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Economic assessment of transport infrastructure and policies

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By:

Nick Cavill
Cavill Associates

Sonja Kahlmeier
WHO European Centre for Environment and Health, Rome
WHO Regional Office for Europe

Harry Rutter
South East Public Health Observatory

Francesca Racioppi
WHO European Centre for Environment and Health, Rome
WHO Regional Office for Europe

Pekka Oja
Karolinska Institute

lebensministerium.at

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Contributors

Lars Bo Andersen*, School of Sports Science, Norway

Finn Berggren, Gerlev Physical Education and Sports Academy, Denmark

Hana Bruhova-Foltynova, Charles University Environment Centre, Czech Republic

Fiona Bull, Loughborough University, United Kingdom

Andy Cope*, Sustrans, United Kingdom

Eva Gleissenberger/Robert Thaler, Lebensministerium, Austria

Maria Hagströmer/Michael Sjöström, Karolinska Institute, Sweden

Brian Martin, Federal Office of Sport, Switzerland

Irina Mincheva Kovacheva, Ministry of Health, Bulgaria

Hanns Moshammer, International Society of Doctors for the Environment

Bhash Naidoo, National Institute for Health and Clinical Excellence (NICE), United Kingdom

Åse Nossum/Knut Veisten, Institute for Transport Economics, Norway

Kjartan Saelensminde, Norwegian Directorate for Health and Social Affairs

Peter Schantz*, Research Unit for Movement, Health and Environment, Åstrand Laboratory, School of Sport and Health Sciences, Sweden

Thomas Schmid, Centers for Disease Control and Prevention, USA

Heini Sommer*, Ecoplan, Switzerland

Jan Sørensen*, Centre for Applied Health Services Research and Technology Assessment, University of Southern Denmark

Sylvia Titze, University of Graz, Austria

Ardine de Wit/Wanda Wendel Vos, National Institute for Health and Environment (RIVM), Netherlands

Mulugeta Yilma, Road Administration, Sweden

* Members of the extended core group

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Contents

1 Introduction

Economic appraisal is an established practice in transport planning. However, the health effects of transport interventions are rarely taken into account in such analyses. This project had two aims: to review recent approaches to cost–benefit analysis of transport-related physical activity; and to develop guidance on approaches to including the health effects of transport-related physical activity in economic analyses of transport infrastructure and policies.

Since calculating the costs of interventions is usually not very complicated, the project focused on approaches to the economic valuation of potential health effects. The result is primarily intended to be integrated into comprehensive economic analyses of transport interventions or infrastructure projects, but can also serve to assess the current situation or investments made in the past.

This project contributed to implementation of the Transport, Health and Environment Pan-European Programme (THE PEP) project "Promotion of safe cycling and walking in urban areas" *(1)*. It followed-up the outcomes of a Nordic Council workshop on "Cost–benefit analysis of cycling" held in Stockholm in February 2005, which had invited WHO to support the further development of methods to evaluate the health effects of cycling. It also brought forward discussions that had been held in Switzerland in September 2005 on the occasion of the Walk 21 Satellite Symposium on Transport-related Physical Activity and Health on open questions related to economic valuation of transport-related physical activity and the way forward.

This project aimed to:

- develop a review of approaches to including health effects in economic analyses of interventions related to cycling and walking (e.g. development of infrastructures for cyclists and pedestrians);
- critically discuss the identified indicators, health effects, relative risks and applied methodological approaches, taking into account scientific accuracy and relevance as well as aspects of feasibility;
- formulate suggestions for options for further developing a harmonized methodology for including health effects in health impact assessments and economic valuations of

interventions, as well as suggestions for data sources and methods to be used for these analyses;

- facilitate, through an international consensus meeting, the achievement of scientific consensus on these options; and
- publish a report on the meeting's outcome, including operational guidance for practitioners.

Implementation of the project was steered by a five-member core project group, which worked in close collaboration with an advisory group of international experts (see the list of contributors above).

In carrying out the project, there was close coordination between THE PEP and the European network for the promotion of health-enhancing physical activity (HEPA Europe). The key steps were as follows.

