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Bicycle infrastructure: can good design encourage cycling?

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This research posits the question that good design of the bicycle infrastructure in a city will encourage more people to cycle. Research is carried out to compare the cycle infrastructure in selected European cities against an adapted Level of Service concept using accompanied ride-alongs. The literature review on the factors that encourage/dissuade cycle use suggests that it is the potential rider's perceptions on the safety of cycling in their neighbourhood that is the deciding feature. Moreover, the literature review showed that contextual factors such as whether the actual infrastructure meets the needs of different cyclists are relatively under-researched. Six case study cities were selected (Edinburgh, Cambridge, Amsterdam, Rotterdam, The Hague, Utrecht) and compared on a range of factors by the riders including the coherence, directness, attractiveness, safety and comfort of the network. A cycle infrastructure scoring system was derived from the cycling research literature and the research was carried out by the researcher, an experienced cyclist, accompanied by an inexperienced cyclist. Using this research, the article makes several recommendations for improving and enhancing existing cycle infrastructure provision.

Keywords: promoting cycling; bicycle infrastructure design; perception of safety; comfort and convenience; accompanied ride-alongs

Introduction

Government bodies in the USA and Europe are sending strong messages to their citizens that physical activity, and in particular, cycling has positive personal and social effects (Cycling Scotland, 2013; Transport Scotland, 2011). This is a consequence of the growing understanding of the global (CO₂ emissions) and local adverse effects (air quality, noise, physical intrusion) of motorised travel and the increasing levels of obesity in society. Government funding has been found for interventions that include awareness raising, personal support and skill training, subsidised equipment and city and workplace bike pool schemes. In many countries the cycling infrastructure has also been improved with segregated and shared tracks mainly catering for the leisure cyclist.

Only a few countries have, however, seen cycling as a means of making their cities more people friendly or as contributing to the green infrastructure in settlements. The Netherlands, Denmark and Germany are characterised, in this respect, as the leading countries in making cycling safe, comfortable and attractive by giving priority for cyclists including extensive bicycle parking, integration with public transport, education and promotion of cycling to a wide circle of recipients (Bertolini & le Clerq, 2003; Martins, 2004; Pucher & Buehler, 2008). At the same time, using a car has become

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more expensive, less comfortable and less necessary through the implementation of taxes and tangible restrictions associated with using a car. Spatial policies in these countries have, also, developed a compact building style offering mixed uses that reduce travel distance enhancing cycle accessibility. The success of these nations appears embedded in an integrated policy approach to promoting cycle accessibility for commuting, shopping and leisure purposes using car restrictive measures where necessary (Hull, 2010).

Government policy towards cycling and the cost of cycling stand out as the two main grouped factors of cycle usage in Rietveld and Daniel's (2004) conceptualisation of the take up of cycling. National, state and local policies which influence the quality and capacity of bicycle dedicated infrastructure, the spatial design and the pricing of private car use will impact on bicycle use. Whilst the perceived costs of cycling includes monetary costs, travel time, physical energy, risk of injury, risk of theft, comfort and personal security also influence bicycle use. There are several challenges in measuring the causal relationships between these variables. Quantitative cross-sectional research has shown a relationship between characteristics of the built environment, such as the availability of routes for cycling and patterns of cycling (Krizek & Johnson, 2006; Ogilvie et al., 2011; Parkin, Ryley, & Jones, 2007; Rietveld & Daniel, 2004) but the direction of the relationship is not clear. Statistical analysis of opinion surveys has focused on individual norms, attitudes and values towards cycling and shown how these vary by socio-demographic group (Department of Transport, 2012, Handy, Xing, & Buehler, 2010; Transport for London, 2010). Whilst Nankervis (1999) studied the effect of weather on ridership, these studies do not readily encompass the influence of external factors in the physical environment. Studies that seek to evaluate complex infrastructural interventions often lack a robust study design and are criticised as exploratory (Chatterjee, Sherwin, & Jain, 2013; Ogilvie et al., 2011).

Qualitative research has focused on individuals to explore their thoughts and feelings about cycling using interviews, semi-structured questionnaires, focus groups and accompanied ride-alongs. The accessibility of the infrastructure and its connectivity are seen as important in some studies with the most important factors reported as travel time (Talihun, Levinson, & Krizek, 2007), safety (Scott, 2009; TfL, 2010), comfort (width of lanes) (Li, Wang, Liu, & Ragland, 2012), and visual interest (Fleming, 2012). van Duppen and Spierings (2013) shared a ride with commuters to analyse their social and built environment experiences as they passed through different parts of the city. Lee and Moudon's (2008) questionnaire survey of the environmental barriers and the facilitating factors in cycling captured the safety, social environment, visual quality, and maintenance issues. The environmental barriers to cycling across all groups included too much traffic (42.0%), too many hills (30.5%), no bike lanes or bike trails (29.0%), no safe place to cycle nearby (20.5%), badly maintained streets such as rough surfaces (16.0%), distances to places too great (12.5%) and no interesting places to which to cycle (12.0%) (ibid: 401). Continuous bike lanes/ trails were the top facilitator across both active groups (74%) and inactive groups (77%). Other factors mentioned were, in order of importance, continuous bike lanes or bike trails, good lighting at night, bike racks at destinations, closer to interesting places to cycle other than parks and recreational facilities, closer to parks and recreational facilities, shower facilities at work, and more trees along streets.

The cycling infrastructure close to the origin of potential journeys and at the destination is, therefore, a key facilitator or potential barrier to encouraging cycling. Having introduced the topic in this first section, the article goes on to review the literature on the

safety, or perceived safety, of the cycling infrastructure that has been provided in our cities. The factors identified in the literature review are used to construct a bicycle infrastructure score, which is explained in the third section and used in the research for this article. The article then goes on to compare the cycling infrastructure in six case study cities against the cycle infrastructure score system. The final section discusses the findings and makes recommendations on infrastructure design for policy implementation.

Perceptions of cycling safety

Most surveys show that the perceived traffic danger of cycling is an important deterrent to more widespread cycling (Cleland & Walton, 2004; Dill, 2009; Directorate-General for Public Transport, 2009; Snelson, Lawson, & Morris, 1993; TfL, 2010). Snelson, Lawson, and Morris (1993) found that while people mostly didn't cycle because they have a car, 11–17% felt it was too dangerous and 7–16% said that the amount of traffic put them off. In a study in Sydney reported in Cleland and Walton (2004) a much higher 36% of women questioned said that lack of facilities was a reason they didn't cycle and 32% said it was lack of on-road safety. Age and gender are factors in cycle ridership in the UK as shown in Figure 1.

Cyclists and potential cyclists have different levels of sensitivity to perceived conflict. Perception of conflict can be more important than actual conflict in determining whether people will use a route. There is a general trend towards decreasing bicycle fatalities in European countries, although there is anecdotal evidence of an increase of those seriously injured. Pucher and Buehler's (2008, p. 505) research uncovered that:

Averaged over the years 2002 to 2005, the number of bicyclist fatalities per 100 million km cycled was 5.8 in the USA and 3.6 in the UK, compared to 1.7 in Germany, 1.5 in Denmark, and 1.1 in the Netherlands.

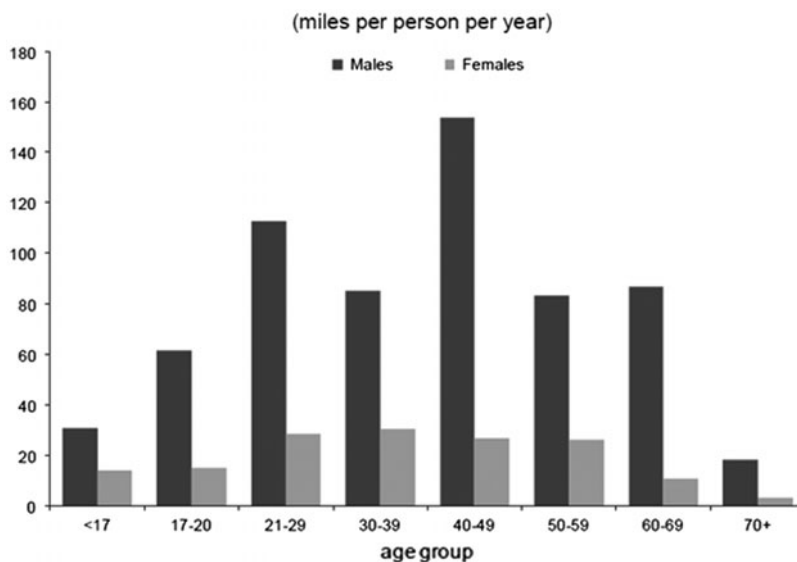


Figure 1. Average distance travelled by bicycle in the UK, By Age and Gender.

Source: Department of Transport (2013a) Table NTS0605. Used with the permission of HMSO.

The perceived possibility of accidents plays a significant factor in travel demand. Even a few incidences of accidents in one town will influence modal choice (Reitveld & Daniel, 2004). A study by Watchtel and Lewiston (1994) of police accident records in California discovered vehicle collisions accounted for 85% of the bicycle accidents with the remaining accidents involving other cycles and pedestrians. Most collisions (74%) occurred at junctions, whilst the remainder were due to opening doors of parked cars and overtaking automobiles. Tesche et al. (2012, p. 2340) found that cycle tracks had the lowest injury risk, with the next lowest risk shared by bike lanes on major streets with no parked cars and off-street bike paths. Route characteristics such as quiet streets (i.e., local streets) and no car parking on major streets were associated with low levels of injury risk. Other studies capture the benefits of segregated bicycle tracks/lanes. Li et al. (2012) found that separated bike lanes scored highly on comfort whereas on road lanes scored very low with the most negative features being: road condition, cars not leaving comfortable room, speed of vehicles and parked cars. The comfort level of the segregated group was 2.62 times higher than of the street group. Similar findings have been produced by Chen et al. (2012), Reynolds, Harris, Teschke, Cipton, and Winters, (2009), and Solomonov and Garcia (2011). Research by Talihun et al., (2007) indicates that cyclists are willing to pay the highest price for segregated bike lanes, closely followed by the absence of street car parking. The presence of kerbside parking can result in a loss of safety due to opening doors, cars pulling out and parking in the bike lane (Kang, Xiong, & Mannering, 2013).

