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Planning for cycling in the dispersed city: establishing a hierarchy of effectiveness of municipal cycling policies

Lukas Adam[1] · Tim Jones[1] · Marco te Brömmelstroet[2] (iD)

Abstract Urban utility cycling is being promoted widely due to various health, social, economic and environmental benefits. This study seeks to identify and rank which municipal-level policies and other factors are most influential in increasing cycling as a means of everyday transport and improving the real and perceived cycling safety in car-oriented urban centres. This is achieved by identifying the key factors thought to influence cycle use and by establishing a hierarchy of effectiveness of municipal cycling policies. Data was collected through interviews with a panel of experts who also completed a Delphi study, a technique rarely used in cycling policy research, to collect and compare expert opinions to predict the outcomes of policies and external factors. Policies and external factors were scored in a theoretical policy framework according to their perceived relative influence on cycling levels and cycling safety. The results reinforce previous findings in the literature but allow for generalisation in car-oriented urban centres due to the breadth of factors evaluated. It was found that providing cycling infrastructure is perceived to be a prerequisite for inducing utility cycling mode share. External factors such as urban form, the relative attractiveness of cycling to travel by car and wider governmental policy were perceived to have a strong influence. The generation and maintenance of political and public support is also suggested to be critical success factor.

Keywords Cycling · Cycling policy · Delphi technique · Dispersed city

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Introduction

Mass utility cycling would go some way to addressing the pressing issues facing modern urban societies such as an obesity epidemic, fatalities and serious injuries resulting from traffic crashes, local environmental degradation, social inequality and global climate change (Blue 2013; Macmillan et al. 2014; Pucher and Buehler 2016). Developing mobility alternatives that work in car-oriented urban areas is a particularly pertinent issue given the legacy of decentralisation and low density urban form (Mees 2010).

This paper examines utility cycling in the dispersed city. 'Utility cycling' refers to trips made by bicycle for practical, transport purposes, for example to and from work, education, for shopping or to visit family and friends. This is as opposed to recreational cycling, which is undertaken purely for leisure or exercise. For the purposes of this study, the 'dispersed city' (Mees 2000) (also referred to as the 'automobile city' by Newman et al. 2016) describes urban centres of any size with car-oriented urban form and transport network design, together with high levels of car ownership and use. Due to common historical trends in transport development, specifically mass motorisation, the dispersed city refers principally to the North American, Australasian and European context, although it is also relevant to other parts of the world that have followed a similar urban planning trajectory. Countries with a majority of the population living in dispersed city urban fabric often have low levels of cycling, which is partly explained by the lack of cycling facilities and traffic-calmed streets and neighbourhoods (Mees 2010; Pucher and Buehler 2008).

The focus of this paper is how utility cycling in the dispersed city can be increased from a low starting point through municipal cycling policy. It asks: *What do cycling experts perceive to be the most effective measures that could be implemented at a municipal level to increase cycling mode share and improve real and perceived cycling safety in dispersed, low-cycling urban centres?*

Previous approaches to understanding effectiveness of municipal cycling policy

A number of studies have been conducted into the effectiveness of municipal cycling policy, with a bias toward cycling conducive environments. Typically, there are two types of approach. The first type evaluates a single intervention or a more comprehensive analysis of municipal cycling policy in a particular setting, often in countries with existing high levels of cycling (such as Rietveld and Daniel 2004; Harms et al. 2014, 2016; Pucher and Buehler 2006, 2008). The second type focuses on a particular element of policy related to cycling, such as infrastructure, commuting, health or environmental conditions (including Jacobsen and Rutter 2012; Jones 2012; Macmillan et al. 2014; Nielsen et al. 2013; Schoner and Levinson 2014). Both of these approaches restrict the potential for generalisation due to the difficulty of applying the findings to different settings or to other areas of policy related to cycling. This study differs in that it allows potential for generalisation of the results in different dispersed city settings and across all parts of municipal cycling policy due to its theoretical standpoint and the Delphi methodology employed.

Numerous studies have been carried out which set out the range of physical infrastructure interventions can be made to improve conditions for cycling (including Pucher and Buehler 2008; Pucher et al. 2010; Buehler and Dill 2015). This has been divided into those factors which increase the attractiveness of cycling ('pull factors') and those that decrease the attractiveness of alternatives to cycling ('push factors'). In the context of this study, the

latter refers principally to the reduction of travel by private automobile as opposed to public transport use, walking and other non-motorised modes.