- The project group commissioned a systematic review of published economic valuations of transport projects, including a physical activity element *(2)*.
- The results of this review were considered by the advisory group, and used to propose options and guidance towards a more harmonized methodology.
- A draft methodological guidance on walking and cycling and an illustrative tool on cycling were developed based on the advisory group's recommendations, and were tested and piloted by members of the advisory group.
- An international consensus meeting was held to facilitate discussion and the achievement of scientific consensus on the options proposed in the draft methodological guidance and illustrative tool.
- Following incorporation of the amendments from the consensus meeting and further bilateral discussions with different members of the advisory group, the products of the project were approved for publication: the review *(2)*, the guidance document *(3)*, the illustrative tool for cycling *(4)* and its user guide *(5)*.

This booklet presents a summary of the results of the project. Chapter 2 contains the main results of the systematic review. Chapter 3 presents the main conclusions on issues regarding the economic assessment of transport infrastructure and policies with regard to the inclusion of the health effects of walking and cycling. A more detailed discussion on the current state of evidence on these issues is presented in a separate report *(3)*, including options and guidance towards a more harmonized methodology for the economic appraisal of health effects related to walking and cycling.

The principles outlined in the guidance have been applied in an illustrative tool, showing how the methodology can be used to assess health effects related to cycling. The tool, introduced in Chapter 4, is available as an MS Excel spreadsheet *(4)* with accompanying user guide *(5)*. Chapter 5 gives instructions for its use and outlines the potential limitations of the approach. All documents are available on the enclosed CD ROM.

This project represents a first step towards an agreed harmonized methodology. In forming the proposed options within this guidance, it has been necessary for the advisory group to make a number of judgements, always based on the best available but sometimes still incomplete evidence. Feedback is therefore welcome to hepa@ecr.euro.who.int, so that the guidance and illustrative tool can be further developed and refined in the light of user experience and new evidence.

2 Systematic review: summary

The review aimed:

- to identify relevant publications through expert consultation and tailored searches of the literature;
- to review the approaches taken to including health effects in economic analyses of transport interventions and projects; and
- to propose recommendations for the further development of a harmonized methodology, based on the approaches developed to date.

The review built on the results of a systematic review that had been carried out by the National Institute for Health and Clinical Excellence (NICE) *(6)*. To be included in this review, a study was required to:

- present the findings of an economic valuation of an aspect of transport infrastructure or policy;
- include data on walking and/or cycling in the valuation;
- include health effects related to physical activity in the economic valuation; and
- be in the public domain.

Sixteen papers were included from an original list of 4267 titles. These covered a range of approaches to economic analysis, the majority being cost–benefit analyses of cycling projects or programmes.

Quality was variable: using the quality scale adopted by NICE, three of the studies were classified as high quality studies with a high probability that the observed relationship is causal (2++), six as well conducted with a moderate probability that the relationship is causal (2+) and six as having a significant risk that the relationship is not causal (2–).

The economic analyses generally showed very positive benefit–cost ratios, the median being 5:1 with a range from –0.4 to 32.5. However, owing to the different methods applied in the studies, this value has to be viewed with caution. Some studies estimated the value attributed to each new walker or cyclist; these ranged from about €120 to €1300.

The review found wide variation in the approaches taken to including health effects of physical activity in economic analyses of transport projects. This is not helped by a lack of transparency in the methods used in many of the studies reviewed. The studies used various sources of data as the basis for calculations, there appeared to be no consensus on the diseases to be included in mortality calculations, and few studies included a measure of morbidity.

One of the most significant challenges is the relationship between observed cycling or walking and total physical activity. Studies 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 sufficiently 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.

One study used an approach based on the relative risk of all-cause mortality among cyclists compared to non-cyclists.

3 Guidance on economic appraisal of health effects related to walking and cycling

This chapter summarizes the key methodological issues concerning the economic appraisal of health effects related to walking and cycling *(3)*.

Mortality or morbidity?

Physical activity has positive effects on many aspects of morbidity, whether related to conditions such as coronary heart disease, stroke, diabetes, some types of cancer, musculoskeletal health and aspects of mental health (including anxiety and depression) to reducing the incidence of falls in elderly people, or to improvements in overall well-being and quality of life. From a public health point of view, these benefits materialize quicker than reductions in mortality. They can also be important in motivating individuals to walk and/or cycle, as people may be more likely to increase their physical activity to improve their immediate health and well-being than to prolong their life. Nevertheless, as of now, evidence on morbidity is still weaker than that on mortality. Therefore, including the impact of morbidity in an economic appraisal leads to greater uncertainty. The consensus meeting therefore recommended taking a more conservative approach, focusing for the time being only on all-cause mortality. It should be noted that this method is likely to produce very conservative estimates of health benefits.

