The benefits of cycling: Viewing cyclists as travellers rather than non-motorists.

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CTS Working Paper 2015:17

Published in Parkin, J. (ed.): Cycling and sustainability, Emerald.

Abstract
Purpose: This chapter provides a think-piece on economic evaluation and policy for cycling. Bicycle investments are often motivated by a desire to improve health, the environment and congestion conditions. However, we argue that since the bicycle is a part of the transport system, it should be evaluated as such. Focusing on implications for cycling appraisal in general, we also discuss two conflicting trends in Stockholm: a sharp decrease in cycling in the outer areas, and a sharp increase in the inner parts.
Methodology: We use i) travel survey data to analyze the potential to reduce congestion through improvements for cyclists, ii) travel survey data from 1986-1987 and 2004 and bicycle counts over 25 years and iii) a value of time survey of Stockholm cyclists including questions of exercise habits.
Findings Additional benefits in appraisal from reduced car traffic and improved health seem to be small. Given bicyclists' high values of time and low investment costs, bicycling investments are still likely to be socially beneficial. The conflicting bicycling trends can be explained by i) increased road congestion and improved bicycle infrastructure, ii) increased visibility of bicyclists generating a 'positive spiral' iii) increased interest in physical fitness and changes in the relative prices of cars versus central residences turn cycling into a high-status mode, iv) in peripheral areas, increasing distances and less dense land use patterns decrease cycling levels.
Practical implications: The results underscore the need for dense, mixed-use spatial planning and 'smart' marketing using the effects of cyclist visibility to reinforce the 'status' of cycling.

Keywords: appraisal, value of time, determinants of bicycling, trends, bicycle, cost-benefit analysis.

JEL Codes: R41, R48.

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1 INTRODUCTION

It appears that cycling has received increasing attention from planners and decision makers in recent years. For example, the EU commission's Green Paper "Towards a new culture for urban mobility" (European Commission, 2007) states that "More attention should be paid to the development of adequate [bicycle] infrastructure". On the face of it, this should not be surprising, considering the many advantages of the bicycle compared to other modes of transport. It is fast, inexpensive and available to nearly everyone; it is space-efficient, both while moving and while parked; it causes hardly any negative external effects such as noise, emissions or accidents; and investments in cycling infrastructure are usually comparatively cheap. So it is not surprising that the cycle provides an excellent option for a traffic planner looking for ways to promote accessibility to a low cost.

What *is* surprising, though, is that bicycle-promoting measures are so often advocated using *indirect* effects. Rather than invoking positive effects on travel costs and travel times – as planners would do for other modes of transport – cycling measures are often motivated by reduced negative externalities of car traffic (congestion, emissions, accidents) or improved population health (reducing overweight, heart diseases etc.). These effects may be significant in some circumstances (we will return to this below), but what is peculiar with this line of argument is that it silently presupposes that the cycle's advantages in itself, as a mode of travel, are not enough to make it competitive. Moreover, the "indirect effects" argument disregards *cyclists as travellers*. Cyclists are only important to the extent that they have become "non-fat non-motorists".

We would argue that this is a weak and possibly self-defeating way to argue for cycle investments – and further, that it also implicitly reveals a discriminating view of different traveller groups, where some travellers' travel times, costs and comfort are more important than others'. It is as if cycling improvements are only worthwhile to the extent that it entices former motorists and non-active people to start cycling – as if solely reducing the generalized cost of cycling has no value. This is in stark contrast to how we motivate and evaluate improvements of other travel modes. Reducing car travel times by reducing road congestion is of course a value in itself. Improving the reliability or comfort of public transport travel is motivated by the benefits for public transport travellers – not because of the value to motorists in reducing road congestion. Resorting to the "indirect effect" line of argument is hence, in its extreme form, discriminating against cyclists. It tacitly assumes that benefits in the form of lower travel times, better comfort or increased road safety for existing cyclists have no value – in contrast to how benefits for travellers with other modes of transport would be viewed.

One reason for the "indirect effects" argument may be lack of self-confidence of cycle promoters: cycling investments can only be important to the extent that they benefit others – motorists (in the form of reduced congestion), urban residents in general (in the form of reduced emissions) or even the healthcare system (in the form of reduced obesity-related diseases). It may have its origin in planning paradigms mainly focused on motorized modes, in particular road transport. This would explain the seemingly pervasive under-investment in cycling infrastructure. Indeed, it seems as if cycling infrastructure does not receive the amount of funding and attention it deserves based on its cost-efficiency compared to other transport modes.

Perhaps one of the reasons for the failure for the bicycle to achieve its rightful position within the transport planning agenda is that bicycle promoters use the wrong arguments: instead of strong, verifiable, "standard" arguments such as short travel times, low transport and investment costs, and low external effects, "indirect effects" arguments are used instead. And if these indirect effects often turn out to be comparatively small (which we will discuss below) –

then it will be no surprise that traffic planners and decision makers are reluctant to commit to cycling investments.

Is it a problem if potentially weak arguments are used to promote a good cause? It may be. If it turns out that the arguments are weak and can be refuted, then the cause may also be lost, or at least discredited. Moreover, the bicycle fits certain travel needs – certain trips, certain travellers, certain situations – but not others. Only by understanding the true strengths and weaknesses of the bicycle can good planning be achieved.

In section 2, we describe the interesting development of cycling in Stockholm over the last two decades, and discuss what underlying factors seem to be driving these trends. Section 3 is devoted to discussing cost-benefit analysis of cycling investments and policy measures. We review values of travel time and discuss "additional benefits" (car traffic reductions and health benefits), again using evidence from Stockholm. The final section provides a discussion and conclusions.

