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Health impact assessment of cycling network expansions in European cities

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ABSTRACT

Introduction: Active transport (i.e. walking and cycling for transport) can provide substantial health benefits by increasing levels of physical activity (PA) and help reduce transport-associated emissions. Our aim was to conduct a health impact assessment (HIA) of cycling networks expansions in seven diverse European cities (Antwerp, Barcelona, London, Örebro, Rome, Vienna, Zurich) that form part of the Physical Activity through Sustainable Transport Approaches (PASTA) project. We modeled the association between cycling network distance (km) and cycling mode share (%) and estimated health impacts of the expansion of cycling networks.

Methods: Cycling network distances were computed for 168 European cities using OpenStreetMap data for designated cycling ways. Cycling mode share was available through the European Platform on Mobility Management. We performed a non-linear least square regression to assess the relationship between cycling network and cycling mode share. We performed a quantitative HIA for five different scenarios (S) (10% (S1); 50% (S2); 100% (S3), Go-Örebro (S4) and All-streets (S5)) assessing how an expansion of the cycling network would lead to an increase in cycling mode share and estimated associated mortality impacts thereof. We quantified mortality impacts in terms of changes to PA levels, exposure to air pollution and traffic incidents for the cyclist.

Results: Our results suggest that the cycling network may contribute to a cycling mode share of up to 25% in European cities. A cycling network as that of Örebro (S4; 255 km/100,000 persons) produced greatest health benefits through increases in cycling for London with 646 (95% CI: 397;1012) annual deaths avoided, followed by Rome (224; 95% CI: 133;359), Barcelona (162; 95% CI: 103;248), Vienna (82; 95% CI: 47;133), Zurich (27; 95% CI: 16;42) and Antwerp (3; 95% CI: 2;6). If all 168 European cities achieved a cycling mode share of 25% over 16,000 deaths (95% CI: 9,861;25,763) could be avoided each year. The largest cost-benefit ratios were found for the 10% increase in cycling network (S1) suggesting it to be most cost-effective (Rome € 40:1; Barcelona € 20:1; Zurich € 16:1; Vienna € 11:1, London € 3:1).

Conclusions: Especially in cities with a currently low cycling mode share, expansion of cycling networks may promote increases in cycling mode share. Increases in cycling mode share were estimated to provide considerable health benefits in European cities.

KEYWORDS: cycling, health impact assessment, mode share, mortality, open data

1. INTRODUCTION

There is increasing awareness of the adverse effects of the car-centric urban mobility plans of previous decades (Nieuwenhuijsen and Khreis, 2016). Concerns are sustained on ecological issues such as high levels of pollution, green house gas emissions, the disappearance of natural outdoor environments and their eco-systems, but also on economic issues of congestion costs and financing infrastructure (Marqués et al., 2015; Khreis et al. 2016).

Recently, also the adverse effects on health of our car-centric lifestyles are more holistically recognized (Nieuwenhuijsen and Khreis, 2016) and were estimated to account for a considerable burden of disease (Briggs et al., 2016; Tainio, 2015, Mueller et al. 2016). Not only the risk of traffic incidents, but also other health consequences associated with poor transport planning are increasingly considered, such as impacts on physical activity (PA) levels or exposure to air pollution and noise (Mueller et al., 2016; Rabl and de Nazelle, 2012; Rojas-Rueda et al., 2011).

Promoting a mode shift to cycling for transport has been proposed as a promising strategy in urban environments to overcome aforementioned issues (Mueller et al., 2015). Cycling for transport can substantially increase total PA levels (Foley et al., 2015; Sahlqvist et al., 2013) and is a non-emitting mode of transport. However, to facilitate a shift to cycling, well-designed and safe infrastructure to accommodate cycling is needed (Mertens et al., 2016a).

Recent research evidence indicates positive associations between cycling network distance and cycling mode share (Buehler and Dill, 2016; Habib et al., 2014; Marqués et al., 2015; Schoner and Levinson, 2014; Schoner et al., 2015). Thus, expansions of cycling networks in cities may promote cycling for transport. We were interested in assessing how the cycling network may contribute to improvements in public health in European cities. In particular, (1) we assessed the association between cycling network distance (km) and cycling mode share (%) and (2) how an increase in cycling mode share might alter expected mortality in terms of changes to PA performance, exposure to air pollution and the risk of traffic incidents.