Intersections, roundabouts and junctions are the main hazard for cyclists on cycle lanes (Dill, 2009; Soren, 2007; Watchtel & Lewiston, 1994). Junctions that are dangerous/ difficult to cross and lanes that suddenly stop (anywhere) are the weak spot in any cycle network and force the user to merge with motor traffic (Krizek & Roland, 2005). Junctions and roundabouts can be made safer if cyclists are given priority or have dedicated separate cycle tracks (CROW, 2007; James, 2012; Reynolds et al., 2009). Dutch roundabout design is comprised of a segregated orbital ring for cycling in which motorists must give way when entering and leaving the roundabout.

Safety, comfort, continuity and speed form the strongest drivers for the uptake of cycling and could influence new cyclists if barriers are tackled. Cycle paths are more beneficial where the lane is wide enough for overtaking; there are few intersections and discontinuities, where there is a detailed route layout with markings and good signage mixed with visibility of all cyclists and cars. The merits of the segregated cycle-lane are contested but there is no doubting the power of this lane in attracting new cyclists. From the literature it seems that it is the intersections and discontinuities that are the problem in terms of safety and flow.

Research methods

The key challenge in this research was how to operationalise the physical infrastructure attributes and characteristics of the built environment. The Level of Service concept is an American perception based technique, which was initially designed for motor vehicle infrastructure but has since been adapted for other modes of transport (National Transport Library, 1998), most notably for pedestrian movement (Atkins et al., 2012). The design factors chosen to audit the cycling network in the selected cities were adapted from the Netherlands Bicycle infrastructure design manual (CROW, 2007) the Bicycle Level of Service (Sustainable Cities Institute, n.d.), Bicycle Stress Level (National Transport Library, 1998) and Bendiks and Degros (2013) 5 + 3 Method. This

research on cyclist's needs highlight five requirements for a properly designed cycle network. These are the coherence, directness, attractiveness, safety and comfort of the network. In addition, two further categories were added to capture the rider's overall experience of the ride-along and their perception of how well the routes chosen linked to the facilities or opportunities in the city cyclists might want to access. The seven categories of design factors used to benchmark the selected cities are shown in Table 1. Each category was broken down to a set of relevant criteria to provide 50 audit criteria which were scored based on a sliding scale of 1–5 with five being the highest rating (see scoring for each city in the Appendix). The riders were asked to observe and reflect upon these criteria when riding the routes selected in each city (CROW, 2007; Dill & Gliebe, 2008; Ogilvie et al., 2011; Snizek, Nielson, & Skov-Petersen, 2013; van Duppen & Spierings, 2013).

The bicycle infrastructure audit is a qualitative, subjective audit to capture the different user perceptions on the comfort, speed and safety of cycling infrastructure in the selected cities. Two UK cities (Edinburgh, Scotland; Cambridge, England) were chosen because they have the highest percentage of bicycle users in their respective countries. Their perceived quality of design was compared with four Dutch cities (The Hague, Rotterdam, Utrecht, Amsterdam) which all have high cycling rates (see Table 2).

The bicycle cycling infrastructure audit was carried out between September 2013 and January 2014 by the researcher, who is an experienced cyclist accompanied by an infrequent cyclist to give a different perspective on the perceived quality of the physical

Table 1. Cycle categories used to evaluate the case study cycle-ways.

Category	Definition
Coherence	Continuity, logically connected destinations
Directness	Infrastructure provides cyclists with shortest fastest routes while taking into account all costs of travel time
Attractiveness	The cycle infrastructure is designed, furnished and illuminated with personal safety in mind to make cycling socially safe and attractive
Traffic Safety	Infrastructure design ensures the traffic safety of all users
Comfort	The cycle infrastructure allows cycle traffic to circulate smoothly e.g. flat, smooth pavement, minimum of inclines
Spatial Integration	Cycle Infrastructure integration into spatial context (city centre, suburbs, historic areas, modern development)
Experience	Enjoyable? Stressful?
Social economic Value	Routes take into account user facilities and developments (commercial, office, residential and industrial)

Table 2. Case study comparison of population and cycling data.

City	Population	Area (km ²)	Density (km ²)	% of people cycling (%)
Den Haag	495, 083	98.2	6210	30
Rotterdam	610,386	319.4	2961	26
Utrecht	311,367	99.32	3279	44
Amsterdam	779,808	219	3699	37
Edinburgh	495,360	264	1828	5
Cambridge	123,900	115	1071	20

Source: Compiled from: UNdata <http://data.un.org/Data.aspx?d=POP&f=tableCode%3A240>. Department of Transport (DfT, 2013b).

infrastructure and the mental/ stress factors associated with the ride. By pairing an experienced cyclist with a novice, the limitation of considering one perspective and ability of cyclist is partially overcome. The cycle route in each city selected included the city centre, a suburb, a train station and an educational facility. A video of each route cycled was taken to provide the users' view and provide visual examples of how the infrastructure was rated by the participants. These were included in the field notes to provide observational data on the route, and with notes on the built environment, were used to assist the analysis. The participants used the cycle infrastructure score system explained above and their findings were combined into a City Cycle Infrastructure Score (CCIS) for each city. The next section gives some context to each city and then goes onto to discuss the results to allow a city comparison and to make recommendations on the cycleway designs encountered by the participants.

Case study context

The design, accessibility and connectivity of the cycling infrastructure in a city will influence the perceived suitability of cycling as a transport mode of choice. Of importance, also, are how cycling fits into the local transport policy and vision and the city spatial structure. This section introduces the spatial and policy context in each city.

Edinburgh

Edinburgh is located on the east coast of central Scotland. A population of 495,360 covering an area of 264 km² and a density of 1828 per km² (CEC, 2011) means that Edinburgh is a compact city therefore ideal for short trips by either walking or cycling. The street structure is highly varied from the cobbled, tight, and winding streets of Edinburgh Old Town to the tarmac uniform streets of Edinburgh New Town as well as the many suburbs. Edinburgh's cycling policy was rated as 4 out of 5 by the Scottish Government's national assessment of local authority cycling policies in 2013 (Cycling Scotland, 2013). Until recently, these policies were rarely activated, but the latest political administration is committed to spending a fixed proportion (6%) of the transport budget on cycling. The Edinburgh Active Travel Action Plan ATAP sets out the target for cycle modal share of 10% by 2020 (CEC, 2010). This is an ambitious target considering the current modal share is 2%. However commuter modal share is 10% dwarfing all other Scottish regions (Scottish Government [SG], 2013). Edinburgh is aiming to be a cycle friendly city by making it possible to travel by bike anywhere in a safe and convenient manner.

The selected cycle routes assessed are shown in Figure 2. Part of the route selected follows the National Cycle Network (NCN), which makes use of old railway lines and canals and is fairly connected passing through each side of the city via the city centre. The local authority routes are very disjointed. The route chosen starts at the South side of Edinburgh on the A702.

Cambridge

Cambridge is located in England, around 50 miles north of London. With a population of 123,900 and covering an area of 115.65 km², a density of 1071 per km² (Cambridgeshire County Council [CC], 2011), Cambridge is fairly dense and flat, making it suitable for cycling. This is evident with the percentage of all journeys undertaken by bike at 18% with

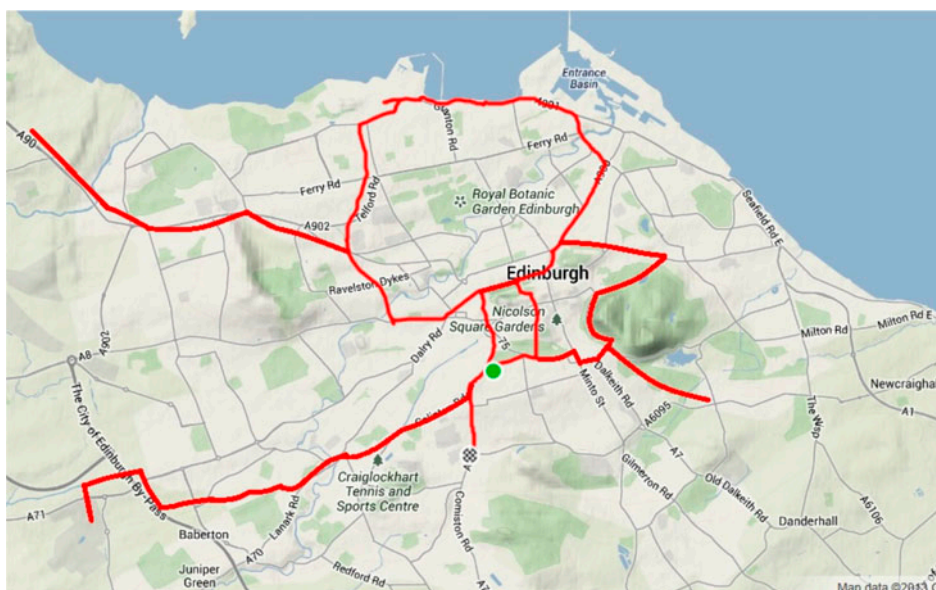


Figure 2. Route undertaken in Edinburgh Audit.
Source: Map Data@2013 Google.

