Economic analyses of transport infrastructure and policies including health effects related to cycling and walking: a systematic review

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ABSTRACT

We reviewed published and unpublished studies that presented the findings of an economic valuation of an aspect of transport infrastructure or policy, and included data on walking and/or cycling and health effects in the valuation. We included sixteen papers, of which three were classified as 'high; six as 'moderate' and seven as 'low' quality. There is a wide variation in the approaches taken to including the health effects of physical activity in economic analyses of transport projects. This is not helped by a lack of transparency of methods in many studies. A more standardised approach is called for, including a clearer description of the applied methods and assumptions taken.

INTRODUCTION

Physical activity is a fundamental means of improving physical and mental health. For too many people, however, it has been removed from everyday life, with dramatic effects for health and well-being. (Cavill, Kahlmeier & Racioppi, 2006). Walking and cycling represent practical opportunities for people to integrate physical activity into everyday life, and are tangible and achievable alternatives to sport and exercise for which important positive health effects have been demonstrated (Andersen et al, 2000; Matthews et al, 2007, WHO, 2002). The promotion of cycling and walking has become an area of emerging interest and high relevance to the development of comprehensive health and environment policies, in particular those related to the implementation of sustainable transport policies. In recent years, support for policies promoting modal shifts towards cycling and walking has been advocated within a number of strategies for health and sustainable development (WHO Europe, 2005; WHO-UNECE, 2008; European Commission, 1999).

In 2006, WHO Regional Office for Europe undertook a project on economic valuation of health effects from cycling and walking. This project built on previous initiatives including a workshop of the Nordic Council on "Cost-benefit Analysis of cycling" held in February 2005 in Stockholm[1]; discussions that were held in Switzerland in September 2005 on open questions related to economic valuation of transport-related physical activity; and extensive work by WHO and partners on cost-effectiveness, including the CHOICE project (Choosing Interventions that are Cost-Effective)[2] and guidance on cost-effectiveness of environmental health interventions (WHO, 2000). This report pointed out that "there is a serious lack of cost-effectiveness studies for all types of environmental health interventions, and therefore decision makers have limited information on the relative cost-effectiveness of health interventions from which to make evidence-based decisions" (WHO, 2000 p.vi). This also applies to methods for including health impacts in economic assessments of transport projects. Economic assessments are a common part of the professional life of a wide range of professionals including transport planners and environmental managers, who see economic valuation (primarily cost-benefit analysis) as an essential pre-requisite to funding any new scheme, programme or policy. A new road will only be built if its projected benefits outweigh its costs. While the costs are relatively straightforward (tarmac, construction, maintenance etc) the benefits are very variable. Many different aspects such as environmental impacts, land use, congestion and time use are already well covered in most cost benefit analysis studies of transport interventions. Yet too often these do not take account of the wide variety of benefits to health of new schemes, projects or policies.

[1] http://www.norden.org/pub/sk/showpub.asp?pubnr=2005:556

[2] http://www.who.int/choice/description/en/

In recent years, a few countries (e.g. the Nordic Council) have carried out pioneering work in trying to assess the overall costs and benefits of transport infrastructures taking health effects into account, and guidance for carrying out these assessments has been developed. However, important questions remain to be addressed regarding the type and extent of health benefits which can be attained through investments in policies and initiatives which promote more cycling and walking.

For example, people have differing views on the value of time, or the importance of issues such as journey ambience. In recent years this approach has begun to be applied to projects concerning cycling and walking, and this opens up many more new issues concerning what should be included in any analysis. If a new bike path is built, what should be counted? All cyclists? New cyclists? New cyclists cycling over a recommended minimum amount? And what health effects should be considered as a result of their cycling? Change in risk of chronic disease such as coronary heart disease or stroke? Improvements to mental health? Or even less tangible outcomes such as quality of life?

This issue is even more important when the results of early cost-benefit analyses of cycling and walking projects are considered. Consideration of the health impacts have, in many cases, resulted in relatively high benefit-cost ratios compared to traditional transport economic appraisals. (Nordic Council, 2005). If these cannot be justified with transparent methods, they may arouse suspicion among supporters of motorised transport. This underlines the importance of developing a strong, agreed, evidence-based methodology to help the decision-making process (Grant-Muller et al, 2001).

The overall aim of this project was therefore to review recent approaches to cost-benefit analysis of transport-related physical activity. Based on the approaches developed to date, options for the further development of a more harmonized methodology were to be proposed as guidance for Member States on approaches to the inclusion of health effects through transport-related physical activity in economic analyses of transport infrastructure and policies. This paper reports on the first part of the project.

METHODS

Study inclusion criteria
To be included in this review, the study had to:

1. present the findings of an economic valuation of an aspect of transport infrastructure or policy;
2. include data on walking and/or cycling in the valuation (including changes in modal share; distance walked; etc);
3. include health effects related to physical activity in the economic valuation;
4. be in the public domain. This included government and other reports that were publicly available; reports on websites; as well as papers from peer reviewed journals.

All age groups were considered. Papers from languages other than English were translated and reviewed where necessary.

Search strategy
A comprehensive literature search was carried out to locate all relevant studies. This was conducted in collaboration with the National Institute for Health and Clinical Excellence (NICE) in the United Kingdom. Economic, health, medical, transport, environmental internet and 'grey' literature databases were searched using search terms tailored for each database. These were drawn primarily from the main components of the study including economic appraisal; walking/cycling; health outcomes. A full description of the search strategy is available at Annex D. Papers were also sought from experts in the field, including the project advisory group.

The literature search resulted in 4,264 titles which were screened for inclusion. Following the application of the inclusion criteria, 57 papers were deemed to be relevant, and were retrieved and read in full. 16 papers were included in the final review and subjected to full data extraction and quality appraisal. Included studies are listed in Annex B. Excluded studies with reasons for exclusion are shown in Annex C. The main reason for exclusion was that the study was not an economic evaluation, or did not include data on walking or cycling in the valuation.

Data extraction
The studies were reviewed and core data extracted from each study. These data are presented in Annex A. Data extraction covered all the main aspects of each study, with a focus on the inclusion of health effects related to physical activity. Results were standardised as far as possible, and values converted into Euros. Data from one Danish study were extracted by a native speaker.

Included studies were rated by two reviewers (NC & SK) to determine the strength of the evidence. Firstly each study was categorised by study type (see below) and each was assessed for methodological rigour and quality against the checklist used by NICE in its appraisal system (NICE 2006). Each study was assigned a code '++', '+' or '-', based on the extent to which the potential sources of bias had been minimised (see Table 1 below). Appraisals were also compared with those conducted on a similar set of studies by the York Health Economics Consortium for NICE in 2006 (Beale et al, 2007).

A brief overview of the main findings is given in the results section. As the main focus of this project is to analyse the approaches taken to the inclusion of health effects related to physical activity, this is the main focus of the analysis.

Table 1: Appraisal system used to determine level and quality of evidence (NICE 2006)

Type and quality of evidence	
1++	High quality meta-analyses, systematic reviews of randomized controlled trials (RCTs), or RCTs (including cluster RCTs) with a very low risk of bias.
1+	Well conducted meta-analyses, systematic reviews of RCTs, or RCTs (including cluster RCTs) with a low risk of bias.
1–	Meta-analyses, systematic reviews of RCTs, or RCTs (including cluster RCTs) with a high risk of bias.
2++	High quality systematic reviews of these types of studies, or individual, non- RCTs, case-control studies, cost benefit analysis (CBA) studies and correlation studies with a low risk of confounding, bias or chance and a high probability that the relationship is causal.
2+	Well conducted non-RCT, case control studies, cohort studies, cost benefit analysis (CBA) studies and correlation studies with a low risk of confounding, bias or change and a moderate probability that the relationship is causal.
2-	Non-RCTs, case control studies, cohort studies, CBA studies, ITS and correlation studies with a high risk – or chance – of confounding bias, and a significant risk that the relationship is not causal.
3	Non- analytic studies (for example, case reports, case series).
4	Expert opinion, formal consensus.
Grading the evidence	
++	All or most of the quality criteria have been fulfilled. Where they have been fulfilled the conclusions of the study or the review are thought to be very unlikely to alter.
+	Some of the criteria have been fulfilled. Where they have been fulfilled the conclusions of the study or the review are thought unlikely to alter.
-	Few or no criteria fulfilled. The conclusions of the study are thought to be likely or very likely to alter.