2 DEVELOPMENTS AND DETERMINANTS OF CYCLING IN STOCKHOLM

One of the mysteries of cycling is the large discrepancies in cycling levels between countries that appear similar in terms of geography, climate and topology. For example, 25% of all trips in The Netherlands are made by bicycle, compared to 8% in Belgium and 3% in France. Cycling represents 4% of trips in Norway, compared to 9% in Sweden and 15% in Denmark (Bassett Jr, Pucher, Buehler, Thompson, & Crouter, 2008). In this section, we present and discuss the development of cycling in Stockholm. This may sound rather particular, but it is interesting since it reveals two conflicting trends: a sharp decrease in cycling in the outer areas (especially among youth), and a sharp increase in the inner parts of the region (especially among women). We will discuss what factors may be behind these trends, focusing on policy conclusions relevant for other cities as well.

We base this section on data from two separate travel surveys conducted in Stockholm County during the years 1986-1987 and 2004. Both surveys provide data at the level of the individual and utilize mail-back travel diaries that represent the total daily travel for the individual respondent. Both surveys have sought a representative sample for the Stockholm County with respect to disparities between different geographical parts of the county. Weekdays and weekends are represented in the same proportion in both surveys.

2.1 Cycling in Stockholm – where, who and why

The county of Stockholm consists of an urban core (the city of Stockholm and a few surrounding municipalities) with approximately one million inhabitants and a surrounding area with another million inhabitants. The urban core is densely populated, while the periphery consists of some relatively densely populated parts along the commuter train and subway corridors, and some sparsely populated parts with mainly single-family housing and poor access to public transport. Central Stockholm is built on several islands connected by bridges, which means that travelling distances are relatively long and road congestion high, compared to other moderately sized cities. The public transport system is well developed, with public transport shares to the inner city reaching 75% during peak hours.

In Stockholm County as a whole, cycling has decreased in the last decades. Figure 1 shows the number of cycling trips per day in 1986 compared to 2004. However, the aggregate figures hide two opposing trends: an increase in cycling in the inner city and the inner suburbs, and a decrease in the outer suburbs. The declining trend in the outer suburbs is particularly pronounced for young people (12-17 years), where the number of cycling trips per day has been halved in two decades. Previous research indicates that cycling at a young age is a good predictor for cycling when older: hence, it seems likely that this decreasing trend will continue and even accelerate.

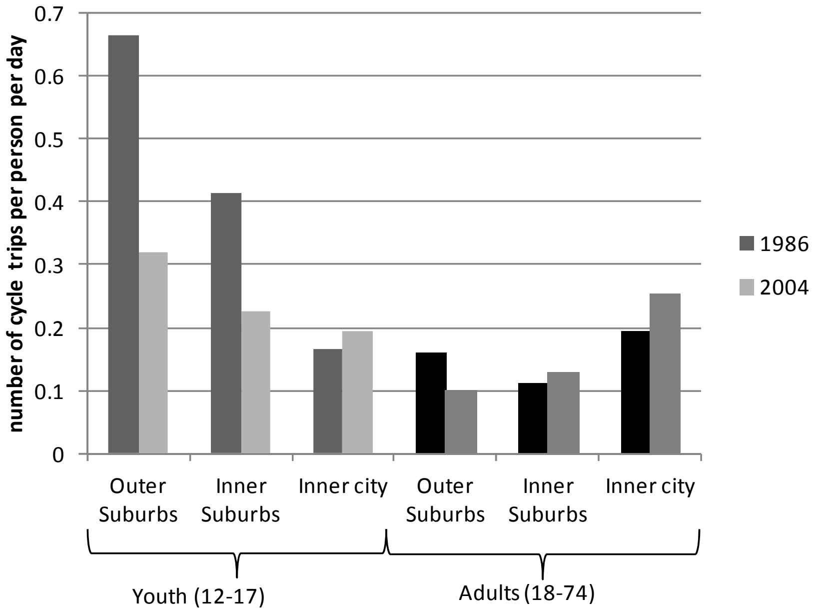

Figure 1. Bicycle trips per person per day, by age group and residential area (Stockholm travel surveys 1986 and 2004).

While cycling has decreased in the outer suburbs, it has increased in the inner suburbs and especially in the inner city for both young people and adults. The increase is largest for women in the inner city, whose cycling frequency has increased by around 50% over two decades.

This trend becomes even clearer when looking at bicycle counts at the cordon around the inner city (Figure 2). The numbers are more variable than the travel survey data, since the counts are only undertaken during a limited period each year. To reduce random variation due to weather and other effects, the diagram shows a five-year moving average. The number of cyclists crossing the city cordon has more than doubled in 20 years, and the growth has become faster over time. In relative terms, the increase is particularly large during the winter months.