29.9% being commuters (Office of National Statistics [ONS], 2011). Street structure is varied, the historic town centre providing a challenge due to limitations of space. The Cambridge Central Area Access Strategy states that it is necessary to restrict cycling at all times in the most densely used pedestrian streets but elsewhere to have safe and continuous links (CC, 2013a). Access to the city, however, is almost radial. Cambridge is one of Cycling England's 'Cycle Towns'. In 2008–2011 15 million US Dollars (11 million EUR) was invested to provide improved cycle routes and training and since 2011 has continued as part of a European funded project called 'Bike Friendly Cities' (CC, 2012). Cambridge Council's vision is for cycling to be promoted as an attractive and practical alternative to driving and be an enjoyable, safe and healthy activity. Their key areas of focus are congestion, road safety, air quality and accessibility (CC, 2013b). To monitor progress the council has automatic cycle counters across the city to collect statistics on a daily basis. One policy impacting greatly on cyclists is that students aren't allowed car parking permits. With a student population of around 43,000 (Laker, 2011) this policy is influential in encouraging other modes of travel.

Figure 3 shows the route taken in Cambridge starting in the suburb of Orchid Park following a trunk road into the centre. The route continues through one side of the centre to the train station and turns to navigate through the university quarter and the town centre, finally taking an alternate route back to Orchard Park. The route follows part of the NCN, which provides four points of access to the city, one from the south and three heading north at different tangents.

The Netherlands

Cycling infrastructure design is very similar in the four Dutch cities selected, which are within 75 km of each other. Den Haag and Rotterdam are situated on the West coast.

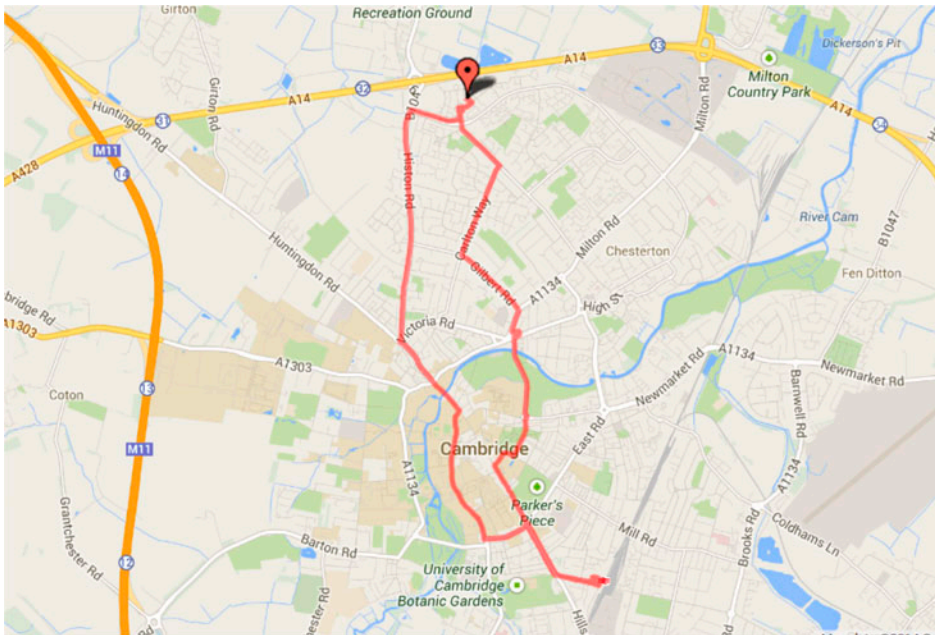


Figure 3. Route undertaken in Cambridge.

Source: Map Data@2014 Google.

Utrecht is centrally located and Amsterdam sits north of the centre. All four cities are different in terms of their size, density, street structure and character. Den Haag is the parliamentary centre for the Netherlands offering a medieval core to the city surrounded by modern infrastructure. Rotterdam is an industrial city with a very busy port and many new striking developments. Utrecht is a medieval city still retaining many old buildings. Utrecht streets are thin and winding, with prominence given to pedestrian areas. Amsterdam, also a medieval city, has the largest population. Amsterdam's streets consist of large avenues crossing all canals and small cobbled streets running between.

All authorities will stimulate walking and the use of the bicycle as the main means of transportation and as a link in the journey chain from door to door. Municipalities water boards, provinces and city areas will do this, amongst other things, by ensuring a bicycle network which complies with the main traffic requirements of cohesion, directness, attractiveness, safety and comfort. The authorities will also ensure parking facilities for cyclists which meet their demands in terms of quality, quantity and location. The Dutch Mobility Memorandum (Ministry of Transport, Public Works and Water Management, 2009, p. 34).

From the statement above we see that regional and local authorities are responsible for the majority of cycle infrastructure and facilities including the local cycle path network. Unusually, the regional water board also has responsibility of cycle infrastructure as many bike paths are alongside canals. The regional authorities are informed by:

- Infrastructuur Verkeer en Vervoer (dIVV) (Transport and Infrastructure department).
- Platform Feits (Cycle platform).
- Dienst Ruimtelijke Ontwikkeling (Spatial Development Department).

- Fietserbond (Cycling Association).
- Fietsberaad (Cycle Consultancy) funded by the government and made up of members from each municipality.

These organisations inform Dutch policy and collate knowledge to inform the CROW design manual, to be applied in practice and provide regulation, guidelines, and recommendations. The policies between the four cities are remarkably similar despite decentralised policy from state to provinces and local areas. Increasing safety and promotion of bicycle use are the main objectives nationwide, with policy, coherence and continuity as their instrument (Directorate-General for Public Transport, 1999; Martins, 2006). Funding available from the government is around 46 US Dollars (34 EUR) per person per annum (Ministry of Transport, Public Works and Water Management, 2009).

Figures 4–7 show the routes taken in the four Dutch cities.

Bicycle infrastructure score findings

The design of the cycling network in the built environment of Edinburgh, Cambridge, Den Haag, Rotterdam and Amsterdam are here assessed to demonstrate how easy,



Figure 4. Route undertaken in Den Haag.
Source: Map Data@2014 Google.

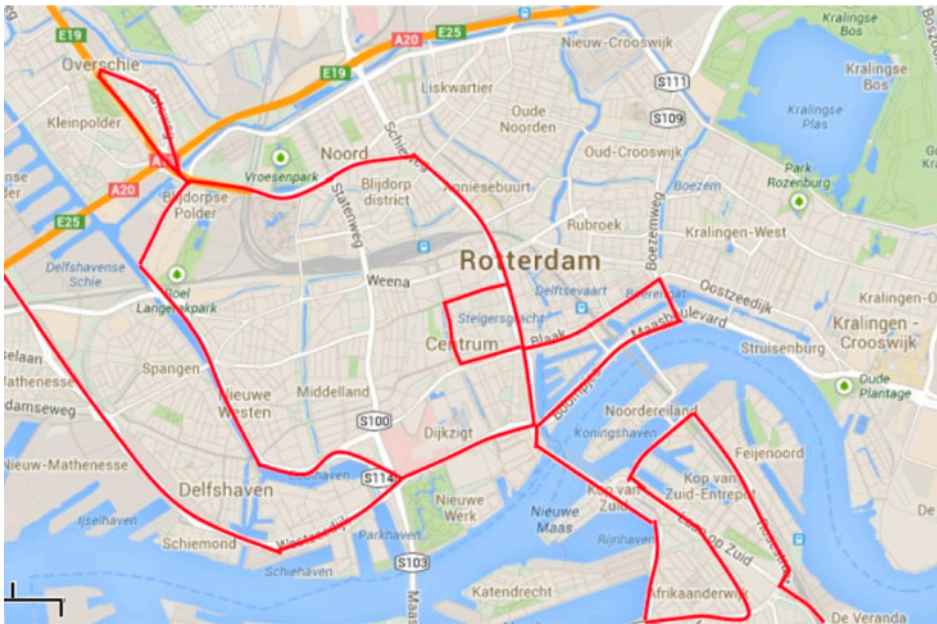


Figure 5. Route undertaken in Rotterdam.
Source: Map Data@2014 Google.

direct, pleasant and interesting this sustainable mode of transportation has been made in the respective case study cities. In each of the cities there were two auditors, one an experienced cyclist and another who was a novice on-road cyclist. As explained earlier, the rating criteria used covered the consistency, directness, attractiveness, safety, comfort, spatial integration, experience and social economic value of the routes. All four Dutch cities are discussed together because infrastructure design is very similar in each.

The summarised results are shown in Figure 8 and Table 3. The breakdown of results by city for each of the 50 criteria can be found in Appendices 1–6. As expected, a country with the reputation of the Netherlands scored highly in all categories. The combined CCIS for all four cities is 4.45. Utrecht scored the highest with Den Haag following closely. Despite being an historic city, Utrecht shows that it is possible to create good infrastructure in constrained space. Rotterdam achieved the lowest marks which is surprising considering that it is very modern and has the opportunity to implement measures to make roads safer and more attractive than the other Dutch cities; an overall score of 4.08 is still high. Cambridge scored a respectable 3.62 and Edinburgh scored the lowest at 2.51.

The six cities compared are varied in terms of demographics and density (Table 2). In terms of area Cambridge, Utrecht and Den Haag are comparable, but population varies highly. Notably Table 2 shows that higher densities do not translate to the percentage of people cycling. Den Haag has the highest density, but both Utrecht and Amsterdam have higher cycle use. This is the same for Cambridge, which is the least dense, yet has a favourable amount of people that use cycling as a means of transport.

The policies in the British cities are fairly similar with local active transport strategies in place alongside active local cycling groups. Despite similar aims, implementation of cycle infrastructure is highly variable being reliant on voter pressure. Cambridge has



Figure 6. Route undertaken in Utrecht.

Source: Map Data@2014 Google.

an excellent monitoring programme with automatic counters to provide the council with up to date and precise statistics. Another influential policy implemented by Cambridge is the restriction on parking permits for students. This might be harder to implement in other university cities in the UK, especially those with a more decentralised structure with key facilities (including the university) located around an outer ring road. The Dutch system has a more decentralised government system, with policy responsibility shared with the regional authority. The infrastructure is very similar due to the CROW design manual being used as best practice with another major factor being funding. Compared to British cities The Netherlands outperforms Edinburgh and Cambridge (Table 4). UK local authorities do not have powers to raise their own funds either from their electorate or from private banks. They are funded to deliver central government policies.

