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Annex I:

Literature search bicycle use and influencing factors in Europe.

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BYPAD
BICYCLE POLICY AUDIT

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Content

1 BENEFITS OF CYCLING

The European Union promotes sustainable transportation (@@white paper and green paper). Sustainable development in general constitutes of 3 pillars: economic development, social development and ecological development. For transportation issues these pillars can be translated into an improved accessibility and welfare (economic development), social equity, health and safety (social development) and an efficient use of natural resources and prevention of pollution (ecological development) (@@Mobility plan Flanders). In each of these domains an increased bicycle use can contribute to reaching the goals.

Mobility is a basic right for everyone. Mobility however is often equated with driving a car. When the right of mobility is confused with the right to use a car no matter what, problems will arise. Cars are partly responsible for the misuse of urban space, consume enormous resources and are a burden on the environment (Dekoster & Schollaert, 1999). Pollution constitutes not only a threat to our historic heritage but is also and above all a health hazard through both atmospheric pollution and noise. A reduction in car use has become necessary if mobility in cars is to be maintained. Cycling is hereby one of the alternatives. An increased bicycle use has many advantages, both for the individual, society and the (urban) environment. Some of these advantages come from cycling itself, other arise when decreasing automobile use in favor of bicycle use.

1.1 Ecological development

In this first section we will discuss the tremendous benefits of cycling instead of car driving for a sustainable ecological development. Cycling is clean and uses the scarce space in a very efficient manner, thereby putting a minimal strain on the (urban) environment.

1.1.1 Low polluting

Cycling is crucial to improve the livability of our cities and towns. Their impact on the environment is much smaller compared to that of cars. The bicycle emits nothing into the atmosphere and is virtually silent. It poses very little threat to the health and safety of other road users, or to the integrity of the environment (Tomlinson, 2003).

Cycling is the most energy efficient way of propulsion (@@Cycling science). A cyclist only needs about $1/5^{th}$ of the energy needed by a pedestrian to travel over 1 km. And although it doesn't take the car driver himself much effort to cover that distance, the car needs @@times more energy to bring the driver (and other occupants, on average maybe 75 kg per person) there, mainly because, besides the passengers it has to move a dead weight of (often) well over 1 ton over the same distance. Furthermore the energy needed for this task comes from gas that has to be imported from oil producing regions. Cyclists can therefore help to reduce our dependency on fossil fuels.

Because bicycles don't use fossil fuels but rely on muscle power they produce no exhaust fumes (apart from some extra CO_2 due to a somewhat higher respiration volume that is). As such they don't contribute to problems with air pollution, global warming, acidification, harmful smog, fine particles, blackening monuments, etc. Several studies indicate that CO_2 emissions by traffic can be reduced by 3-4% by substituting short car trips by bicycle trips @@ref?@@).

In times of increased smog levels (caused by, a.o., motorized traffic), physical activity (including cycling) is often suggested to be avoided. It's obvious that it is less healthy to cycle in polluted air than in clean air. But should one not cycle because of the pollution? If there is a cleaner alternative the answer is yes. But several studies (Rank et al, 2001; van Wijnen et al, 1995; @@villes d'enfants, villes d'avenir; @@) show that car occupants are submitted to significantly higher indoor pollutant concentrations, since cyclists mostly operate on the side of the vehicle streams where concentrations are lower. Because of the higher respiration rate (2,3 times greater air intake) the total uptake of pollutants as CO, benzene, toluene and xylenes sometimes approach that of car drivers, but usually doesn't exceed this intake (depending on relative speed and the relative volume of air taken in). Air quality varies a lot depending on the location. Air quality is worse near busy arterials. Peak concentrations occur when heavy vehicles are passing by. By providing cyclists with separate cycle routes apart from busy arterials, the intake of pollutants by cyclists can be further reduced.

It should be noted that children transported on the back of a bicycle will inhale a lower concentration of pollutants than they would inside a car, because they, as passive passengers, exhale the same amount of air in the two situations. As a consequence it is healthier for children to be transported by bicycle than by car.

Traffic noise is another major nuisance to a lot of people. It causes problems such as insomnia, stress and mental health disorders. According to doctor Johannes Spatz traffic noise is considered to be responsible for 3% of all deaths from heart attacks (Buis & Wittink, 2000). By reducing car traffic and lowering of speed the noise levels in cities will go down thus creating a more livable city environment.

1.1.2 Space efficient

Where car emissions in future probably will further be reduced due to technological improvements, car manufacturers will never be able to solve the problem of the excessive claim by driving and parked cars for the scarce space in cities. By reducing the space available for car traffic city centers can again become the attractive places they were (and many are today) where people can meet and local businesses flourish.

Private cars are by far less space efficient than other modes of transport in town, even without taking into account the space they take up for parking (Dekoster & Schollaert, 1999). During a 1-hour period 2000 persons using private cars can cross a 3,5 m wide space in an urban environment. With busses the number of people increases to 9000. In the same time period 14000 cyclists can cross the same space and 19000 pedestrians. Via the tramway 22000 can cross the same space. According to official guidelines (of the Danish Road Directorate) a 2 m wide one-way cycle way has a capacity of 2000 cyclists, but is actually able to unroll 5200 cyclists per hour. A road lane with a vehicle capacity of 2000-2200 cars per hour will have a typical width of 3,5-4 m. Special lanes for cyclists are therefore certainly space efficient. When being integrated into urban traffic the extra needs for space is virtually zero (ECF, 1993). This is mainly due to the flexibility of the bicycle as a means of transportation. Cyclists don't need much space to be able to progress in traffic, even when the roads are clogged with car traffic. As such when cycling is promoted more space is left for those cars that are really necessary in city centers. So it's clear that far more cyclists can be moved over the same amount of road space compared to car occupants.

The space consumption of a parked bicycle was calculated to be only 8% of the space consumption of a car (Wittink (ed), 2001; Héran, 2002). On one car park space 12 bicycles (and thus consumers) can easily be parked. Driving cars even take up until 30 times more road space than bicyclists.

Cars have an important impact on space in cities. The direct uptake of space by cars was mentioned above. In the past decades cars have also shaped cities to their benefit. Cities have expanded, because of auto-accessibility. Stores, hospitals, schools have moved from the city centers to the periphery, thereby increasing distances and making it less appealing for cyclists and thus inducing more car traffic and less opportunities for car-less people (Peeters, 2000). By choosing for car traffic the traditional scale of settlements will be destroyed and immobility by progressive traffic jams will be the result (Monheim, 2003). A fixation with automobiles destroys urbanity and paves the way for purely auto-fixated megastructures.

The car even decided on the architecture of individual buildings. Instead of windows on the street side, garage doors now link the street to the house (Peeters, 2000). Cars get their place right in the house of its owners. The domestication of the holy cow must be complete. At the same time activities have moved away from the street side decreasing social control.

1.2 Social development

The second pillar of sustainable transport in which cycling can play a very important role is social development. Health, safety and social equity will all benefit from more cycling and less car driving.

1.2.1 Health

More than 30% of European adults are insufficiently physically active (WHO, 2002). A sedentary life style gives rise to coronary heart diseases, strokes, obesity and type II diabetes. In most European countries e.g. the prevalence of obesity is estimated to have increased by 10-40% from the late 1980s to the late 1990s. Physical inactivity is the second most important risk factor for poor health, after tobacco smoking, in industrialized countries. Physical activity is probable one of public health's "best buys", having the following benefits (WHO, 2002):

- a 50% reduction in the risk of developing coronary heart disease, non-insulin-dependent diabetes and obesity;
- a 30% reduction in the risk of developing hypertension;
- a decline in blood pressure among hypertensive people;
- helping to maintain bone mass and thus protecting against osteoporosis;
- improving balance, coordination, mobility, strength and endurance;
- increasing self-esteem, reducing levels of mild to moderate hypertension and promoting overall psychological wellbeing.