RESULTS

Table 2 shows the quality assessment for each study. Three studies were classified as (2++) quality, i.e. as being of 'high' quality: Macdonald (2006); Rutter (2006); and Sælensminde (2004). These studies were very transparent in their methods, explained their calculations and assumptions, and included a wide variety of appropriate costs and benefits. The authors reported sensitivity analyses and included a thorough and clear discussion of the results.

There were six studies classified as (2+) quality, i.e. being of 'moderate' quality: Department for Transport (DfT), (2007); Foltýnová et al, (no date); Jones & Eaton (1994); Sustrans (2006); Transport for London (TfL) (2004); Wang (2005).

These studies all included the appropriate costs but either made assumptions about the relationship between cycling/walking and physical activity, or did not give details of the methodology used for calculating the included benefits.

There were seven studies classified as (2-) i.e. 'low' quality: Buis (2000); Ege et al, (2005); Krag (2007); Lind (2007); Saari (2007); Thaler (2006); Troelson (no date). These studies tended to involve many assumptions in calculating the benefits, or used figures with little or no justification, which might affect the validity of the findings.

Table 2: Quality of reviewed studies

By study quality	
2++	Macdonald (2006) Rutter (2006) Sælensminde (2004)
2+	DfT (2007) Foltýnová et al (no date) Jones & Eaton (1994) Sustrans (2006) TfL (2004), Wang (2005)
2-	Buis (2000) Ege et al, 2005 Krag (2007) Lind (2007) Saari (2007) Thaler (2006) Troelson (no date)
By study design	
Cost benefit analysis	Dept for Transport (2007) Ege et al, 2005 Foltýnová et al (no date) Jones & Eaton (1994) Krag (2007) Lind (2007) Rutter (2006) Saari (2007) Saelensminde (2004) Sustrans (2006) Thaler (2006) Transport for London (2004) Wang (2005)

Table 2: continued

By study design: continued	
Cost effectiveness analysis	Troelson (no date)
Case study	Buis (2000)
Review	Macdonald (2006)
By country of origin	
Austria	Thaler (2006)
Czech Republic	Foltýnová et al (no date)
Denmark	Ege et al, 2005 Krag (2007) Troelson (no date)
England	DfT (2007) Sustrans (2006) Transport for London (2004) Rutter (2006) Macdonald (2006)
Finland	Saari (2007)
Netherlands	Buis (2000)
Norway	Saelensminde (2004)
Sweden	Lind (2007)
USA	Jones & Eaton (1994) Wang (2005)
By coverage of walking and cycling	
Walking and cycling	DfT (2007) Sustrans (2006) Wang (2005) Saelensminde (2004) Saari (2007)
Walking only	Jones & Eaton (1994)
Cycling only	Ege et al, 2005 TfL (2004) Rutter (2006) Macdonald (2006) Buis (2000) Thaler (2006) Krag (2007) Lind (2007) Troelson (no date) Foltýnová et al (no date)

Description of studies

Table 2 also shows other key characteristics of the studies. The majority of studies were cost-benefit analyses. Studies came from nine countries. Five studies covered both walking and cycling, and ten cycling only. One study focused only on walking.

Overview of results

The studies considered a wide variety of health outcomes (Table 3) with reduction in risk of coronary heart disease the most common positive outcome, and risk of injuries the most common negative outcome. Some of the studies did not specify the health endpoints included but used summary measures such as reduced health costs associated with physical activity.

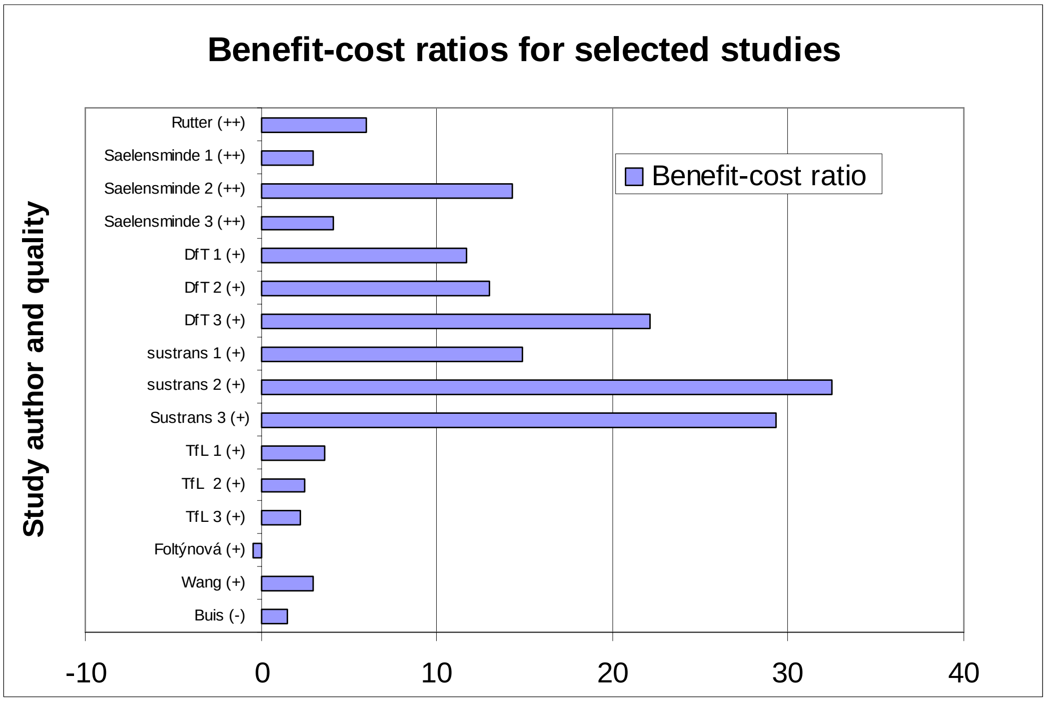
Table 3: Overview of health outcomes considered in the included studies

	Health outcome considered (where stated)					
Study reference	**Coronary heart disease**	**Stroke**	**Cancer**	**Diabetes type II**	**Injuries**	**Other**
Buis (2000)					Injuries	Absenteeism; reduced medical costs
DfT (2007)	Mortality	Mortality	Mortality		'possible decrease in accidents'	
Ege et al, 2005						Reduced use of health service
Foltýnová et al (no date)	Mortality Morbidity		Colon cancer morbidity	Morbidity	Cost of accidents	Reduced medical costs. Air pollution
Jones & Eaton (1994)	Mortality				Risk of injury	
Krag (2007)	'Heart attacks'	Mortality	Colo-rectal and breast cancer mortality	Mortality	Accidents	Oseoporosis high blood pressure; depression; back-pain;
Lind (2007)					Injuries	Obesity 'excess morbidity'
Macdonald (2006)	Mortality	Mortality	Colon cancer mortality		Discussed but not included in calculations	
Rutter (2006)	All-cause mortality				Increased risk of death (adjusted for safety in numbers hypothesis)	
Saari (2007)					Accidents	
Saelensminde (2004)	Mortality		Mortality	Mortality		Hypertension Musco-skeletal
Sustrans (2006)	Mortality	Mortality	Mortality			
Transport for London (2004)	Mortality	Mortality	Colon cancer mortality			
Thaler (2006)						
Troelson (no date)	All-cause mortality					Reduced medical costs
Wang (2005)						Reduced medical costs

The studies reviewed were very heterogeneous and presented a wide variety of results using different outcome measures, making it difficult to summarise the findings. However, there were two measures that were frequently reported: benefit-cost ratios and the value attributed to each new cyclist or walker on a trail or as a result of a policy.