If a study nevertheless prefers to use disease-specific mortality, the strength of evidence can be considered to be sufficient for the following causes:

- cardiovascular disease
- stroke
- colon cancer
- breast cancer
- type II diabetes.

For guidance on which relative risks to use, refer to the guidance document *(3)*.

The nature of the relationship between physical activity and health: dose–response or thresholds?

A common aspect of epidemiological studies is that they report relationships between health outcomes and different categories or levels of exposure. For example, sedentary people may be compared with people who are active beyond a specific threshold, such as 150 minutes of activity per week. However, there is a strong consensus that physical activity has a dose–response relationship with most health outcomes, higher levels of physical activity being associated with greater health benefits. It is therefore recommended that a dose–response relationship be incorporated into economic appraisals of walking and cycling. This means that all increases in walking or cycling would be associated with a reduction in risk, irrespective of whether the individual reached some predetermined threshold.

Activity substitution

This guidance is concerned with the health impact of transport infrastructure and other types of transport interventions that are expected to result from walking or cycling. However, most of the literature on risk of disease relates to total physical activity – usually a composite index expressing overall energy expenditure (often measured as kcal per week) or time spent active – including a wide range of non-transport activity such as leisure time and occupational activity. This therefore raises the question of activity substitution: i.e. does an observed increase in rates of walking and cycling necessarily mean there has been an increase in total physical activity? For example, people may have stopped jogging when they started cycling; or a new cycle path may have meant their new journey was actually shorter. In these examples, total physical activity would have remained unchanged or even declined.

It is recommended that activity substitution is accounted for in economic analyses as far as possible. This means not making an assumption that any increase in cycling or walking automatically leads to an increase in total physical activity (as people may cycle more and do less of another activity as a result). Again, taking account of activity substitution results in more conservative estimates.

Walking and/or cycling?

Ideally, a methodology for economic appraisal would allow one to assess the health effects related to both walking and cycling. For a number of reasons, however, the currently included evidence suggested that cycling should be addressed in the first instance.

- The systematic review found that economic appraisals of cycling were more common than those of walking.
- Data are readily available on reductions in all-cause mortality among cyclists, controlling for other physical activity. While studies of good quality exist for walking *(7,8)* they do not readily lend themselves to the development of an illustrative tool as they studied either specific population subgroups or health outcomes.
- Cycling is likely to be a more memorable behaviour than walking, and therefore to be less subject to measurement error.

It is intended to use this approach to economic appraisal of cycling as the basis for developing the illustrative tool for walking in a subsequent project phase.

Age groups

An ideal tool would be able to take account of the differential effects of physical activity on children and adults, and on adults of different ages. However, the evidence base for the health effects of physical activity on children is not yet as large as that for adults. The advisory group therefore concluded that economic appraisals should focus on adults only in the first instance. The age groups to which the results may be applied should be made explicit. If any model is subsequently applied to children or older adults, any related assumptions should be made explicit.

Interactions between transport-related physical activity, air pollution and road traffic injuries

With the introduction of transport-related physical (in)activity as a relatively new topic in the discussion of transport-related health effects, the question arises of possible interactions between exercise through cycling and walking and exposure to ambient air pollution, as well as the risk of road traffic injuries. No review on active transport and physical activity is available that takes the possible negative effects of ambient air pollution into account. Evidence from individual studies indicates, however, that benefits from exercise are probably more important for health than possible negative effects of air pollution.

Regarding road traffic injuries, evidence suggests that if promotion of active commuting is accompanied by suitable transport planning and safety measures (which could at the same time lead to less exposure to air pollution if more cycling occurs away from main roads), active commuters are likely to benefit from a "safety in numbers" effect.

Costs applied

In order to conduct an economic appraisal of walking and cycling, it is necessary to agree a method of valuing health, or life. There are a number of ways that this can be done.

- A standard "value of a statistical life" can be agreed. This is often used in transport appraisals and reflects the willingness of a middle-aged person to pay to avoid sudden death. A common example is the value of €1.5 million agreed by the UNITE study *(9)*.
- A "cost of illness" approach can be taken. This applies costs (for example costs to the national health service or loss of earnings) to each specific disease.
- A "years of life lost" approach can be taken. This allows a more comprehensive assessment of health effects.