2. METHODS

2.1 Association between cycling network and cycling mode share

2.1.1 Non-linear least square regression

We obtained data on population size, cycling mode share and cycling network distance for 168 cities located in 12 European countries (4 Austria, 7 Belgium, 2 Denmark, 20 France, 47 Germany, 15 Italy, 23 Netherlands, 1 Portugal, 14 Spain, 9 Sweden, 2 Switzerland, 24 United Kingdom) (**Table S1**). Data on cycling mode share and population size were obtained through the European Platform on Mobility Management (EPOMM) Modal Split Tool (TEMS) (EPOMM, 2011). Official spatial administrative municipality boundaries were obtained from the Database of Global Administrative Areas (GADM) (Hijmans, 2009), the UK data service (Office for National Statistics, 2011) or the Swedish lantmäteriet (Swedish Ministry of Enterprise and Innovation., 2016). We used OpenStreetMap (OSM) to compute cycling network distances for all 168 cities using labels of designated, non-shared cycling ways (**Table S2**). We also computed the street network distance (km) for all cities. The 168 cities were chosen based on (1) their geographic representativeness of Northern, Central and Southern Europe, (2) population size ≥100,000 persons, (3) the availability of mode share data not being older than 2006 and (4) the availability of spatial boundaries. Amongst the 168 cities were the seven case cities of the Physical Activity Through Sustainable Transport Approaches (PASTA) project (i.e. Antwerp, Barcelona, London, Rome, Örebro, Vienna, Zurich) (Gerike et al., 2016) (**Figure 1**).

Analyses were conducted in R and Microsoft Excel. Used Rpackages were ggplot2 (Wickham, 2009), ggmap (Kahle and Wickham, 2013), rgdal (Bivand et al., 2016), plyr (Wickham, 2011), ggsn (Santos Baquero, 2016), overpass (Rudis and Lovelace, n.d.), geosphere (Hijmans, 2016a), dplyr (Wickham and Francois, 2016), purr (Wickham, 2016a), raster (Hijmans, 2016b), sp (Pebesma and Bivand, 2005), rgeos (Bivand and Rundel, 2016), tibble (Wickham et al., 2016a), maptools (Bivand and Lewin-Koh, 2016), readr (Wickham et al., 2016b), htmltools (RStudio and Inc., 2016), readxl (Wickham, n.d.), httr (Wickham, 2016b) and lubridate (Grolemund and Wickham, 2011).

We standardized the computed cycling network distance of the 168 cities by population size. We used 'cycling network km/ 100,000 persons' as the explanatory variable and performed a non-linear least square regression to calculate the corresponding cycling mode share (%) with $y(t) = ae^{-be^{-ct}}$, where a is the asymptote (i.e. maximal cycling mode share), b and c are positive numbers, b sets the displacement along the *x*-axis and *c* sets the growth rate (*y*-scaling).

2.2 Health impact assessment

To address our second objective of assessing how an increase in cycling mode share impacts public health we carried out a quantitative health impact assessment (HIA) for the seven PASTA cities. Baseline demographic, transport and health data were available through the PASTA project.

2.2.1 Scenarios

Across different scenarios (S), we assessed how the cycling mode share would change with an increase in the cycling network distance by 10% (S1); 50% (S2); 100% (S3); by how much the cities would need to increase the length of their cycling network to achieve the cycling mode share of the city with the highest cycling mode share (i.e. Örebro) (S4

– Go-Örebro); how the cycling mode share would change if all streets of the city provided cycling infrastructure (S5 – All-streets).

2.2.2 Health impact assessment model

The increase in cycling share and the resulting new cycling trips were assumed to be shifted from previous car (25%) and public transport (75%) trips (Rojas-Rueda et al., 2016). We assumed the new cycling trip to have a distance of 5 km traveled at a speed of 13km/h, as we considered this distance not exceeding the willingness to cycle at a speed requesting a light effort (Ainsworth et al., 2011; Rabl and de Nazelle, 2012). The walking share was assumed to stay constant. Across the scenarios, we were interested in the impact on all-cause mortality due to changes in PA levels, exposure to air pollution for the cyclist and the risk of a fatal traffic incident. Baseline data on all-cause mortality and exposures levels were collected for all seven cities (**Tables S3-S13**).