Participation in regular, moderate physical activity can delay functional decline. From age 50 onwards, the benefits of regular physical activity can be most relevant in avoiding, minimizing and/or reversing many of the physical, mental and social hazards that often accompany advancing age (WHO, 2002). Cycling is an ideal activity to fight the diseases mentioned. By improving leg muscle strength, cycling and walking contribute also to reducing the risk from falls among older people. Several articles and editorials have explicitly advocated more walking and cycling for daily travel as the most affordable, feasible and dependable way for people to get the additional exercise they need (Pucher & Dijkstra, 2003).

Several studies report that modest physical activity leads to a longer and healthier life. Even 30 minutes per day of physical activities of medium intensity provide such benefits. A person who cycles 6 hours each week reduces his chances of an early death by coronary heart disease more than 4 times compared to his chances of an early death by a traffic accident (Kifer, nd). Cycling strengthens the heart, lungs and respiratory system and cures depression. Fats are burnt while cycling inducing a weight control and stress flows away. A Danish study (Andersen, 2000 as cited in van Loon & Broer, 2006) showed that people that didn't cycle to work had a 40% higher mortality risk compared to those who did. A Norwegian study (Saelensminde, 2002 as cited in van Loon & Broer, 2006) revealed that investment in cycle use are earned back by savings in public health. Gains in life years through healthier life styles exceeds loss of life years through traffic accidents 20 to 1 (Hillman, @@). A Danish study leads to analogous results (ratio about 1 to 10). In PROMISING the health aspect is estimated to be 5 to 10 times the safety aspect.

Apart from the direct benefits of physical activity, replacing some motorized trips by walking and cycling brings additional and important health benefits by reducing air pollution and noise and contributing to improve the quality of urban life (WHO, 2002). By emitting exhaust gasses and producing high noise levels, cars are responsible for creating unhealthy conditions. Traffic-related air pollution in Berlin is even considered to cause twice as many deaths as traffic accidents (Buis & Wittink, 2000). 3% of all cancer-related deaths can be attributed to motorized traffic. By reducing car traffic and promoting cycling a better air quality will be obtained. Because of this better air quality there will be less health problems.

1.2.2 Safety

Safety is of particular concern in cycling. Cycling is almost always perceived to be the most dangerous means of transportation regardless of the mode actually used (Noland, 1995). In this section we will give an overview of the actual risks faced by cyclists. In table @@ an overview is given of cycling risk in 14 EU countries. The table contains both exposure and risk measures.

	Distance per person per year [km]	Total cycling distance [@@bio km]	Population [mio]	Killed cyclists (2002)	Killed cyclists per mio inhabitants	Killed cyclists per @@bio km
Belgium	325	3,30	10,3	108	10,4	32,7
Denmark	893	4,70	5,2	52	9,7	11,1
Germany	287	23,50	82,5	583	7,1	24,8
Spain	20	0,80	42,2	96	2,3	120,0
France	75	4,40	59,6	223	3,7	50,7
Ireland	181	0,70	4,0	18	4,5	25,7
Italy	157	9,00	57,3	314	5,5	34,9
Luxembourg	39	0,02	0,4	-	-	-
Netherlands	853	13,30	16,2	169	10,4	12,7
Austria	143	1,20	19,9	80	9,9	66,7
Portugal	30	0,30	10,5	58	5,5	193,3
Finland	254	1,30	5,2	53	10,2	40,8
Sweden	271	2,40	8,9	37	4,1	15,4
United Kingdom	76	4,50	59,6	26	2,2	29,6
TOTAL	186	69,60				

Table 1: Cycling risk and exposure in the EU

Source: Van Hout (2007) and IRTAD (www.bast.de, consulted on 3/11/05)

We find the highest number of killed cyclists in Germany, the highest risk per capita in the Netherlands and Belgium. The highest risk to get killed as a cyclist per distance traveled is found in Portugal and Spain. The first measure (number of killed cyclists) does not take into account the number of inhabitants nor the amount of cycling. The second measure accounts for population, but still doesn't account for the amount they cycle. The third measure takes also into account the amount of cycling that is done in a particular country. We find that in general countries where people cycle a lot, the risk of getting killed in traffic as a cyclist is lowest (fig. @@). Countries with little cycling have the highest accident risks. Jacobsen (2003) called this (common) phenomenon 'safety in numbers'. The more prevalent a phenomenon is (in this case: the more people cycle) the less unsafe it becomes. A general trend of decreasing risk with increasing exposure is found in several studies (Jacobsen, 2003; Van Hout et al, 2005; Leden et al, 2000; Ekman, 1996; Busi, 1998; Jonsson, 2005).

@@insert fig (Van Hout (2007), p. 29)

Several studies compare the risks cyclists face with the risks faced by car occupants (@@ref@@). When risks are calculated as the number of victims per kilometer traveled, the accident risk of cyclists is usually significantly higher then that of car occupants. There are two main explanations to this. Firstly cyclists are far more vulnerable than car occupants. Secondly cyclist trips are shorter. Therefore they are more likely to be found in built up areas where more conflicts occur. When compensated for travel on safe highways (which is prohibited for cyclists) the difference between risk for cyclists and risk for car occupants diminishes or even disappears (@@ref@@).

How comes then that cycling risks are estimated far worse than risks faced as a car driver? When risks are small (and the risk of getting injured in a traffic accident is small, no matter which means of transportation) people tend to base their judgment on the possible outcome of the accident. By incorporating both perceived accident probability and perceived severity, Noland (1995) found that perceived probability was not a significant predictor for cycle use, while the perceived severity is. De Blaeij and van Vuuren () state that most people simply lack intuition to estimate very small probabilities in an adequate fashion. With small probabilities individuals base their decisions on the possible outcomes rather than on the probabilities involved. They also refer to a study by Liu and Hsieh (1995) who concluded that individuals will overestimate the risks of highly publicized events. So telling all the time how dangerous cycling is will increase the perceived risk.

Another way of looking to injury risk is the risk someone poses to other road users. When the risk of accident involvement (no matter the outcome) is studied, we find that car drivers are, per km driven, more likely to be involved in a traffic accident than cyclists (Van Hout, 2007). In accidents involving cars and cyclists, it will (almost) always be the cyclist who gets hurt. So it's safe to conclude that cycling is somewhat unsafe (risk of getting injured), bicycles as such pose little threat on others.

@@Wardlaw resp. Krag nog invoegen@@

1.2.3 Social equity

Not everyone owns a car or is allowed to drive it. 21% of Europeans are children under 18 who are unable to drive a car (because of the minimum driving age). Nevertheless everybody has the right of mobility, of participating in outdoor activities. When space is built to accommodate cars, this right is under pressure. Distances increase and walking or cycling are no viable options anymore. In that case the car-less are trapped at home (because public transportation often can't provide a sufficient solution either), or at least dependent (and a burden?) on others (with a car). Less children are nowadays allowed to go to school in an independent way (in the UK 1 of 9 students travels to school independently compared to 1 of 5 only 10 years earlier (@@villes d'enfants, villes d'avenir@@). A study on the York school youth reveals that 34% of them is being driven by car to school while only 15% likes being driven to school. On the other hand 40% would like to ride his/her bike to school but only 3% does. Limits on children's mobility are however critical for the development of children's spatial awareness and spatial activity, and affect children's social and physical development (Fotel & Thomsen, 2004). Even when distances can be covered by bicycle, the car traffic is often perceived causing to much danger, to dangerous to risk cycling in it and thus limiting choice of travel. A system that favors the use of cars over other more-affordable means of travel increases the disparities between rich and poor (Tomlinson, 2003).