As this project was aimed primarily at transport appraisals, it was thought more helpful to use the "value of a statistical life" approach, as this is more common in transport appraisals such as in the United Kingdom's New Approach to Appraisal *(9)*. Other methods, such as a quality-adjusted life year (QALY)-based approach, could be adopted if data were available to permit a more comprehensive assessment.

Time period for build up of benefits

It is recognized that many economic appraisals are conducted without taking account of the dynamic nature of transport and physical activity patterns, and the time needed for them to have an impact on mortality levels. It is important to recognize that there will be a delay between increases in physical activity and measurable benefits. Based on the best available evidence, it was concluded that for a "build-up" period to reach its full effect, five years was a reasonable assumption to use.

In addition, there should be room for different assumptions about the speed or level of uptake of cycling or walking. For example, one new cycle path may stimulate immediate uptake, while another might take a year or more to see levels increase. This component should be built into appraisals to allow for varying levels of uptake.

Discounting

In most cases, the economic appraisal of health effects related to walking and cycling will be included as one component into a more comprehensive cost–benefit analysis of transport interventions or infrastructure projects. The final result of the comprehensive assessment would then be discounted to take account of inflation and allow a calculation of the present value.

If the health effects are to be considered alone, however, it is important that the methodology allows for discounting to be applied to this result as well.

4 The health economic assessment tool for cycling (HEAT for cycling)

The principles and guidance set out in Chapter 3 have been developed into an illustrative tool, the health economic assessment tool for cycling (HEAT for cycling) *(3,4)*. The tool estimates the maximum and the mean annual benefit and values (per cyclist, per trip, and total annual benefit) in terms of reduced mortality as a result of cycling. It can be applied in a number of situations.

- When planning a new piece of cycling infrastructure, it allows the user to model the impact of different levels of cycling and attach a value to the estimated level of cycling when the new infrastructure is in place. By comparing it with the costs, this can be used to produce a cost–benefit ratio (and help make the case for investment).
- It can be used to value the benefits (in terms of mortality) from current levels of cycling, such as to a specific workplace, across a city or in a country.
- It can provide input into a more comprehensive economic appraisal or prospective health impact assessment. For instance, it can be used to estimate the benefits of achieving national targets for increases in cycling or to illustrate potential cost consequences to be expected in the case of a decline in current levels of cycling.

It will help to answer the following question:

If x people cycle a distance of y kilometres on most days, what is the economic value of the health benefits that occur as a result of the reduction in mortality due to their physical activity?

4.1. Basic functioning of the tool

The tool is based on relative risk data from the Copenhagen Centre for Prospective Population Studies, which found a relative risk for all-cause mortality of 0.72 among commuters aged 20–60 years who regularly cycled to and from work, relative to the general population *(10)*. The study controlled for the usual socioeconomic variables (age, sex, smoking etc.) as well as for leisure time physical activity. As recommended (3), it therefore also took account of a possible activity substitution, i.e. whether an observed increase in rates of commuter cycling could be compensated by a reduction of leisure time physical activity.

The tool applies the data entered by the user to calculate the total economic savings due to reductions in all-cause mortality among these cyclists. Assuming a linear dose–response relationship, the risk reduction for the actual days spent cycling is calculated based on estimates of total number of days cycled, distance cycled and average speed. The tool produces a global estimate of economic savings from reduced all-cause mortality as well as savings per cyclist, per kilometre cycled or per trip.

The basic functioning of the tool is shown in Fig. 1.

4.2. Who is the tool for?

The tool is based on the best available evidence and transparent assumptions. It is intended to be simple to use by a wide variety of professionals at both national and local levels. These include:

- transport planners
- traffic engineers
- health economists
- special interest groups working on transport, public health, physical activity, cycling or the environment.

4.3. What can the tool be used for?

The tool is to be used mainly as input to comprehensive cost–benefit analyses of new transport infrastructures or for assessment existing infrastructures.

The tool provides an estimate of the economic benefits accruing from cycling as a result of lower death rates. Ideally it would be supplemented with additional data on other potential health outcomes from cycling (morbidity) and combined with other transport-related outcomes such as less congestion or reduced journey times for a comprehensive assessment. These and other enhancements will be considered for inclusion in future versions of the tool.