2.2.2.1 Physical activity

We estimated the impact on mortality due to changes in PA levels resulting of increased cycling. Metabolic equivalents of task (METs) were used as a measure of energy expenditure during PA (**Tables S4-S10**). We calculated the gain in METs resulting of replacing car and public transport trips with the bicycle. A public transport trip was assumed to include a 10 minute walk to/ from public transport (Rojas-Rueda et al., 2012), therefore we considered a 10 minute reduction of PA for each replaced public transport trip.

We assigned the new bicycle trip the speed of 13 km/h with an energy expenditure of 6.8 METs (Ainsworth et al., 2011; World Health Organization, 2014a). The replaced 10 minute walking trip to public transport was assigned the energy expenditure of 3.3 METs (Woodcock et al., 2011). We calculated the difference in METs between current and gained PA for replacing car and public transport trips with the bicycle.

The association between PA and mortality was quantified using a curvilinear exposure response function (ERF) (Relative Risk (RR) = 0.81; 95% CI: 0.76;0.85 per 11 MET-hr/week), applying a 0.25 power transformation (Woodcock et al., 2011). We calculated the RR and the population attributable fraction (PAF) for both baseline PA and gained PA (Woodcock et al., 2011). The estimated preventable deaths for current PA were subtracted from estimated preventable deaths for the additional PA.

2.2.2.2 Air pollution exposure cyclist

Particulate matter (PM) with a diameter of $\leq$2.5 μg/m^3 ($PM_{2.5}$) is a commonly used proxy for air pollution coming from fossil fuel combustion sources (i.e. motorized transport) (Mueller et al., 2015) (**Table S11**).

We considered the altered personal air pollution exposure for the person shifting from car or public transport (including a 10 minute walk) to cycling. Due to immediate traffic proximity, the $PM_{2.5}$ concentration to which car drivers and public transport users are exposed to was set 2.5 and 1.9 times higher, respectively, than the reported background concentration (**Table S12**) (de Nazelle et al., 2017). Also pedestrians and cyclists were assumed to have 1.9 and 2.0 times higher $PM_{2.5}$ exposure, respectively, than background levels due to traffic proximity (de Nazelle et al., 2017). Ventilation rates for different leisure and transport activities were available (Rojas-Rueda et al., 2012). We calculated the daily inhaled $PM_{2.5}$ dose (μg/m^3/24-hr) stratified by activity and the total dose

($\mu g/m^3$/24-hr) stratified by transport mode. For each scenario, we calculated the equivalent $PM_{2.5}$ dose difference between cycling and passive transport (i.e. car or public transport) (de Hartog et al., 2010). We used a linear ERF (RR=1.07; 95% CI: 1.04;1.09 per 10 $\mu g/m^3$ $PM_{2.5}$ annual mean) to quantify the association between $PM_{2.5}$ exposure and mortality (World Health Organization, 2014b) and calculated the corresponding RR and PAF.

2.2.2.3 Traffic incidents

Traffic fatalities were estimated based on injury records and distance traveled. Across the scenarios, for each transport mode the risk of having a fatal traffic incident per billion kilometers traveled was estimated using the annual average number of fatalities and the annual average kilometers traveled in each transport mode (**Table S13**). We calculated the RR of a fatal incident for a 5 km cycling trip compared to a car and public transport trip (including a 10 minute walk) of the same distance.

2.2.2.4 Sensitivity analyses

As sensitivity analyses, we estimated health impacts assuming the new cycling trips to be shifted by 75% from previous car trips and by 25% from previous public transport trips. We also applied a safety-in-numbers effect assuming a less than proportional increase in traffic incidents with increases in traffic volume using the summary coefficient of 0.43 for cycle volume of a recent meta-analysis (Elvik and Bjørnskau, 2017). Finally, we performed a rapid HIA for all 168 cities of our analysis, supposing achievement of the maximal cycling mode share attributable to the cycling network. For model input, we used mean PASTA city transport, exposure and mortality data.