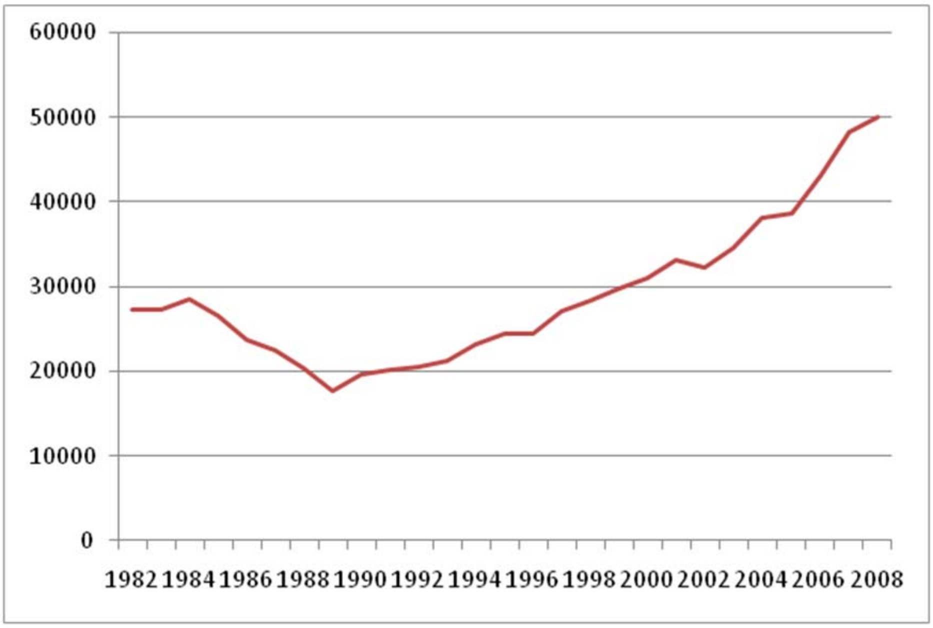

Figure 2. Five-year moving average of May count of number of cyclists per day across the Stockholm inner city cordon.

In a survey in 2008, Stockholm cyclists were asked to state their most important reason for having chosen to cycle. Perhaps surprisingly, the most common reason mentioned for cycling was "exercise" (Figure 3). The older the cyclists, the more important the exercise argument becomes – but it is quoted as the most important reason to cycle in all age groups. The classic reasons "speed" and "flexibility" came in as the second and third most common reasons for cycling, confirming the competitiveness of the cycle in terms of travel speed. The fourth most important argument was that cycling is "inexpensive"; and this was important primarily for younger cyclists.

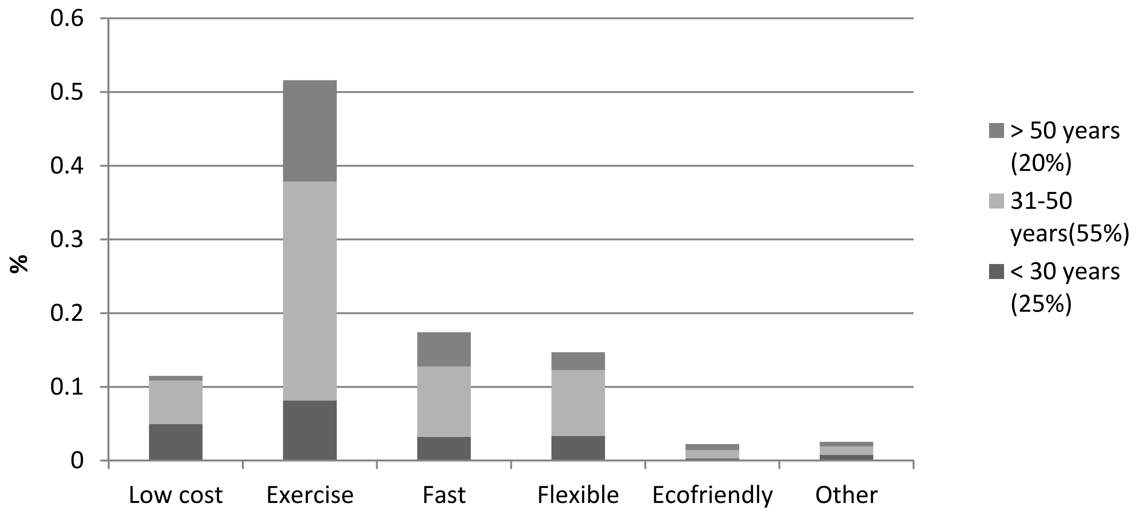

Figure 3. Most important reasons for cycling by age group (Stockholm survey, 2008).

Several studies have shown that cyclists often have high values of time (see further below). This may partly explain the large share of people choosing to cycle primarily for the exercise: it saves time. Half of the cyclists in Stockholm state that they if they did not cycle, they would spend more time on other forms of exercise.

2.2 Explaining cycling trends in Stockholm

The previous section showed that cycling has declined in the outer suburbs of Stockholm over the last decades (especially among young people) while it has increased in and around the inner city, and that the increasing trend in the inner city is becoming stronger over time. What may explain this?

Determinants of cycling can be grouped into four partially overlapping categories: the generalized cost of cycling; urban form and land-use patterns; socioeconomic factors; and cultural variables such as attitudes and preferences. (A recent literature overview can be found in Heinen, van Wee, & Maat, 2010).

The *generalized cost of cycling* is affected by several factors (see e.g. Goetzke & Rave, 2011); Pucher & Buehler, 2006); Pucher & Buehler, 2010); Rietveld & Daniel, 2004)). First, there are infrastructure factors, such as the number of stops at traffic signals and crossings, and the prevalence of bicycle lanes and bicycle parking facilities. Second, there is the level of traffic safety for cyclists, which obviously depends on the infrastructure, and also on general streetscape, motor traffic speeds, attitudes of motorists and the number of cyclists on the streets (car/cycle accidents decreases the more cyclists there are; see Jacobson, 2003). The third factor is the topography of the city: hillier cities have fewer cyclists, all other things being equal. Obviously, the hilliness of a city is difficult to change, but in fact, the "actualised" topography of routes in a city is to some extent a policy variable: it is to some degree influenced by the steepness of bridges (which can be influenced), and the location of destinations. The competitiveness of the bicycle also depends on its relative generalized cost compared to other modes: higher driving costs, high road congestion and poor public transport all tend to increase bicycle use.