Figure 1 shows the benefit-cost ratios (BCRs) from selected studies. The studies are presented in order of quality, with the highest quality at the top. The median BCR is 5:1 with a range from -0.4 to 32.5. It should be treated with caution however as the values are based on many different assumptions.

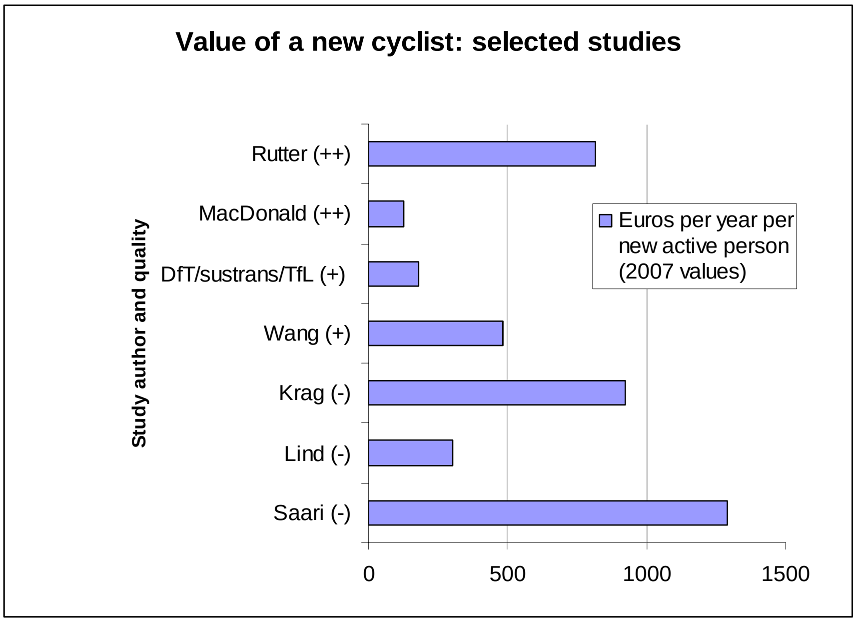
Figure 1[3] Benefit cost ratios for selected studies



[3] Studies by Saelensminde; DfT; Sustrans and TfL included more than one example with different inputs and outcomes to the CBA. They are therefore included as separate studies and labelled 1, 2, 3 etc.

Six studies presented results in terms of the value attributed to each new walker or cyclist. This is a helpful measure as it can be applied in combination with projections on future use of new infrastructure to calculate a total value.

Figure 2. Value of a new cyclist from selected studies



Values have been adjusted and converted from local currencies to 2007 Euro values. This was performed by a two step process[4]:

- Firstly costs and benefits were converted to Euros using a historical conversion rate[5].
- The costs and benefits were then inflated[6] to March 2007 Euros.

Figure 2 shows the variation in values attributed to one new walker/cyclist. These ranged from €127 to €1290. Much of this variation is accounted for by different assumptions – for example Lind and Saari based their valuations on the same overall estimates but use different assumptions when reporting the data.

Methodological approaches taken to including health effects related to physical activity

The findings are presented in a number of categories, according to the methodological approach taken. This enables broad conclusions to be drawn about the applicability of each method. Within each category, the studies with the highest quality rating are described first.

1. Studies considering relative risk[7] of all-cause mortality

Rutter (2005) conducted a cost-benefit analysis (2++ quality) to estimate the economic and other benefits that would accrue from achieving cycling targets set for levels of cycling in London. He used data from the Copenhagen Center for Prospective Population studies (Andersen 2000) to estimate the reduction in mortality arising from persons who take up cycling for commuting. The Copenhagen study found a relative risk (RR) for all-cause mortality of 0.72 among regular commuter cyclists. This equates to a 40% lower chance of dying from any cause in a given year compared to non-cyclists. Rutter's CBA was based on modelling of hypothetical change, in which he assumed that 50% of the increased number of commuter cyclists were not previously cycling. Although the assumption was not directly justified by the author, this does seem reasonable, if not conservative. The strength of this approach lies in its use of all-cause mortality, and the use of relative risks that are directly applicable to (regular) commuter cycling, and are not extrapolated from studies of general physical activity. The main weaknesses are

[4] Method as used by York Health Economics Consortium for NICE, 2007.

[5] Exchange conversion: http://www.oanda.com/convert/fxhistory

[6] Inflation Indices: http://www.statistics.gov.uk/statbase/tsdataset.asp?vlnk=229& More

[7] In epidemiology, relative risk (RR) is the risk of developing a disease relative to exposure. It provides a measure of the ratio of the probability of the disease developing in an exposed versus a non-exposed group.

that there are no benefits related to morbidity considered, and no consideration of walking is made.

2. Analyses based on modelling of the impact of a change in physical activity on risk of specific diseases

Five reports presented analyses primarily based on calculations originally published by the UK National Heart Forum (NHF) (McPherson et al, 2002), and The Northern Ireland Physical Activity Strategy Implementation Group (Swales, 2000). Transport for London (TfL) published a business case for cycling using figures from these two reports (Transport for London, 2004). This approach was in turn adopted by the UK Department of Transport (DfT) in their draft Transport Analysis Guidance (DfT 2007) and by Sustrans in an economic appraisal of cycling and walking routes (Sustrans, 2006).

TfL (2004) conducted an assessment of the business case for cycling (2+ quality). They applied the population attributable risk data[8] from Swales (2000) to the mortality data for London to calculate the proportion of deaths avoidable if sedentary people became moderately active, and in turn used this to calculate the number of preventable deaths through cycling, applying three levels of additional cycling. However their assumption that 9% of the deaths attributable to physical inactivity (33% of all deaths) would be avoided if sedentary people became physically active remains unclear as based on McPherson et al (2002) it should be 9% of the total number of deaths. Applying this figure, the impact of cycling is significantly underestimated. The other weaknesses of this approach include the application of data on CHD to colon cancer and stroke with no adjustment; and an assumption that increases in cycling equate to increases in total physical activity.

DfT (2007) used the TfL methodology as a component of a comprehensive economic analysis of cycling (2+ quality), again applying the combined PAR of 33% for CHD, stroke and colon cancer discussed above. As TfL, they assumed that 9% of these deaths were preventable by moderate physical exercise and used this figure to calculate the number of preventable deaths per person taking up physical exercise. They then used this figure to calculate the annual benefit of an individual taking moderate physical exercise (see Table 9). This again led to a significant and incorrect under-estimation of the value of cycling.

Sustrans (2006) applies the TfL/DfT model to three walking and cycling routes. They used the TfL/DfT finding that the annual benefit of an individual taking moderate physical exercise is 0.0001 times the statistical value of a life to calculate the value of an additional walker/cyclist as £122.93 (€176). Again this was based on the incorrect assumptions made by TfL.

[8] Population attributable risk describes the burden of a risk factor in the population. For example the percentage of all deaths in England that can be attributed to smoking.

Foltýnová & Braun Kohlová (no date) conducted a cost-benefit analysis (2+ quality) to analyse the impacts of improved cycle infrastructure on demand for cycling in a town in the Czech republic. This was one of the small number of studies to include both mortality and morbidity in its calculations. Mortality savings were calculated based on the assumption of a 9% reduction in CVD mortality if all people previously active at sedentary and light levels became moderately active from the NHF study (McPherson et al, 2002),. Morbidity savings were calculated assuming a 50% reduction in risk of CHD and 40-50% reduction in risk of colon cancer and using these to calculate the cost of illness. This was the only study among those reviewed which found a negative benefit-cost ratio. This is likely to be due to the low predicted demand for the cycle infrastructure, or to conservative assumptions. The main strength of this approach is that it used reasonable assumptions for changes in level of physical activity, and included morbidity. The main weaknesses of this approach were that it assumed that more cycling will lead to a shift upwards in overall level of activity for all groups; it was unclear how many of the calculations were conducted; and it assumed benefits only apply to those cycling to work.