2.3 Cost-benefit analysis

We also conducted a cost-benefit analysis estimating at what possible economic costs the cycling network expansions would come and what the health cost-benefit trade-off might look like. Following the example of the Netherlands, where cycling infrastructure is commonly well-developed we assumed that each additional 1 km of cycling infrastructure would come at costs of € 2 million, which were estimated costs for reconstructing a road with mixed traffic including buying land and reconstructing intersections (Schepers et al., 2015). An additional € 4,000 per km/ year were considered for maintenance purposes (Schepers et al., 2015). We also considered a discounting rate of health benefits of 5% as benefits in the future are less valuable than if they occurred immediately (World Health Organization, 2014a). We applied a time horizon of 30 years (Schepers et al., 2015), as strategic transport plan typically plans for 20-40 years into the future (Litman, 2014) and benefits of active transport a rather long-term in nature (Mueller et al., 2015). We monetized expected health benefits by applying the value of statistical life estimated at € 3,370,891 for EU28 (World Health Organization, 2014a).

3. RESULTS

3.1 Association between cycling network distance and cycling mode share

Örebro and Antwerp showed to have the largest standardized cycling network distance (i.e. 256 and 91 km/ 100,000 persons, respectively) followed by Vienna, Zurich, London, Barcelona and Rome (**Table 1**). Likewise, Örebro and Antwerp reported the largest cycling mode share at baseline (25% and 23%, respectively) followed by Vienna, Zurich, London, Barcelona and Rome (**Table 2**).

The association between cycling network and cycling mode share in European cities is described in **Figure 2**. According to our model and dataset, with a cycling network of 315 km/ 100,000 persons a cycling mode share of 24.7% could be achieved (99.9% of asymptotic value). As in Örebro already 25% of all trips were carried out cycling, no increase in cycling was expected that could be explained by the further expansions of the cycling network. Also in Antwerp where already 23% of all trips were done cycling, the cycling network distance would need to be doubled to achieve a 1% increase in cycling mode share (**Table 3**). The remaining five PASTA cities, however, had great potential to increase their cycling mode share through expansions of the cycling network, even though growth rates were expected to vary depending on baseline cycling network distance and corresponding mode share.

3.2 Estimated health impacts

The PASTA cities were estimated to benefit from an increase in cycling as a result of increases in cycling network distance, except for Örebro, and Antwerp benefiting only to a small extend (**Table 4**). A theoretical cycling network distance as that of Örebro (255 km/100,000 persons) produced greatest health benefits through increases in cycling for

London with 646 (95% CI: 397;1,012) annual deaths avoided, followed by Rome (224; 95% CI: 133;359), Barcelona (162; 95% CI: 103;248), Vienna (82; 95% CI: 47;133), Zurich (27; 95% CI: 16;42) and Antwerp (3; 95% CI: 2;6).

In standardized terms, and throughout the proportional increases in cycling network distance (S1 to S3), Vienna and Zurich reaped most benefits (annually 1 to 3 premature deaths/ 100,000 persons avoided). In the Go-Örebro (S4) and All-streets (S5) scenarios (absolute increases) and in standardized terms, Barcelona, Rome and London reaped most benefits (annually 7 to 10 premature deaths/ 100,000 persons avoided).

Already small increases in cycling network distance (i.e. S1; 10%) provided substantial benefits to health with Vienna benefiting the most in absolute terms with 17 (95% CI: 10;28) annual deaths avoided, followed by Rome (11; 95% CI: 6;17), Barcelona (8; 95% CI: 5;11), London (6; 95% CI: 4;10) and Zurich (4; 95% CI: 3;7). Benefits were due to increases in PA levels that outweighed associated detriments of air pollution exposure and traffic incidents. Across the cities, the mode shift to cycling provided greater risks in terms of air pollution exposure than the expected increase in fatal traffic incidents.

The sensitivity analysis assuming the new cycling trips being shifted by 75% from previous car trips and by 25% from previous public transport trips, showed even greater benefits with the Go-Örebro scenario (S4) resulting in 740 deaths (95% CI: 442;1178) avoided in London, followed by Rome (243; 95% CI: 139;395), Barcelona (180; 95% CI: 113;279), Vienna (93; 95% CI: 52;154), Zurich (30; 95% CI: 18;47) and Antwerp (4; 95% CI: 2;6) (**Table S14**). Also the safety-in-numbers effect provided additional health benefits with 679 deaths (95% CI: 430;1045) avoided in London for Go-Örebro (S4), followed by Rome (231; 95% CI: 140;366), Barcelona (168; 95% CI: 109;254), Vienna (84; 95% CI: 49;135), Zurich (28; 95% CI: 17;43) (**Table S15**). The rapid HIA for all 168 European cities achieving a cycling mode share of 25% resulted in 16,270 avoidable deaths (95% CI: 9,861;25,763) each year (**Tables S16-S18**).

