COST-BENEFIT ANALYSIS OF CYCLING INFRASTRUCTURE: A CASE STUDY OF PILSEN

Hana FOLTÝNOVÁ[1] and Markéta BRAUN KOHLOVÁ[2]

Abstract. The paper analyses impacts of improved cycling infrastructure on demand for this means of transport. We use a stated preferences design for the elicitation of willingness to use the bicycle in the event of various improvements to the cycling environment in the city (in strict and tolerant level).
In the CBA applied to the planned cycling infrastructure network in Pilsen we include the following benefits: i) improvements in health by regular physical activity of new cyclists (quantification of impacts is based on costs of illness); ii) changes in number and severity of accidents (based on accident costs); iii) changes in atmospheric pollution (using the ExternE data).
When the demand change is calculated according to the strict level, the social benefits do not cover social costs of building the new cycling infrastructure.

1. Introduction

The share of cycling in the total modal split is relatively low in most medium-sized and large cities in the Czech Republic. It is about 0.5% in Prague and 0.3% in Pilsen compared to e.g. Munich (13% in 2002, see [12]) or Vienna (4,5% in 2001, [12]).
To make cycling more attractive, sums invested in cycling infrastructure gradually rise in the Czech Republic, even if they still only make up a tiny part of the public funds expenditures (about 0.2% of total expenditures from the State Transport Infrastructure Fund). Logically, the question of social benefits of these investments and their economic efficiency appears. Extensive literature exists dealing with CBA of transportation projects, but substantially less deals with that of cycling projects. As Elvik [5] summarizes, CBA of measures for pedestrians and cyclists should apply the same methodology that is used for transport projects in general. However, the specific impacts to be considered will not be the same as in projects that mainly benefit motorised travel.
The essential question to be answered before starting CBA is: what is the potential demand for a new cycle-way network in the Czech cities and what increase in the number of cyclists and share of kilometres and time ridden by bicycle can be expected in case cycling facilities are improved and expanded. We aim to answer the question on the case of the Czech city of Pilsen using individual data from a transport behaviour survey.

[1] Charles University Environment Centre in Prague, U Krize 8, 158 00 Prague 5, hana.foltynova@czp.cuni.cz
[2] Charles University Environment Centre in Prague, U Krize 8, 158 00 Prague 5, marketa.braun.kohlova@czp.cuni.cz

There are only a few studies focused on estimation of demand for cycling facilities from individual data, e.g [8] or [6]; in addition, they usually neglect the variability in purposes of individual journeys. Moreover, the studies of transport demand are often limited to a short segment of cycling infrastructure [6]. The focus of our study is the whole cycling network in a particular city, similarly [8].
The paper is structured in the following way: CBA methodology and literature review (Chapter 2); demand estimate for the city of Pilsen (Chapter 3); cost-benefit analysis for the planned infrastructure in Pilsen (Chapter 4); sensitivity analysis (Chapter 5). The final chapter concludes.

2. Demand estimate

Our approach to the demand estimate is based on the current transportation behaviour of the target population (18+). Using a questionnaire, we asked respondents about trips made during the previous working day (Tuesday, Wednesday, and Thursday). We focused on each trip on the given working day separately.
The data used come from a standardized questionnaire survey carried out in June and July 2005 in the Czech city of Pilsen (N=763). A quota sample (residential area, age, gender, education level) was used.
The daily journeys including purpose, distance, duration and the means of transport as described in the interviews were taken for reference values for the state of demand before the change.
The demand change itself is estimated from stated preferences of the following wording: “How significantly would the following changes in transport situation in Pilsen influence your willingness to use the BICYCLE more than currently?” Stated preferences are confronted with mutual fulfilment of current preconditions for bicycle use such as bicycle ownership/accessibility, at least experimental or recreational use of the bicycle, perception of bicycle use as an alternative (revealed preference) corresponding to the stages in the process of travel behaviour change as identified in [11].
The stated willingness to use the bicycle more often, measured on a 5-point scale, for a certain purpose is used for the potential demand estimate in two different levels. The tolerant level (Level 1) derives estimated demand from the positive stated willingness (two most positive answers on the 5-point scale) only. The strict level (Level 2) requires other preconditions as well.
Consequently, two different demand scenarios are estimated for each level and each purpose. The change in demand on a given working day is estimated as (1) a change in the number and/or share of travellers using the bicycle; (2) a change in the number and/or share of kilometres ridden by bicycle; and (3) a change in the amount of time spent on the bicycle and/or its share. The switch from car use to the bicycle is estimated separately.
For the estimate of potential demand, the residence, the purposes of the trips and their locations are fixed. We suppose that the time spent travelling by those who do not switch stays constant. The changes in lengths and durations of the trips are estimated using the CUBE model.