Macdonald (2006) applied a different approach, costing the benefits of cycling by re-working the data from the NHF report (McPherson et al, 2002). This was also the approach taken by Foltýnová et al (no date) who used the NHF's calculations in a cost-benefit analysis of cycling in the Czech Republic.

MacDonald (2006) conducted a review (2++ quality) to examine the economic benefits of cycling for Cycling England. He reviewed a number of the approaches in this review, including those by Rutter (2005), Sustrans (2006), Sælensminde (2004), but also conducted new analysis based on the reports from Swales (2000) and the NHF (McPherson et al, 2002). This analysis was more sophisticated for a number of reasons:

- it was based on more conservative estimates: instead of assuming that all sedentary people became active, it assumed that all people went up one level of activity as a result of their cycling: sedentary people becoming irregularly active, irregularly active people becoming active and so on
- it conducted analysis using different population attributable risks (PARs) for different age groups
- it modelled the changes in PAR from changes in levels of cycling rather than applying a blanket assumption of reduction in risk across the population

The main weaknesses of this approach were that no was account taken of morbidity; it assumed that more cycling will lead to a shift upwards in overall level of activity for all groups; and no consideration was made for walking.

3. Studies using a population attributable risk of inactivity for specific diseases

Sælensminde (2004) conducted a cost benefit analysis of walking and cycling track networks in three Norwegian Cities, taking a large number of factors into account. This was one of the most comprehensive CBAs found in the literature. Jones and Eaton (1994) conducted a cost-benefit analysis of walking to prevent coronary heart disease. They conducted modelling, using decision-analysis simulation, among hypothetical cohorts.

Sælensminde's assessment (2004) (2++ quality) included two categories of health benefits through cycling and walking:

- "Less severe diseases and ailments and less short-term absence". This used the assumption that short-term absence from work is reduced by 1 percentage point and used average wage costs to estimate the economic saving. Twenty five percent of all journeys are assumed to be trips to or from work. Rather than assuming that all new pedestrians and cyclists would improve their health through additional walking and cycling, they assumed that this applied to only 50% of the new pedestrians and cyclists, 'in order not to overestimate this benefit' (Sælensminde et al p. 598).
- "Severe diseases and ailments and long-term absence/disability". This included risk reductions related to cancer (five different types), high blood pressure, type-2 diabetes and musculoskeletal ailments. The authors also estimated costs due to welfare loss for people suffering from these diseases or ailments, estimated to be 60% of the total costs. It was assumed that 50% of new pedestrians and cyclists will enjoy better health due to the additional walking and cycling. The actual relative risks used to calculate the improvements in health are not stated in the paper.

The strengths of this approach are that it was a more complete analysis than most others since including sickness absence as well as chronic diseases; it was based on relative risks of four health conditions; and produced a conservative analysis since including assumption that health benefits only apply to 50% of new cyclists and walkers. However, the study suffered slightly from some unclear sources of data

Jones and Eaton (1994) used a modelling approach to explore the relationship between costs and benefits of hypothetical approaches to increasing walking to prevent CHD (2+ quality). They used published RRs from meta-analyses and applied these to a hypothetical cohort of sedentary men and women, assuming changes in levels of walking. They then conducted a sensitivity analysis to see how the cost-benefit relationship would vary according to the RR used. The strengths of this approach are that it used realistic assumptions based on published relative risks; and used a variety of estimates to conduct sensitivity analysis. The weaknesses are that it used a hypothetical cohort, so projected changes may not be achievable in reality, and it studied only walking and impact on coronary heart disease.

4. Studies using data on reduced medical costs for active people

Studies carried out in this category included Wang et al (2005), who conducted a CBA based on data from a development of bike/pedestrian trails. Buis et al (2000) conducted a CBA on behalf of the Interface for Cycling Expertise in the Netherlands. This described four case studies, of which only the one on Amsterdam presented health data. Troelsen et al (no date) conducted an evaluation of the Odense national cycle city project, which included a calculation on the savings in medical costs among those who took up cycling. Ege et al (2005) conducted a cost-benefit analysis to examine the benefit of an investment in promotion of use of cycling, based on savings in health service costs.

Wang et al (2005) (2+ quality) conducted a count of all users of bike and pedestrian trails in Lincoln, Nebraska. "The direct health benefit was measured using the estimated difference in the direct medical cost for active persons and their inactive counterparts" (p. 175). In other words, all trail users were assumed to be active at a level sufficient to be classified as active (at least 30 min in moderate or strenuous physical activity three or more times per week) and were therefore liable to lower medical costs of $564 (€ 390) compared to inactive people. This was a simple approach, based on real counts, and linked to real medical costs not values of a statistical life. However, the study was based on an assumption that one count on a trail equates to being active three or more times per week, and there was no account taken of the value of reduced mortality.

Buis et al (2000) conducted a CBA to illustrate the costs and benefits of cycling policies in a number of case studies (2- quality). They included savings on absenteeism and medical treatment, stating a 9% increase in the amount of km cycled in Amsterdam resulted in savings of 7 million Guilders per year (approx €3m). However the authors provided no detail of the basis for these calculations. The study was linked to real medical cost data, not values of a statistical life, but it was not transparent in many aspects of its calculations.

Troelsen et al (no date) conducted a comprehensive evaluation of the Odense national cycle city project (2- quality). The full report contained only a short summary in English which made a full appraisal of the methods used to calculate the health benefits arising from increased cycling in the city difficult. From this summary it appears that they used the data from estimated increases in levels of cycling to calculate savings in health expenditure, and gains in life years.

The study's strengths were that it was based on estimated increases in cycling; it used an assessment that included health expenditure; applied a 'life years' approach rather than a cost per death; and included a control area. However, some aspects of the methodology (in the English summary) were unclear especially as it appeared from the main report that the actual level of cycling went down (even though it did not decline as much as the control area) making the claimed health gains difficult to justify

Ege et al (2005) used a simple cost/km assumption to calculate the savings in medical costs among cyclists, based on other countries' studies (primarily Nordic Council 2005). This was a very user-friendly approach, and appropriate for users from the non-health sector as it would facilitate integration into transport assessment methods. However, it suffers from a lack of transparency, leading to uncertainty over the estimates used.

5. Approaches using general estimates

In 2005 the Nordic Council of Ministers convened a meeting on CBA of cycling, and considered a number of approaches (Nordic Council 2005). As this brought together some very similar approaches, using simplified values per hour of cycling; per km cycled; or per new person active, this seems to warrant consideration as a separate category. Two of the studies considered by the Nordic Council are considered elsewhere in this review: Sælensminde (2004); and Rutter (2005).

Lind (2005) conducted a CBA of investment in cycling infrastructure in Sweden. Saari et al (2007) described approaches to CBA and conducted a 'model' CBA using unit values for persons who become active. Krag (2007) conducted a cost-benefit analysis using values for health benefits per hour. Separately, Thaler et al (2006) used estimates from the Nordic Council report to conduct a basic cost benefit analysis for the Austrian Cycling Strategy.

Lind (2005) (2- quality) used estimates based on 'new international published literature', which was, however, not referenced. For example the decreased cost for an activated inactive person aged 50-60 years was estimated at €1,300 per year. This was adjusted for age, so if no efforts were made to reach older and inactive persons, €280 per generated cyclist should be used. Where a focused effort is made to target older inactive people, a maximum value of €900 per generated cyclist should be used.

