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Interventions in bicycle infrastructure, lessons from Dutch and Danish cases

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Abstract

Today the interest in cycling is increasing worldwide and in many countries authorities are faced with the question how cycling can be promoted efficiently. In the Netherlands and Denmark, this question came up already in the 1970s when the downsides of the rapidly increasing motorisation became evident. At the time, in both countries large scale interventions in bicycle infrastructure were introduced and evaluated extensively in order to create knowledge on efficient promoting of cycling in urban areas. The interventions included the construction of new bicycle routes on urban arterials in some larger cities and an area wide comprehensive upgrade of the bicycle network one medium sized city (Delft). The evaluations were based on before and after studies where in the case of Delft also a long-term after study was performed. The evaluations produced a wealth of information about the impacts of interventions in bicycle infrastructure on travel choices, safety, design appreciation, and other factors. These clarify under which conditions certain measures are effective or not and inform about the effectiveness of improving a single route versus upgrading a whole network. The information from the studies was used in both countries for formulating guidelines for road and bicycle infrastructure design. However, at that time the study results were not shared with the international scientific audience. The paper describes briefly the classical cases and the main study results.

The outcomes of the classical studies are compared with those of some more recent cases of assessed interventions in urban bicycle infrastructure in the Danish largest cities. Generally the outcomes are in line with those from the classical studies. This indicates that results of the latter are rather timeless and are likely to be still generally valid. In addition to studies that traditionally focus on dedicated bicycle infrastructure, two cases of shared space are discussed, a rather new type of intervention that assumes mixed use of infrastructure. One case is from Denmark, the other from the Netherlands.

The paper will so uncover the valuable results of the possibly largest evaluations of interventions in bicycle infrastructure ever made, verify these by examining more recent studies, and contribute to the discussion of shared space.

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1. Introduction

In countries all over the world a growing interest in the bicycle can be observed. There is an increasing acknowledgement that a shift from motorized modes to the bicycle relieves traffic problems regarding congestion and environment, and that cycling contributes to the fitness and health (Oja *et al.*, 1998). The importance of bicycle promotion is recognized in a number of European countries (ECMT, 2004) and the United States (U.S. Department of Transportation, 2010), and in many other regions initiatives are taken to raise the level of bicycle use. The higher interest in cycling generates demand for knowledge on effective bicycle promoting policy.

The Netherlands and Denmark, the two countries with the highest level of bicycle use in the western world (Pucher and Buehler, 2008), are credited with a guiding role. Phil Jones Associates (2014) report in their search for best practices for cycling infrastructure that “almost every authority we visited outside the Netherlands or Denmark explicitly stated that they had looked to cities in these countries for guidance on how they might grow cycling” (p. 16). In these countries, the acknowledgement that the bicycle is an important mode that should be promoted came up early, in the 1970’s, and gave cause for a number of sometimes extensive research projects. The projects gave a wealth of knowledge on design, travel behaviour, safety, and other aspects that are relevant for a good bicycle policy, and they are at the root of the current leading role of the countries regarding cycling. However, at the time it was no common practice to publish results in international journals, even if studies had good scientific standards, and dissemination to an international audience was almost lacking. Recently, the largest early Dutch projects were extensively described by Van Goeverden and Godefrooij (2011).

The paper aims to give a brief overview of the results of a number of the older classical studies in both the Netherlands and Denmark, to discuss the results of these studies in connection with those of later research in the two countries, and to indicate what policy makers can learn from these studies. Inclusion of some recent studies gives the opportunity to verify the current validity of the old results and to discuss a topic that became more recently subject of discussion: shared space. Shared space cuts across the general notion that cyclists preferably can use dedicated infrastructure, which was fed by the results of most of the early studies.

Section 2 outlines the development of political attitudes towards the bicycle in the Netherlands and Denmark, and the related demand for research. It also lists the case studies that are reviewed in the paper. Sections 3 to 6 discuss the study results by theme: travel behaviour, safety, appreciation of design, and economy. The concluding Section 7 summarizes the study outcomes and gives recommendations for enhancing bike-ability.