Consistency/continuity

After auditing it is apparent that the cycle infrastructure in the Dutch cities was the most consistent (Table 3). There is continuity to the bicycle lanes making it easy to move around all four cities. Amsterdam was the weakest, mainly due to the urban fabric of short, narrow streets and junctions that provide many stopping points. This has,



Figure 7. Route undertaken in Amsterdam.
Source: Map Data@2014 Google.

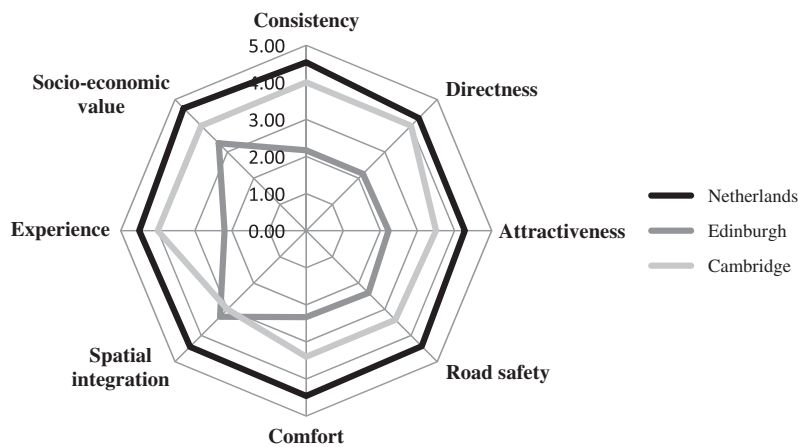


Figure 8. Spider web diagram comparing the Bicycle Infrastructure Scores.

Table 3. Comparison of the bicycle infrastructure scores.

Measure	Netherlands	Edinburgh	Cambridge
Consistency	4.54	2.17	2.83
Directness	4.29	2.17	3.83
Attractiveness	4.28	2.22	3.56
Road safety	4.41	2.38	3.5
Comfort	4.46	2.33	3.33
Spatial integration	4.43	3.29	3.86
Experience	4.50	2.20	4.40
Socio-economic value	4.67	3.33	3.67
Overall Score	4.45	2.51	3.62

Table 4. Governmental spend per person on cycling provision.

Case study area	Governmental funding per person	
	US Dollars	Euros
Edinburgh	6.5–8	4.4–6
Cambridge	17	12.5
The Netherlands	45	34

Source: Compiled from: Cyclist Touring Club (2013) and Pedal on Parliament (2014).

however, been ameliorated with bicycle priority lights at junctions. In Edinburgh and Cambridge the NCN has the most favourable infrastructure. The Cambridge local cycling network is highly regarded but the cycle lanes are continually interrupted where side streets intersect with main roads making the inexperienced cyclist wary of traffic approaching from the left. Many cycle lanes also end abruptly at major junctions with no instructions on how to proceed. Cycling infrastructure is not apparent in Edinburgh with cyclists sharing roads (predominantly two lanes) with automobiles and car parking on each side. The predominant cycle infrastructure in Edinburgh and Cambridge consists of an Advanced Stop Line for cyclists at traffic lights with the cyclist given their own bike box at the head of the queueing vehicles. This area was found to be frequently occupied by cars. Both cities had limited segregation. Edinburgh has made good use of disused train lines and Cambridge has segregation along the guided bus route. Many junctions and roundabouts are difficult as they have to be crossed in two sections and at times three.

Directness

Table 3 shows that the Dutch cities scored the highest with Edinburgh at the bottom. Cambridge has scored well on this measure; while it had many discontinuities the routes were direct. The Dutch cities were signposted with destinations and distances, and routes were extremely easy to join. Where obstacles were presented such as large junctions, cycle infrastructure either bypassed it or cycle priority traffic lights were installed. Only one cycle priority traffic light was found in the UK study, in Cambridge. A major weakness in Edinburgh is the cycle speed calming. Barriers or gates are placed in needed locations to slow down cyclists on paths shared with pedestrians. Infrastructure in Edinburgh can be highly circuitous. To achieve the shortest routes many cyclists will use the busiest roads. Cyclists are not necessarily riding for leisure. To increase cycling,

direct routes are needed to encourage other users, with good access to shopping, commuting and education. Not only are Dutch cycle lanes connected, they provide quick access to all land uses and also provide alternate leisure routes.

Attractiveness

The CCIS (Table 3) has scored the Netherlands highly. This was due to attractive infrastructure that had a high degree of personal safety. Even at night in the suburbs the main routes were lit using high quality lighting. Parking was also of high quality and frequent. The suburbs close to Rotterdam Airport have a lot of heavy traffic and motorway overpasses, but cyclists can bypass these using underpasses. The public transport system allows cycles on all forms of public transport but only a certain number at a time, such as two cycles per carriage on a tram.

In Cambridge the conversion of car parking spaces into cycle parking was striking. This however needed to be more frequent as these were all full and many bikes were informally parked on railings. Edinburgh's cycle issues were apparent with parking few and far between. The transport hubs had cycle parking, but insufficient for the demand. Cars parked in cycle lanes were a major issue in Edinburgh; Cambridge had some examples of this and impressively only two were observed in the Netherlands. The attractiveness of Edinburgh's cycle-ways is mixed. Narrow bike lanes and streets with poor surface material, coupled with heavy traffic and parked cars in cycle lanes can easily dissuade cyclists. The National Cycling Network routes, however, are mainly off road and of better surface quality. Some of these routes, such as the Union canal, are used heavily for commuting but some parts are extremely narrow at 1 metre for two way traffic and pedestrians.

Road safety

Edinburgh has scored the lowest in this category. This is due to poor maintenance of cycle and car lanes. There are many potholes, some of which were extremely dangerous. The issue of parked car doors opening was also apparent in Edinburgh and Cambridge, less so for the latter due to some extra wide lanes and total segregation at points. In the Netherlands maintenance was extremely high and segregation led to the feeling of safety. Where cars are parked near cycle lanes there is adequate space to allow doors to open safely. Traffic speed and volume pose no problem due to the practice of segregating streets at different volumes and speed of cars. Due to speed restrictions and other speed reduction/calming measures, Cambridge feels safe for cyclists even when alongside automobiles. These measures also prevent fast overtaking and the high proportion of cyclists means that drivers are aware. Notably during the case studies most drivers were observant and patient in all cities and there were no altercations with them or pedestrians. The safety of cyclists at junctions in both Edinburgh and Cambridge could be improved with little guidance currently given to the approaching cyclist.

Comfort

Comfort goes hand in hand with safety. What was noticed was that the materials used by the Dutch were more resilient, and comfortable to cycle on. This material also offered little rolling resistance yet provided a high level of grip. This gave the Netherlands the highest score (Table 3). Den Haag did share tram tracks in the centre, however

the rail is filled with soft rubber stoppers to prevent bike tyres getting caught. Intersections were also comfortable to navigate, providing clear indication where the bike should be. Roundabouts, with cycle infrastructure were a new experience for the auditors, with cars having to give way in and out of each road. Infrastructure both in Edinburgh and Cambridge showed signs of wear and little maintenance. Their infrastructure offered a bumpy ride. Cambridge provided more comfort than Edinburgh due to some wide lanes and automobile traffic calming measures. In Edinburgh, bikes can share bus lanes but this can be off-putting for new cyclists as the most vulnerable user is being merged with the largest road user. Parked cars in cycle lanes force cyclists out onto the road. As many as 35 parked cars were found in cycle lanes during the Edinburgh audit.

Spatial integration

All cities offered different urban fabrics. Nevertheless, the implementation of infrastructure in each can inform the others. Utrecht and Den Haag show that the historic fabric of a city can still be used to create a cycle (and pedestrian) friendly place. Amsterdam was the biggest challenge due to the shared narrow streets, especially with many tourists not used to the volume of cyclists. Wide avenues however did provide ample room to get from the centre in a radial format. Each city's infrastructure complimented each area and allowed continuous freedom of movement. Rotterdam had the least greenery but the waterfront provided a tree lined bicycle highway and modern bridge leading to the south. Evidence of cultural identity is present in each city and in its surrounding areas. The problem in the United Kingdom seems to be that city centres in Britain still have the private car at the top of the transport hierarchy. Edinburgh has still scored the lowest (Table 3), however it is the highest score Edinburgh has achieved through good implementation of the NCN sections. It still has a long way to go with many areas capable of supporting cycle infrastructure. Cambridge city centre had good infrastructure (even with discontinuities) in the centre because of the street density and structure, but this deteriorated towards the suburbs.

Experience

It is immediately obvious that in the Netherlands most people cycle as it is easy, quick and convenient. The auditors encountered people of all ages and gender easily identifying commuters, shoppers and leisure riders. This provided a welcome experience and a feeling of inclusiveness. Cambridge claimed its highest mark in this category even though the infrastructure was not as good as the Netherlands. This was due to a high amount of people cycling, some segregation and some wide lanes. The experience in Edinburgh had a dual nature. Experience was good in some parts (Meadows, Union Canal, & NCN route), but cycling in the city centre was highly intimidating especially when sharing with many cars, buses and a tram track.

Socio-economic value

Due to the connectivity of the cycling infrastructure with a variety of destinations and facilities, the audit shows that the Dutch provide best value to the public. All cyclists and destinations are catered for with end trip facilities at most locations. There are electric cycles charging points. Getting from A to B is a quick and pleasurable experience incorporating comfort and safety. The auditors also noticed training facilities for school

children, showing that road and traffic awareness and infrastructure use is embedded at an early age. Cambridge also shows value despite a varied infrastructure as routes provide choice to the cyclist. This was apparent due to the many different types of cyclist and uses observed. Edinburgh has the lowest score with many cyclists being male and typically cycling for leisure/sport or hard-core commuter cyclists. In Edinburgh, the cycle infrastructure is connected to some extent, varying from good to minimal.