The CBA results are calculated for the following demand change (level 2 – strict) regarding cycling as a means of transport: 1) increase in the number of cyclists commuting from 6% to 8.3% and 2) increase in the number of kilometres ridden by bicycle from 8% to 9.9%.

3. Cost-benefit analysis

The demand estimates reflect demand for the same adult population (18+) on a working day in the same period of the year in which the infrastructure is improved. To calculate the change in demand for the entire year, we assume that people in Central European geographical conditions cycle only six months in a year (April to September). We assess benefits connected to two different scenarios of demand intensity: (1) the willingness to cycle on every convenient working day (neutral scenario); (2) the willingness to cycle on every second convenient day (conservative scenario). For the sake of the simplicity of the presentation, the benefits for the strict level (both the neutral and conservative scenarios) are displayed first. The results for the tolerant level are shown later in Chapter 4.

The costs side of the CBA includes infrastructure investments and maintenance costs. The table below shows the existing and planned networks of cycling infrastructure and estimated costs of their construction. The costs of infrastructure construction vary between 1,000 and 2,000 CZK per square metre [10]. Such a difference in costs per square metre is caused by a broad range of material being used, the terrain conditions, etc. For the further analysis we use the average value of 1,500 CZK. The results of the CBA for the lower (1,000 CZK) and the higher (2,000 CZK) values of the infrastructure construction costs are reported in the sensitivity analysis.

Table 1: Costs: existing and planned cycling infrastructure

	Cycle path	Cycle lane	Combined walking + cycling path	**Total**
Planned network for cycling (km)	34.2	39.2	52.2	125.5*
Remaining parts of the network (km)	26	19	34	78
Cost estimates for completing the network (mil. CZK / mil. Euro**)	51.8	18.6	50.4	120.8 / 4.2
Maintenance costs per year (mil. CZK / mil. Euro)				21.6 / 0.7
Total costs (mil. CZK / mil. Euro)	111.9	76.4	136.2	**345.9 / 11.9**

* calculated construction costs 1,500 CZK/m^2
** the exchange rate is 29 CZK/Euro

In the CBA applied to the planned cycling infrastructure network in Pilsen we include the following **benefits**:

i) improvements in health by regular physical activity of new cyclists (quantification of impacts is based on costs of illness);

ii) changes in number and severity of accidents (based on accident costs);
iii) changes in atmospheric pollution (using the ExternE methodology for impact quantification);
iv) benefits from reduced insecurity;
v) changes in travel times.

Improvements in health by regular physical activity of new cyclists. Because there are no reliable figures for the Czech Republic concerning impacts of regular physical activity on mortality, we assume a 9% decrease in mortality by cardiovascular diseases as [3] did. The value of a statistical life (VSL) for the Czech Republic used is 18.52 mil. CZK [1].

To calculate benefits of improved health from regular cycling (morbidity), we estimate the cost of illness using the prevalence approach (costs connected to an existing case during the assigned period). The benefits from improved health are calculated only for new cyclists regularly cycling to work. The reason is a higher probability of regular everyday trips by bicycle.

First, we focus on the coronary heart disease. We use the 50% reduction in the risk of coronary heart disease [13]. The costs are calculated separately for in-patient and out-patient treatment. The value of social costs includes treatment, drugs and technical treatment, and the loss of productivity.

According to [13], there is a strong evidence of a relationship between physical activity and colon cancer (an average risk reduction of 40-50%). The social costs are again estimated separately for in-patient and out-patient treatment.

Physical inactivity is a major risk factor for the development of type 2 diabetes and increases the risk of its development by 33-50% [3]. Because of unavailability of data specifying the loss of productivity, this item is not included.

Reduction in the number of accidents involving cyclists. According to [5], a review of evaluation studies of impacts of separated crossings indicates that the number of pedestrian accidents is reduced by about 80% and the number of accidents involving motor vehicles only is reduced by about 10%.

No comparable figures for accident reduction connected to infrastructure improvement are available for the Czech Republic. Even if there is no proven evidence for the risk of accidents related to cycling, we assume a 10% reduction in accidents involving cyclists and no change in accidents involving motor vehicles only. To calculate impacts of the injuries, we use the value of 200 thousand CZK per light injury (as suggested by [7]) and the accident statistics of 2005.

Reduced external costs of motorized road transport connected to air pollution. Atmospheric pollution (caused also by emissions from transport) has an inauspicious impact on human health (e.g. on respiratory diseases, cancer, and premature deaths). It is also a cause of material damages on buildings and plants. At the regional level, pollution causes acidification and globally it is a contribution to the greenhouse effect.

We apply the ExternE data (for more see [4]). The value of external costs of atmospheric pollution includes emissions of NOx, SO_2, carbohydrates, particular matters (PM10) and their impacts on human health and early death and CO_2. The structure of the vehicle fleet in Pilsen was derived from [2] summarizing data from a vehicle census done in Pilsen in 2001.