The use of cars is also expensive. In several studies a clear relationship is found between car possession and household income. The bicycle is an inexpensive means of transportation well within the (financial) reach of almost everyone. As such the bicycle makes a wider range of destinations possible for more people. As a main transportation mode it should be able to compete with cars for (relative) short distances. In combination with public transportation it can even take on the competition with the car over large distances. The bicycle can hereby increase the catchment area for public transportation while the public transportation covers the largest part of the journey. By promoting this beneficial partnership car use can be further reduced.

1.3 Economic development

Cyclists are often overlooked when it comes to economic development. Cars are perceived to be the drivers of economic growth. Nevertheless bicycling can contribute significantly to a better accessibility of city centers and lead to substantial money savings, both for individuals and society. Especially for local shop keepers cyclists are of great value.

1.3.1 Accessibility

The important thing about accessibility is that people can get to a particular location in a short time (Buis & Wittink, 2000). However, more and more cities are experiencing that, despite the ever faster means of transport, the average speed of transport is decreasing and traveling time is increasing. This is the result of congestion due to lack of space. This lack of space is mainly due to the inefficient use of space by the car (see also section 2.1.2). An increasing share of the bicycle as an alternative for short car trips creates more space on the roads thereby also creating more space for vehicles that are useful in the cities. Because workers and goods suppliers are less stuck in congested traffic substantial gains for industry can be expected.

When motorized vehicular demand volumes on our roadways approach or exceed capacity, every additional one car adds to the travel time and delay for all other cars in the system (Aultman-Hall, n.d.). Above capacity, this marginal increase in travel time for each additional car is significantly more than at volumes below system capacity. Eliminating those marginal car trips (e.g. by replacing them by cycling trips), which push the system over capacity offers travel time benefits to all users. Therefore even modest increases in bicycle trips and reductions in car trips can cause relatively large improvements of travel times.

The bicycle is a quick means of transport in urban areas, often the quickest mode possible (ECF, 1993). The low space requirements for parking make a short distance possible between parking and origin or destination, contributing to a low overall time consumption. Cyclists often turn out to be winners in competitions (who will go from A to B in the shortest time?) between pedestrians, cyclists, public transport users and car drivers in urban drivers. Especially on tours with multiple stops cyclist have a large advantage over car drivers and public transport users. Even when driving speeds may (sometimes) be lower this is in urban areas by far compensated by decreased waiting times and searching time for a parking space.

While the European project WALCYNG found that time is an argument for not cycling or walking, another project ‘ADONIS’ found that the main reason for cycling in Amsterdam and Copenhagen is that it is quick (Wittink, 2001). WALCYNG points out that until people have actually experienced it, they are unlikely to be aware of how fast cycling can be.

Time savings can also occur in another way. As stated a daily cycling trip is an easy and convenient way to integrate physical activities into an urban life style. By cycling time can be saved because you don’t need to go to the fitness to keep in shape. Parents (usually moms) don’t need to take their children everywhere (by car). They can fill the spare time to fulfill more useful needs. Time is gained in still another way. As discussed before cyclists just tend to live longer. In the additional life years a lot of interesting activities can be undertaken especially because cyclists also have healthier lives.

1.3.2 Money savings

Bicycles are an inexpensive means of transportation with low cost to purchase and no need for fuel. Furthermore there are usually no parking fees needed for bicycles. Therefore a bicycle is affordable for many. A downside of this fact is that a bicycle is regularly seen as something of low status, as something cheap and by far inferior to cars. For each traveled kilometer, travel costs for the bicycle are lower than any other means of transport, with the exception of walking. Travel budgets can therefore be reduced considerably by cycling. By increasing bicycle use the need for a second car may also disappear, again leading to considerable savings.

Not only the individual benefits from reduced travel budgets, society as a whole benefits as well. Investments in bicycle infrastructure and maintenance are much cheaper than investments in (extension of) car infrastructure. Considerable savings can be made when investment in bicycle facilities make expansion of the car infrastructure unnecessary (Buis & Wittink, 2000). Bicycles cause much less wear and tear than motor vehicles. On the other hand, bicycle infrastructure should be repaired more frequently after suffering just limited damages, because cyclists are more vulnerable than motorists to bumps and cracks in the road surface. Bicyclists deserve the highest quality. The construction costs of parking space for a bicycle only amounts also to approximately 5% of the cost of a parking space for a car.

Significant savings can also be made in public health and environmental policies. In one US study costs associated with inactivity were between 24,3 and 37,2 billion USD (2,4 to 3,7% of total health care costs) (WHO, 2002). A Swiss study estimated that insufficient levels of physical activity cause 1,4 million cases of disease and 2000 deaths and cost about 2,4 billion Swiss franks per year (WHO, 2002). Saelensminde (2004) performed a cost-benefit analysis of walking and cycling track investments in 2 Norwegian cities. He took into account insecurity, health effects and external costs of motorized traffic. He concluded that the benefits of investments in cycle networks are estimated to be at least 4-5 times the costs. Such investments are thus more beneficial to society than other transport investments. Other studies confirm the net benefits of the development of cycle networks (Wittink, 2001).

The health and environmental costs of transport in the EU countries, Switzerland and Norway amounted to about 7% of the gross domestic product in 2000 (ECF, 2004). When the costs of congestion are added, the total external costs are 10%. The main categories are climate change (30%), damage to health caused by traffic-generated air pollution (27%) and the external costs of accidents involving lorries and cars (24%). 83% of the health and environmental costs of transport are caused by road transport. The contribution of cycling is negligible.

Employers also have a lot to gain when their employees cycle more often. In North America various assessments of the benefits of a physically active labor force have been carried out (Ege & Krag, nd). Not only the number of days off work due to illness seem to be less for the physically active employees, their ability to take complex decisions and general productivity is also better than those who are physically inactive. Gains for the employer have been assessed to 3-4000 euro per physically active employee per year. WHO carefully suggests the improved productivity for physically active employees to be in the range 2-52%.

1.3.3 Economic value

Cycling does not only provide financial savings for the individual and society. Cycling and cyclists have also a significant economic value in itself. Cyclists are especially beneficial for local shop keepers. And opposed to popular belief a significant decrease in the number of car trips does not have to mean a decrease in economic activity.

A Dutch survey held in the city of Breda (Christiaens, 2000 as cited in Héran, 2003) showed that car drivers spend more during each visit compared to a cyclist. But cyclists are more loyal, they return more often. So, on a weekly basis, cyclists spend more compared to the car drivers. A survey conducted in the Brussels Capital Region confirms these findings as does a study in the city center of Utrecht (Buis & Wittink, 2000). From a Munster example (@@Cycling: the way ahead for towns and cities) cyclists visited shops 11 times a month compared to 7 times per month for car drivers. A study in Grenoble (by Fubicy) reveals that only 4% of shopping trips involves a total amount of goods exceeding 10 kg, a quantity than can be easily transported by bicycle.

Nevertheless shop keepers overestimate the share of people shopping by car. In Nantes e.g. the local shop keepers estimated the share of customers coming by car on 70% while in reality 70% of the customers came by foot (Viennet, 1999 as cited by Héran, 2003). In Utrecht 26% of the customers came shopping by bike, compared to the 17% that came by car (Buis & Wittink, 2000).