Conclusions

This research has used a detailed template to benchmark the Level of Service provided to cyclists in six European cities. The methodology has been tested using an experienced and a novice cyclist to capture their perceptions of the design of the cycle infrastructure in these cities. The literature review identified one of the barriers to encouraging more cycling is the potential/ inexperienced cyclist's perception of the safety, comfort and continuity of the cycling network in their city. The ride-alongs have produced insights into how diverse urban landscapes are perceived by cyclists of different abilities. There are limitations with the research in that the audit was not carried out by sufficient numbers of riders of different abilities and different socio-economic characteristics to generate a greater understanding of their perceived issues. Five of the case studies were undertaken in the months of September and October, whilst the Cambridge audit was undertaken in the month of January. The weather, however, was fairly similar in all case studies therefore should not impact on the outcomes. Amsterdam may have been the anomaly through the number of visiting tourists creating a different experience of cycling through the city. While an effort was made to visit all land uses, the case studies never undertook a comprehensive study of all areas due to the limited time in each city and resources available.

Whilst each city is unique, many of them share the same transportation issues. The growth of car use and the subsequent perceived problem of congestion, particularly during peak hour travel cause financial loss and negatively effects residents who live in the central areas. City administrations have been given a responsibility to improve the health and well-being of their electorate, to enhance infrastructure investments and the spatial legibility of their urban structure, provide convenient transportation options within the city centre and to create an attractive structure of public spaces. Over-dependence on the car is very important from the standpoint of current economic development and urban transformation. One of the solutions to the connectivity and accessibility issues that affect the city, and particularly congested city centres, is to invest in a network of cycling infrastructure. Of the case studies assessed within this research, the Dutch have the most experience to share.

What comes out in this research is that the design of cycle infrastructure involves several spatial and behavioural factors. It requires strong government support to create priority for cyclists and to provide a safe, comfortable and attractive network that integrates with a spatial policy that encourages the concentration of spatial opportunities. The Dutch have followed a spatial policy promoting a compact building style offering mixed use that reduces travel distance, which can be easily made by bicycle. To be safe and convenient to use, government policy must, at least, treat cyclists on an equal footing to car users, public transport users, and walkers. If the spatial policy can make the car less necessary and convenient to use, government financial policy can reinforce this through car taxation and tangible restrictions associated with owning a car and using it. They could change the legal system so that there is an insurance bias to protect vulnera-

ble road users. At the local level, promotion of cycling must involve more than physical infrastructure, it must integrate across policy delivery areas including spatial planning, transport, health and education.

With a supporting institutional structure pursuing agreed goals, as discussed above, the design of cycle infrastructure can have a big impact on choice. The strongest factors were safety, comfort and continuity. These will have to be at the forefront of design, which will need to be flexible enough to plan for any changes in cyclist's needs through using a palette of policy solutions. UK cities are starting to reduce the speed of motorised traffic, and/ or reduce the space for cars, in their cities. Funding is being found for new cycle lanes. This research has shown that these need to be wide to ensure that cyclists can overtake and are not obstructed by car doors opening. Burchfield (2009) and CROW (2009) both recommend a minimum width of five feet and eight feet for new sections of cycle-way. The Edinburgh and Cambridge case studies also highlight the importance of the consistency and continuity of the bicycle network to ensure that there are no discontinuities and difficulties at junctions. Dutch roundabout design which incorporates cycle lanes on roundabouts increases the visibility of the cyclist and moves conflict with other users away from the junction, without impeding queueing traffic (CROW, 2007; James 2012). Cyclist confidence and participation may be higher where cycle routes are segregated from other modes of transport, but there is still the issue of discontinuous cycle lanes at junctions where the risk of conflict will be present. The case studies also highlighted the necessity of continually upgrading and maintaining the cycle infrastructure, particularly the surface material, which effects perceptions of comfort and safety.

To conclude, this research has found that cycle infrastructure design can encourage more cycling. It is recommended that when designing cycle infrastructure the following should be considered:

- Wide cycle lanes.
- Direct routes connecting all land uses.
- Segregation where possible, especially on trunk roads and busy centre roads. Segregation does not have to be expensive. Bollards/vegetation can offer segregation through provision of a visual deterrent from driving and parking in cycle lanes. Adoption of the Dutch guidelines for cycle infrastructure.
- Clear signage. Include signage in order to join a cycle lane.
- No discontinuities of cycle lanes at hazardous locations (Junctions and roundabouts).
- For intersections implement either a system to bypass the danger or provide bicycle priority traffic lights.
- Use of high quality material for cycle lanes can offer comfort and reduce maintenance.
- Speed barriers that are visible (night) and do not make the cyclist dismount.
- High quality lighting on darker cycle lanes.
- Attractive settings, e.g. Greenery and place making.
- Frequent and high quality bicycle parking, not just at transport hubs.
- Design of end of route facilities to be discussed with business and employers. (showers, bike storage).
- Funding needs to be forthcoming, otherwise good quality infrastructure cannot be implemented.

- Don't implement cycle infrastructure as an add-on. Consider when designing all transport mode networks.

Other recommendations that are not included in design of cycle infrastructure, but have been noted in the case studies:

- Regular maintenance of roads.
- Enforcement (Cars and Cyclists) i.e. cars parking in cycle lanes, idling in Advanced Stop Lanes, dangerous overtaking of bicycles, cyclists running red lights (only noticed once during audit) and cycling on pedestrian only pavements.
- Cycle training for all new drivers.
- Continuing cycle training for schoolchildren.

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Appendix 1. Bicycle Infrastructure Score Sheet for Edinburgh

City: Edinburgh Date: 30/10/2013		Weather: Clear, Windy
Auditor:		
BLOS (Bicycle Level of Service)	Score	Comments
Consistency/Continuity		
Is there a choice of connections?	3	Within the City there is choice. This reduces with distance
Is there continuity to lanes?(no discontinuities, sudden stops)	1	There are many examples of lanes stopping suddenly on busy roads
Are lanes clear of obstruction? (Lamp posts, bins etc.).	2	A lot of lanes obstructed by parked cars. No public furniture blockage
Are lanes clear of multiple driveways?	3	Where lanes are present multiple driveways are minimal
Can lanes bypass junctions?	1	No. Only bike infrastructures at junctions are bike boxes/ ASLs
Can cyclists move quickly over junctions?	3	No. many bike boxes are blocked by busy car lanes
Average Score	2.17	
Directness		
How accessible are the bike paths/lanes?	3	Accessible in centre, but many routes not direct
Is signage present?	2	Signage's only present on NCN cycle routes. Even then it is minimal
Is speed/flow maintained?	2	A combination of parked cars indirect routes and poor road surface make speed and flow difficult to maintain
Is there bike priority traffic lights?	2	Many traffic lights have a bike symbol next to the green man but no priority given to cyclists. In Bruntsfield there is traffic buttons before sidewalk so you don't have to dismount
Is there a choice in destinations?	2	Not really unless you use the NCN route
Is it possible to overtake other cyclists?	2	Thin lanes make this hard to do
Average Score	2.17	
Attractiveness		
Does route feel safe?	1	Tight streets, tight bike lanes and poor surfaces can impair confidence
How secure are bikes from theft?	3	Bike parking being implemented more by the council. New lamppost bike parking. Most parking in the centre looks robust and secure. More is needed. Many full
Is there adequate lighting?	3	Street lights offer good lighting. Canal route has inspired light design to show route but it does not illuminate the area
Is there sufficient bicycle parking?	3	A lot of the bike racks are full. Many bikes informally locked to railings
Is there frequent bike parking?	2	Frequent on streets that are near Princes Street, otherwise No

(Continued)

Appendix 1. (Continued).

City: Edinburgh Date: 30/10/2013		Weather: Clear, Windy
Auditor:		
Ease of connection with public transport	2	Only the Train station has sufficient bike parking for connection with public transport. Bus station has minimal
Can Public transport accommodate bikes?	1	Only regional and national trains. Two at a time. Taxis can hold one bike
Are bike lanes free of parked cars?	1	No. A lot of on road bike lanes are blocked
Are bike lanes litter free?	4	Yes
Average Score	2.22	
Road safety		
Are other road users aware of cycle lanes and cyclists?	3	Edinburgh car drivers were mainly observant and patient. Many cars were stopping in the bike box at traffic lights
Are cyclists safe from parked cars door opening?	2	Not a lot of room between road lanes and car doors. Cars parked on curved roads are unlikely to see cyclist in wing mirrors
Does road design discourage fast overtaking automobiles and turning? (e.g. fast curved corners, slow right angled corners)	2	Residential roads with speed calming measures and a 20 mph speed limit discourage overtaking however on main roads cars always took their chances at overtaking
Is segregation available?	3	Yes, but only on off street lanes. Found near Arthurs Seat, the Meadows, and the old railway to Crammond from Haymarket. All NCN routes
Is the volume of traffic safe for cyclists?	1	Edinburgh Traffic very busy
Is traffic speed of automobiles safe for cyclists?	3	In residential areas yes, but main roads No
How safe is the navigation of Junctions?	2	ASL/ Bike boxes at junctions often blocked or cars waiting in them
How safe is the navigation of roundabouts?	3	Roundabouts on Calder road work with traffic lights making it safer to cross these busy roundabouts. But they are so busy
Average Score	2.38	
Comfort		
Is width of path/lane sufficient?	2	Apart from NCN off road cycle routes lanes are very thin. Some of the canal path is dangerously thin especially when shared with walkers and oncoming cyclists
Are high quality materials used?	2	Mostly rough tarmac on road and gravel for off-road paths
Is there a presence of gradients/hills that effect movement?	4	Most lanes have been rerouted to avoid many hills. Steepest gradient found was at the Mound
Is route maintained and free from cracks and foliage?	1	No. a lot of cracks and potholes. Means lots of weaving around
Is lane shared with public transport? (Bus, tram, taxi)	3	Yes, where available bus lanes are shared with cyclists and taxis. Central area shared with the Tram. (Tram tracks Dangerous to cyclists with thin tyres)

(Continued)

Appendix 1. (Continued).