In Stockholm, there have been considerable upgrades made to cycling infrastructure in the last decade, especially in and around the inner city. This is likely to be one factor behind the increase in cycling in central Stockholm – although most likely not the most important one. The generalized cost of cycling relative to other modes is declining, since road congestion is increasing and public transport crowding has become a significant problem during peak hours. For peak-hour trips in the inner city and the inner suburbs, the bicycle is a very competitive mode in terms of travel time. This is evident from Figure 4, which shows the areas within which one can travel to the Central Railway Station within 30 minutes with different travel modes during the morning peak.

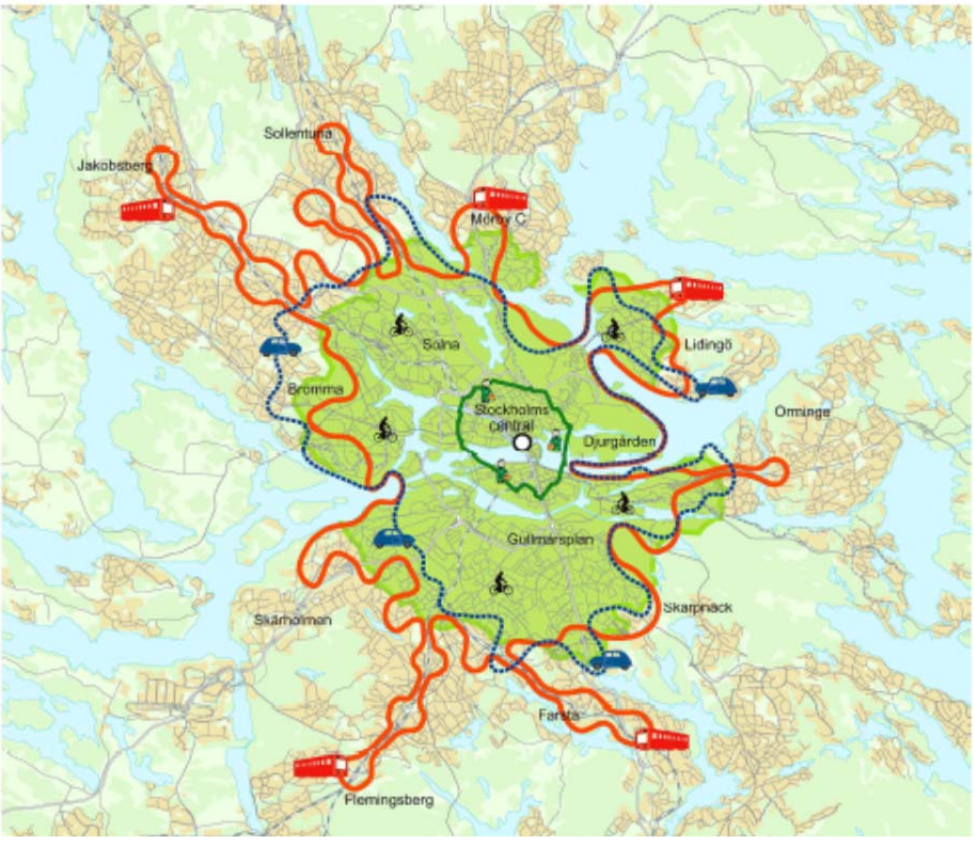

Figure 4. 30 minute isochrones to Stockholm Central Station during the morning peak. Walk (green line), cycle (green area), car (blue line) and public transport (red line).

Urban form and *land-use patterns* are among the most important determinants of cycling (see e.g. (Pucher & Buehler, 2006), (Pucher & Buehler, 2010)). A well-planned, dense land-use pattern will create short distances between origins and distances. In a sprawling city, the bicycle will eventually lose its competitiveness. While infrastructure measures such as bicycle lanes can, as a means of last resort, be built as an after-thought if they are neglected during the planning and building of new parts of a city, land-use patterns change very slowly, and once established become very difficult to change. This means that planners, in particular in growing cities, need to think decades ahead to a time when the city areas which are new and peripheral become well established and more central compared to other even more peripheral future areas. In other words, land use must be planned more densely than is called for in the short-term perspective, if cycling is to maintain its competitiveness in the long run.

Having compact cities will become increasingly important as increased specialization of labour markets, production and consumption all increase the demand for accessibility. In low density areas, travel distance has to increase proportionally more to attain a given increase in accessibility. The trend for increases in trip distances – which is a long-term trend which has been evident for centuries in all developed countries – tends to weaken the competitiveness of the bicycle, in particular when density is low, since its relative comfort and speed advantages decrease at long distances. Land-use planning aiming at creating compact cities is a prerequisite for keeping the increasing demand for accessibility – a trend which is unlikely to slow down – from resulting in ever longer trip distances, with obvious detrimental consequences on congestion, environment, energy use and quality of life.

In Stockholm, as in many other countries, there is a clear long-term trend of increases in travel distances for all trip purposes owing to specialization in trip end activity. Trip lengths are increasing for all modes. Moreover, there is a long-term trend of mode switching from low-speed to high-speed modes. Hence, as travel distances increase, cycling tends to lose market share to car and public transport. The decline in bicycle use is particularly pronounced in the peripheral areas, where travel distance has to increase proportionally more to meet increased demand for accessibility, compared to inner, denser parts. The increase in travel distances seems to be the main driver behind the decline in cycling in the outer suburbs.

The increase in distances is larger for young people: their average trip length has increased from 5.8 to 9.9 km/trip in the period 1986-2004. Trip lengths for the journey to school have increased the most, from 4.1 to 9.5 km/trip, but the trip length has increased substantially also for other trips, from 6.2 to 10.0 km/trip. The increase in school trip lengths is most likely a result of the "school choice" reform, which has allowed children and young people to choose their school without geographical restriction. Increasing trip distances explain the steep decline in cycling among young people. However, the increase in bicycle use in the inner city demonstrates that within a compact centre, increased demand for accessibility need not necessarily lead to substantially longer travel distances or decreasing bicycle use.