Maybe surprising are the results of a survey among shopkeepers in the Dutch cities Utrecht and Enschede. More shopkeepers found the accessibility by foot and bicycle more important than the accessibility by car (Buis & Wittink, 2000).

Promoting shopping by bike is therefore in the same time promoting local businesses. Bicycles (and pedestrians) bring back the activities to the city centers. In Ghent the city center was made car free at the end of the nineties. The share of vacant shop locations has dropped, the activities in all sectors have increased (+15% for catering industry). In Strasbourg 30% more visitors to the shops in the city center are counted after closing it for through traffic. The same was noticed in Utrecht (Buis & Wittink, 2000). Less cars and more cyclists and pedestrians improve the quality of the environment and people are attracted to more appealing centers. They also tend to spend more time in such surroundings.

As for the industry as a whole researchers in Germany have calculated the effect of a different means of transport, which is less harmful to the environment on the number of jobs (Buis & Wittink, 2000). In the scenario with a significant decrease in car trips (53% to 42%) while the share of bicycle, walking and public transport increase, they find a loss of 130.000 jobs, mainly in the car industry, but 370.000 new jobs are created, mainly in public transport and the bicycle sector.

1.4 Motives for cycling

We might almost forget. People mostly choose to use a bicycle for positive reasons: it's fun, it's healthy exercise, good for the environment, it's fast, it's inexpensive (Fietsverkeer, feb. 2004, p. 3-4; Ege & Krag, n.d.; Stinson & Bhat, 2004). Furthermore, concerns regarding automobile use (environmental impact) are an important consideration. Almost all bicycle commuters make the conscious choice of using the bicycle and are not captive to bicycle use.

@@aanvullen@@

1.5 Conclusion: cities need cyclists, people need cycling

There are numerous advantages associated with cycling. Cycling is probably the best way to obtain a sustainable transportation system, especially in urban areas. Therefore the question mustn't be 'is it safe to promote cycling?'. Cycling must be promoted and policies must provide the right (safe) conditions to do so. There is just to much to gain from it.

@@cartoon to conclude

2 CYCLING IN EUROPE: STATE OF THE ART

2.1 Differences in bicycle use

Cycling levels vary among different European countries. But also within the different countries large differences in bicycle use can be found, both in the total amount of cycling as well as the kind of people that cycle and the purposes they cycle for. This chapter will provide an overview of bicycle use, mainly, in Europe.

2.1.1 Amount

@@Figures differ somewhat depending on the source.

The bicycle accounts for 27% of all trips made in the Netherlands (Frulanu & de Munck, 2007). For distances up to 7,5 km the bicycle is even the most popular means of transportation with a share of 35%. Compared to most other European countries the bicycle use in the Netherlands is far higher. Only Denmark comes close with an overall share of 19%. Other countries have shares of 10% or less (@@table).

The Netherlands	27%	The top municipalities score between 35-40%, cities with the lowest bicycle use rate between 15-20%
Denmark	19%	The differences between the larger cities are relatively small, in general at the level of 20% of all trips
Germany	10%	The western federal states have a higher average bicycle use, especially Nordrhein-Westfalen, several cities with bicycle shares between 20-30%
Austria	9%	Top: Graz (14%) and Salzburg (19%)
Switzerland	9%	Several cities at a higher level, like Bern (15%), Basel (17%) and especially Winterthur (approx. 20%)
Belgium	8%	The bicycle share in the Flanders region approaches 15%, in some cities higher levels are reached, top: Bruges – almost 20%
Sweden	7%	Cities: 10%, extremes: Lund and Malmö (20%), the small city of Västerås (33%)
Italy	5%	A few striking exceptions, especially in the Po Plains, with places like Parma (over 15%) and Ferrara (around 30%), another top city: Florence (over 20%)
France	5%	Top: Strasbourg (12%) and Avignon (10%)
Ireland	3%	Virtually no upward extremes (Dublin 5% at most)
Czech Republic	3%	A few cities with some degree of bicycle use (Ostrava, Olmouc and Ceské Budejovice, between 5 and 10%) and some with an even higher bicycle use (Prostejov 20%)
Great Britain	2%	Some isolated cities with a much higher degree of bicycle use (York and Hull 11%, Oxford and especially Cambridge nearing 20%)

Table 2: Bicycle use in different countries and cities

Source: Frulanu & de Munck, 2007

Hydén et al (1999) give the share of bicycle trips in total number of trips for 9 European countries and 2 French cities (table @@). The figures sometimes differ from those in the previous table.

Country	**Share of trips**
Norway	6,2%
Sweden	12,6%
Finland *	7,4%
Denmark *	17,2%
Great Britain *	1,7%
Netherlands	27,0%
Germany 1989	12,1%
Austria (Ober)	6,9%
Switzerland	9,4%
France – Grenoble	4,5%
France - Lyon	1,8%

Table 3: Bicycle use (share of trips) in different countries and cities

Source: Hydén et al, 1999

* Trips longer than 200-500m

Within some countries there might be some regions with a significantly higher bicycle share. Even in countries with a very low bicycle share there might be cities with a far higher bicycle use. These cities are also mentioned in @@table@@. An extensive overview of the bicycle share in some Dutch cities in 1995 is given by de La Bruhèze and Veraart (1999) (table @@). Factors that can explain these differences will be discussed in the next chapter.

	All journeys	Journeys <5 km
Zwolle	39,5%	52,3%
Groningen	39,2%	47,5%
Hengelo	36,9%	48,0%
Leiden	35,9%	45,9%
Enschede	35,6%	44,7%
Utrecht	32,4%	42,7%

Apeldoorn	31,9%	43,8%
Nijmegen	28,0%	36,1%
Amsterdam	27,6%	36,8%
Eindhoven	27,3%	34,7%
Den Haag	24,0%	30,3%
Maastricht	23,7%	31,7%
Vlaardingen	23,3%	30,4%
Arnhem	21,1%	29,0%
Rotterdam	19,4%	27,3%
Heerlen	12,9%	15,4%
Kerkrade	10,3%	14,9%

Table 4: Bicycle use in different Dutch cities

Source: de La Bruhèze & Veraart (1999)

Finland is not really known for having a mild climate. Yet in Oulu, a city of over 100.000 inhabitants, cycle usage is 35% of all trips (Wittink (ed), 2001). It is just over 160 km south of the Arctic circle. In Padova and Ferrara in the Po valley of Italy, cycle usage is also at this level, but is distinctly hot here for many months of the year, and cold and damp in the winter. Basel in Switzerland is scarcely flat, but has 17% cycle use and only 27% car use. Just to say location is not the only aspect to influence bicycle use.

In Germany also bicycle use is considerable in several cities. Muenster tops the list with 32% of all trips by bicycle (Pucher, n.d.). Bremen has a share of bicycle of 22%, Freiburg 19%, Munich 14%, Cologne 11%. The lowest bicycle use is found in the industrial cities of the Ruhr Region (Essen, Bochum, Wuppertal) where bicycle modal split is only 5%.

2.1.2 Distance

In table@@ an overview is given of the mean distances covered by bicycle per person per day (or per year) in 15 EU countries, according to 3 sources. The Dutch have the largest figure for bicycle use per inhabitant in Europe: more than 1000 cycle km per inhabitant per year (Wittink (ed), 2001). Denmark follows with 960 cycle km per inhabitant. Sweden, Germany, Belgium and Finland follow with around 300 cycle km.