City: Edinburgh Date: 30/10/2013		Weather: Clear, Windy
Auditor:		
Does the lane/shared space offer comfort to pedestrians?	2	Witnesses 3 cyclists using non-shared pavement. The Meadows and national route offer adequate space
Average Score	2.33	
Spatial Integration		
Suitability of infrastructure	2	Not very suitable. Most infrastructures consist of bike boxes at traffic lights and many short cycle lanes that end on busy roads
Is greenery present?	4	Yes, The canal route and Sustrans routes go through green and pleasant areas
Is town centre clearly distinguishable?	4	Yes, Edinburgh's compact city centre is distinguishable
Do areas have distinct identities?	4	Yes. It is easy to tell the boundary between local identities, especially on the canal route. And the innocent railway
Is there a sense of cultural identity?	4	Yes, from the old town, new town and Leith and many other neighbourhoods have a cultural identity
Does infrastructure compliment the area?	2	Only the Sustran routes compliment areas
Are the purposes of space clear?	3	
Average Score	3.29	
Experience (BSL)		
Does environment feel welcoming?	2	No, only off road provisions feel welcoming
Is it suitable for vulnerable users?(Young, elderly physical handicapped)	1	Many schools are situated near main roads and I could not recommend usage unless they were using the off road facilities which only reach a few areas
Are cyclists free of intimidation or abuse from other users of other transport modes?	3	Mostly. However items have been thrown off bridges that go over the canal
Are there other user types?		
Commuting/education	4	Most cyclists I encountered were commuting or they were students
Leisure/shopping	1	Hardly any cyclists
Average Score	2.20	
Socio-economic value		
Does Cycle infrastructure connect all land uses?	3	No, to get A to B in the city you would have to take a circuitous route costing time
Are businesses and workplace offering cyclist facilities?	3	Universities are offering the best cycle parking and changing rooms via their gyms. Heriot- Watts is adequate and usually full however Edinburgh university has Secure Electronic Access to bike parking. A lot of business places however provide minimal parking and it is not clear what facilities they offer employees such as showers
Inclusion of locals	4	There is a youth programme in Calder (Bridge8) that offers cycling training and days out on the canal
Average Score	3.33	

Appendix 2. Cycle Infrastructure Score Sheet Cambridge

City: Cambridge	Date: 02/01/2014	C & K	Weather: Overcast, damp
Auditor:		OHolleran	
BLOS (Bicycle Level of Service)	Score	Comments	
Consistency/Continuity			
Is there a choice of connections?	3	Yes, but not apparently clear	
Is there continuity to lanes?(no discontinuities, sudden stops)	2	A lot of cycle lane ends on main roads at driveways and junctions	
Are lanes clear of obstruction? (Lampposts, bins etc.)	5	Yes, no obstructions on lanes	
Are lanes clear of multiple driveways?	3	Yes and no, varies around the city	
Can lanes bypass junctions?	2	Cyclist would have to dismount to use pedestrian crossings	
Can cyclists move quickly over junctions?	2	No. Some ASL boxes, but varies	
Average Score	2.83		
Directness			
How accessible are the bike paths/lanes?	4	They are accessible	
Is signage present?	4	Yes signage is present, showing destinations and distances	
Is speed/flow maintained?	3	Not always, on some sections of road and segregated lanes speed and flow maintained. Suburbs had a lot of stopping and starting	
Is there bike priority traffic lights?	2	Only a few	
Is there a choice in destinations?	4	Yes, compact centre provided access to all destinations	
Is it possible to overtake other cyclists?	3	Some lanes were very wide allowing overtaking; however some in the town centre and suburbs were extremely thin	
Average Score	3.83		
Attractiveness			
Does route feel safe?	4	Routes feel safe due to many cyclists	
How secure are bikes from theft?	3	Some evidence of bike theft/vandalism	
Is there adequate lighting?	3	Yes, very good lighting in the centre, however suburbs had none	
Is there sufficient bicycle parking?	2	All cycle parking full, a lot of informal bike parking with cycles chained to fences	
Is there frequent bike parking?	4	Yes, with car spaces adapted to bike parking	
Ease of connection with public transport	3	Good connection with train station and trains	
Can Public transport accommodate bikes?	3	Standard 2–4 spaces per train journey	
Are bike lanes free of parked cars?	5	Yes, I never encountered and illegal parking in bike lanes	
Are bike lanes litter free?	5	Yes	
Average Score	3.56		

(Continued)

Appendix 2. (Continued).

City: Cambridge	Date: 02/01/2014	C & K	
Auditor:		OHolleran	Weather: Overcast, damp
Road safety			
Are other road users aware of cycle lanes and cyclists?	5	Yes due to mass cycling	
Are cyclists safe from parked cars door opening?	4	Where there is car parking, the cycle lanes are double width avoiding conflict with car doors	
Does road design discourage fast overtaking automobiles and turning? (e.g. fast curved corners, slow right angled corners)	5	Yes there is a lot of traffic calming measures (hard and soft)	
Is segregation available?	4	On some main roads connected to the centre, traveling beside guided bus lane	
Is the volume of traffic safe for cyclists?	3	High volume of traffic	
Is traffic speed of automobiles safe for cyclists?	3	Yes. Slow speed limits	
How safe is the navigation of Junctions?	2	Most junctions carry bike to priority crossings	
How safe is the navigation of roundabouts?	2	Standard roundabouts some had red colouring the same as bike lanes. Confusing as it is not an ASL bike box	
Average Score	3.50		
Comfort			
Is width of path/lane sufficient?	3	Where available yes	
Are high quality materials used?	2	No, a lot of lane colouring and marking lifting	
Is there a presence of gradients/hills that effect movement?	5	No	
Is route maintained and free from cracks and foliage?	2	A lot of deep potholes in cycle lane and road	
Is lane shared with public transport? (Bus, tram, taxi)	4	Just some bus lanes	
Does the lane/shared space offer comfort to pedestrians?	4	The main shared areas were cycle routes through parks, and immediate historic centre. Shared areas in centre (including some buses)	
Average Score	3.33		
Spatial Integration			
Suitability of infrastructure	3	Because of the street density and structure, it is as suitable. However maintenance is a big issue. There is a large amount of cycle traffic, this is one city where cycling in numbers is in action despite available infrastructure	
Is greenery present?	4	Yes, there are a lot of parks in the centre and suburb. Greenery is not as apparent in the centre	
Is town centre clearly distinguishable?	5	Yes. It is easy to distinguish when you are in the centre	

(Continued)

Appendix 2. (Continued).

City: Cambridge	Date: 02/01/2014	C & K	
Auditor:		OHolleran	Weather: Overcast, damp
Do areas have distinct identities?	5	Yes, an historic core, and University quarter provide character	
Is there a sense of cultural identity?	4	as above	
Does infrastructure compliment the area?	3	There could be a lot done in terms of width and maintenance, to properly compliment the area	
Are the purposes of space clear?	3	The shared space in the centre could be clearer; I got a fright when I saw a bus heading for me in a thin shared space	
Average Score	3.86		
Experience (BSL)			
Does environment feel welcoming?	4	Yes, despite many discontinuities and maintenance issues the environment felt welcoming	
Is it suitable for vulnerable users? (Young, elderly physical handicapped)	3	It is suitable for locals and those who know the network, but it is advised that other users get training first	
Are cyclists free of intimidation or abuse from other users of other transport modes?	5	Yes, due to drivers acceptance of the amount of cyclists in the area	
Are there other user types?			
Commuting/education	5	I encountered all user types, of all ages and gender	
Leisure/ shopping	5	As above	
Average Score	4.40		
Socio-economic value			
Does Cycle infrastructure connect all land uses?	4	Yes	
Are businesses and workplace offering cyclist facilities?	3	The University offered cyclist facilities, however it was hard to determine if businesses were also providing	
Inclusion of locals	4		
Average Score	3.67		
DEN HAAG			

Appendix 3. Bicycle Infrastructure Score Sheet for Den Haag

City: Den Haag	Date: 01/09/2013	OHolleran/ Fern	Weather: Clear, Windy
Auditor:			
BLOS (Bicycle Level of Service)	Score	Comments	
Consistency/Continuity			
Is there a choice of connections?	5	Very good	
Is there continuity to lanes?(no discontinuities, sudden stops)	4	Good long sections of cycle infrastructure	
Are lanes clear of obstruction? (Lampposts, bins etc.)	5	No obstructions	
Are lanes clear of multiple driveways?	5	Yes	
Can lanes bypass junctions?	4	Around the main centre, on road lanes present cycle priority lanes. Otherwise cycle priority traffic lights are present	
Can cyclists move quickly over junctions?	4	Not many crossing points, allowing a good flow	
Average Score	4.50		
Directness			
How accessible are the bike paths/lanes?	5	Very accessible and easy to join	
Is signage present?	5	Clear signage everywhere including distances to main areas	
Is speed/flow maintained?	5	Yes	
Is there bike priority traffic lights?	5	Yes	
Is there a choice in destinations?	5	All areas appear to be accessed easily providing a wealth of destinations	
Is it possible to overtake other cyclists?	3	Segregated lanes offer adequate space, however on road lanes less so	
Average Score	4.67		
Attractiveness			
Does route feel safe?	5	Yes. Easy to get around and feeling safe	
How secure are bikes from theft?	5	All areas felt secure to leave bike	
Is there adequate lighting?	5	Lighting is very good	
Is there sufficient bicycle parking?	5	Yes	
Is there frequent bike parking?	5	Yes	
Ease of connection with public transport	4	Good, easy to find stations	
Can Public transport accommodate bikes?	4	Yes. On busses, train and tram	
Are bike lanes free of parked cars?	5	Yes no parked cars on cycle infrastructure	
Are bike lanes litter free?	5	Yes	
Average Score	4.78		
Road safety			
Are other road users aware of cycle lanes and cyclists?	5	Yes signage, everywhere, and lanes clearly. Public and motor traffic aware	
Are cyclists safe from parked cars door opening?	5	As above, no parking near cycle lanes	
Does road design discourage fast overtaking automobiles and turning? (e.g. fast curved corners, slow right angled corners)	5	Yes. Low speed limits throughout centre and no road markings in residential areas discourage motor vehicle overtaking	
Is segregation available?	4	Yes	

(Continued)

Appendix 3. (Continued).