Measures designed to increase utility cycling mode share through programmes of non-infrastructural interventions are promoted by several authors as being important facets of a cycling policy package. This includes a wide variety of initiatives at the local level that generally focus on raising awareness of the benefits of cycling and also opportunities for cycling. Programmes intend to induce psychological changes in individuals and encourage positive social interaction and learning associated with the bicycle (Harms et al. 2016; Forsyth and Krizek 2010). Conclusions on the effectiveness of programmes vary, although it is generally recognised that the impacts of such measures are not often thoroughly and systematically evaluated (Pucher and Buehler 2012b; Pucher et al. 2010, 2011; Forsyth and Krizek 2010).

Several studies postulate that the success of municipal cycling policy is influenced by the governmental setting in which policy is formulated, funded and delivered. This covers areas such as policy formulation, funding and implementation, citizen engagement and civic leadership (see Pucher et al. 2011; Pucher and Buehler 2008).

Socio-spatial contextual factors or 'exogenous factors', are also thought to have an influence on cycling mode share. Exogenous factors can be divided into those that can be influenced by some level of policy (although are typically outside of the remit of municipal cycling policies)—policy amenable factors—and physical environment and climate variables that cannot reasonably be impacted by any policy—non-policy amenable factors.

An overarching theme in the literature is that no single solution suffices to induce increased utility cycling mode share (Pucher and Buehler 2012b; Pucher et al. 2010; Forsyth and Krizek 2010). Successful programmes commonly employ a coordinated, integrated suite of cycling-specific, land use, urban form and transport planning interventions which influence the relative attractiveness of modes (Pucher and Buehler 2012b; Forsyth and Krizek 2010). Pucher et al. (2010) observed that isolating the impacts of individual policy interventions is almost impossible and recommended that pro-cycling policies should be designed to interact with one another and leverage synergies.

There is a consensus in studies in mature cycling countries such as the Netherlands that a combination of pull and push conditions must be applied in order to increase cycling mode share and improve real and perceived safety of cycling (Harms et al. 2016; Pucher and Buehler 2008). Recommendations are commonly made to transpose this approach to low-cycling environments. This paper outlines a study that applied an innovative method to investigate what are perceived by professionals to be the most effective combination of measures that could be implemented in dispersed, low-cycling urban centres, to improve cycling safety and increase cycling mode share.

Methodology

In this study, the Delphi technique was used in combination with semi-structured interviews to elicit the professional opinions of a panel of cycling experts on the best methods of inducing increased levels of utility cycling in dispersed cities globally (as opposed to in their home countries) (Fig. 1). Experts from diverse professional backgrounds were brought together from the Netherlands and New Zealand. These countries are at opposite ends of the spectrum of levels urban cycling—cycling is a mainstream mode of transport in the Netherlands, while NZ has very low levels of utility cycling (Table 1).

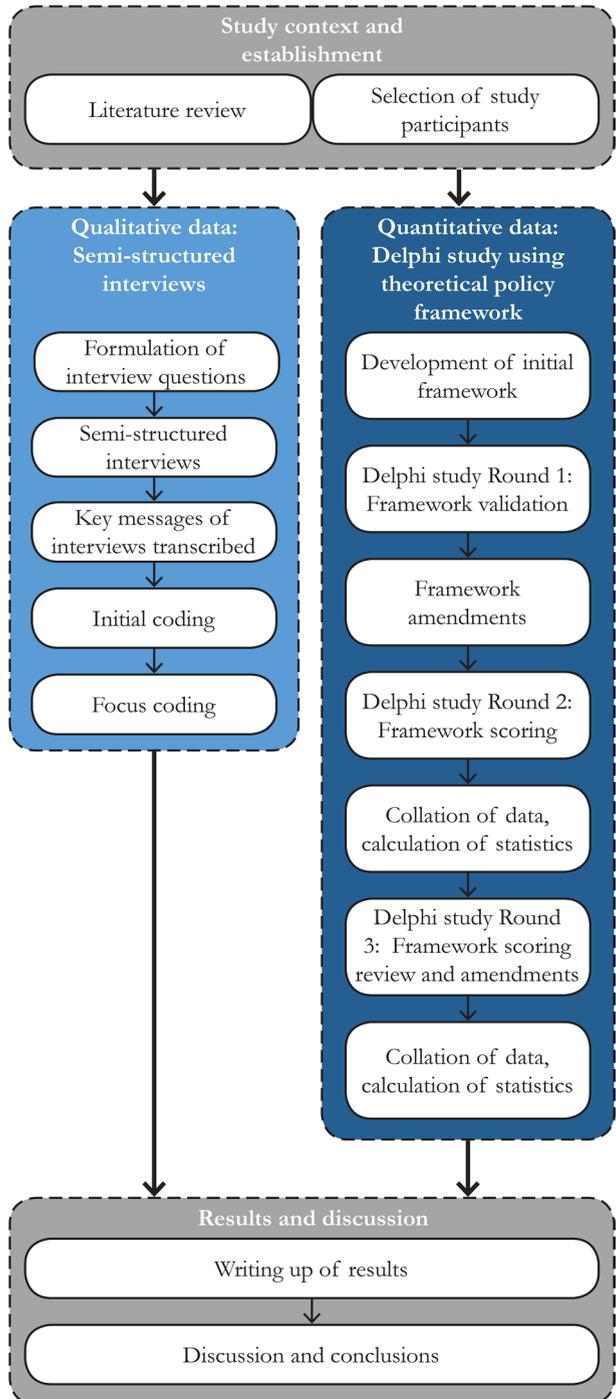**Fig. 1** Study methodology showing qualitative and quantitative data collection and analysis