Socioeconomic factors also affect cycling. Traditionally in Sweden, young people and low-income groups cycle more, all other things being equal. To the extent that this is because these groups have lower car availability, increasing car ownership will tend to decrease cycling shares. Nevertheless, increasing car ownership does *not* seem to be the cause of falling cycling levels among Stockholm's young people. As Figure 5 shows, cycling levels have decreased by around half for all categories of car ownership for young people. The diagram also shows the counterintuitive fact that cycling actually increases with increasing car availability for youth. This is because high car availability is strongly correlated with residential location and type – car availability is much higher in peripheral locations and for families in single-family houses.

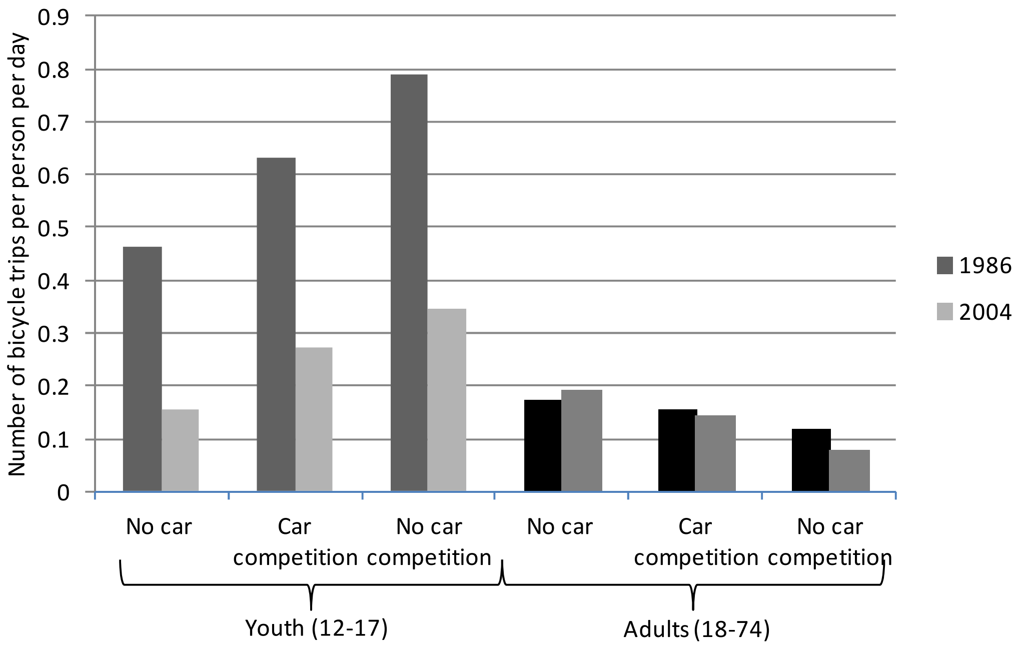

Figure 5. Bicycle trips per day, by age group and car availability (Stockholm travel surveys 1986 and 2004).

There is no correlation between income and cycling levels irrespective of age or residential location. Hence, it is not the case that people "only cycle if they cannot afford a car". This observation becomes even more interesting when we move away from socio-economics into a consideration of cultural factors.

The most intriguing, but so far the least well-studied, determinants of cycling are *cultural factors* –general attitudes to cycling, such as views on status, social connotation and the extent to which people actively consider the bicycle as a travel option. Cultural factors are probably the main reason behind the fact that seemingly similar cities and countries may develop very different levels of cycling. Cultural aspects relate both to attitudes of travellers and attitudes of planners – see the interesting discussion in Chapter 2 which discusses among other things why the planning cultures in The Netherlands and Denmark developed in a different direction than in surrounding countries.

Goetzke and Rave (2011) show that "bicycle culture" affects cycling levels in German municipalities. A similar finding is obtained by Vandenbulcke et al. (2011), who show that high rates of bicycle use in one municipality stimulate cycling in neighbouring municipalities. Goetzke and Rave define "bicycle culture" as three types of spillover effects: improved safety through "strength in numbers", establishment of social norms, and an "information" or "awareness" effect. The latter may be dubbed a "choice set effect": it can be conjectured that the higher the number of cyclists in a city, the more people will, actively or subconsciously, consider the bicycle as an option when deciding how and where to travel. In other words, the bicycle will be included in the traveller's "choice set".

To the cultural factors mentioned above, we would like to add a hypothesis that can be called the "post-car status effect". We conjecture that while bicycle *used to* be a low-status signal - "I can't afford a car, so I have to cycle" – this changes in a society where everyone can afford a car, housing prices in central locations are high, and health and fitness are increasingly important signals of social status. In such a society, cycling to work instead signals "I am healthy and fit and I can afford to buy a house so close to the city centre that I can cycle there". In other words, the status of cycling has to do with the relative price increase of centrally located residences compared to car prices. While the relative prices of cars have decreased with rising incomes, relative prices of central residences are soaring in major cities. Hence, saving travel time by buying a central residence is far more expensive than saving time by buying a car, and it is hence a stronger signal of wealth. Add to this the increasingly strong connection between physical fitness and social status, and it seems likely that cycling as a status signal will grow in importance.

Although our conjecture that the status of cycling increase over time is still only supported by anecdotal evidence, it seems inevitable that the rapidly changing relative cost of car ownership versus cost of proximity to the city centre would lead in this direction. Improved status would be one driver of the development in Stockholm, where affluent, middle-aged car owners cycle to a much larger extent than a decade ago. The status effect would also explain why this development is only visible in central locations: by cycling to a workplace in the inner city, you signal that you can afford to live in central areas. If, in addition to this, you have a family and hence likely own a house or a large apartment, this signal becomes even stronger – which is consistent with the fact that cycling increases the most for middle-aged people.