Costs of travel time. We assume that cycling on a cycle track could reduce travel times by comparison with cycling on an ordinary sidewalk only negligibly. We - similarly to [9] -

assume that travel times for the already cycling will stay unchanged. Because congestion is not a significant problem in Pilsen, we assume that even travel times for car drivers who do not substitute cycling for driving stay unchanged too.

It should be pointed out that travel times increase for those who make the shift from the car to the bicycle (by about 21 minutes for an average trip made by bicycle instead of by car). If an individual declares the willingness to change the mode of transport even if it would lead to a longer travel time, however, we can assume that the individual's benefit overweighs the private costs connected to this choice (for example as an increase in travel time). That is why this private negative benefit does not represent a social cost.

Benefits from reduced insecurity. These benefits are included in the 'ideally designed' CBA by [5] and also in the CBA done by [9]. Both the authors distinguished between the reduced insecurity of those who already cycle and those who do not. Nevertheless, we do not include these benefits in the CBA. Similarly to the costs of travel time, this benefit is already internalized in the personal benefits of each cyclist.

4. Results

The CBA results are calculated for the following demand change regarding cycling as a means of transport:

- increase in the number of cyclists commuting from 6% to 8.3%, and
- increase in the number of kilometres ridden by bicycle from 8% to 9.9%.

The following adjustments are made:

- the present values of benefits are calculated using a discount rate of 7%,
- and a 25-year lifetime of the project (as for example in [9]).

The costs and benefits of the partial CBA analysis for level 2 (strict willingness to change the current means of transport) are summarized in the following table.

Table 2: Costs and Benefits of cycling infrastructure in Pilsen (in thousands of CZK)

Benefit and cost components	Impacts per year	Neutral scenario	Conservative scenario
Benefits of cycling infrastructure (present value)			
Changes in health	20 persons	8,596.62	Assumed as
Accidents	4 accidents	9,533.10	14,299.65
Mortality	0.57 persons	122,201.78	61,100.89
Emissions	122, 000 km / day	22.93	9.94
TOTAL BENEFITS		140,354,43	75,410.47
Costs of cycling infrastructure (present value)			
Capital costs	78 km	181,200.00	181,200.00
Maintenance costs		8,053.33	8,053.33
Tax-cost factor (20%)	78 km	37,850.67	3,7850.67
TOTAL COSTS		227,104.00	227,104.00
Net benefit/costs ratio		-0.62	-0.33

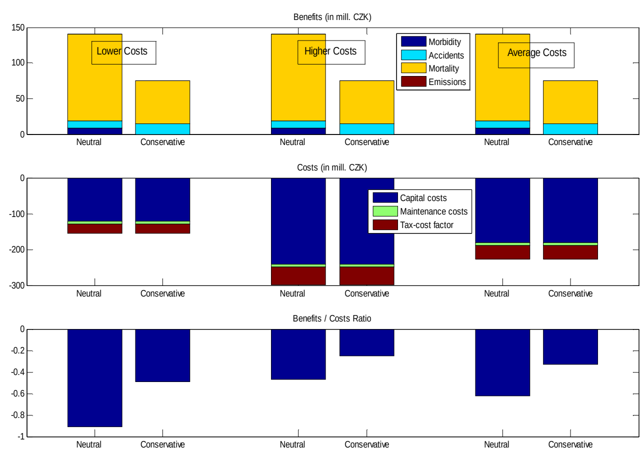
It can be said that when the demand change is calculated according to the strict level, the social benefits do not cover social costs of building the new cycling infrastructure. The net benefit/cost ratio is -0.62 for the neutral scenario (i.e., 168 cycling days a year), and -0.33 for the conservative scenario (i.e., 84 cycling days a year).

5. Sensitivity analysis

There are many factors which influence the results of the cost-benefit analysis substantially. The sensitivity analysis includes the effects of uncertainties present in the applied procedure: (1) the construction costs; (2) the estimate of change in cycling demand (strict vs. tolerant levels); (3) the change in the number of accidents; and (4) the discount rate and lifetime of the project.

Firstly, the costs of construction vary between 1,000 CZK and 2,000 CZK. Using the lower costs of construction (1,000 CZK per m^2), the net benefit/costs ratio is -0.91, while the higher costs of construction (2,000 CZK) only yield -0.47 for the neutral scenario.

Figure 8: Impacts of construction costs on the CBA (strict level of demand, neutral and conservative scenarios, lower, higher and average construction costs)



Secondly, the level of change in demand influences the results of the CBA substantially. When using the tolerant level of demand, the net benefit/costs ratio is 3.08 for the neutral scenario of demand and the lower costs of construction, and 1.59 for this demand and the higher construction costs (2,000 CZK per m^2). Using the tolerant level of demand, the present value of benefits always overweighs the costs with the exception of the conservative scenario for the higher costs.