Study context and establishment

Literature review

Selection of study participants

Qualitative data: Semi-structured interviews

Formulation of interview questions

Semi-structured interviews

Key messages of interviews transcribed

Initial coding

Focus coding

Quantitative data: Delphi study using theoretical policy framework

Development of initial framework

Delphi study Round 1: Framework validation

Framework amendments

Delphi study Round 2: Framework scoring

Collation of data, calculation of statistics

Delphi study Round 3: Framework scoring review and amendments

Collation of data, calculation of statistics

Results and discussion

Writing up of results

Discussion and conclusions

Table 1 Key statistics on the Netherlands and NZ. *Source*: 1. CBS (2015), 2. Statistics NZ (2013), 3. 2008 data (Pucher and Buehler 2012b), 4. NZ Household Travel Survey 2015–2017 (2018), 5. The World Bank (2016), 6. OECD transport data (2016)

	Netherlands	NZ
Population (millions)	16.9[1]	4.2[2]
Cycling mode share (% total trips by bicycle)	26%[3]	1%[4]
Gross domestic product (USD per capita, nationally)[5]	42,295	39,427
Private vehicle ownership rate (passenger cars per 1000 inhabitants nationally)[6]	476	626

A total of 54 experts from the Netherlands and New Zealand were approached to take part in the study. The final panel experts consisted of 28 individuals from research, professional practice, policy and advocacy backgrounds (Table 2). Data collection took place between May and July 2016.

Delphi technique

The Delphi technique is a systemic group communication process that examines or discusses a particular issue. It has been used previously for policy investigation (Hsu and Sandford 2007).

The Delphi technique is used in diverse types of futures research to achieve a convergence of opinion based on the real-world knowledge of experts in a specific field. It is applied to predict future events or scenarios where imperfect or limited knowledge exists (Tolley et al. 2001; Pikora et al. 2003; Hsu and Sandford 2007). Where conventional surveys seek to establish "what is", the Delphi technique is centred on the question "what could/should be?" (Hsu and Sandford 2007). The data collected is based on intuitive judgements in multiple iterations, which can be used to complement the extrapolation of trends generated through other types of enquiry (Tolley et al. 2001). The Delphi technique encourages a problem-solving orientation by maintaining anonymity of participants and allowing initial judgements to be revisited based on the responses of the wider group in a controlled feedback process. This reduces the effects of distortion of the data through dominant actors or individual or group interests (Hsu and Sandford 2007).

The Delphi technique was chosen for this study as it allows the perceived likelihood of the potential success of particular municipal cycling policies and the influence of exogenous factors in dispersed, car-oriented urban centres. Limited knowledge of the