Country	**Kms/person/day***	**Kms/person/day (proportion of total distance)****	**Kms/person/year*****
Netherlands	6,66	2,3 (6%)	1019
Denmark	5,48	2,5 (5%)	958
Germany	2,47	0,8 (2,5%)	300
Belgium	2,42	0,9 (2,5%)	327

Sweden	1,95	0,7 (2%)	300
Finland	1,82	0,7 (2%)	282
Ireland	1,62	0,5 (1,3%)	228
Austria	1,11	0,4 (1%)	154
Italy	0,97	0,4 (1%)	168
Greece	0,63	0,2 (0,7%)	91
UK	0,60	0,2 (0,5%)	81
France	0,49	0,2 (0,5%)	87
Portugal	0,26	0,1 (0,2%)	35
Spain	0,18	0,1 (0,2%)	24
Luxembourg	0,00	0,1 (0,2%)	40
EU15	1,42		

Table 5: Average distance cycled per person per day

*Source: Rietveld & Daniel, 2004

**Source: Hydén et al, 1999

***Source: Dekoster & Schollaert, 1999

@@include figure p11 from Jensen et al, 2000?@@

2.1.3 Purpose

In the Netherlands the use of bicycles is not restricted to school-going children (Frulanu & de Munck, 2007). Certainly, bicycle use among those involved in ‘education/study is the highest (48%), but this only relates to a limited percentage of all journeys (9%). The high overall cycling proportion is far more due to the fact that the bicycle achieves a more or less comparable share in all travel motives – and particularly in the most important motives, such as commuting and shopping. In the Netherlands many people do not make absolute choices between using the car or the bicycle over shorter distances. The image of ‘sometimes the bike and sometimes the car’ is dominant.

@@include table p6: Frulanu & de Munck, 2007?@@

A similar picture exists in Denmark. About 40% of all cycle trips made by Danes are between home and work/education (Jensen et al, 2000). The importance of the bicycle as an everyday transport mode is illustrated by the fact that twice as many kilometers are cycled on weekdays as on Saturdays and Sundays. In contrast, bicycles are rarely used for trips made during working hours. The bicycle is also popular in spare time. Every fourth cycle trip is between home and leisure activities. In most cases the bicycle is used to visit family and friends or go to the cinema or sports. A cycle trips is rarely a leisure activity in itself.

@@ include fig p10 Jensen et al, 2000?@@

In Germany most bike trips are leisure trips (37%) or shopping trips (23%) (ECF, 2004). Only 22% of bike trips are for work, educational or business purposes. @@other countries?@@

2.1.4 Who cycles?

In the Netherlands people of all ages cycle (Pucher & Dijkstra, 2003). Youngsters between 18-24 years make 30% of their trips by bicycle, but elderly (75+) still make about a quarter of their trips by bicycle. All age groups make between a fifth and a quarter of their trips by bicycle. In Germany similar tendencies are noticed although on a global lower level. Dutch cyclists can be found among every social subgroup. Workers, staff, members of parliament and even the queen, all can be seen cycling.

In Germany 19% of people aged 14 and over ride a bike (almost) every day (ECF, 2004), 34% every week or month and 47% rarely or never. Children and young people between the ages of 10 and 17 make the highest proportion of their journeys by bicycle (16%).

Half of all pupils at primary and lower-secondary schools in Denmark cycle to school (Jensen et al, 2000). A good 30% cycle to upper-secondary institutions, which tend to be further from home than schools for younger pupils. Almost 40% of the students cycle to the institutions.

2.1.5 Bicycle ownership

Bicycle ownership varies among European countries (@@table) as does bicycle use. The Netherlands is the only European nation with more bicycles than people (Frulanu & de Munck, 2007). On average the Dutch own 1,11 bicycles per person. The number of bicycles sold in the Netherlands is also high: 1,2 million bicycles in 2005 (for 16 million inhabitants). 4,9 millions bicycles were sold in Germany (82 million inhabitants), 3,2 million bicycles in France (60 million inhabitants) and 2,5 million bicycles in Great Britain (also 60 million inhabitants).

Country	Bicycles/person*	Bicycles/1000 persons**
Netherlands	1,11	1010
Denmark	0,83	980
Germany	0,77	900
Sweden	0,67	463
Finland	0,63	596
Belgium	0,50	495
Italy	0,45	440
Ireland		250
England/UK	0,40	294
Luxembourg		430
Austria	0,40	381
France	0,34	367
Greece		200
Spain	0,18	231
Portugal		253

Table 6: Bicycle ownership in different countries

*Source: Frulanu & de Munck, 2007

**Source: Dekoster & Schollaert, 1999 (based on Europbarometer 1991)

2.2 Potential

More than 30% of trips made in cars in Europe cover distances of less than 3 km and 50% are shorter than 5 km (Dekoster & Schollaert, 1999).Taking into consideration 3-5 km we could get rid of half of all car trips in many European cities (Hydén et al, 1999). Brög and Erl (1994, as cited in Wittink (ed), 2001) have studied the potential for modal shift from car to cycling in German cities. They have shown that at least 30% of car trips in urban areas could be replaced by cycling trips. Just by replacing a quarter of short car trips by cycle trips, the cycle share would be doubled in Finland and Norway, and multiplied by about 3 in Great-Britain, and by 4 in France.

In Flanders around 50% of all car trips are shorter than 5 km, a distance commonly assumed to be suited for cycling. Nuyts and Van Hout (2007) therefore investigated the potential for cycling in the Flanders region of Belgium. They took not only the distance covered into account, they also incorporated trip chaining, social safety, the length of the activity and the age of the road user. It was found that 17% (12-21% according to the assumptions made) of all car trips could be easily replaced by bicycle and about one third of all short journeys (<5 km) as a car driver. When this shift could be accomplished the modal share of the bicycle would increase from the current 15% to 25% (22-28%, to be compared with the objective of 19% posed by the Flemish government) while the share of cars would decrease from the current 62% to 51%.

Yet another study on the potential for substituting car trips with bicycle trips was performed by James et al (1999) for cycling in Perth (Australia). They found that 29% of all motorised private mode trips are in principle replaceable by bicycle (car trips with no constraints (e.g. <6 km), bicycle available).

By improving the maintenance service level of cycleways, it might be possible to increase the number of bicycle trips during winter by up to 18% representing a decrease of car trips of up to 6% (in Sweden, Bergström & Magnusson, 2003).

Policies should be oriented in a way that this potential can be converted in a real cycling share. To that goal it is interesting to know that 73% of Europeans believe that bicycles should benefit from preferential treatment compared with cars (Dekoster & Schollaert, 1999 referring to the Walcyng-project).

2.3 Trends

Bicycle use changed little in the Netherlands between 1994 and 2003 (Ververs & Ziegelaar, 2006) and 1991 and 2004 (Fietsberaad, 2005). The average number of bicycle journeys keeps oscillating around 0,8 journeys per person per day (on a total of around 3,1 journeys). As such the temporal dispersal is far less pronounced than spatial variability. The modal split of the bicycle varies in the period 1991-2004 between a low of 25,0% in 1998 and a high of 26,4% in 2003.

De La Bruhèze & Veraart (1999) studied bicycle use in nine European cities during the twentieth century. Most of these cities knew a high bicycle use up to the fifties. Then a period of decreasing bicycle use followed (1950-1975). A third period is distinguished from 1975 when bicycle use increases again in most cities. Different policies in these periods make that the present bicycle use differs quite a lot between different cities. In areas with a high current bicycle use, the bicycle always was accepted as a normal means of transportation and was therefore imbedded in transportation policies.