2. Bicycle research in the Netherlands and Denmark

After the rise of the bicycle in the 19th and first half of the 20th century in Europe, usage of this mode dropped in the 1950’s and 1960’s when the private car manifested a breathtaking growth. Whereas initially the policies supported and facilitated the rapidly growing motorization, in the 1970s people became aware of its downsides. The toll on the roads soared; the report of the Club of Rome noticed that growth has its limits; and the oil crisis in 1973 demonstrated that motorized transport is vulnerable. In some countries, including the Netherlands and Denmark, the policies changed dramatically in favour of the non-motorized modes (Pucher and Buehler, 2008). To create knowledge on efficient promotion of cycling, in the 1970s and 1980s in both counties a number of bicycle projects were implemented and evaluated. The Dutch national government funded the construction and extensive evaluation of two demonstration projects, new bicycle routes traversing the cities of Tilburg and The Hague, and contributed significantly to the funding and evaluation of the upgrade of the bicycle network in the city of Delft. In Denmark, there were several initiatives at the national level and particularly the cities of Copenhagen and Odense were active

in improving bicycle infrastructure and evaluating the impacts on cycling volume (Bach, 1985, Engel and Iversen, 1978).

The political attitudes in the two countries remained bicycle-friendly since. In the 1990s a Bicycle Masterplan was launched in the Netherlands (Ministry of Transport, Public Works and Water Management, 1999) while in Denmark promoting cycling was one of the targets of the Masterplan for Transport (Herrstedt, 1999). The latter was followed by a National Bicycle Action Plan (ECMT, 2004). These plans aimed at supporting lower authorities in promoting cycling, partly by creating and disseminating relevant knowledge. In the Netherlands, this proved to be effective. Bicycle promotion became an essential ingredient in local transport plans (Van Goeverden & Godefrooij, 2010). In Denmark, the observation that the bicycle lost market share was reason for a national programme to promote cycling which included funding for municipal projects (cykelpuljen), upgrading of facilities on national roads, as well as an annual cycling conference (Regeringen *et al*, 2009; Nielsen *et al*, 2013). The acknowledged challenge of maintaining and increasing cycling was also the offset of a new bicycle research project (Bikeability; www.bikeability.dk) that should enlarge knowledge on how bike-ability can be enhanced in urban areas.

This paper reviews a number of the early Dutch and Danish studies and adds the results of some recent studies. Table 1 gives an overview of the reviewed studies. The ‘naming’ column indicates the name that is used for the project in the paper, and includes also the name of the city if the project name differs from the city name. The ‘reference’ column includes the publication that reports the study. If (and only if) there are more publications for one study, hereafter references will be made to the publications referred to.

Table 1. Overview of reviewed studies.

Naming, city	Description of intervention	Year, period	Evaluation	Reference
<i>Early studies</i>				
Tilburg	Improved cycling route traversing the city from west to east, continuing to neighbouring villages (4 km inside the city, 12 km outside the city). Includes new bicycle paths outside the city centre and restricted car access on the route at the streets in the centre.	1976-1977	Before and after study including bicycle counts and surveys among cyclists and among residents of and commuters to the area served by the improved route. Assessed impacts: bicycle use, appreciation of cycling quality, actual and perceived safety, design, and economy.	Many thematic reports
The Hague	Improved cycling route from southwest to the city centre, routed between two main arterials through densely built urban districts (6 km). Includes new cycling paths and priority for cyclists at intersections.	1976-1977	The evaluation scheme is identical to that of Tilburg	Many thematic reports
Delft	Upgrade of the bicycle network in the whole city. Three networks were defined on different hierarchical levels: city network, district network, and neighbourhood network. The upgrade raised the quality to defined quality requirements for each network. It included various projects, like constructing new cycle paths, abolish one way traffic for bikes, building new bridges and tunnels. In total 128 different projects were carried out covering 24 km.	1983-1985	Before, short-term after, and long-term after study (ca 8 years after the interventions). For assessment of short-term impacts a control area and two experimental areas were defined. Includes bicycle counts at a cordon around one experimental area and travel surveys among residents of the three defined areas. Assessed impacts: bicycle use, appreciation of cycling quality, actual and perceived safety.	Many thematic reports
Engel and Iversen (1978)	General study, not related to a specific intervention		Study of bicycle use, route choice, road user assessment of problems.	
Bach (1985), Copenhagen and Odense	Construction of a large number of new bicycle paths in the two cities.	1975-1983	Before and after bicycle counts, evaluating the impact on cycling volume.	Bach (1985)