The tool could also be used to illustrate potential consequences, in terms of cost, of a potential future decline in levels of cycling.

4.4. What should the tool not be used for?

The current tool cannot be directly applied to walking, as it is based on a study that compared the relative risk of all-cause mortality between regular cyclists and non-cyclists *(10)*. Moreover, the tool is to be applied only to adult populations, not to children.

As mentioned above, the tool does not produce comprehensive assessments of all the benefits of cycling, so it should not be used in place of a full cost–benefit analysis. For methodological reasons, it only considers the impact on mortality and not morbidity. A number of other limitations of the tool are described in more detail in the guidance document *(3)*.

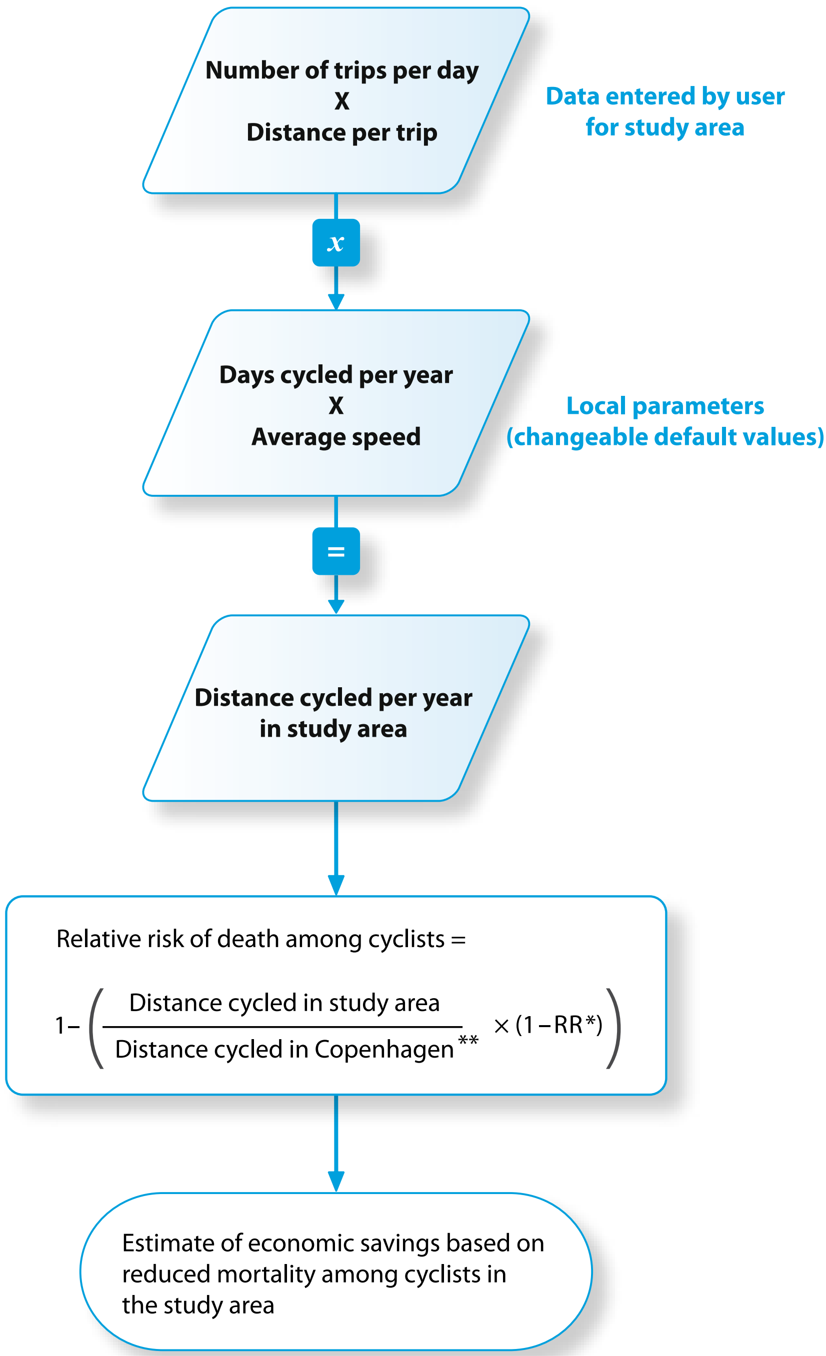
4.5. What input data are needed?