In summary, the cycling trends in Stockholm – decreasing in the peripheral areas but increasing in the central areas - seem to be explained by the following factors:

- Improved cycling infrastructure, especially in the inner city, has lowered the generalized cost of cycling
- Increasing road congestion and public transport crowding have lowered the relative cost of cycling
- Increasing specialization of labour and consumption increases travel distances and therefore weakens the competitiveness of the bicycle. This effect is strongest in peripheral, low-density areas. Distances in central, high-density areas are less affected because increasing demand for accessibility translates, to a lesser extent, into substantially longer travel distances.

- The increase in travel distances, and hence in cycling frequency, is particularly strong for young people in peripheral areas. This is most likely amplified by the school-choice reform of the 1990s.
- Increasing income and car ownership does not seem to reduce the frequency of cycling
- Spillover effects in terms of safety through numbers, establishment of social norms and the "choice set effect" may have triggered a spiral of increasing cycling
- The "post-car status signal" effect may vastly increase the social status of cycling, which may be particularly strong among affluent people living close to the city centre

From this, a number of policy conclusions can be drawn:

- It is possible to promote cycling through better infrastructure. As we will discuss below, cycling investments are often very cost-efficient compared to investments in other modes.
- As cities grow and increased specialization drives up the need for good accessibility, it is of paramount importance for the competitiveness of cycling to plan land uses well – for instance through dense and mixed land-use. The planning horizon must be set decades ahead, since established land-use patterns are difficult to change.
- Marketing efforts, making more people aware of the bicycle and considering it as an alternative, may prove to be very effective. Targeted information, role-models and increased visibility of cyclists should be most effective.
- Positioning the bicycle as a high-status travel mode, for instance through marketing and role-modelling, will probably become more feasible as the bicycle becomes increasingly associated with high-status signals, such as physical fitness and central residential locations.

3 CYCLING APPRAISAL

Cost-benefit analysis (CBA) has long been a fundamental method for traffic planners trying to identify investments and measures that give the most value for the given budget. The basic idea is to identify the effects of a given measure, value them in monetary terms and add them together. The ratio between the net benefits and the cost of the measure can then be used to rank different investments with respect to value for money. The effects in a bicycle CBA consist of accessibility benefits (travel times, comfort etc.), safety benefits, health benefits and reduced external effects from other modes (such as decreased emissions and congestion from road traffic).

Computation of the value of accessibility improvements requires a valuation of cycling time reductions, and (if applicable) valuations of other factors such as prevalence of bicycle lanes, frequency of stops etc. Börjesson and Eliasson (2010) estimate the value of cycling time reductions to 16 €/hr for cycling on a street and 10 €/hr for cycling on a separate bicycle lane, using stated preference (SP) data. Wardman et al. (2007), combining SP and revealed-preference (RP) data, estimate a value of 12 €/hr. Stangeby (1997), also using SP data, finds a value of time of 10 €/hr. Compared to values of time on other modes, these values are fairly high. This is not surprising, though, considering that cycling is after all a more onerous activity than going by car or public transport. The high values of time will mean that accessibility benefits of cycling improvements will result in high social benefits.

The general comfort of the trip influences the valuation. Hopkinson and Wardman (1996) estimate the value of separate paths for cyclists to 3 €/trip relative to no cycling facilities. Börjesson and Eliasson (2010) estimate the value of bicycle lanes to be 6 €/hr. They estimate the value of bicycle parking to nearly four cycling minutes, and the value of waiting time at intersections to a little more than twice the value of cycling time.

The value of *safety benefits* for cyclists is to some extent captured by the valuation of bicycle lane facilities and the like. But just as with other modes, safety benefits can also be valued using engineering relationships between accident rates and infrastructure design, and then mortality and injury rates can be valued using the standard valuation of statistical life.

Investment costs of cycling facilities are often low compared to most other travel modes. While investment costs for bicycle paths can vary widely, a typical value could be 6 MSEK per km (City of Stockholm, 2002). Using the Börjesson and Eliasson estimate of bicycle path valuation, and typical CBA assumptions[1], this would mean that bicycle paths are socially profitable at average cycling volumes of a little less than 300 cyclists per day – which in urban contexts is very low. Major bicycle paths can easily carry 3000 cyclists per day, which gives an incredible benefit/cost ratio of around 13. Note, however, that this is excluding the opportunity cost of land, which in urban contexts can be a considerable cost.

In recent years, much attention has been given to the "additional benefits" of increased cycling, in terms of reduced car traffic (and hence reduced emissions and congestion) and health benefits. For example, Saelensminde (2004) and CBA practice in Nordic countries (Krag, 2005); Saari & Metsäranta, 2005); Swedish Environmental protection Agency, 2005) argue that additional health effects constitute a major benefit in bicycle CBA, and the World Health Organisation has published a guide to quantify health benefits in economic terms (WHO, 2011). The next two sections are devoted to discussing the likely magnitude of the "additional" benefits.

3.1 Benefits of reduced car traffic

At least in public debate, cycle improvements are often motivated by the need to reduce car traffic. There seems to be great expectations that improvements for cyclists will entice significant numbers of car drivers to switch to the bicycle, thereby reducing congestion, emissions, noise and accidents. Reductions of external costs from car travel should obviously be added to bicycle CBA. On the other hand, a significant portion of the external costs are already internalized through fuel taxes (with the exception of congestion costs), and it is only the non-internalized part of the external cost that should be added to the CBA[2]. Outside congested urban areas, external costs of private car traffic such as noise, emissions, accidents and road maintenance are almost entirely internalized through fuel taxes in Sweden (Wieweg, 2011), and hence, the potential social benefits of reducing car traffic by improvements for cycle traffic is less than sometimes expected. The rate of internalization varies between countries, however, and this conclusion is thus country-specific.