Table 2 Summary of study participants

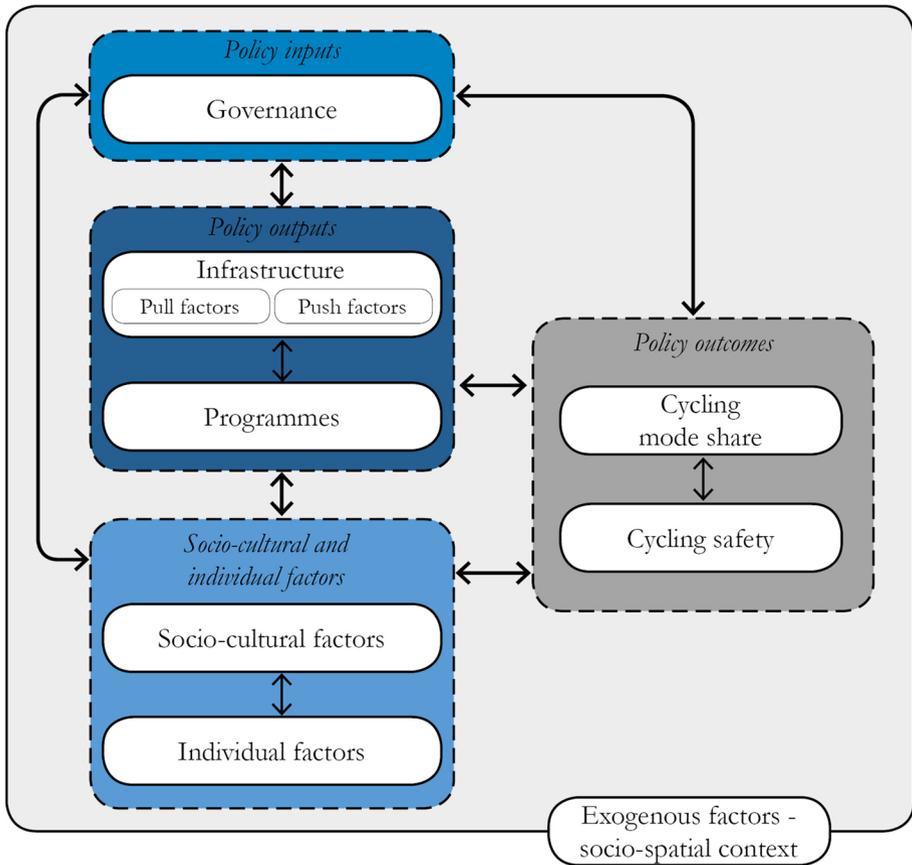| Professional group	Location		Total
	Netherlands	NZ	
Research	5	5	10
Practice	6	–	6
Policy	4	2	6
Advocacy	1	5	6
Total	16	12	28

Fig. 2 Conceptual framework (adapted from Harms et al. (2016))

most successful cycling policies exists due to a shortage of policy and research experience in dealing with cycling specifically.

Although the selection of subjects for the Delphi study is identified as the most important step in the process, the literature reviewed did not offer strict standards for the selection of panellists. The list of potential participants was compiled from the corresponding authors' professional networks and authors of relevant publications.

The Delphi technique was used to establish a hierarchy of effectiveness of potentially relevant policy measures. The hierarchy of policy measures was structured on a framework developed by Harms et al. (2016) for the assessment of the performance of municipal cycling policy in medium-sized cities in the Netherlands. This was organised into policy inputs, policy outputs, socio-cultural and individual factors, and policy outcomes (Box 1, Fig. 2).

Box 1: Conceptual framework

In the conceptual framework, municipal cycling policy is conceived to operate within a socio-spatial context (referred to as exogenous factors in this study).

Policy inputs, or 'governance' is thought of as the governmental setting in which policies are formulated. Policy outputs are divided into two sub-categories: infrastructure—physical interventions including cycling-specific provision, which improves conditions of cycling; and programmes—measures aimed at altering perceptions, beliefs and attitudes which could induce a voluntary change of transport mode. The infrastructure category is further divided into pull factors (increasing the attractiveness of cycling) and push factors (decreasing the attractiveness of alternatives to cycling).

Policy outcomes are determined by policy inputs, policy outputs, socio-cultural and individual factors and exogenous factors and represent measures of success of municipal cycling policy. For the purpose of this study, two of the definitions of success from Harms et al. (2016) are adapted to the low-cycling environment and taken forward. The first is cycling mode share, the proportion of journeys to work and education made by bicycle. The second is real cycling safety (in terms of the number of people killed or seriously injured per million kilometres cycled) as well as perceived cycling safety (as measured by surveying cyclists as well as non-cyclists).

Socio-cultural and individual factors, such as social norms and personal beliefs are not taken forward for testing through the data collection and analysis. Despite being likely to be influenced by public policy over the long term and shown to have an influence on individual decisions on whether to cycle (for example, Heinen and Handy 2012), socio-cultural and individual factors are considered to be too remote to the purpose of this study to be included.