Table 1 (continued)				
Naming, city	Description of intervention	Year, period	Evaluation	Reference
<i>Recent studies</i>				
Bryggebroen, Copenhagen	New bridge for bicycles and pedestrians, connecting urban development areas across the harbour with southern parts of the city.	2006	After surveys among cyclists. Assessed impacts: frequency of bicycle use, appreciation of design and cycling quality, perceived safety.	Andrade Carneiro da Silva <i>et al</i> (2011) COWI (2009a)
Åbuen, Copenhagen	New green cycle route in central area but circumferential. Includes bicycle/pedestrian bridge crossing main road.	2008	Survey among cyclists, assessing modal shift and appreciation of cycling quality.	COWI (2009b)
Århus	Construction of cycle paths at each side of a road that connects a suburb with the city centre (0.4 km).	2010	The evaluation scheme is identical to that of Bryggebroen.	Andrade Carneiro da Silva <i>et al</i> (2011)
Vestergade, Odense	Transformation of a crowded street with mixed traffic in the central area into shared space where motorized traffic is not allowed, except for delivery freight vehicles (0.3 km).	2010	The evaluation scheme is identical to that of Bryggebroen.	Andrade Carneiro da Silva <i>et al</i> (2011)
Albertslundruten, Copenhagen	Improved connectivity of existing cycle paths between suburbs and the city centre (18 km). The routing is 'patchy' through various residential districts avoiding the main road arterials.	2012	Before and after study, including bicycle counts and questionnaire among cyclists. Assessed impacts: bicycle use, appreciation of cycling quality, perceived safety	COWI (2012)
Farumruten, Copenhagen	Improved existing cycle route between suburbs and the city centre (21 km). It is mainly a dedicated cycling highway along a motorway.	2013	The evaluation scheme is identical to that of Albertslundruten	COWI (2014)
Haren	Reconstruction of the main road traversing the city of Haren a suburb of Groningen (0.4 km). The road with separated zones for cars, bicycles and pedestrians was converted into one shared space area with mixed traffic and lower permitted speeds.	2002	Telephonic interviews with residents of the city	Van der Velde and Bos (2008)

In the Delft study, the short-term analyses were more elaborate and gave more sound results than those for the long term. It was difficult to separate long-term impacts of the interventions from those of other developments in the same period (ca 8 years). The review in this paper regards the short-term analyses, except when otherwise stated.

3. Travel choices

Most of the reviewed studies give some evidence of impacts of the interventions on either cycling volume or one of the choices that affect this volume: modal choice and route choice.

3.1. Cycling volume

The impact of an intervention on cycling volume generally is assessed by either traffic counts before and after the intervention or questions about changes in bicycle use asked in a questionnaire among bicyclists after the intervention. Traffic counts principally register the changes in cycling volume most accurately, but they cannot link changes to either causes for a change or characteristics of the trip (e.g. purpose) and the traveler. A questionnaire can at least include questions about trip and traveller characteristics. Traffic counts can be limited to the improved route or include alternative parallel routes in order to assess the net impacts in the corridor. Table 2 shows the results for a number of studies.

Table 2. Changes in cycling volume.