To what extent cycling improvements reduce car traffic will obviously depend on the cross-elasticity between the car and the bicycle. Compared to its ubiquitous presence in public debate, this figure is surprisingly little studied. Rietveld and Daniel (2004) conclude that the bicycle competes primarily with public transport, while the bicycle/car cross-elasticity is low. Wardman et al. (2007) reach the same conclusion, showing that a set of policy measure forecasts to double cycling volumes only reduce car traffic by 5%. Börjesson and Eliasson (2010) find that only 13% of Stockholm cyclists quote car as their second-choice mode, implying that an increase in cycling is not likely to consist of former car drivers to any considerable extent.

We will provide some evidence from Stockholm concerning the potential of reducing congestion by improve conditions for cycling. Instead of studying cyclist's preferences, we will directly estimate the potential to achieve significant reductions in car traffic by diverting motor car users

[1] 40 years investment lifespan, 4% discounting rate, 1% yearly traffic growth, average cycling speed 14.5 km/h, conversion factor from producer to consumer prices 1.21.

[2] In Swedish CBA practice, this is handled by presenting the total changes in external costs (emissions etc.) in the CBA, and then adding changes in fuel taxes to the CBA as well. In this way, only the non-internalised parts of the external costs remain in the CBA. Other countries may have other practices.

to the bicycle. The most important characteristic of the trip is in this respect the travel distance. It is unlikely that even very good bicycle facilities could attract a major share of car drivers with trips longer than, say, 15 km. For shorter trips, however – say, 5 km or shorter – the potential to make car drivers switch modes should be high. Hence, we explore the potential for reducing car traffic on the most congested routes by studying the share of this traffic that is made up of vehicles making short trips (5 km or shorter) and moderate-length trips (15 km or shorter). The potential for achieving benefits from emission reductions by diverting car users to the bicycle would be highest in the inner city, partly because exposure to low air quality is highest there, and partly because average trip distances are short. Hence, we also study the share of short and moderate-length car trips in the inner city.

Realistically, not all car trips can be replaced by cycle trips, even for short distances. We assume that trips with main purpose "grocery shopping" and "giving someone a lift" cannot be undertaken by bicycle. Further, we assume that of the remaining car trips, 50% would be an optimistic but not completely unrealistic estimate of the potential share of car trips that could be diverted to bicycle, while the remaining 50% of car trips will not change to bicycle irrespective of policy measures and improvements, due to factors such as luggage, need to have access to car during the day, physical constraints etc. (As a comparison, Wardman et al. (2007) found that 60% of all respondents could in principle consider going by bicycle.) With these assumptions, Table 1 shows the maximum reduction in car traffic.

Table 1. Decrease of motor traffic volume if half of car trips up to given length switch to the bicycle.

Travel distance	Arterials to/from the inner city	Vehicle kilometres within inner city
Up to 5 km	0.3 %	2 %
Up to 10 km	3 %	7 %
Up to 15 km	8 %	11 %

The general conclusion is that the potential for bicycle promotional measures to lead to significant reductions of car traffic is limited. First, we can conclude that moving only short or medium-distance trips (below 5 or below 10 km) would lead to hardly any measurable congestion reductions, even if one reached the rather optimistic market potential that 50% of all such car trips switched to bicycle. Aiming for moderate-length trips (up to 15 km), the market potential becomes large enough to have a small but measurable impact on congestion and emissions, but given the optimistic nature of the estimated market potential, it seems foolhardy to claim that improvements for cyclists can reduce road congestion to any significant extent.

This conclusion is in accordance with most of the research literature, but stands in stark contrast to the hopefulness often encountered in public debate about the possibility for reducing car traffic through bicycle improvements. At least two reasons for this hopefulness can be identified. First, it is not uncommon that debaters confuse the share of "short trips" of *all car trips* with the share of "short trips" of *vehicle kilometres*. While "short trips" make up a considerable share of all car trips, it represents only a small share of vehicle kilometres – and the harmful effects of car traffic are, generally speaking, proportional to vehicle kilometres, not the number of car trips. For example, emissions are almost directly proportional to vehicle kilometres; and congestion and accidents depend on the number of cars on given links, which in turn depends on vehicle kilometres. Second, a considerable part of road traffic consists of professional traffic – lorries, business trips, taxis, buses etc. Depending on the time of day, this share can reach 30-50% of traffic in central areas. The potential to move these trips to bicycle is very limited indeed.

In conclusion, we should point out that increased volumes of cycling may have long-term effects on land use, car ownership, and urban form and infrastructure that may be larger than the short-term effects that have been the focus here. For example, if cycling levels are high, shops and workplaces may tend to cluster in cycling-friendly locations – whereas if car is the dominating mode, 'sprawl forces' will be stronger. The structure of a compact city will then continue to benefit cycling, creating a virtuous circle. This being said, it seems dangerous to have high hopes that cycling promotional measures can significantly reduce problems with car traffic – since such an argument may harm bicycle promotion in the long run if expectations are not met.

3.2 Health benefits

In recent years, increasing attention has been given to the potential health benefits of increased cycling. It is well established that these benefits are considerable, ranging from impacts on obesity to heart diseases and cancer (Oja et al., 2011), (de Hartog, Boogaard, Nijland, & Hoek, 2010). There are difficulties in estimating how large the health benefits of increased cycling are, however, since the magnitude of the effects depend on the characteristics of the "new" cyclists, such as their previous exercise and health levels, diet, lifestyle and genetics. There is likely to be an effect relating to self-selection further confounding observed effects. Hence, it is a difficult task to translate an observed increase in aggregate cycling levels into health effects, since such information about the "new" cyclists is seldom available.