Process of gathering data

The first method of data collection was semi-structured, conversational style interviews. While each of the questions was asked in all interviews, the sequence of the questions changed as responses were provided to allow the conversation to flow and new themes to emerge organically. The seven interview questions were developed based on the abovementioned conceptual framework and were designed to stimulate broader conversation. Themes included modal segregation, real and perceived safety and cycling culture. The qualitative data collected in the interviews was analysed in a three-step process: transcription of key messages and two-phase coding. An example of the qualitative data analysis carried out is provided in Box 2.

Box 2: Example of quantitative data analysis

Interview question:
"One approach to cycling policy in low-cycling cities is to focus on those communities which are most likely to respond based on social and spatial characteristics.
If you were advising a municipality with a majority of low density suburban housing and high levels of car use, what you suggest as priority interventions?"

Transcript of interview answer (partial):
"You are probably already aware of the idea of 'if you build it, they will come'—if you build very good infrastructure people will cycle. There is a lot of discussion around whether that is true or not, whether you should start with good infrastructure as a base. I think it's more complex. If you're looking at low density suburbs in a way you should have a good base of cycle-friendly infrastructure."

Initial code (abbreviation into themes):
Not as simple as 'if you build it, they will come'
A good base of infrastructure essential

Focus code (grouped with other interview responses):
Base level of on-street infrastructure

The second method of data collection was through a Delphi study which asked panel members to enter scores into a theoretical policy framework ('the framework') for cycling policies in low-cycling cities. This was based on their experience and intuition. The structure of the framework was based on literature reviewed, specifically Harms et al. (2016) (categorisation of interventions) and Pikora et al. (2003) (hierarchy of components). The framework's content was further informed by interview responses.

The Delphi study was conducted in three rounds. In the first round, participants were asked to validate the contents of the framework and make suggestions for additions, deletions and re-categorisations. In the second round, participants were asked to distribute a total score of 100 at each level of the framework according to the relative perceived importance of each component. This took place across two levels of the framework; features and elements. At the first level, six features were scored: infrastructure-pull factors, infrastructure-push factors, programmes, governance, exogenous factors-policy amenable and exogenous factors-non-policy amenable. At the second level, scores were distributed across elements under each feature (between one and four in number). In the third round, participants were presented with average framework scores alongside their round two scores and given the opportunity to revise their scores.

After the three rounds of the Delphi study were completed, the quantitative data gathered was collated and a statistical analysis was carried out. This comprised calculation of mean and interquartile range (the difference between the 25th and 75th percentiles as a measure of statistical dispersion) of the scores entered at each level of the framework. Scores across the six features were compared, and within each feature scoring of the elements was analysed. Detailed characteristics of the results were also distilled by calculating the mean scores of the responses according to the country of location (the Netherlands or NZ) and the professional backgrounds (research, practice, policy or advocacy) of the panellists.

Findings

Interviews

The interviewees' responses suggested a broad categorisation of issues influencing cycling mode share in low-cycling urban environments. The six categories have been defined largely following the structure used in the Delphi study.

Infrastructure

There was a consensus on the importance of providing a basic level of safe, high quality infrastructure as an essential starting point for inducing utility cycling mode share. It followed that without this, changes in other measures and exogenous factors would make little difference. Safety was a constant theme present through many of the interviews, especially prevalent in discussions regarding the provision of physical infrastructure. Aspects such as personal safety (from criminal attack, as opposed to traffic safety) were referred to. Other themes included strategies for developing a network of cycling infrastructure, segregating

modes, integrating with public transport to overcome large distances and re-purposing disused transport infrastructure.

Programmes

Frequent references were made to understanding the perspectives of people who do not cycle for transport and catering to their needs. This was seen as crucial to broadening the appeal of utility cycling to a broad spectrum of people with different backgrounds and motivations in car centric environments.

There was a consensus that, to increase mode share, attention needs to be paid to utility cycling familiarisation, marketing and messages being emitted through policy decisions. Proposed initiatives included cycling education, local cycling 'champions', cycle-based tourism and 'ciclovía' or 'open streets' type events (temporary weekend closures of roads to motor traffic to allow carriageway use by pedestrians and cyclists).

Governance

The expert panel members demonstrated strong awareness of the importance of the formulation and crucially the implementation of policies, with references frequently being made to the political nature of road space re-allocations in particular. It was acknowledged that a specific approach and a fundamental shift in policy direction is required by municipalities to induce a significant increase in utility cycling from a low base. Interview responses commonly included an opinion that this could be achieved by developing a critical mass of cycle infrastructure and encouraging the normalisation of cycling and increases in diversity of cycling culture. This requires the relative attractiveness of different modes of transportation for different trip distances and types to be taken into account.