The user only has to enter data on two basic elements of the observed or modelled cycling patterns:

- the number of cycle trips per day
- the mean trip length.

The tool then calculates the overall value of this level of cycling, based on a number of default values. These have been derived from the literature and agreed as part of the expert consensus process, and should be used unless more relevant or accurate data are available.

Fig. 1. Basic functioning of the HEAT for cycling



* RR = relative risk of death in underlying study (0.72) *(11)*

** Distance cycled in Copenhagen calculated based on 3 hours per week for estimated 36 weeks/year at estimated 14km/h

In addition, users can enter data on the proportion of trips that are one part of a return journey and the value of a statistical life. These will help to make the estimates more appropriate for the respective local situation.

- The proportion of trips that are one part of a return journey (or "round trip") will be high if the route in question is regularly used as a commuter route (or route for regular transport-related cycling). This is likely to be the case in most situations.
- A default value of a statistical life (in economic terms) commonly used across Europe is provided in the model but users may adapt this value by, for example, adopting agreed values for their own country.

Other measures, such as years of life or quality-adjusted life years (QALYs), could also be included to provide a more sophisticated analysis. For pragmatic reasons at this stage, however, the basic functions of the tool are based on the "value of statistical life" approach, as it is more easily available, is easier to understand by non-specialists, and results in more conservative estimates.

4.6. Data sources

Input data for the model might come from a number of sources including:

- cycle route user surveys or monitoring
- population-level travel surveys
- traffic counts
- informed estimates.

In all cases it is important to use the most reliable data possible, and to validate these with secondary sources where available. Default values are provided for the main parameters of the model, based on best evidence and expert consensus.

4.7. What data will the tool produce?

The tool will produce an estimate of the following outputs:

- maximum annual benefit
- savings per km cycled per individual cyclist per year
- savings per individual cyclist per year
- savings per trip
- mean annual benefit
- present value of mean annual benefit.

The *maximum annual benefit* is the total value of reduced mortality due to the level of cycling entered by the user. This is a maximum value, as it assumes that the maximum possible benefits to health will have occurred as a result of the entered level of cycling. In reality, the health benefits are likely to accrue over time, and this build-up period can be adjusted.

The *mean annual benefit* is therefore the key output of the model. It adjusts the maximum annual benefit (total value of lives saved due to the level of cycling entered by the user) by three main factors:

- an estimate of the timeframe over which benefits occur, a default value since there is evidence to suggest that mortality reductions are likely within five years of a change in level of cycling *(3,11,12)*;
- a build-up period for uptake of cycling, which allows the user to vary the projections in uptake (such as for a new cycle path that may see increasing use over time) and varies for full usage occurring between 1 and 25 years; and
- the present value of mean annual benefit, which adjusts the above outputs to take the diminishing value of costs and outcomes over time into account (the model suggests a discount rate of 5% but this can be varied).

5 HEAT for cycling: instructions for users

5.1. How to access the tool

The tool is available to download as an Excel spreadsheet *(4)* and on the enclosed CD ROM.

When first opening the spreadsheet you may find a warning about macro security. The user needs to allow the spreadsheet to use macros so that it can work correctly. Macros are simple instructions contained within the spreadsheet that allow it to make basic calculations. To enable macros, click Enable macros when you see a security warning.

You may need to change the security setting on your computer to allow macros. To do this you should:

- close the spreadsheet but keep Excel open (by clicking the black X at the top right of the spreadsheet);
- go to Tools, then Options;
- within Options, click the *Security* tab;
- select the *Medium* button, which allows you to choose whether or not to run potentially unsafe macros; and
- reopen the spreadsheet.

You should now see a security warning. Click *Enable macros*. The spreadsheet should now open correctly.

If you encounter problems with macros or use a Macintosh computer, you can use the alternative version, from which the auto screen formatting macros have been removed.

5.2. How to use the tool: 3 simple steps

Step 1: entering your data

All assessments require the two fields in Step 1 to be completed (see Section 4.5 above).

- For the number of trips per day, enter the number of cycle trips observed (or estimated) per day. This could be on a particular cycle route, across a city or on a cycle network, in any direction. Examples of data sources are given in Section 4.6. If the specific data are not available, or the tool is being used to assess projected increases (or decreases) in cycling, this figure should be estimated as accurately as possible.
- The mean trip length is the average length of each cycle trip, in kilometres. This will usually be taken from surveys of cyclists, either on the

cycle route or from a random sample across the population. There are three main method of estimating distance *(13)*.