Study	Counted increases of bicycle use		Persons reporting increase (decrease) in frequency of bicycle use	
	Along the route	In the corridor	All trips	Trips with the same purpose
Tilburg (DHV <i>et al.</i> , 1980)	140%	10-15%		28% (6%) ¹
The Hague (DHV <i>et al.</i> , 1980)	76%	10-20%		27% (8%) ¹
Bach (1985)		0-30%		
Bryggebroen (COWI and Andrade <i>et al.</i>)		12-19%	31%	42% (2%)
Århus			13%	24% (3%)
Vestergade			7%	11% (9%)
Albertslundruten	8%		35% (2%) ²	
Farumruten	52%		35% (2%) ²	

¹: excluding commuting trips

²: cycling trips on the route

The larger increase on the route in Tilburg compared to The Hague can partly be explained by the provision of new route segments for cyclists in Tilburg, including a new tunnel under a main road. Both the Tilburg and The Hague cases demonstrate that growth along the route can be considerably higher than growth in the corridor, indicating that significant changes in route choice in favour of the improved route can occur. The same two studies suggest that *reported* changes in frequency of bicycle use are in the same order as, but somewhat larger than counts on corridor level. However, the Albertslundruten and Farumruten studies give quite different and ambiguous results.

To the results of Bach (1985) should be added that in several of the studied cases no increase in bicycle use could be detected. However, when new bicycle paths were added to road segments with large traffic volumes in a complex traffic environment and bicycle paths along parallel roads were absent, growths between 15% and 30% were observed.

In the Delft study, the impacts were studied on city level by conducting before and after travel surveys among residents of a control area where no improvements were implemented before the data collection for the after study, and two experimental areas where the interventions were fully implemented. The control area (Wippolder) and one experimental area (Noordwest) are old districts close to the city centre, the other experimental area (Tanthof) is a new district 3-4 km from the city centre. The survey expresses cycling volume in two indicators: usage of a bike for one or more trips on the reporting day, and number of bicycle trips per person per day. Table 3 shows that a very small increase of persons using a bike is observed in the two experimental areas and a decrease in the control area. Results for bicycle trips pppd are more articulated: increases of 3% and 6% in the two experimental areas and no increase in the control area.

Table 3. Changes in bike use in the experimental areas and the control area.

District	Persons using a bike on the reporting day		Bicycle trips per person per day	
	Before	After	Before	After
Noordwest	49.5%	50.0%	1.80	1.86
Tanthof	49.7%	50.8%	1.57	1.67
Wippolder (control area)	46.0%	44.4%	1.70	1.70

The figures of Table 3 relate to the short-term after study of Delft. The long-term analysis suggests that the short-term impacts on bicycle use have been retained and might even have increased somewhat. However, the results do not allow to draw strong conclusions. Observed changes are small and other factors might have influenced bicycle use as well.

The studies give no clear indication for general differences between trip purposes. The surveys of Tilburg and The Hague produced similar results for the considered purposes; commuting trips were here excluded. The Delft study suggests that the effects are somewhat larger for commuting trips; no clear differences between the other purposes were found. The Farumruten appeared to be especially attractive for leisure cyclists. This route enables cyclists to ride long distances unhindered at a fairly high speed.

One may conclude from the different results that the growth of cyclist numbers can be large along the improved route, is at the most moderate in the corridor, and is only small in the whole city. The smaller growth in the corridor can be explained by significant changes in route choice, the even smaller growth on city level might indicate changes in destination choice. Possibly, cyclists take the quality of bicycle infrastructure into account when choosing a destination. The observations on city level in the case of city-wide improvement might be the best indicator for the real (net) growth in cycling volume. In the case of Delft, the observed growths are small, less than 10%. One should note that the figures in this paper regard cities where bicycle use was already high before the implementations. The absolute and relative growths in cities with a low initial level of bicycle use might be quite different.

3.2. Modal choice

One of the explanations for the increase of cycling volume is a shift to cycling from other modes. In a number of studies cyclists were asked in the questionnaire after the intervention about which mode they would have used if no improvements were implemented. Table 4 presents the results.

