated unit prices are city values. The similar unit prices are lower for non-city. The following load factors have been applied: Car, peak: 1.11, Car, off-peak; 1.54, bus: 12, electrified trains: 80, diesel trains: 100.
*) It is assumed that a passenger train weighs 150 tonnes on average why 2.86 DKK per kilometre have been added in gross tonne kilometre dependent costs.
**) For busses the congestion cost for vans from the official unit price catalogue has been applied.

The benefits from avoided external costs when transferring one road user from car to bicycle are thus 0.73 DKK per kilometre in the off-peak hours. To this amount, the external benefit of 1.22 DKK per km from cycling should be added, ref. Table 2.2.

The benefits from avoided external costs for one transferred person from car to cycle are 1.98 DKK per kilometre in peak hours. The higher figure in peak hour is mainly due to a higher cost of congestion and a lower load factor compared to off peak.

## 4 Conclusions

The unit prices presented in this summary is the result of a first look into the economics of bicycling.

They illustrate that it is possible to use economic cost-benefit analyses to evaluate bicycle projects, in line with the tradition within the road and railway sector.

The results of the two case studies illustrate that bicycle projects are likely to yield a positive economic return which is (at least) comparable to road and rail projects carried out by the public sector.

Based on these conclusions it is recommended that more focus should be devoted to economic cost-benefit analyses of bicycle projects in the future.