Nevertheless, the correlation between cycling and health is well established, and for this reason, various authors have claimed that health benefits will constitute a major part of the social benefits of cycle investments ((Saelensminde, 2004); (Krag, 2005);(WHO, 2011)). But whether health effects should be added as additional benefits in a cost-benefit analysis depends on the extent to which they are already factored in when people make their decision concerning how much to cycle (if at all). If, hypothetically, travellers do consider the health effects they will get from cycling, and make an accurate judgment of them, then the health benefits will turn up as part of the consumer surplus – both as increased demand for cycling and as a lower value of cycling time – compared to a situation where travellers do not consider health effects. Adding health effects to the social benefits of cycling improvements will hence be double-counting, if (but only if) cyclists already factor in the health effects they are getting. The size of "additional" health benefits in a cost-benefit analysis depends on four factors: the extent to which cyclists get health benefits out of their cycling; the extent to which improvements for bicycle traffic increase volumes of cycling[3]; substitution between cycling and other forms of exercise; and the extent to which cyclists take health effects into account when making their travel decisions.

A survey in Stockholm from 2008 sheds some light on this (Börjesson & Eliasson, 2010). For the cyclists in the survey, cycling is an important exercise form for cyclists. For most, cycling is their primary form of exercise: more than 60% of cyclists exercise less than 2 hours per week apart from cycling. However, the additional health benefits from increased cycling may to some extent be reduced by the fact that cycling is a substitute for other forms of exercise. Moreover, cyclists exercising more than four hours a week in addition to the cycling get considerably less additional health effects out of their cycling. We can estimate the magnitude of these effects by noting that around 60% of the cyclists state that they would exercise more if they cycled less, or that they already exercise considerably in other forms (more than 4 hours a week). Older cyclists are overrepresented in this group, and since they are the ones who get the most health benefits out of cycling, the potential total health benefit is reduced by up to 60%, depending on the rate of substitution between cycling and other forms of exercise.

The most difficult question is to what extent health benefits are internalized, i.e. to what extent travellers take health benefits from cycling correctly into account when making their travel choices. To shed some light on this, note that more than 52% of the cyclists state that exercise is the most important reason to choose bicycle. This share is even higher for older cyclists: for cyclists over 50 years of age, 61% state that exercise is the most important reason for choosing

[3] Ideally by getting more people to start cycling, i.e. not primarily by making current cyclists cycle more.

bicycle. Clearly, older cyclists take health benefits into account, although they may over- or underestimate these health benefits. Obviously, other cyclists may also consider health effects when choosing mode, even if exercise was not their most important reason. If there is a difference between the two groups regarding the extent to which they consider health effects, this should show up as a lower value of bicycle time for the group that quote exercise as the most important reason to cycle. But the value of time estimates of the two groups (based on an SP exercise in the same survey) were in fact not significantly different. Hence, there is no evidence that the group stating other reasons than exercise as the primary reason for cycling disregard the health effects of cycling.

Hence, it seems that health benefits are to a large extent internalized in travellers' decisions. However, there is an important exception to this: children and young people. It would be unrealistic to assume that children (and their parents) and young people can fully appreciate the long-term health benefits of cycling. In particular, they are almost certainly underestimating the long-term benefits of establishing exercise and mobility habits (which are large, see e.g. (Mackett, 2010)). To state it in the language of economics, they are not rational decision-makers from a lifecycle perspective, both because of lack of information and almost certainly because they apply discounting factors that are too high – they underestimate the value of their own long-term benefits.

4 CONCLUSIONS

In the last decade, cycling has increased rapidly in the central parts of Stockholm. At the same time, the decreasing trend in cycling seems to continue in the outer parts of the region. We argue that both these trends are examples of factors influencing cycling that have been identified in earlier literature. In the central parts, increased road congestion, public transport crowding and improved cycle infrastructure have lowered the generalized cost of cycling relative to other transport modes; spill-over effects seem to generate a positive spiral; and we conjecture that increased interest in physical fitness and changes in the relative prices of cars versus central residences are beginning to turn the bicycle into a high-status mode of transport. In the peripheral parts, on the other hand, increasing travel distances and sparser land use patterns combine to decrease cycling levels.

From a policy perspective, this underscores the need to increase cycling levels through dense, mixed-use, walk/cycle/public transport oriented planning, and by "smart" marketing using the "choice set" effect of visibility and social networks, and reinforcing a possible "status" effect.

We have argued that cycling investments are often highly cost-efficient from a social profitability point of view, given cyclists' high values of time, the generally low investment costs and that bicycle travel makes effective use of valuable urban land compared to other modes. However, we have also argued that the size of "additional benefits" in the form of reduced car traffic and health benefits are likely to be relatively small.

To conclude, we argue that the many advantages of the bicycle – speed, space-efficiency, low investment and travel costs, no external costs, health effects – means that it deserves to assume a more important role in the transport system, and receive more attention from spatial and transport planners. But we also argue that to achieve this, cycle promoters need to focus on the bicycle as a highly efficient means of transport, and not reduce it to a second-best remedy for obesity or climate issues. Not only do such arguments risk being harmful to cycle policy in the long run, if exaggerated expectations are not met; it is also discriminating against cyclists as travellers, since improvement measures are only judged according to the number of former motorists or non-active people it attracts, placing no value on benefits for existing cyclists. After all: cyclists are travellers, not just non-fat non-motorists.

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