Table 4. Modal shifts in share of all cyclists in trips in the after situation

Study	Shift from walking	Shift from car	Shift from PT	Shift from all motorized modes
Tilburg (Goudappel en Coffeng and Rijkswaterstaat, 1980)		2%	0%	
The Hague (DHV <i>et al.</i> , 1980)		2%	0%	
Delft (Katteler <i>et al.</i> , 1987)	3%	3% ¹	0%	3%
Bryggebroen (COWI, 2009a)		2%		11%
Åbuen		2%		
Albertslundruten		2.5%		9%
Farumruten		5%	6%	10%

¹: 1% car driver, 2% car passenger

The shifts from car to bicycle are in most cases marginal. In the case of Tilburg and The Hague this can partly be explained by low car ownership; only 20-25% of the bicyclists owned a car. Some Danish studies indicate a significantly larger shift from other motorized modes – especially public train and bus services; substitution of car-use by cycling generally follows public transport in order of magnitude. Substitution of other modes such as walking and mopeds is marginal in these studies.

3.3. Route choice

The results of Section 3.1 demonstrated that significant changes in route choice can appear. In the Tilburg and The Hague surveys, 60% and 30% of the respondents indicated that they changed the route (DHV *et al.*, 1980). In spite of these large shifts, cyclists did not to accept large detours. The latter is a general outcome of bicycle route choice studies. Engel and Iversen (1978) found that even safety aspects were generally secondary to distance. The Delft study demonstrated that bicyclists are less inclined to accept detours in *time* than detours in *distance* (Bovy, 1984). This is illustrated in Table 5. The detours are defined as the actual distance or duration divided by the shortest distance or duration.

Table 5. Cumulative frequency of detours in distance and detours in time.

Class of detour	Distance	Time
1.00	9%	21%
1.01-1.05	44%	51%
1.06-1.10	71%	72%
1.11-1.15	84%	82%
>1.15	100%	100%

In Delft, significant changes in the chosen routes were observed after implementation of the network improvements (Gommers and Bovy, 1987). New network links tempted a lot of cyclists to reroute their trips via these links. New bicycle paths along roads proved to be very attractive as well. The volume of cyclists on bicycle lanes (not physically separated from the road) and on roads with mixed traffic decreased.

4. Safety

Safety studies sometimes discern between objective (measured) safety based on accident statistics and subjective (perceived) safety reported by cyclists. The safety impacts are discussed separately for cases of traditional interventions, generally aimed at separating bicycle flows from motorized traffic, and shared space that intends to create safe room for mixed traffic.

4.1. Traditional interventions

In both the Tilburg and The Hague cases no impact on the number of accidents with personal injury was found on corridor level (Goudappel en Coffeng and Rijkswaterstaat, 1981, 1 and 2). Still, the ‘mix’ of accidents changed. There was a shift from cyclist-motorist accidents to cyclist-cyclist accidents, cyclists-pedestrian accidents, and single cyclist accidents. Because accidents where no motorized vehicle is involved are generally less harmful, one could say that the objective safety improved somewhat.

The subjective safety in both cities clearly increased (Van den Broecke and Rijkswaterstaat, 1980). A majority of survey respondents had the opinion that cycling became safer while very few had the opposite view. The perception of safety correlated with the enjoyment of cycling. A possible interpretation is that perceived safe cycling is a precondition for enjoyment.

The Delft evaluation suggests an increased objective safety for the two kinds of users of the bicycle network: cyclists and moped riders (Bovy and Gommers, 1988). For both modes the number of accidents where cyclists were involved decreased by 10%, the number of casualties by 30%. Like in Tilburg and The Hague, the consequences of accidents became less serious. Firm conclusions on the impact of the interventions cannot be drawn, because the number of observed accidents was rather small, and there was a nation-wide decrease of 20% of casualties for both bicycles and mopeds in the same period (1980-1986).

A minority of the survey respondents indicated that using the network became safer: 16% in Noordwest and 32% in Tanthof (Katteler *et al.*, 1987). However, the perceived safety increased much more for a number of specified spots where measures were implemented (75% in Noordwest and 46% in Tanthof).