1. The most reliable method is to ask cyclists to draw their route on a map, so that it can then be measured with a digital curvimetric device.
2. The second best method is to ask cyclists for their starting and finishing points, and to multiply the straight-line distance between the two points by 1.25.
3. Another method is based on subjective cyclists' estimates of distance travelled. However, there is evidence that this leads to distances being overestimated by about 8% and that the method is not always reliable. Thus, if subjective measures are used, it is suggested to correct for overestimation by multiplying with the factor 0.92.

Step 2: checking the parameters
Most users will not need to change any of the parameters in Step 2. These have been set according to the best information currently available, and have been agreed by the advisory group at a consensus workshop. They represent the most likely appropriate default values in real-life situations. They should only be changed if reliable local data are available, as changes to these parameters can have a significant impact on the final values. They may be checked to ensure that they apply to the local situation but must be changed only if necessary. To change any of these parameters, click on the *Click here to change local parameters* button.

- The *mean number of days cycled per year* is the estimated number of days per year that people cycle. This figure has a default value of 124 days per year, which was the reported level of cycling in a study carried out in Stockholm *(14)*. Change this figure only if you have reliable local data, as this will influence the final calculation.
- *The proportion of these trips that are one part of a return journey (or "round trip")* allows the user to adjust the assessment to take account of cyclists who are observed on a route at a specific point in time and who then return on the same route later the same day. This is particularly important for assessments done on routes used for commuting. This adjustment enables the assessment to take account of the number of unique cyclists on each route. The default value is set at 0.9, as it is assumed that 90% of cyclists observed cycling in one direction will be making a return trip later the same day. Setting this figure at 1 assumes that all cyclists will be making return journeys. Change this figure *only* if reliable local data are available.

  Note that, when conducting an audit of existing levels of cycling (for example, assessing the value of all cycling across a city), it is important to set this figure to zero; this means that all trips entered in Step 1 will be assumed to be undertaken by individual cyclists.

- *The proportion of trips undertaken by people who would not otherwise cycle* is a key variable that makes a significant difference to the calculation. It allows the model to take account of the proportion of cyclists who are new users directly as a result of the infrastructure or policy being assessed. This allows for the notion that a certain proportion of cyclists observed on any route will have cycled anyway – irrespective of any change in cycling facilities or policy – so their health is unlikely to have benefited directly. It enables the model to calculate the net increase in physical activity as a result of the increased level of cycling.

Note that the default value is 0.5, meaning that 50% of observed cyclists will be assumed to be benefiting their health through cycling, which is a conservative estimate. For evaluations of existing levels of cycling for example in a city, this can be changed to 1 so that the model assumes all cyclists to be benefiting their health through cycling and not as part of a return journey on a specific cycling path.

- The *mean proportion of the working-age population who die each year* can be derived from published mortality data for people of working age for the study country. Enter the number of deaths among people aged 25–64 per year, divided by the total number of people aged 25–64. This allows the tool to focus on the age groups most likely to cycle, and reflects the relative risk of all-cause mortality in that age group. The default value is set at 0.005847, which is the average for the WHO European Region according to the European Mortality Database *(15)*.
- For the *value of statistical life (in local currency),* enter the standard value of a statistical life used in the country of study (in Euros). This will form the basis of the cost savings in the model. If not known, use the default value of €1.5 million, which is the standard value used across Europe *(7)*.
- For the *discount rate,* enter the rate to be used for calculating the value of future benefits. Savings that occur in future years will be discounted by this percentage per year, and will be shown in the "present value" section of Step 3. As default value, a rate of 5% has been set.

Step 3. Reading the economic savings resulting from reduced mortality

The results of the assessment depend on a number of assumptions.

- The *build-up of benefits* is the estimated time it will take for cyclists in the model to realize the benefits in terms of mortality of the cycling entered at Step 1. The default value is 5 years, based on the results of the systematic review and expert consensus *(3)*. This should be changed only if reliable local data are available.
- The *build-up for uptake* allows adjustment for the estimated time it will take for the level of cycling entered at Step 1 to be achieved. This can be particularly useful for assessing new interventions. For example, if a new cycle path is built and it is estimated it will take 5 years for usage to reach a steady state, this figure should be changed to 5. The default value has been set at 1 year.
- The *timeframe for calculating mean annual benefit* is the period over which the discounted mean annual benefit will be calculated. This is usually standardized within each country; the default value has been set at 10 years.