Certain cities have been very successful in the past decades to increase bicycle use. @@examples@@ Just to show that it is possible to create a bicycle friendly environment were people love to cycle. 80% increase in cycling in London since 2003, Darlington +56,8%, Derby +10,8%, Exeter +20,9% and Lancaster +2,4% (based on data of Sustrans, as mentioned in @@).

3 INFLUENCING FACTORS

Many factors influence bicycle use. Several authors attempt to group different factors in a number of groups, depending on the purpose of the research. In this text we follow the classification proposed by Xing, Handy & Buehler (2008). They include individual factors (such as preferences, beliefs), social environment factors (bicycle culture) and physical environment factors (infrastructure, land use).

Other authors use different classifications that are better suited for their needs. Ververs and Ziegelaar (2006) @@fig invoegen?@@ include transportation policy variables (including bicycle policy), spatial-economical characteristics of the municipality, population characteristics and physical characteristics. Moudon et al (2005) found a strong role of socio-demographic variables on bicycle use. Nevertheless some environmental variables proved to be significant determinants of bicycle use.

3.1 Individual factors

Several individual factors influence bicycle use. Population characteristics such as age and gender have a distinct impact on bicycle use, that may be different for different locations. The perception of the relative importance of different factors will also vary according to the level of experience of the cyclist.

3.1.1 Age

In most studies found age has a negative effect on cycling (Xing, Handy & Buehler, 2008; Winters et al, 2007; Moudon et al, 2005). Younger people tend to cycle more than older. Most of these studies are performed in the USA and Canada however, regions with a low cycling level. While the same findings may be true for European countries with low cycling levels, in countries with a high bicycle use we find in general that people of all ages cycle (see also section 3.1.4). The main explanation for this might be that younger children are not allowed to drive a car. Therefore their travel choice is somewhat restricted. @@vbn Europa toevoegen, eventueel obv OVG's@@

As in many countries cycling is before all the transport mode for younger people, student status is an important modifier of cycling behavior (Winters et al, 2007). Cities with a higher proportion of students have in general higher cycling rates. Rietveld and Daniel (2004) also found that a higher proportion of young people (15-19 years) and the presence of a school for higher vocational training include a higher bicycling share.

3.1.2 Gender

In many countries (especially in those with a low bicycle use) females are less likely to be cycling than men. Winters et al (2007) studied the influence of personal characteristics and climate on the levels of utilitarian cycling in Canadian cities. In the general population older age, female gender, lower education and higher income were associated with lower likelihood of cycling. Women were only half as likely as men to cycle. Moudon et al (2005) found similar results for the USA. About 2/3 of cyclists are male there. In countries with a high bicycle use on the other hand women tend to cycle as much as men. @@Europese vbn, relatie met ritmotief@@

3.1.3 Status

Higher education levels are in general associated with an increased odds of bicycling (Xing, Handy & Buehler, 2008). After adjusting for income and other demographics, Winters et al (2007) also found that people with higher education were more likely to cycle.

Moudon et al (2005) found no significant relationship between household income and the likelihood of cycling. A likely proxy for income, number of cars in the household, is however found to be significant. A higher number of cars per capita was also found to be positively correlated with a lower bicycle use in Dutch municipalities, as were a higher proportion of VVD-voters (liberal party), a higher proportion of foreigners and more hilly municipalities (Rietveld & Daniel, 2004).

3.1.4 Cyclist type

Preferences and perception about (safe) cycling differ among different kinds of cyclists and non-cyclists. Stinson and Bhat (2004) indicate that the most important factors in choosing a commute mode are travel time, convenience, needing a car for work or other purposes and cost. Other deterrents to bicycle commuting to work include dangerous traffic conditions, lack of bicycle infrastructure facilities, physical exertion (especially in hilly terrains) and adverse weather conditions. Bicycle commuters more often cite unpleasant weather and an injury/illness as being deterrents than do non-bicycle commuters. On the other hand, non-bicycle commuters have a much higher likelihood of identifying lack of daylight, unsafe neighborhoods, distance to work being too long, dangerous traffic and lack of bicycle facilities as being deterrents than bicyclists. While some of these differences may be reasonable, others may be due, at least in part, to misperceptions and misconceptions on the part of the non-bicycle commuters.

Stinson & Bhat (2005) also found a clear distinction between the sensitivity towards different aspects according to the level of cycling experience. In general, experienced commuter bicyclists are far more sensitive to factors related to travel time and far less sensitive to factors related to separation from automobiles than the inexperienced individuals. Compared to route choices for the inexperienced cyclists, the route choices made by experienced bicycle commuters are not as impacted by variables that reflect perceptions of safety from automobile traffic. Comfort with automobile traffic allows experienced bicycle commuters to place a higher premium on travel time. While safety-related attributes are also clearly important to experienced bicyclists, they are much less influential in the route choice selections of experienced bicyclists compared to inexperienced bicyclists. On the other hand, travel times and delays are not as influential for the inexperienced group as for the experienced group. From this it may be clear that *the* cyclist does not exist. This makes it more difficult for policy makers to do the right thing for all (potential) cyclists. @@other studies to back this up?@@

Stinson and Bhat (2004) finally suggest that, like other modes of commuting, bicycle use for commuting is also habit forming. Alternatively, it may be that comfort in bicycle commuting comes from experience.

3.2 Social environment

The social environment entails bicycle culture (social values and norms) and policy as well as some other characteristics inherent to the community. Bicycle use can be increased everywhere. If and the amount it will increase depends to a large degree on the policy measures taken in a certain location. These policy measures reflect the importance attached to certain problems or opportunities. Municipalities or regions that take cycling serious usually spend relatively more resources on measures that promote cycling. The importance policy makers attach to cycling depends on the actual amount of cycling (more cyclists mean more cyclist voters), the pressure exerted by bicycle groups and the vision and influence of the right person on the right place. On the other hand cyclists can be encouraged to cycle more when they see policy makers take cycling seriously. It's all about changing minds.

3.2.1 Policy

A policy in favor of the bicycle works best when both push and pull (stick and carrot)-measures are taken. Cycling has to be made more attractive while the alternative of car driving should be made more costly and time consuming. Pucher & Buehler (2006) found that higher gasoline prices encourage cycling (by discouraging car use) and that cycling safety is crucial to increasing cycling levels. Rietveld and Daniel (2004) looked into the influence of a large number of variables on bicycle use. They also provide a general framework in which they take into account, aside from some individual features, the generalized costs of cycling (including monetary cost, travel time, physical needs, risk of injury and theft, comfort and personal security) and the generalized costs of other transport modes. Many of these variables reflect aspects that can be changed through policy. The results implicate that there are essentially two ways of encouraging bicycle use (push and pull): (1) improving the attractiveness of a mode by reducing its generalized costs; and (2) making competing modes more expensive.

Ververs and Ziegelaar (2006) constructed an elaborate prediction model for bicycle use in Dutch municipalities as well. The model contains policy variables (which can be influenced by policy) as well as more autonomous variables (which (almost) cannot be influenced by policy). Both have a similar influence on bicycle use. The variables are grouped into 3 categories: strongly policy relevant, moderately policy relevant and weakly policy relevant. Among the strongly policy relevant variables parking fees (for cars) have the strongest positive influence on bicycle use. The share of public transportation and travel time competitiveness both have a negative impact on bicycle use. Moderately policy relevant variables include the number of one-person households (a strong positive influence on bicycle use), number of unemployed inhabitants (a negative influence), number of young people (positive influence) and the size of the built-up area (negative influence). Among the weakly policy relevant variables we find the share of Muslims (which has the strongest negative influence on bicycle use), share of Protestants (positive effect), average amount of precipitation (negative impact) and the hilliness (strong negative influence).