3.3 Estimated cost-benefit impacts

Our cost-benefit analysis showed generally positive cost-benefit trade-offs, except for Örebro and Antwerp where no or only small health benefits were expected. The largest cost-benefit ratios were found for the 10% increase in cycling network (S1) suggesting it to be the most cost-effective scenario (Rome € 40:1; Barcelona € 20:1; Zurich € 16:1; Vienna € 11:1; London € 3:1) (**Tables S19, S20**). In the Go-Örebro (S4) and All-street (S5) scenarios, benefits barely outweighed estimated costs due the huge amount of additional cycling infrastructure required and the time horizon of 30 years almost not being enough time to compensate for the implied costs. Applying a horizon of 40 years, however, showed strong positive cost-benefit trade-offs throughout the cities (except for Örebro and Antwerp).

4. DISCUSSION

In European cities the cycling network may contribute up to 25% of cycling mode share. We estimated that a large number of deaths (1,144 deaths, 95% CI: 698;1,800) could be avoided each year in six of the seven PASTA cities if the cycling network was the same as that of Örebro. Already with a 10% expansion of the cycling network, a considerable number of deaths (47 deaths, 95% CI: 28;73) could be avoided each year in five of the seven PASTA cities, which also showed to be the most cost-effective scenario outweighing estimated costs by 3 to 40 times. If all 168 European cities achieved a cycling mode share of 25% over 16,000 deaths (95% CI: 9861;25,763) could be avoided each year.

To our knowledge, this is the first and largest study evaluating the associations between cycling network, cycling mode share and associated health impacts across European cities. We found the length of the cycling network to be associated with cycling mode share, which coincides with previous research findings (Buehler and Dill, 2016; Buehler and Pucher, 2012; Heesch et al., 2015; Panter et al., 2016). We also estimated an increase in cycling to result in net health benefits, which is also in line with previous research findings (Rojas-Rueda et al., 2016, 2013; Woodcock et al., 2013).

A recent WHO study estimated almost 10,000 deaths avoidable each year in over 50 European cities under the assumption that the cycling mode share of Copenhagen (i.e. 26%) was achieved (WHO. Regional Office for Europe, 2014). Our sensitivity analysis for all 168 cities achieving the estimated maximal mode share of 25% attributable to the cycling network, resulted in over 16,000 deaths avoidable each year and is thus comparable to the WHO estimation, suggesting that cycling does provide considerable health benefits and should be promoted.

The benefits of increases in PA were estimated to outweigh detrimental effects of air pollution exposure and the risk of traffic incidents across the PASTA cities and therefore net benefits of cycling are independent of geographical context (Mueller et al., 2015). In contrast to some studies (Dhondt et al., 2013; Holm et al., 2012; Rabl and de Nazelle, 2012; Woodcock et al., 2014), but in agreement with other studies (Rojas-Rueda et al., 2012, 2011), we found air pollution exposure for the cyclist to be a greater mortality risk than having a fatal traffic incident. This can be explained by our implied modeling assumption. First, cycling a distance of 5 km implies a longer exposure duration than traveling the same distance by car or public transport because of varying speeds. Second, a cyclist has a higher ventilation rate due to the implied physical strain. Thus, a cyclist experiences a higher uptake of pollutants for a longer duration. Moreover, we assumed a public transport trip to include a 10 minute walk to/ from public transport. Across all seven cities, walking was the most hazardous mode of transport (**Table S11**). Hence, the assumption that 75% of the new cycling trips replace previous public transport trips, also shifts the risk of having a fatal traffic incident. The reduced risk of having a fatal traffic incident while walking to/from public transport makes the estimated increased risk of having a fatal traffic incident while cycling appear less severe.

Örebro and Antwerp, which currently have a larger standardized cycling network, likewise have a higher cycling mode share. As the length of the cycling network was estimated to maximally contribute to a cycling mode share of 25%, for Örebro and Antwerp no or only small increases in cycling mode share due to increases in cycling network are expected, which in return results in no or only small health benefits. On the other hand, Vienna and Zurich have great potential to benefit from proportional increases in cycling network distance due to the fact that they are at the steeper slope of the growth curve and thus are more sensitive to expansions in the cycling network in terms of increases in cycling mode share (**Table 3**).