All of these default values can be changed by clicking on the *Click here to change the timeframe used in calculation* button. However, this should be done only if reliable local data are available.

5.3. Interpreting results

Results are presented in six different ways, depending on the assumptions above.

- The *maximum annual benefit* is the total value per year of lives saved (mortality only), assuming that a "steady state" of health benefits has been achieved. This builds on the value achieved at the end of the "build-up of benefits" period, and therefore assumes that all cyclists will have realized the benefits of reduced mortality due to their cycling. This should always be quoted as a maximum rather than an average value.
- The *savings per kilometre cycled per individual cyclist per year* is the average value for every kilometre that each cyclist rides per year. This figure is €0.81 as long as the default values are used.
- The *savings per individual cyclist per year* value is most sensitive to the distance that cyclists travel on average (with longer average trip length leading to greater benefits).
- The *savings per trip* value is also most sensitive to the distance that cyclists travel on average, with longer average trips leading to greater benefits.
- The *mean annual benefit* is the main output of the model. This takes the period set for the build-up of benefit into account (see above) and averages the benefit over the timeframe for calculation of mean annual benefit. This output is highly dependent on the number of years entered.
- The *present value of mean annual benefit* is the second main output of the model, using the discount rate from Step 2 to calculate the present value, taking the diminishing value of costs and outcomes over time into account.

5.4. Assumptions

The model uses a number of assumptions, which were agreed at the consensus meeting:

- the relative risk data from the Copenhagen Centre for Prospective Population Studies *(11)* can be applied to cyclists in other settings, as suggested by Matthews et al. *(12)*;
- there is a linear dose–response relationship between risk of death and distance cycled (assuming a constant average speed);
- no thresholds have to be reached to achieve health benefits; and
- men and women have the same level of relative risk.

5.5. Advanced data entry

There are a number of features of the tool that can be used to fine-tune the assessment. In general, these should only be amended by users with a good understanding of economic assessment methods. If in any doubt please direct enquiries to hepa@ecr.euro.who.int.

- The *underlying study parameters* used in this tool come from the Copenhagen Centre for Prospective Population Studies, a prospective study on different types of physical activity, including cycling to work and for leisure, on mortality risk. The study included some 30 000 men and women who were followed up for an average of 14½ years and adjusted for a large number of potential confounders. These are critical to the functioning of the tool and should not be changed unless the assessment is to be based on a similarly robust study.
- The parameters average speed and *mean number of days cycled per year* are assumptions based on best available evidence, but could be varied by the user if better local data were available. The speed value is based on hours of commuting per week from the Copenhagen study *(11)* combined with data

from the Stockholm commuting studies *(13, 14)*. Based on an estimated distance of 4 km per trip, the observed distance–speed relationship produces an estimated average speed of 14 km/hour *(16)*.

- The main elements of the *timeframe used in calculations* and the nature of relationship between benefit and time are described above. However, as well as varying the basic elements (time build-up for benefits; time build-up for uptake; time for mean annual benefit calculation) one can also determine whether the relationship between benefit and time is linear, exponential or logarithmic in shape and the strength of the exponential/ logarithmic factor.
- The final button, *Click here to view full calculation, graphs and adjust error*, shows the full calculations behind the spreadsheet as well as all the main outputs in graphical form. The bottom half of the spreadsheet contains a number of slider controls for error adjustment. These can be used to include error margins (or confidence intervals) around any of the entered data. Move the slider until the values correspond with the desired error values. The upper and lower limits will then be shown in the graphs. Note that confidence intervals concerning the relative risk estimates from the underlying Copenhagen study have already been entered, and there is an option to enter them for the mean proportion of the population who die each year.

The *Reset all default values* button restores all the values to their defaults, including values for mean number of days cycled per year, proportion of trips as part of a return journey, and all other key parameters.

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World Health Organization
Regional Office for Europe
Scherfigsvej 8, DK-2100 Copenhagen Ø, Denmark
Tel.: +45 39 17 17 17. Fax: +45 39 17 18 18.
E-mail: postmaster@euro.who.int
Web site: www.euro.who.int