Rietveld and Daniel (2004) also found that municipalities with a higher degree of satisfaction (about bicycle policy) have in general a higher share of short trips by bicycle.

3.2.2 Car availability and cost

Availability of a car has a significant impact on cycle use (Ege & Krag, n.d., according to the national Danish travel survey). Very little cycling takes place in multi-car households. Pucher & Buehler (2006) state that due to the higher overall cost of owning and operating a car in Canada compared to the USA and the lower per-capita incomes bicycling rates in Canada are higher. Stinson and Bhat (2004) also found that the propensity to bicycle commuting is greater among individuals who have fewer cars in their household. It remains an open question whether a lower number of motorized vehicles causes a higher bicycle commuting propensity or whether individuals (as part of their household) decide on the number of cars based on their propensity to commute by bicycle.

3.2.3 Bicycle culture and social values

Bicycle culture is mostly associated with cities and countries that feature a high rate of bicycle usage as part of their cultural identity. In cities with a real bicycle culture it is common for all kinds of people to make journeys with different motives by bicycle. These cities usually have a well-developed infrastructure favoring cyclists. The bicycle is part of the ‘normal’ transportation policy.

3.2.4 Bicycle theft and other crime/stranger danger

A survey in Haarlem (NL) revealed that 14% of the respondents had a bicycle stolen in the past year (the survey was held in 2002). This means that around 12.000 were stolen in a year (www.fietsersbond.nl). Only 1860 bicycle thefts were reported to the police. An estimation for the Netherlands as a whole comes to around 1 million bicycles that are stolen during one year. Amsterdam tops the list with 19,4 bicycles per 100 bicycles that were stolen. Bicycle theft is seldom a priority of the police departments. Recent efforts in the Netherlands have however reduced the number of stolen bicycles. From a survey of the Dutch Fietsersbond they found that 45% of the people chooses an other vehicle instead of the bicycle for shopping or going out because they are afraid their bicycle might get stolen. As such bicycle theft is a major concern when it comes to promoting bicycling. Often it is not really the fact of the stolen bicycle that concerns people but rather the fact they can't properly return home. Another consequence of bicycle theft is that people tend to ride inferior defective bicycles which poses a safety threat.

3.2.5 Road safety

The unsafety on the roads also withholds many people from using a bicycle (PROMISING, 2001). If cycle use is to be increased and maintained, there has to be an answer to the concerns of people, both real and perceived, of cycle use and its safety. Improving the safety of cyclists on the road is therefore a precondition for cycle promotion.

Regardless of the mode actually used, the bicycle is almost always perceived as the riskiest mode for commuting (Noland, 1995). Individuals are more likely to choose a given commute mode the safer they perceive it to be. By incorporating both perceived accident probability and perceived severity, Noland (1995) found that perceived probability was not significant, while the perceived severity is. Perceived safety improvements in bicycle transportation have an aggregate elasticity value that is greater than one. This means that bicycle safety improvements attract proportionately more people to bicycle commuting (Noland, 1995). When perceptions of bicycling risk are reduced without any change in objective risk, increases in fatalities can be one possible outcome. Rietveld and Daniel (2004) found that Dutch municipalities with a higher safety level for cyclists also have a higher share of bicycling for short trips.

Ryan (2000) states that the more a person cycles, the less likely they are to fear having an accident. Utility cyclists' increased willingness to cycle in traffic is probably a combination of increased skill, experience and confidence, and changed perceptions about the level of risk.

3.3 Physical environment

A third group of elements influencing bicycle use can be grouped under the flag of the physical environment. These elements include geographical issues as well as man-made infrastructure.

3.3.1 Weather/climate

Weather and climate have a distinctive effect on bicycle use. Nevertheless we find cities with a high bicycle use in region with a less suitable climate. Oulu in Finland has cold winters while Ferrara is hot in summer and cold and damp in winter. Yet about 1/3 of all trips are made by bike. Many regions with better meteorological circumstances have far lower bicycle rates.

Several weather conditions influence bicycle use: temperature, precipitation, wind conditions. Bicycle use in the Netherlands is especially related to the amount of warm days (maximum temperature over 25°C) in a year (van Boggelen, 2007). The number of wet and cold days in a year also influences the amount of cycling albeit in a lesser way. In Germany a mobility survey revealed that on sunny days 10% of all trips were made by bike, compared with 7% on rainy days and 3% on snowy days (ECF, 2004).

In general discretionary travel is more affected by weather than commuter trips (Nankervis, 1999 referring to Hansen & Hansen, 1975). Nankervis (1999) studied the effects of weather and climate on the bicycle commuting patterns among tertiary students in Melbourne. He found a significant effect of temperature, wind and rain. Rider numbers are particularly sensitive to extremes of temperature. Rain was only found to be marginally significant. It should be noted that students are a atypical social group. Also the likelihood of rain seemed to affect the number of riders. They have to make the journey and often have no other choice than to cycle. Nankervis concludes that, for the students studied, neither weather nor climate needs to be a strong barrier to cycle commuting. Winters et al (2007) found for Canadian cities that more days of precipitation per year and more days of freezing temperatures per year were both associated with lower levels of utilitarian cycling. In the proportion of students only the number of days with freezing temperatures influenced bicycling. Brandenburg et al () found that precipitation and the Psychological Equivalent Temperature thermal comfort index both influenced the number of cyclists in recreation areas in Vienna, but recreational bicyclists are more sensitive to these weather conditions than are commuting cyclists.

As weather conditions are also seasonally it shouldn't be a surprise that workers commute by bicycle more frequently in the summer than in spring or fall and less frequently in winter than during other seasons (Stinson & Bhat, 2004). From general travel surveys the same picture can be drawn. Bergström and Magnusson (2003) also found clear differences in mode choice between seasons. In two Swedish cities the number of bicycle trips decreased by 47% from summer to winter. Temperature, precipitation and road condition were the most important factors to those who cycled to work in summer but not in winter. Exercise was the most important to those who cycled frequently in winter. Travel time was the most important for those who never cycled to work.

3.3.2 Topography

Cyclists have a preference for riding on flat ground (Stinson & Bhat, 2005) since cycling in hilly terrain demands more effort of the riders. This preference is more pronounced by inexperienced cyclists. Ververs and Ziegelaar (2006) found a strong negative effect of hilliness on bicycle use. Still this does not mean that cycling is impossible in hilly communities. Cycling levels in Basel (Switzerland), which is hardly flat, are high.

3.3.3 Distance/land use

Distance (and strongly correlated trip time) is probably the most important determinant of bicycle use. Distance and time are mentioned as the most important factors for cycling to work as well as not cycling to work in Copenhagen (Ege & Krag, n.d.). In general bicycle use highest in the range up to about 5 km (except for very short distances where walking takes over). Bicycle use decreases sharply when the trip distance increases above 5 km. Nevertheless some bicycle trips are much longer.

The average length of a bicycle trip is 2 km (Hydén et al, 1999). In Denmark and in the Netherlands the bicycle trips are longer than in other European countries. The willingness to cycle over longer distances differs between countries with good amenities and a flat topography (Denmark and the Netherlands) and other countries. However, in general we should not expect people to use a bike for transport on distances longer than 3-5 km. The average bicycle trip in Germany was 3,3 km and took 21 minutes (ECF, 2004). Distance also seems to be more significant for the mode choice during the winter period (Bergström & Magnusson, 2003). Most people don't seem to like cycling to long under the adverse weather conditions that are more prevalent during winter.