Saari et al (2005) (2- quality) used a unit value of €1200 euros/person/year to calculate the health benefits of cycling or walking investment projects. This was "proposed by the Ministry of Transport and Communications" based on the work of Saelensminde (2004).

Krag (2005) conducted analysis (2- quality) based on (unreferenced) "typical" values from other studies, such as €3.09/hour in Switzerland; €5.37/hour (Norway) € 4.04/h (UK). Krag used the value of 4.7 €/hour.

The summary of the Nordic Council report (2005) suggested that for the public health benefits, the value of €900/year per activated person should be used, or € 0.15/ km cycled. Thaler et al (2006) used this figure in their CBA for the Austrian Cycling Strategy (2- quality).

All these approaches are seen to be very user-friendly, and appropriate for users from the non-health sector as can be integrated into transport assessment methods. However they suffer from a severe lack of transparency, leading to uncertainty over the estimates used.

DISCUSSION

This review has focused on the methodologies used to including the health impacts of physical activity in economic analyses of walking and cycling. First we will briefly consider the results of the studies however, before going on to comment on the methods.

This review has shown that cost-benefit analyses of cycling and walking infrastructure generally produce positive benefit-cost ratios (BCRs). Although these should be treated with caution due to the diverse methods used, it can be concluded that eight authors produced sixteen benefit-cost BCRs for various cycling/walking projects, and only one was negative (Figure 1). The BCRs were also of an impressive magnitude: the median BCR was 5:1, which is far higher than BCRs that are routinely used in transport infrastructure planning. In the United Kingdom for example, a BCRs of over 2 is counted as 'high value for money' and if this is demonstrated, 'most if not all' projects should generally be funded. Even some projects with BCRs as low as 1.5:1 are sometimes funded (Department for Transport, 2007). It appears that health benefits make a significant contribution to the high BCRs for cycling and walking projects. It can also be noted that neither the size of the BCR (Figure 1) nor the average value per cyclist (Figure 2) did seem to be systematically related to the quality of the study, i.e. it was not the case that lower quality studies produced higher values or vice versa. This makes it even more important that the methods for conducted economic analyses of cycling and walking projects should be sound and transparent: it is only when they are evaluated using the same methods as used on other transport projects that their high value becomes apparent.

Methods

This review has shown that there is wide variation in the approaches taken to including the health effects of physical activity in economic analyses of transport projects. This is not helped by a lack of transparency of methods in many studies, with many of the assumptions taken not being well explained. The studies use varying sources of data as the basis for calculations, and there appeared to be no consensus on the diseases to be included in mortality calculations, and few studies include any measure of morbidity. An additional issue of concern is the assumptions made about transferability of data (from one country or setting to another).

One of the most significant challenges is the relationship between observed cycling or walking and total physical activity. Ideally, models should refer to continuous data on energy expenditure regardless of how it was accrued. As such data are rarely available, the studies generally used relative risk data that related to total physical activity. Hence, they needed to make assumptions regarding the extent to which any observed cycling or walking has had an impact on total physical activity. This is complicated further by the issue that while there is a dose-response relationship between physical activity and health benefits, physical activity data are usually collected in such a way as to categorize people into groups of activity or activity levels. The review found that studies either had to use modelling to make assumptions about how cycling or walking might influence total physical activity; assume that all observed cyclists or walkers could be classed as active (and therefore had a reduced risk and/or reduced medical costs); or make some sort of estimate of the scale of benefit somewhere between these two extremes. The exception was the study by Rutter (2005), as it used relative risks for cycling which controlled for leisure time physical activity (Andersen et al, 2000). This neatly avoids the issue of activity substitution, (the notion that additional activity in one domain such as cycling may be associated with reduced activity in another) and means that any model can focus on the benefit accruing from the activity of cycling itself.

Strengths and weaknesses of the review

The main strength of this review is its comprehensiveness: due to the search and screening strategy employed we can be fairly certain that we have captured the vast majority of studies on this subject. A weakness of the review is that the heterogeneity of approaches in the studies made a meta-analysis impossible, so we had to rely on a narrative analysis of the results and approaches taken.

Conclusion

To our knowledge, this is the first review conducted on this topic. The Nordic Council report brought a number of economic appraisals together but it did not objectively review the approaches. The Department of Transport in the UK is currently reviewing its 'New Approach to Transport Appraisal' including additional focus on health, but again this is not based on a systematic review of approaches to date. This comprehensive review has demonstrated the need for a more harmonized approach to the inclusion of health effects related to physical activity through cycling and walking in economic analyses of transport infrastructure and policies. It has highlighted the issues that need to be taken into account when developing guidance on this issue. Since transport policy decisions are taken every day and sometimes on approaches that often lack transparency and scientific rigour, an approach based on the best available evidence seems opportune at this stage. The study by Rutter (2005) has identified an approach that appears to have the greatest potential thus warranting further development to lead to a more uniform approach. It is worth noting that while Rutter is an author on this review, the decision to select his study for further consideration was reached by the other authors, and endorsed by a project advisory committee. Follow-up work to this review has therefore focused on developing as separate products of this project guidance and a model based on this approach using relative risks for cycling which controlled for leisure time physical activity as best available evidence to date in the absence of models based on energy expenditure (WHO 2007a, 2007b). Future phases of this project will also investigate applying this approach to walking.

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Annex A. Data extraction tables