City: Den Haag Date: 01/09/2013 Auditor:	O'Holleran/ Fern	Weather: Clear, Windy
Is the volume of traffic safe for cyclists?	5	Yes
Is traffic speed of automobiles safe for cyclists?	5	Yes
How safe is the navigation of Junctions?	4	Very good. Larger junctions offer bicycle markings across with priority lights
How safe is the navigation of roundabouts?	5	
Average Score	4.75	
Comfort		
Is width of path/lane sufficient?	4	Lanes generally wide. On road lanes are not as wide
Are high quality materials used?	5	Very smooth asphalt
Is there a presence of gradients/hills that effect movement?	5	None
Is route maintained and free from cracks and foliage?	5	No maintenance issues
Is lane shared with public transport? (Bus, tram, taxi)	4	Only in the old centre cycles share (trams), otherwise it is a mix of on road cycle lanes and segregated lanes
Does the lane/shared space offer comfort to pedestrians?	4	Yes. The Old Centre where the streets are narrow is shared space with cyclist and trams. Speed limits are in force for cyclists
Average Score	4.50	
Spatial Integration		
Suitability of infrastructure	5	Den Hagg utilises many different styles of cycle infrastructure due to the cities diverse structure. All which is suitable
Is greenery present?	5	A lot of parks present, with off-road cycle routes throughout
Is town centre clearly distinguishable?	5	8 main districts are clearly distinguishable
Do areas have distinct identities?	5	North Quarter, Historic Core, New Core, Old centre all clearly have distinct identity
Is there a sense of cultural identity?	5	Yes. Old town is preserved as well newer areas offering their own identity
Does infrastructure compliment the area?	5	Infrastructure between areas is implemented to fit in with the distinct characteristics and limitations of each area
Are the purposes of space clear?	5	Yes
Average Score	5.00	
Experience (BSL)		
Does environment feel welcoming?	4	Yes. The city was a joy to navigate and at no point did I or the other auditor feel threatened

(Continued)

Appendix 3. (Continued).

City: Den Haag	Date: 01/09/2013	O'Holleran/ Fern	Weather: Clear, Windy
Auditor:			
Is it suitable for vulnerable users? (Young, elderly physical handicapped)	3	Yes. The infrastructure is suitable to an extent. This is due to the on road lanes present in some areas	
Are cyclists free of intimidation or abuse from other users of other transport modes?	5		
Are there other user types? Commuting/education	5	We met many helpful locals, who would stop and ask if we needed any directions if we took out a map. (We didn't) there were many user types. One gentleman we met cycled to his work each week (50 miles!) and back again for the weekend	
Leisure/shopping	5	Yes, as above	
Average score	4.40		
Socio-economic value			
Does Cycle infrastructure connect all land uses?	5	Very good. Easy to get to public transport, centre, educational facilities and suburbs	
Are businesses and workplace offering cyclist facilities?	5	Cycle parking and electric bike charging points at office buildings	
Inclusion of locals	5	There were a lot of local cyclists	
Average Score	5.00		

Appendix 4. Bicycle Infrastructure Score Sheet for Rotterdam

City: Rotterdam Date: 02/09/2013		OHolleran/ Fern	Weather: Fair/Overcast
Auditor:			
BLOS (Bicycle Level of Service)	Score	Comments	
Consistency/Continuity			
Is there a choice of connections?	4	Yes	
Is there continuity to lanes?(no discontinuities, sudden stops)	4	Only one discontinuity (left hand looser)	
Are lanes clear of obstruction? (lampposts, bins etc.).	5	No Obstructions at all	
Are lanes clear of multiple driveways?	4	Lanes are only stopped for roads	
Can lanes bypass junctions?	5	Lanes surround Spaghetti Junction at north of city	
Can cyclists move quickly over junctions?	4	A lot of crossing points but have bicycle priority lights	
Average Score	4.33		
Directness			
How accessible are the bike paths/lanes?	5	Very good	
Is signage present?	3	Signage present but is vague or misleading. I.e. same location on 2 signs pointing two different ways	
Is speed/flow maintained?	4	Yes	
Is there bike priority traffic lights?	4	Present on large/busy junctions	
Is there a choice in destinations?	3	Suburbs to centre is main choice	
Is it possible to overtake other cyclists?	5	Lanes are wide enough for 2–3 bikes	
Average Score	4.17		
Attractiveness			
Does route feel safe?	3	A lot of suburb housing on route clearly stood out as social housing, with neighbourhood maintenance low. Graffiti on motorway underpasses	
How secure are bikes from theft?	3	Some areas were not the cleanest, with bikes parked haphazardly	
Is there adequate lighting?	5	Lighting was good, even when leaving city	
Is there sufficient bicycle parking?	3	Not as many bike parking as other Dutch cities	
Is there frequent bike parking?	3	In most of the city centre parking is frequent. But the historic part has less parking frequency	
Ease of connection with public transport	2	Not that easy. Public transport hard to spot	
Can Public transport accommodate bikes?	3	Only tram and train. Accommodate for 2 bikes per carriage	
Are bike lanes free of parked cars?	5	Not one car found parked in a bike lane	
Are bike lanes litter free?	4	Mainly in the centre, the further out some litter was present but minimal	
Average Score	3.44		

(Continued)

Appendix 4. (Continued).

City: Rotterdam Date: 02/09/2013 Auditor:	OHolleran/ Fern	Weather: Fair/Overcast
Road safety		
Are other road users aware of cycle lanes and cyclists?	5	Roads, paths and cycle-ways clearly defined
Are cyclists safe from parked cars door opening?	5	There is a lot of segregation, but where cycle lanes are on road, there are adequate clearances beside parked cars
Does road design discourage fast overtaking automobiles and turning? (e.g. fast curved corners, slow right angled corners)	4	There is a lot of shared space areas, which car drivers are aware of cycle priority. Tight corners. Cars have to give way for cyclists
Is segregation available?	5	Yes
Is the volume of traffic safe for cyclists?	3	Roads were multi-lane with heavy traffic
Is traffic speed of automobiles safe for cyclists?	3	As above
How safe is the navigation of Junctions?	4	Cycle priority lights allow safe crossing
How safe is the navigation of roundabouts?	2	Whereas most of the Netherlands implemented roundabouts effectively I did not find any roundabouts in Rotterdam
Average Score	3.88	
Comfort		
Is width of path/lane sufficient?	5	Lanes/Paths 3 m wide
Are high quality materials used?	5	Smooth asphalt (coloured in city)
Is there a presence of gradients/hills that effect movement?	5	Flat apart from bridges
Is route maintained and free from cracks and foliage?	4	Route is well maintained apart from some foliage creeping in the north of the city
Is lane shared with public transport? (Bus, tram, taxi)	3	Only in the immediate centre
Does the lane/shared space offer comfort to pedestrians?	4	Mostly segregated but beside paths. Pedestrians aware of bikes
Average Score	4.33	
Spatial Integration		
Suitability of infrastructure	5	Materials and use of segregation are suitable for this modern city with heavy traffic and a block structure
Is greenery present?	2	Trees beside segregated lanes allowing for informal mental barriers between path uses
Is town centre clearly distinguishable?	4	High density office and retail clearly different to residential areas. Modern city
Do areas have distinct identities?	4	The centre, dockyards and the immediate south quarter are distinct
Is there a sense of cultural identity?	2	Very modern city, with some good architecture but it could have been anywhere
Does infrastructure compliment the area?	4	The waterfront had the most complimentary use for bike infrastructure

(Continued)

Appendix 4. (Continued).

City: Rotterdam Date: 02/09/2013 Auditor:	O'Holleran/ Fern	Weather: Fair/Overcast
Are the purposes of space clear?	4	Purposes clearly defined
Average Score	3.57	
Experience (BSL)		
Does environment feel welcoming?	4	
Is it suitable for vulnerable users? (Young, elderly physical handicapped)	5	It was noted that there were a large mix of elderly and youngsters on bikes confident about cycling through the city
Are cyclists free of intimidation or abuse from other users of other transport modes?	5	Yes, there was not one incident of intimidation
Are there other user types?		
Commuting/education	5	Commuting looked to be the main purpose
Leisure/ shopping	4	Many shoppers traveling with bikes that had lots of storage/and multi-capacity bikes
Average Score	4.60	
Socio-economic value		
Does Cycle infrastructure connect all land uses?	5	
Are businesses and workplace offering cyclist facilities?	4	At office buildings there were dedicated bike parking and signs for changing facilities and even charge points for e-bikes
Inclusion of locals	4	Everyone was cycling; I stood out due to luggage and type of bike
Average Score	4.33	