Increasing trip length has an important and significant negative effect on the attractiveness of cycling (Hunt & Abraham, 2007). The sensitivity to cycling trip time varies thereby substantially with cycling facility type. For the typical cyclist, 1 minute cycling in mixed traffic is as onerous as 4,1 minutes on bike lanes or 2,8 minutes on bike paths.

There is an intimate relationship between urban land-use development and transportation (Tomlinson, 2003). Journey lengths are strongly related to land use. Journeys in densely populated areas with mixed land use tend to be shorter. A comparative study of bicycle use in Canada and the USA revealed that the higher bicycle use was, amongst others, caused by Canada's higher urban densities, mixed-use development and the shorter distances caused by these (Pucher & Buehler, 2006). Higher densities and mixing of land uses probably encourage more cycling, simply because trip origins and destinations are less spread out, so that trip distances tend to be shorter and thus more bikeable.

Rietveld and Daniel (2004) include a large number of variables in order to explain the differences in bicycle use in Dutch municipalities. Several city characteristics seem to be significant predictors of bicycle use. The share of bicycle trips under 7,5 km decreases when the population number increases and the human activity indicator (basically the density of addresses) increases. Jensen (n.d.) also found that land use has a major influence on transport mode choice. Next to topography population density influences the level of cycling the most (in Danish towns). The number of inhabitants only influences the level of cycling when the number of inhabitants in the town is less than 10.000. People choose the bicycle more often in a densely populated, circular, flat town with more than 10.000 inhabitants, where most housing are located in the town center.

The spatial distribution of activities is very much defining both the need for travel and the distances to be covered (PROMISING, 2001). Decisions on this level have a direct impact on the requirement of directness. Segregation of functions will generate more need for traveling. Space consumption has a direct impact on distances between the functions. Long travel distances are restricting the usability of the bicycle. There is a need to develop a land use planning based on the principle of 'spatial proximity'. Urban planning and street design are also important to fulfill the required needs of bicycle networks (PROMISING, 2001). Urban planning is necessary in order to meet the coherence requirement. It also contributes to an increased safety. In street design the needs of cyclists should be taken into account where cyclists are treated on a level equal to other road users.

Car traffic is, at least partly, responsible for this destruction of urbanity (Monheim, 2003). Low density housing, commercial and industrial districts group around giant parking lots and superhighways far from the city center. As a consequence distances become larger and therefore less suitable for cycling. A more compact land use pattern leads to overage trips distances that are shorter and thus easier to cover by bike (Pucher & Dijkstra, 2003).

3.3.4 Infrastructure

Based on the benchmarking project 'Fietsbalans' a clear relationship is found between bicycle use in municipalities and the quality of their infrastructure (Cycling in the Netherlands). More cycle tracks and more even roads are mentioned as the most important factors by people from 2 Danish cities in order to make people cycle more (Ege & Krag, n.d.). Lack of even roads and stops at traffic lights are mentioned as the most important inconveniences by those who already cycle to work in Copenhagen. Safety has a minor importance, both as an impediment and as a reason not to cycle. Both cyclists and non-cyclists indicate that changes in the built environment would help them bicycle more (Moudon et al, 2005). Frequently mentioned environmental changes that can encourage cycling include: more bike lanes and trails (mentioned by almost half of the respondents), good lighting at night (33%) and bicycle racks at destinations (31%). Dill and Carr (2003) also found that new bicycle lanes in large cities will be used by commuters.

Krizek and Johnson (2006) investigated the effect of proximity to bicycle facilities and neighborhood retail on urban cycling, controlling for individual, household and other characteristics. They found that bicycle use did not differ significantly by proximity to any bicycle facility, although people that live closer to these facilities are slightly (but not significantly) more likely to use their bicycle. After adjusting for individual and household characteristics the difference between those living closer than 400 m and those living further than 1600 m became significant. They add that it would be inappropriate to use the results from their research to conclude that adding retail or bicycle paths would directly induce walking or bicycling.

Hunt and Abraham (2007) performed a stated preference experiment in Edmonton (Canada). The results indicate, among other things, that time spent cycling in mixed traffic is more onerous (and thus a deterrent) than time spent cycling on bike lanes or bike paths. Furthermore secure parking is more important than showers at the destination (although still appreciated). Cycling times on roadways tend to become less onerous as level of experience increases.

Stinson & Bhat (2004) state that the presence of bicycle racks or bicycle locker facilities at work increases the likelihood of commuting by bicycle. The presence of showers and clothing lockers did not show any significant influence in this study.

Inexperienced cyclists perceive major and minor arterials as much greater deterrents to choosing a route than individuals who are experienced bicycle commuters (Stinson & Bhat, 2005). Bicyclists (both experienced and inexperienced) tend to avoid routes with links on which parallel parking is permitted, presumably because parked cars can pose a safety threat to bicyclists with car doors swinging open or cars pulling out in front of the bicyclist's path. Bicyclists have a preference for routes designed for bicycle use, that offer some or total separation from motorized traffic. Especially inexperienced cyclists value a separate path or a bicycle lane more than experienced users. Bernhoft & Carstensen (2008) found similar results when comparing different age groups. The older respondents valued cycle paths more than did the younger as did women more than men. Although both older and younger cyclists agree that it is quite nice to have a cycle path, less younger people find it dangerous when no cycle path is available and still less would alter their route for it. They find cycling alongside parked cars more dangerous and routes for cycling should be direct and fast. A clear preference for a smooth pavement riding surface exists, especially with the more experienced cyclists (Stinson & Bhat, 2005). A Dutch survey revealed that cyclists prefer an asphalt pavement above a pavement made up of tiles (mainly used because of the ease of replacing when pipes below the surface have to be replaced) (Fietsberaad, 2006).

More frequent stop signs along a bicycle route discourage the use of that route, with experienced individuals being more sensitive to this than inexperienced users (Stinson & Bhat, 2005). While inexperienced riders value routes with many traffic lights, experienced riders tend to dislike them as they feel more confident in their ability to handle intersections without the need for any kind of control.

From the above it is clear that cyclists come in many shapes, sizes and abilities. Advanced, basic and child or elderly cyclists have different abilities. Each type of cyclist should be served with bicycle network designs suited for their needs. Meeting all their needs will therefore be a tricky balance (Aultman-Hall, n.d.).

Rietveld and Daniel (2004) found that a higher stop frequency (more places where cyclists have to stop) or hindrance frequency (badly placed posts and narrowings) reduce bicycling share (Stinson & Bhat (2005) found similar results). Increasing parking costs (for cars) and improving on bicycle speed (relative to the speed of car traffic) increase bicycling share. Quality of the bicycle network is certainly an aspect that must be taken into account. In PROMISING (2001) the main requirements for bicycle infrastructure are mentioned: safety, coherence, directness, comfort and attractiveness (these requirements were first mentioned in the Dutch Bicycle Manual (Sign up for the bike)). Separate bicycle facilities are thereby not always necessary, in fact even not always recommended. Most bicycle manuals (@@ref@@) recommend that of-road cycle facilities only be provided where motor vehicle speeds and volumes exceed particular threshold values. Experienced utility cyclists largely prefer to cycle on the road because it generally provides a higher level of service.

Road condition seems to be an important factor for the choice of mode (Bergström & Magnusson, 2003). More people (in Sweden) would cycle (more) during winter when the maintenance service level of cycleways was improved. Snow clearance seems to be a bit more important than skid control and a lot more important than the occurrence of grit or debris and surface unevenness. The road condition factor does not seem to be as important for winter cyclists as they are to others (in particular to cyclist who only cycle during summer).

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