Category	Ref	Objective of study	Study design	Methods	Inclusion of walking and/or cycling	Population groups included	Costs included	Main benefits (mortality and morbidity)	Health effects included (state relative risks if appropriate)	Other outcomes considered	Inclusion of risks or unintended consequences?	Main Results	Study type and quality (++) (+) or (-)	Issues
All-cause mortality approach	Rutter H. Mortality benefits of cycling in London. Transport for London	estimate the economic and other benefits that would accrue from achieving cycling targets	Cost benefit analysis	Uses data from Copenhagen heart study to estimate the reduction in mortality arising from additional cyclists. Assumes 50% of increase in cycling would be new cyclists	cycling only	aged 20-59	Excess deaths among cyclists	All-cause mortality	All-cause mortality relative risk = 0.72 observed in regular cyclists	morbidity benefits mentioned but not included	included increase in risk of death; applied safety in numbers adjustment	Nett benefit per cyclist per year of £533. **[EURO] BCR = 6 (but NB no costs of intervention included - cost only = increase in death/injury)**	2 ++	Only study to use copenhagen. Strength is in being based on distance cycled NOT physical activity levels. Solid assumptions and transparent. Weakness: only used mortality; unpublished
Based on modelling of the impact of a change in physical activity (from National Heart Forum report) on risk of specific diseases	Macdonald, B. 2006. Valuing the benefits of cycling. Draft report to Cycling England. SQW Ltd	Examine the economic benefits of cycling	review	used results of review to apply values to various scenarios of increased cycling	cycling only	age groups 16-44 and 45 - 64	mainly hypothetical costs	i) Uses PAR of inactivity data for chd stroke and colon cancer to calculate no of deaths preventable through cycling. Ii) uses NHF 'staged' approach assuming stepped increase in activity level	PAR: CHD 29.3%; stroke 44.3%; colon cancer 24.8% (from Swales et al Northern Ireland study)	NHS savings; productivity gains; pollution, congestion, social inclusion.	possible decrease in injuries through cycle and walk accidents. Discussed but not included in calculations.	value of health benefit values for adult cyclists = £11.16 (16-44 year olds); £99.53 (45-64 year olds); £83.50 mean	2++	uses best data and realistic assumptiuons but still assumes shift upwards in activity levels for all groups
	Department for Transport (2007). Transport Analysis Guidance (TAG). Cycling and Walking schemes TAG Unit 3.14.1	To provide guidance on various aspects of the analysis of cycling and walking schemes	Guidance - but also includes three case studies	Guidance on conducting prospective cba including using 'fitness' as a benefit.	both	No data reported on population groups	Full costs of scheme	"Fitness" - defined as benefits due to increased physical activity. Uses methodology from TfL (2004) which uses PAR of inactivity data (from NHF) to provide cost of an "individual taking moderate physical exercise". BUT appears to apply this only to the 1/3 of the population rather than the total.	CHD; stroke; colon cancer. Combined PAR for inactivity = 33%. Proportion preventable by moderate PA = 9%	Environment; Economy; Accessibility; Integration	yes - possible decrease in cycle and walk accidents	"annual benefit of an individual taking moderate physical exercise is 0.0001 times the statistical value of a life". Applied to case studies gives BCRs of **11.7; 13.0; 22.1**	2+	Simple PAR calculations provide benefit of someone taking pa, but the model appears to assume that everyone using the walk/cycle facility will benefit. No reference to influence of new cycling or walking on total pa
	Sustrans. Economic appraisal of local walking and cycling routes. 2006. Also methodology paper	Conduct a cba on three local walking and cycling routes	Cost benefit analysis	Compare costs with benefits including health effects; calculate net benefit cost ratios . Uses methods from DfT (2007)	both	None specific though the projects are all schools	all construction and maintenance costs	"Fitness" - defined as benefits due to increased physical activity. Uses methodology from TfL (2004) which uses PAR of inactivity data (from NHF) to provide cost of an "individual taking moderate physical exercise" BUT appears to apply this only to the 1/3 of the population rather than the total. Value set at £122.93	CHD; stroke; colon cancer. Combined PAR for inactivity = 33%. **NB this may be a simple average using NI data.** Proportion preventable by moderate PA = 9% (from NHF study)	Absenteeism	Assume reduced risk thorugh decreased car km	Project 1: benefits 12.6M; costs 430k; **BCR 29.3.** Project 2: benefit 5.7M; cost 177k; **BCR 32.5.** Project 3: benefit 16.7M, costs 1.1M; **BCR 14.9**	2+	Simple PAR calculations provide benefit of someone taking pa, but the model appears to assume that everyone using the walk/cycle facility will benefit. No apparent reference to influence of new cycling or walking on total pa. Uncertain how estimates of new users generated.
	Transport for London. A Business Case and Evaluation of the Impacts of Cycling in London. Draft 6. 2004. London. Transport for London.	to summarise all costs and benefits that might arise if adequate cycling facilities are provided throughout London	cost-benefit analysis	Compare costs with benefits including health effects; calculate net benefit cost ratios . Uses methods from DfT (2007)	cycling only	adults and children	costs of a comprehensive programme including infrastructure, training; promotion; information; marketing.	Uses PAR of inactivity data (from NHF) to provide cost of an "individual taking moderate physical exercise" BUT appears to apply this only to the 1/3 of the population rather than the total. Use this to project figures for deaths saved through three scenarios.	CHD PAR 29%; stroke 44%; colon cancer 25%. **Proportion preventable by moderate PA = 9% (from NHF study?)**	Travel time reductions; Decongestion benefits for other road users; Comfort improvement; Short-term absence reduction	Decreased risk of death through cycling addressed but not included in calculations	3, 7, and 16 deaths saved through three levels of intervention. Costed at £4m £9m and £20m. **BCR = 2.2; 2.5; 3.6.**	2 +	No account taken of link between increased cycling and increased overall physical activity in the calculations
	Foltýnová H & Braun Kohlová M (no date). Cost-benefit analysis of cycling infrastructure: a Case study of Pilsen.	to analyse the impacts of improved cycle infrastructure on demand for cycling in a town in the Czech republic	cost-benefit analysis	stated preference	cycling only	18+	infrastructure investments and maintenance costs	i) CHD mortality ii) morbidity (cost of illness approach) from CHD; colon cancer;	i) 9% reduction in CVD mortality (from NHF study) ii) 50% reduction in risk of CHD and 40-50% reduction in risk of colon cancer used for morbidity estimates	pollution; insecurity; travel time.	Number and severity of accidents	Negative BCRs of -0.62 to -0.33. May be due to low predicted demand or conservative assumptions	2+	Unclear how calculations conducted especially mortality and morbidity estimates. Assumes benefits only apply to new cyclists regularly cycling to work.

using population attributable risk of inactivity	Sælensminde K. 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: Policy and Practice. 2004, 38 (8), October, pp 593-606	Conduct a cost benefit analyses of walking and cycling track networks in three Norwegian Cities	Cost benefit analysis	Compare costs with benefits including health effects and external costs of road traffic; calculate net benefit cost ratios	Both	No data reported on population groups	i) capital costs ii) maintenance costs iii) tax-cost factor	Reduced costs related to less severe diseases and short term absences. Assume reduce from 5% to 4% ii) reduced costs related to severe diseases	cancer; high blood pressure; hypertension; Type 2 diabetes; muskulo-skeletal conditions. Assumes 50% of new cyclists and peds will benefit.	travel time; insecurity today; insecurity future; costs school chidren transport; external costs motorised road transport; parking costs employees	Considered decreased risk of accidents	Total benefit NOK 153M; 309M; 3.023Bn Total costs 30M; 20M; 767M. BCR 4.09; 14.34; 2.94	2++	Presented as 'complete'[cost benefit analysis. Best estimates. Includes discounting. Calculations not shown.
	Jones and Eaton, 1994 Cost-benefit analysis of walking to prevent coronary heart disease, Archive of Family Medicine, 3(8)	to quantify the cost-benefit relationship of walking to prevent coronary heart disease	cost-benefit analysis	Modelling, using decision-analysis simulation, among hypothetical cohorts of sedentary men and women	walking only	Hypothetical cohorts of sedentary men and women 35-74 years	shoes; time; cost of physician exam; injury	RRs for CHD mortality	CHD RR: analysis used varying RRs range: 1.15-2.4 (median 1.9)	none	Risk of injury considered	If 1.9RR used for CHD, $5.6bn would be saved annually if 10% of adults began a regular walking programme. $4.3bn saved if all sedentary populaiton began walking regularly. BCR positive above RR of 1.7	2 +	Hypothetical only.
Used data on reduced medical costs of active people	Wang G, Macera CA, Scudder-Soucie B, Schmid T, Pratt M, Buchner D. A cost-benefit analysis of physical activity using bike/pedestrian trails. Health Promot Pract. 2005 Apr;6(2):174-9.	Conduct a cost-benefit analysis of physical activity through bike/ pedestrian trails	Cost benefit analysis	Compare costs with benefits to produce simple ratio; conduct sensitivity analysis	All trail users	No data reported on population groups	i)construction and ii) annual maintenance of trails	Difference in direct medical costs (comparing active with inactive person) (from Pratt et al 2000)	Pratt et al 2000 did not look at specific health effects, only overall costs, controlled for some confounders	None	No	Costs $209.28 pppa Benefits $$564.41 pppa CB ratio 2.94 (1.65 – 13.40)	2+	No consideration of indirect benefits No consideration of indirect costs. Assumes trail use equates with Pratt's definition of active Not age-specific
	Buis J, Wittink R. (2000) Interface for Cycling Expertise. The economic significance of cycling. The Hague. VNG	To illustrate the costs and benefits of cycling policy	Four case studies, of which only Amsterdam uses health data.	cost benefit analysis	cycling	not stated	bicycle network; bike parking		Savings on absenteeism and medical treatment	pollution ; noise; theft; time	Reduction in injuries	9% increase in the amount of km cycled in Amsterdam results in savings of 7 million guilders per year. (ref: Stichting voor Economisch Onderzoek). **BCR 1.5**	2 -	site searched but no data found on origin of these calculations
	Troelsen J, Underlien Jensen S, Andersen T. (no date). Evaluering af Odense – Danmarks Nationale Cykelby.	Evaluation of Odense's "cycle city" programme	Evaluation of a 4-year project (50 subprojects) aimed at improving the use of bicycles, safety and acceptability	Cost-efectiveness analysis. Panel study of transport habits, safety and public health. Analysis of transport data including comparison with predicted levels	Cycling	Population of Odense Municipality aged 15-60	Intervention cost 2,7 mio. Euro	Mortality and illness, trafic accidents	All cause mortality, sickness benefit; health expenditures;			Estimated saving: 4,4 mio. Euro; 2131 life years gained. Claimed lower mortality rate and average 5 months longer lifespan.	2 -	Unsure how life years gained calculated. Didn't the actual level of cycling go down? SEE Table 4f [p90] NB Data only obtained from English summary
	Ege et al, 2005	Esamine the benefit of an investment in promotion of use of cycling	CBA - scenario analysis	Modelling	Cycling	Whole population in larger cities	Public investment in infractructure and campaign; transport cost; health service cost;		Less use of health service (accounted for by a cos/km)			Net benefit rate: 1,35	Assume 2- until more details provided	Sensitive to assuptions of health effects; assumptions relating to consequences of change in transport from car to cycle; valuation of time cost