Two improved long distance routes in Copenhagen contributed to the perceived safety. For the Albertslundruten that runs through the urban fabric, the perceived safety index increased by 3%, for the Farumruten that includes longer sections where cyclists can drive unhindered, the index increased by 11%. Analysis of accidents in connection with these projects remains to be done. A Danish study of safety effects from providing cycle paths and lanes, drawing upon interventions between 1976 and 2004 in Copenhagen, however, presents mixed evidence. Cycle paths may reduce the number of accidents on road segments, but increase the number of accidents in intersections – the net result on accidents and injury being negative. The type of bicycle infrastructure, whether the lanes are protected by parked cars, and how they are marked or connect to intersections is important (Jensen, 2007). In addition specific changes to the location of parking space connected to cycling interventions on urban streets is

judged to be highly important to the objective safety result. However, irrespective of mixed objective safety effects of implementing cycling infrastructures on urban streets, the perceived safety level is strongly associated with the provision and form of cycling infrastructures (Jensen *et al.*, 2007).

4.2. Shared space

Shared space is a rather new development that cuts across the traditional intend to provide dedicated infrastructure. It regards integrated use of public space by pedestrians and vehicles, generally both motorized and non-motorized vehicles, where the infrastructure is designed in a way that makes it inherently safe. The design should impel drivers of vehicles to take full account of the slower road users and for that adapt (lower) the speed. Decreasing speed differences is the main reason for achieving a high safety. Two of the reviewed studies evaluate shared space projects: Vestergade in Odense, Denmark and Haren, the Netherlands.

The Vestergade-project in Odense includes the transformation of a crowded road for mixed traffic into a space where motorized traffic is not allowed except for delivery freight vehicles. The new design allowed non-transport related activities that should create a more lively urban area, like outdoor sitting at cafes and playing table tennis. The project-evaluation included no impact assessment of objective safety. The results for subjective safety were troublesome. About half of the respondents answered that the infrastructure was less safe in the after situation, while less than 30% had the opinion that safety had increased. The main safety problems had to do with conflicts between different transport modes and obstacles. The low appreciation of safety is particularly true for women, and this is valid for both of the two main problems mentioned.

The Haren case includes both an objective and a subjective assessment of safety. The main road in the (small) town that consisted of a wide zone for cars, rather narrow separated bicycle paths at each side, and two sidewalks, was transformed into a shared space area. Height differences across the road were removed, the road was made optically narrower, and the maximum speed was reduced from 50 to 30 km/h. There was still a visual separation between the main zone and two side zones, which separated the space for cars and pedestrians. Bicyclists could use both zones.

Despite the very low number of observed accidents and casualties, one may conclude from accident statistics that the objective safety increased significantly. In the before period (1994-2001) the average number of annual accidents was nearly 11 and fluctuated between 6 and 14. In the after period (2003-2007) the annual average was 5 with fluctuations from 3 to 9. The highest number of 9 accidents was observed in 2003, shortly after the implementation. Possibly users need time to become familiar with the new situation. The share of accidents where cyclists were involved did not change. An even stronger decrease was observed for the number of casualties (fatalities and injured persons). In the before period the annual average was about 2.5 and the number fluctuated between 1 and 5. In the after period only one casualty was registered in the whole 5-year period. The nature of the accidents changed somewhat. In the before situation the largest category of accidents was related to insufficient distance to vehicles in front; rear-end collision was a typical accident. In the after situation the most observed accidents were those related to not giving priority, wrongly turning a corner, and driving too far to the right.

In contrast to the strong increase of objective safety, respondents of the survey reported that they felt a decrease of safety. This feeling was mainly related to the unclear position of the bicycle that was allowed to use both the main zone in the middle of the road and the side lanes. Based on this result it was decided to allow cyclists only in the middle zone that they had to share with the cars. This might have increased the perceived safety.

Summarizing, shared space has the potential to increase the objective safety significantly, which is presumably the result of harmonizing speeds, but sharing space by different modes seems not conducive to the perceived safety.

5. Design appreciations

The studies gave sometimes detailed information (Instituut voor Zintuigfysiologie, Rijkswaterstaat, 1982) and more often general evidence about the appreciation of design of cycling infrastructure. The discussion in this paper is limited to some general results that achieve wide agreement in cycling research. Cyclists prefer:

- Direct routes,
- Connectivity; cyclists appreciate for instance coloured pavement that marks their route,

- No or minimal exposure to hindrance of motorized traffic. Cyclists prefer dedicated infrastructure, and routing through a traffic calming area is more appreciated than routing along a main arterial.
- Sufficient width of bicycle paths, depending on the traffic flow and on one- or bidirectional use,
- Smoothness and quality of pavement.