Especially, Barcelona, Rome and London benefit in the Go-Örebro (S4) and All-streets (S5) scenarios. Since both scenarios imply an absolute increase in the cycling network distance, Barcelona, Rome and London benefit especially from the large absolute increase in the cycling mode share (i.e. 2%, 1% and 3% at baseline, respectively). In both scenarios and considering population size, all three cities greatly benefit from the estimated large increases in PA levels, however face health losses due to increased air pollution exposure (especially Rome) and increased fatal traffic incidents (especially Barcelona and London). Generally speaking, the cities baseline levels of PA, air pollution levels and traffic fatalities impact benefit estimations significantly (Rojas-Rueda et al., 2016). Health benefits will be largest if at baseline the population is less physically active, air pollution levels are lower and traffic fatalities occur less. Moreover, the greatest health benefits occur by getting people out of their own cars as seen in the sensitivity analysis, as public transport provides some health benefits through implied physical activity (Rojas-Rueda et al., 2012) and by being the safest mode of transport (Mueller et al., 2015).

Practical policy implications of our findings may be – also under the consideration of the supportive literature – that expansions of cycling networks can contribute to increases in cycling mode share (up to 25%). While other research also provides insight on 'where' cycling infrastructure should be prioritized (e.g. the propensity to cycle tool) (Lovelace et al., 2016), we would like to emphasize ‘that’ it should be prioritized. Especially in cities with a currently low cycling mode share (i.e. Rome, Barcelona, London, Zurich and Vienna), already a 10% increase in cycling network distance, which we perceive as a realistic and achievable policy for city governments, was estimated to provide considerable health benefits and also shows to be most cost-effective. Supporting this notion, previous research has identified designated cycling infrastructure as one of the most important environmental factors for preferring cycling for transport (Heesch et al., 2015; Mertens et al., 2016a, 2016b).

Nonetheless, our study has limitations. Other built-environment, transport and socio-economic factors that determine cycling mode share substantially were not considered, as data on these parameters were not available. Mixed land-use design, street density and connectivity (Beenackers et al., 2012; Cervero et al., 2009; Sallis et al., 2015), car-ownership, individual’s mode choice behavior, proportion of students among the population, urban sprawl, gasoline prices and traffic safety (Buehler and Pucher, 2012; Habib et al., 2014), as well as urban greenery (Heesch et al., 2015; Sallis et al., 2015) have all been associated with cycling mode share. All of these factors were not taken into account in the current analysis, but are expected to alter variability in cycling mode share considerably. In addition, reversed-causality (i.e. a high cycling mode share leading to reinforcement of the cycling network) cannot be ruled-out since no longitudinal data on cycling network and cycling mode share were available. This implies that our results need to be interpreted with caution.

As all HIAs, our analyses were limited by data availability and assumptions on causal inferences. Benefit estimations are sensitive to the contextual setting and underlying population and exposure parameters. The estimated mortality impacts considered exclusively the impacts for the actively traveling person, although, further societal co-benefits of reduced air and noise pollution (Mueller et al., 2016), reduced CO_2 emissions (Woodcock et al., 2009) and improved social cohesion and mental health (Litman, 2016a, 2016b) are expected with reductions in motorized traffic and increases in active transport. Also quality of life or morbidity impacts have not been considered, but are expected to be considerable. Active transport has been suggested as a measure to improve the total urban environment (Rojas-Rueda et al., 2016). In addition, we did not stratify our impact estimations by age, sex, or socio-economic status even though health benefit variations hereof are expected (Mueller et al., 2015)

Strengths of this analysis include the novelty of being the first study to look comprehensively into the association between cycling network, cycling mode share and associated health impacts across Northern, Central and Southern European cities. Using open-access OSM data, which for cycling infrastructure has been described of fairly good quality (Hochmair et al., 2013), and applying the same standardized data extraction method across all cities adds strength to the study and ensures reproducibility. We intentionally decided not to rely on city-level aggregated data that will most likely vary in definitions of cycling network (Buehler and Pucher, 2012).

5. CONCLUSIONS

Especially in European cities with a currently low cycling mode share, expansion of cycling networks can promote increases in cycling mode share. Increases in cycling mode share provide considerable health benefits in European cities, which result of increases in

PA levels that were estimated to outweigh associated detrimental effects of air pollution exposure or the risk of traffic incidents.

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