Thirdly, the impact of the improved cycling infrastructure on the safety of cyclists (the number and severity of accidents) also influences the results of the CBA. When the number of accidents decreases by 25%, the costs equal benefits for the low construction costs level

and strict level of demand. Nevertheless, the benefits never exceed the costs when assuming the average rate of construction costs (1,500 CZK) for the strict level of demand.
Fourthly, other important factors influencing the results of the CBA are the discount rate. The change in distribution of benefits during the lifetime of the project can make the project socially profitable. For example when using a discount rate of 5%, the net benefit/costs ratio reaches 1.1 for the lower construction costs estimate for the strict demand level. When assuming a very low discount rate (nearly zero), the project is profitable even for the higher construction costs estimate.

6. Conclusions

This paper presents the first systematic attempt to calculate the costs and benefits connected to the construction and improvement of cycling infrastructure in the Czech Republic. For this purpose, we analyzed the cycling network construction in Pilsen.
The estimated change in demand is relatively small: an increase in persons cycling from 11.6% to 14.2% (strict level) and to 20.9% (tolerant level) for all the regular trips, and from 6.0% to 8.3% and to 14.3%, respectively, for commuting.
The following benefits were included: improvements in health by regular physical activity of the new cyclists; changes in the number and severity of accidents; and changes in atmospheric pollution. The impacts on health (mortality and morbidity) hold the major share.
When the demand change is calculated according to the strict level, the social benefits do not cover social costs of building new cycling infrastructure. The net benefit/cost ratio is -0.97 for the neutral scenario and -0.52 for the conservative scenario. It should be mentioned that other possible benefits such as noise reduction and further health impacts are not included.
Still, the results are very sensitive to a range of factors, which can influence the results of the CBA substantially. Above all, the demand estimate plays an important role. Even if the net benefit/costs ratio is -0.91 for the strict level, it is already 3.08 for the tolerant level. These results differ when the higher and average costs of construction are used. Using the higher construction costs (2,000 CZK per m^2), the costs do not overweigh the benefits even when the tolerant level of demand is applied. The discount rate is another important factor. When the future benefits are given high priority (using a discount rate close to zero), the project is profitable even for the strict level of demand and higher construction costs.

References

[1] A. Alberini, M. Ščasný, M. Braun Kohlová, J. Melichar. The Value of a Statistical Life in the Czech Republic: Evidence from a Contingent Valuation Study. In: B. Menne, K. L. Ebi, editors, *Climate Change and Adaptation Strategies for Human Health*, Steinkopff Verlang Darmstadt, 2006.

[2] ATEM. Zjištění aktuální dynamické skladby vozového parku a jeho emisních parametrů. Technical report, ATEM, Prague, 2001.

[3] N. Cavill, A. Davis. Cycling and Health: A Briefing Paper for the Regional Cycling Development Team. Final draft, London, 2003.

[4] CUEC. Externí náklady výroby elektřiny a tepla v podmínkách ČR a metody jejich internalizace. Final report, Charles University Environment Centre in Prague, prosinec 2005.

[5] R. Elvik. Which are the relevant costs and benefits of road safety measures designed for pedestrans and cyclists? *Accident Analysis and Prevention*. No. 32 (2000). 37-45.

[6] P. Hopkinson, M. Wardman. Evaluating the demand for new cycle facilities. *Transport Policy*, Vol. 3, No. 4, pp. 241-249, 1996.

[7] Ministry of Transport. Cyklostrategie. Ministry of Transport, Prague, 2004

[8] J. D. Ortuzar, A. Iacobelli, C. Valeze. Estimating demand for a cycle-way network. *Transportation Research Part A*, 34(2004), 353-373.

[9] K. Saelensminde. Cost-benefit analyses of walking and cycling track networks taking into account insecurity. health effects and external costs of motorized traffic. *Transportation Research Part A*, 38 (2004), 593-606.

[10] SVS. Vývoj nehodovosti v Plzni. Zpráva pro Centrum pro otázky životního prostředí UK v Praze, Plzeň, květen 2006.

[11] TAPESTRY. Common Assessment Framework (Deliverable 3). In: *Childen's Attitudes to Sustainable Transport*, Scottish Executive Social Research, 2003.

[12] Transport for London. A Business Case and Evaluation of the Impacts of Cycling in London. Cycling Centre of Excellence. Surface Transport, Transport for London, January 2004.

[13] WHO. A physically active life through everyday transport with a special focus on children and older people and examples and approaches from Europe. World Health Organization, Regional Office for Europe, Copenhagen 2002.

Acknowledgements. The research has been supported by the grant of the Ministry of Transport No. 1F43E/045/210 „CYCLE 21 – Analysis of Demand for building of cycling infrastructure" and Operation Program Infrastructure. The support is gratefully acknowledged.