Appendix 5. Bicycle Infrastructure Score Sheet for Utrecht

City: Utrecht	Date: 04/09/2013	OHolleran	
Auditor:		/ Fern	Weather: Clear, Windy
BLOS (Bicycle Level of Service)	Score	Comments	
Consistency/Continuity			
Is there a choice of connections?	5	Very good	
Is there continuity to lanes?(no discontinuities, sudden stops)	4	Good long sections of cycle infrastructure	
Are lanes clear of obstruction? (Lampposts, bins etc.)	5	No obstructions	
Are lanes clear of multiple driveways?	5	Yes	
Can lanes bypass junctions?	4	Most of the centre Pedestrianised, allowing easy movement	
Can cyclists move quickly over junctions?	5	A lot of crossing points (quick change lights)	
Average Score	4.67		
Directness			
How accessible are the bike paths/lanes?	5	Very accessible and easy to join	
Is signage present?	5	Clear signage everywhere including distances to main areas	
Is speed/flow maintained?	5	Yes	
Is there bike priority traffic lights?	5	Yes	
Is there a choice in destinations?	5	All areas appear to be accessed easily providing a wealth of destinations	
Is it possible to overtake other cyclists?	3	More shared areas(Public/bikes) than other Dutch Cities, centre busy	
Average Score	4.67		
Attractiveness			
Does route feel safe?	5	Yes. Easy to get around and feeling safe	
How secure are bikes from theft?	5	All areas felt secure to leave bike	
Is there adequate lighting?	5	Lighting is very good	
Is there sufficient bicycle parking?	5	Yes	
Is there frequent bike parking?	5	Yes	
Ease of connection with public transport	4	Good, easy to find stations	
Can Public transport accommodate bikes?	4	Yes. On busses, train and tram	
Are bike lanes free of parked cars?	5	Hard to find any car parking in the centre	
Are bike lanes litter free?	5	Yes	
Average Score	4.78		
Road safety			
Are other road users aware of cycle lanes and cyclists?	5	Yes signage, everywhere, and lanes clearly. Public and motor traffic aware	
Are cyclists safe from parked cars door opening?	5	As above, no parking near cycle lanes	
Does road design discourage fast overtaking automobiles and turning? (e.g. fast curved corners, slow right angled corners)	5	Yes. Main road circles the centre	
Is segregation available?	4	Yes	

(Continued)

Appendix 5. (Continued).

City: Utrecht Auditor:	Date: 04/09/2013	O'Holleran / Fern	Weather: Clear, Windy
Is the volume of traffic safe for cyclists?	5	Yes	
Is traffic speed of automobiles safe for cyclists?	5	Yes	
How safe is the navigation of Junctions?	4	Very good. Larger junctions offer bicycle markings across with priority lights	
How safe is the navigation of roundabouts?	5		
Average Score	4.75		
Comfort			
Is width of path/lane sufficient?	4	Mostly shared space, however segregated near ring road. Width is very good	
Are high quality materials used?	5	Very smooth asphalt	
Is there a presence of gradients/hills that effect movement?	5	None	
Is route maintained and free from cracks and foliage?	5	No maintenance issues	
Is lane shared with public transport? (Bus, tram, taxi)	5	No	
Does the lane/shared space offer comfort to pedestrians?	3	Less comfort to both parties in the centre. Especially when busy	
Average Score	4.50		
Spatial Integration			
Suitability of infrastructure	4	Medieval centre, with thin streets. However no cars in main centre (I Wonder how they get deliveries)	
Is greenery present?	4	A lot of parks present, with off-road cycle routes in the suburbs. Not a lot of greenery in centre	
Is town centre clearly distinguishable?	5	Yes.	
Do areas have distinct identities?	5	Quite a compact city, however very distinct identities	
Is there a sense of cultural identity?	5	Yes. Old town is preserved as well newer areas offering their own identity	
Does infrastructure compliment the area?	5	Infrastructure between areas is implemented to fit in with the distinct characteristics and limitations of each area	
Are the purposes of space clear?	5	Yes	
Average Score	4.71		
Experience (BSL)			
Does environment feel welcoming?	4	Yes. However I had to walk my bike in a few busy pedestrianised streets in the centre	
Is it suitable for vulnerable users? (Young, elderly physical handicapped)	5	Yes	
Are cyclists free of intimidation or abuse from other users of other transport modes?	5	None witnessed or experienced	

(Continued)

Appendix 5. (Continued).

City: Utrecht	Date: 04/09/2013	OHolleran	
Auditor:		/ Fern	Weather: Clear, Windy
Are there other user types?			
Commuting/education	5	Yes, cycle lanes were busy with all types of cyclists	
Leisure/ shopping	5	As above	
Average Score	4.80		
Socio-economic value			
Does Cycle infrastructure connect all land uses?	5	Very good. Easy to get to public transport, centre, educational facilities and suburbs	
Are businesses and workplace offering cyclist facilities?	5	Cycle parking and electric bike charging points at office buildings	
Inclusion of locals	5	There were a lot of local cyclists	
Average Score	5.00		

Appendix 6. Bicycle Infrastructure Score Sheet for Amsterdam

OHolleran/Fern		Weather: Sunny, clear, High temperature
BLOS (Bicycle Level of Service)	Score	Comments
Consistency/Continuity		
Is there a choice of connections?	City: Amsterdam Date: 04/09/2013 Auditor:	Only time I have got lost in the Netherlands. Confusing signage to locations. Mostly all signs point lead to the city centre
Is there continuity to lanes?(no discontinuities, sudden stops)	3	A lot of short streets with many junctions
Are lanes clear of obstruction? (Lampposts, bins etc.)	5	Yes
Are lanes clear of multiple driveways?	4	Yes
Can lanes bypass junctions?	5	Bike priority traffic lights everywhere
Can cyclists move quickly over junctions?	4	Very busy city. Bike queues at junctions
Average Score	4.17	
Directness		
How accessible are the bike paths/lanes?	4	Only when out of the city centre are they really accessible
Is signage present?	4	Not as prevalent as other Dutch cities. There is not much in the city centre but there is a lot in the suburbs pointing towards the CC
Is speed/flow maintained?	3	Lots of stopping and starting at junctions
Is there bike priority traffic lights?	5	Many
Is there a choice in destinations?	3	The hardest city in the Dutch case studies to find your way around
Is it possible to overtake other cyclists?	3	A lot of shared road space with cars in immediate centre. Overtaking not recommended
Average Score	3.67	
Attractiveness		
Does route feel safe?	3	Very busy and hectic in centre, only when in suburbs does it feel safe again. Yet graffiti is present, but not to a great extent
How secure are bikes from theft?	4	A lot of 'shifty' looking characters around train station. I was even offered a bike for 10 euros!
Is there adequate lighting?	5	Yes
Is there sufficient bicycle parking?	5	Yes
Is there frequent bike parking?	5	yes
Ease of connection with public transport	4	A good tram system that serves most areas
Can Public transport accommodate bikes?	4	Trams hold 2 bikes per carriage.

(Continued)

Appendix 6. (Continued).

	OHolleran/Fern	Weather: Sunny, clear, High temperature
Are bike lanes free of parked cars?	4	spotted 2 cars in bike lanes (only 2 of the whole Dutch trip)
Are bike lanes litter free?	3	A lot of streets in the centre were dirty, however the suburbs were very clean and well maintained
Average Score	4.11	
Road safety		
Are other road users aware of cycle lanes and cyclists?	4	Yes due to mass cycling
Are cyclists safe from parked cars door opening?	4	In the centre you are not completely safe, however segregation in the suburbs you are
Does road design discourage fast overtaking automobiles and turning? (e.g. fast curved corners, slow right angled corners)	5	Yes, even though the centre is mainly composed of thin shared roads, they are usually so thin they can't overtake. Slow speed limit in centre
Is segregation available?	4	On main roads and the suburbs
Is the volume of traffic safe for cyclists?	3	Recommended to cycle elsewhere in the Netherlands before coming here. Traffic volume is very high for cyclists and cars
Is traffic speed of automobiles safe for cyclists?	5	Yes. Slow speed limits
How safe is the navigation of Junctions?	4	Most junctions carry bike to priority crossings
How safe is the navigation of roundabouts?	5	Segregation on roundabouts
Average Score	4.25	
Comfort		
Is width of path/lane sufficient?	4	Where available yes
Are high quality materials used?	5	Same as everywhere in the Netherlands
Is there a presence of gradients/hills that effect movement?	5	No
Is route maintained and free from cracks and foliage?	5	Yes
Is lane shared with public transport? (Bus, tram, taxi)	5	Cycle lanes segregated from tram ways
Does the lane/shared space offer comfort to pedestrians?	3	A lot of the crossing were shares with public crossing
Average Score	4.50	
Spatial Integration		
Suitability of infrastructure	4	Because of the street density and structure, it is as suitable as it can be without pedestrianizing the centre (like Utrecht). Considering the amount of cycle traffic, this is one city where cycling in numbers is in action

(Continued)

Appendix 6. (Continued).

	O'Holleran/Fern	Weather: Sunny, clear, High temperature
Is greenery present?	5	Yes most streets have trees running beside the canals
Is town centre clearly distinguishable?	5	Yes. East holds the industrial quarter, while the centre itself is distinguished by its street structure and architecture
Do areas have distinct identities?	5	The centre alone has a few distinct identities the suburb areas all feel like different towns
Is there a sense of cultural identity?	5	As above
Does infrastructure compliment the area?	4	There is no overpowering infrastructure. Mostly it is subtle
Are the purposes of space clear?	3	
Average Score	4.43	
Experience (BSL)		
Does environment feel welcoming?	3	Hustle and bustle of a tourist destination
Is it suitable for vulnerable users? (Young, elderly physical handicapped)	3	It is suitable for locals, but it is advised that other users get training first
Are cyclists free of intimidation or abuse from other users of other transport modes?	5	Even though this is a busy city not one did I encounter any abuse
Are there other user types? Commuting/education	5	Everyone was cycling (including tourists)
Leisure/shopping	5	As above
Average Score	4.20	
Socio-economic value		
Does Cycle infrastructure connect all land uses?	3	It does, but is harder to find than other Dutch cities.
Are businesses and workplace offering cyclist facilities?	5	
Inclusion of locals	5	
Average Score	4.33	