Phil Jones Associates (2014) observe that in countries where the level of cycling is low, conditions for a coherent cycling network are generally not satisfied, while these are a matter of course in cycling countries. They mention the following conditions: there is clarity about the overall cycling network, with connectedness, continuity, directness and legibility all being key attributes; and there is clear, widely-accepted and routinely-used guidance on the design of cycling infrastructure.

Andrade Carneiro da Silva *et al* (2011) found that street design (lightning, pavement, greenery, etc.) plays a rather limited role in the decision to ride a bike. In the three cases they examined (Bryggebroen, Århus, Vestergade), a minority (27-40%) of the addressed cyclists reported that street design was more or less important.

6. Economy

In Tilburg and The Hague the impacts of the interventions on shop sales were studied (Economisch Instituut voor het Midden- en Kleinbedrijf and Rijkswaterstaat, 1981). The trend in shop sales along the bicycles routes were compared with national trends and (only in the case of The Hague) with a control group of similar shops. The impacts were quite different in the construction phase and in the operation phase, and also for shops in the food sector and shops for durable consumer goods. In the construction phase, the business of all shops was negatively affected. The negative impacts were small for shops in the food sector (that attract their clients from a small area), and large for other shops. After the construction was finished, shop sales in the food sector recovered and increased to a higher level than before the interventions, while shops selling durable consumer goods continued to perform worse. For this type of shops the negative impacts of reduced parking space for cars presumably exceeded the positive impacts of improved access by bicycle.

In the Delft case, economic impacts were not included in the evaluation studies. However, in the framework of the Transecon-project that assessed the socio-economic impacts of investments in urban transport infrastructure, afterwards an estimation was done (Transecon, 2003). In the construction phase, the estimated added value of the GDP was 2.3 million ECU per annum which was more than two times the annual investment costs (1 million ECU). The added value in the operation phase was assumed to be larger but difficult to quantify. Interviews with key actors learned that the bicycle network probably had no impact on housing prices, raised the business for bicycle dealers somewhat, strengthened the economic position of the city centre, and contributed to civic pride.

7. Conclusions

The paper presents ex-post evaluation results from a number of Dutch and Danish cases of cycling infrastructure provisions and formats. Infrastructure varies from per-urban cycle highways over intra-urban cycle routes to segments of cycle path and urban streets established as 'shared spaces'.

Counts of cycle volumes highlights that new bicycle infrastructures generally are embraced by users. An important part of the user-response involves riding new routes, and area-wide bicycle flow measures are substantially less affected than the flows on the improved route/segment. The evidence from most infrastructure cases does, however, point towards new users or bicycle trips being created following the intervention. Modal change – especially from cars to bicycles - appears to be a more marginal effect of bicycle infrastructures. Generally between 2% and 3% of infrastructure users after completion reported that a car would have been their alternative before the intervention.

Safety effects of cycling infrastructure provision in Dutch and Danish cases alike points to a clear connection to perceived safety. The bicyclists highly appreciate the separated bicycle route designs. In terms of objective safety the evidence is more uncertain and ranges from status quo or improvement in Dutch cases – to negative effects in Danish cases which may be due to reconfiguration of parking and conflicts with bicyclists on treated streets. Especially city streets are highly complex and sensitive environments and any *ceteris-paribus* evaluation of bicycle infrastructure effects is very difficult.

The two shared space cases reported display the reverse association with perceived safety compared to separated designs. Perceived safety deteriorated. On the other hand analysis of objective safety from the Dutch study points to improvements.

Bringing together available evidence from ex-post studies can provide a basis for setting expectations towards interventions, anticipate plausible responses and results, as well as contribute to turning attention towards project details to avoid or promote effects. Planners and policymakers in Denmark and the Netherlands, as well as in the many aspiring cycling countries, can draw valuable lessons from these cases in intervention for import or adaptation. Adding to the cases by securing comparability and methodological advancement for learning outcomes should receive further attention in the future.

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