Nordic Council of Ministers. CBA of Cycling. Copenhagen 2005. (Seminar to compare different approaches. Includes studies mentioned separately in this table)	Sælensminde K. (2004). Cost–benefit analyses of walking and cycling track networks in Norway	See study (18)											2++	
	Rutter H. Valuing the mortality benefits of regular cycling	See (16) Rutter 2005											2++	
	Lind G, Hydén C, Persson U. Benefits and costs of bicycle infrastructure in Sweden.	Hypothetical CBA of an investment in bicycle infrastructure	cost benefit analysis	Compare costs with benefits including health effects and external costs of road traffic; calculate net benefit cost ratios	cycling	younger and older age groups	Cost of infrastructures based on experience from earlier bicycle projects, estimated values and documentation from contractors.	Obesity; 'excess morbidity'	No RRs stated	travel time, delay, comfort,	Injuries	Estimates used based on 'new international published literature'. Estimate decreased cost for an activated inactive person aged 50-60 years= 12000 SEK per year (**1,300 EUROS**). If no efforts to reach older and inactive persons, used 2600 SEK (280 EUROS) per generated cyclist. Where a focused effort is made to target older inactive people, a maximum value of 8300 SEK (900 EUROS) per generated cyclist used	2 -	Unclear where estimates come from
	Saari R, Metsäranta H, Tervonen J. (2007). Finnish guidelines for the assessment of walking and cycling projects	describe approaches to CBA		Model CBA using unit values for persons who become active	refers to walking and cycling	not stated	Investment' costs; maintenance	not clear	not clear	emissions, congestion	Accidents considered	unit value of **1200 euros/person/year** used to calculate the health benefits of cycling or walking investment project. (proposed by the Ministry of Transport and Communications)	2 -	Mention that CBA should only be applied to "only those kilometres that exceed the threshold criteria of health benefits (30 min per day)
	Krag T. (2007) Cost Benefit Analysis of Cycling – Denmark	describe approaches to CBA	cost benefit analysis	CBA using values for health benefits per hour (of cycling?)	cycling	not stated		Refers to heart attacks; diabetes 2; osteoporosis; colorectal and breast cancer; high blood pressure; depression; back-pain; stroke.	not clear		Accidents considered	Presents typical values from other studies. 3.09 €/hour (Switzerland, Brian Martin et. al, 2001); 5.37 €/h (Norway, TØI, 2002); 4.04 €/h (UK/Harry Rutter). In the Danish calculations, the value **4.7 €/hour** is used. Equates to **860 euro/year**	2 -	Study presents data on typical values for benefits per hour of cycling
	Summary of Nordic Council report	Summarise findings from above studies							unclear			**Summary of study suggets €900/year per activated person should be used or € 0.15/ km cycled**		not clear how this summary figure was calculated
Cost/km assumption	Thaler R, Gleissenberger E. Austrian Cycling Strategy. 2006. Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft	Policy document setting out strategy for cycling in Austria	includes basic cost benefit analysis	health benefit valuation based on average figure taken from Nordic Council of Ministers CBA (14)	cycling			mortality benefits occur primarily if previosuly sedentary people take up cycling for 30 minutes per day	unclear			Quoted health benefit equivalent to € 0.15euro per km cycled - but acknowledged that this is an estimate	2 -	unclear which cycling scenario was used for benefit estimation

Annex B. Included studies

Buis J, Wittink R. (2000). Interface for Cycling Expertise. The economic significance of cycling. The Hague. VNG

Department for Transport (2007). Guidance on the Appraisal of Walking and Cycling Schemes. Transport Analysis Guidance (TAG) Unit 3.14.1. London. Dept of Transport.

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Thaler R, Gleissenberger E. Austrian Cycling Strategy. 2006. Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft

Wang G, Macera CA, Scudder-Soucie B, Schmid T, Pratt M, Buchner D. A cost-benefit analysis of physical activity using bike/pedestrian trails. Health Promot Pract. 2005 Apr;6(2):174-9.

Review of transport economic analyses including health effects related to cycling and walking. Transport Policy, vol. 15(2008):291–304. doi:10.1016/j.tranpol.2008.11.001

Annex C. Excluded studies

Id No.	Reference	Reason
1	T Andersen, H Lahmann, J C Overgaard Madsen, Kørelys på cykel - en effektundersøgelse, 2006	No walking or cycling
2	Buis, J. The economic significance of cycling. Interface for Cycling Expertise. Published not stated. Netherlands.	Summary of included study
3	Cawley J. An economic framework for understanding physical activity and eating behaviors. Am J Prev Med. 2004 Oct;27(3 Suppl):117-25.	General model
4	Cope A M, Doxford D, Hill T. (1998). Monitoring Tourism on the UK's First Long-Distance Cycle Route. Journal Of Sustainable Tourism Vol. 6, No. 3, 1998	Expenditure not health impacts
5	Department for Transport (2003). The Physical Fitness Sub-Objective TAG Unit 3.3.12 Transport Analysis Guidance (TAG). http://www.webtag.org.uk/ (accessed 21 Feb 2007).	Additional detail only for DfT 2007
6	Eddington R. The Eddington Transport Study. HM Treasury; Dept for Transport. London. 2006. http://tinyurl.com/yek22h	Makes only passing reference to health benefits and quotes Sustrans 2006
7	Elvik R. Which are the relevant costs and benefits of road safety measures designed for pedestrians and cyclists?, Accident Analysis & Prevention, Volume 32, Issue 1, January 2000, Pages 37-45.	Review. Concludes that walking and cycling should be included in future CBAs
8	Frank LD. Economic determinants of urban form: resulting trade-offs between active and sedentary forms of travel. Am J Prev Med. 2004 Oct;27(3 Suppl):146-53.	Review focusing on urban form. No CBA
9	Stephen Glaister, Dan Graham and Ed Hoskins. Transport and health in london. London. NHS Executive. http://www.doh.gov.uk/london/hstrat1.htm (accessed 15 Feb 2006)	Focus on air quality and accidents.
10	ICLEI/A-NZ Walking school bus quantification tool. http://www.iclei.org/index.php?id=4288#c9541	Not a study – template only
11	Infras F, Beratung B. Efficiency of public investment in slow transport. Bern. Bundesamt fur Strassen (ASTRA). 2003.	Only qualitative description of health effects
12	Swales C. (2000). A health economics model: The cost benefits of the Physical Activity Strategy for Northern Ireland Belfast. Health Promotion Agency for Northern Ireland.	Not a CBA of walking and cycling

Id No.	Reference	Reason
13	Hill, J. Sallis, J. Peters. (2040) Economic analysis of eating and physical activity. A next step for research and policy change. American Journal of Preventive Medicine, Volume 27, Issue 3, Pages 111-116	discussion and overview
14	ICLEI, Health Benefits Economic Model, Cities for Climate Protection, International Council for Local Environmental Initiatives (www3.iclei.org/ccp-au/tdm/index.html), 2003.	Not a cba
15	Korve, M.J., Niemeier, D.A., 2002. Benefit-cost analysis of added bicycle phase at existing signalized intersection. Journal of Transportation Engineering 128 (1), 40–48. Lodden, U.B., 2002. Sykkelpotensialet i norske byer og te	Does not include health benefits
16	Litman T A. Economic Value of Walkability (2004). Victoria Transport Policy Institute.	Descriptive review.
17	Litman T A. Economic value of walkability . Transportation Research Record 1828, Transportation Research Board (www.trb.org), 2003, pp. 3-11	Duplicate of Litman (2004)
18	Litman T A. Economic value of walkability . Volume 10, Number 1, 2004, of World Transport Policy & Practice	Review only.
19	Litman T A. (2003). Integrating Public Health Objectives in Transportation Decision-Making. American Journal of Health Promotion, Vol. 18, No. 1 pp. 103-108,	Review with no CBA
20	Litman T A. (2006). If Health Matters Integrating Public Health Objectives in Transportation Planning. Victoria, VTPI. www.vtpi.org/health.pdf (accessed 15 Feb 2006)	Review
21	Litman T A. (2004). Quantifying the Benefits of Nonmotorized Transportation For Achieving Mobility Management Objectives. Victoria, VTPI. http://www.vtpi.org/nmt-tdm.pdf (accessed 15 Feb 2006)	Review
22	J C Overgaard Madsen, H Lahrmann, A Lohmann-Hansen, Cykelbus'ter projekt i Århus: Fra bil til cykel eller bud med positive virkemidler - Projektevaluering, Transportrådet, 2001	No costs of activity included
23	Nordic Council of Ministers. CBA of Cycling. Copenhagen 2005	Studies in this report included individually
24	Pratt M, Macera CA, Sallis JF, O'Donnell M, Frank LD. Economic interventions to promote physical activity: application of the SLOTH modell. Am J Prev Med. 2004 Oct;27(3 Suppl):136-45.	Not a CBA
25	Sælensminde K. Walking- and cycling track networks in Norwegian cities Cost- benefit analyses including health effects and external costs of road traffic. Oslo. Institute of Transport Economics.	Summary only available in English. Data same as Saelensminde 2004
26	Sorenson J. Health Economic Consequences of Physical Activity. 11th annual Congress of the European College of Sport Science. 2006	not a cba

Id No.	Reference	Reason
27	Sørensen J, Horsted C, Andersen L B. 2005. Modellering af potentielle sundhedsøkonomiske konsekvenser ved øget fysisk aktivitet i den voksne befolkning. CAST. Odense.	Physical activity in general not walking or cycling
28	Sturm R. The economics of physical activity: societal trends and rationales for interventions. Am J Prev Med. 2004 Oct;27(3 Suppl):126-35.	review of trends
29	Sustrans. The economic potential of active travel. Active Travel information sheet FH03. 2002. Bristol. Sustrans.	Review
30	Veisten K, Saelensminde K, Hagen, K E. 2005. Bicycle injuries, risk of cycling and the tool for cost-benefit analysis of measures towards cycling. Inst of Transport Economics, Oslo, 2005.	Focus on injury. No data on health impacts of physical activity
31	Victoria Transport Policy Institute. Evaluating Nonmotorized Transport. Techniques for Measuring Walking and Cycling Activity and Conditions. TDM encyclopedia Updated July 10, 2009. http://www.vtpi.org/tdm/tdm63.htm	No data on health effects
32	Trafikministeriet København (2003) . Manual for samfunds-økonomisk analyse.	General guidelines and not empirical studies
33	Vejdirektoratet København. (1999). Trafikuheldsomkostninger	General guidelines and not empirical studies
34	Victoria Transport Policy Institute. Health and Fitness. Strategies That Improve Public Health Through Physical Activity. TDM encyclopedia. Updated July 10, 2009. http://www.vtpi.org/tdm/tdm102.htm	No data on health effects
35	Wang G, Macera CA, Scudder-Soucie B, Schmid T, Pratt M, Buchner D, Heath G. Cost analysis of the built environment: the case of bike and pedestrian trials in Lincoln, Neb. Am J Public Health. 2004 Apr;94(4):549-53.	Cost analysis only
36	Wang G, Macera CA, Scudder-Soucie B, Schmid T, Pratt M, Buchner D. Cost effectiveness of a bicycle/pedestrian trail development in health promotion. Prev Med. 2004 Feb;38(2):237-42.	No health data used – cost effectiveness of reaching set levels of physical activity
37	Wardman M, Hatfield R, Page M. The UK national cycling strategy: can improved facilities meet the targets? Transport Policy, Vol. 4, No. 2, pp. 123-133, 1997	No data on health effects
38	WHO Europe & UNECE. Transport-related health effects with a particular focus on children. Economic Valuation. 2003.	Presents data from Sælensminde 2004
39	WHO Europe, Swiss Federal Office of Sports, Swiss Federal Office of Public Health. Economic Valuation Of Transport-Related Physical Activity	No specific cba data
40	Wendel-Vos G C W, Ooijendijk W T M, van Baal P H M, Storm I, Vijgen S M C, Jans M, Hopman-Rock M, Schuit A J, de Wit G A, Bemelmans W J E. Cost-effectiveness and health gains in realising policy ambitions for physical activity and overweight: underpinning the National Action Plan for Sport and Physical Activity. Netherlands. RIVM.	Not walking and cycling
41	Andersen L.B. Sørensen, J. Sykelister lever lenger, Samferdsel, 9, p. 26-27, 2006	Only preliminary analysis, full paper in process

Annex D: Search strategy

1. Databases:

Medline; Embase; Cinahl; PsychInfo; SPORTDiscus; TRIS on line; Global Health; Geobase; Cochrane Library; ISI Science Citation Index and Social Science Citation Index; Sociological Abstracts; Cambridge Scientific Abstracts (CSA) ERIC, CSA Environmental Sciences.

2. Search terms

Transport terms

1 automobile$1.tw.

2 (car or cars).tw.

3 commut$3.tw.

4 congest$.tw.

5 driver$1.tw.

6 (mechanised transport$5 or mechanized transport$5 or motor$4 transport$5 or personal transport$5).tw.

7 (motoring or motorist$1).tw.

8 road us$3.tw.

9 traffic.tw.

10 vehic$4.tw.

11 railtrail$1.tw.

12 (bus or buses).tw.

13 non-auto.tw.

14 non-motor$4.tw.

15 travel$4.tw.

16 pedestrian$.tw.

17 trail$1.tw.

18 speed hump$1 or speed bump$1

19 path$1

20 Transportation/

21 Motor Vehicles/

22 Automobile Driving/

23 exp Accidents, Traffic/

24 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23

Physical activity terms

1 (fit$4 or train$3 or activ$4 or endur$4).tw.

2 (physical$2 adj5 (fit$4 or train$3 or activ$3 or endur$4)).tw.

3 (train$3 or physical$2 or activ$3).tw.

4 (exercis$3 adj5 (train$3 or physical$2 or activ$3)).tw.

5 sport$3.tw.

6 walk$3.tw.

7 bicycl$3.tw.

8 (bike$1 or biking).tw.

9 (swim$1 or swimming).tw.

10 (exercis$3 adj aerobic$1).tw.

11 exertion$1.tw.

12. travel mode$1

13. trip$1

14. active travel$

15. active transportation

16. multimodal transportation

17 exp Exertion/

18 Physical Fitness/

19 exp "Physical Education and Training"/

20 exp Dancing/

21 exp Sports/

22 Exercise Therapy/

23 2 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22

Combine transport terms and physical activity terms

24 and 23