Recurring themes included political will, courage and capital, social capital, funding and the economy of interventions. Broadly it was agreed that behaviour change would most likely be achieved by applying incentives for cycling in combination with disincentives for car use, with the incentives employed first. Equity was raised as an important issue with regard to the geographical distribution of cycling policy interventions, for example the favouring of high income suburbs associated with predominantly European ethnicity.

Exogenous factors

The context sensitivity required to formulate and implement effective cycling policy was mentioned in a third of the interviews. The socio-demographic and the physical characteristics of an urban centre in particular were deemed to have a significant influence on levels of utility cycling according to a number of participants. Some underlined the importance of proximity for cycling to be attractive and promoted urban planning policy as a means of addressing dispersion. Others cited data which demonstrated that trip distances in dispersed city environments often remain comfortably within most people's range when travelling by bicycle. Physical environment factors which have an impact on cycling mode share were mentioned, particularly topography in the context of the potential for the increased usefulness and popularity of power-assisted bicycles (e-bikes).

Socio-cultural factors

Social and cultural factors were often mentioned across different topics of conversation. Social and cultural norms and acceptance of cycling was seen as an important factor, both through interview responses and in feedback on the content of the theoretical policy framework used in the Delphi study. Physical interventions should be carefully implemented to exploit the symbolic value of public bodies providing for cycling as well as the practical benefits. Other topics covered included cyclist-motorist relationships; the role of confident, assertive cyclists; encouraging cultural diversity perceived biases within the cycling community and profession; and providing for utility cycling as opposed to recreational cycling.

Individual factors

Emotions, rational considerations, attitudes and beliefs at the individual level gained some attention during the interviews. These were thought to influence the amenability to modal switch to cycling. Themes covered included the comfort and convenience of cycling infrastructure; the relative attractiveness of available modes; safety and risk aversion; and feelings of freedom and individuality.

Delphi study

Eighteen people from the original pool of 28 experts took part in the first round of the Delphi study with 19 experts taking part in Round 2 and Round 3 (Table 3).

Round 1

Of the participants who responded to Round 1 of the Delphi study, 10 did not make any recommendations for changes to the framework, while eight made recommendations ranging from suggesting the addition of a small number of items through to a comprehensive review of its contents. As a result of the recommendations, a total of 27 amendments were made.

Final results (Rounds 2 and 3): general characteristics

Table 4 and Fig. 3 show the results of Rounds 2 and 3 of the Delphi study. Participants scored the framework by dividing scores of 100 at two levels. At the first level of the framework, scores were divided across six features; at the second level scores were divided between one and for elements within each feature.

At the features level, infrastructure attracted almost a half share (47%) of the scores on average. This comprises two features. A mean score of 27% was attributed to

Table 3 Response to rounds of the Delphi study

Country	Country		Total
	Netherlands	NZ	
Round 1: framework validation	8	10	18
Round 2: framework scoring	9	10	19
Round 3: scoring review and amendments	9	10	19

Table 4 Delphi study results

Component code		Component title	Average score (%)	Consensus level
Features	Elements			
A		Infrastructure-pull factors	26	**
	1	Linear components	30	***
	2	Nodal components	22	***
	3	Discrete components	15	*
	4	Network quality, completeness and integration	33	***
B		Infrastructure-push factors	21	**
	1	Relative network speed interventions	44	**
	2	Private motor vehicle 'system' supply	27	**
	3	Changes to the cost of travel by car	29	*
C		Programmes	11	***
	1	Education	33	*
	2	Information and promotional campaigns	29	***
	3	Traffic laws and police presence	39	*
D		Governance	15	***
	1	Policy formation	27	***
	2	Policy implementation	25	***
	3	Involvement of stakeholders	21	***
	4	Strong leadership	27	***
E		Exogenous factors-policy amenable	19	***
	1	Socio-demographic and household characteristics	13	***
	2	Spatial characteristics	35	**
	3	Quality of provision and cost of alternatives to cycling	30	***
	4	Media and social dynamics[a]	22	***
F		Exogenous factors-non-policy amenable	9	***
	1	Physical environment and climate	100[b]	–

N.B. Average *feature* scores are in bold, average *element* scores are not bolded

*** High level of consensus (IQR < 10); ** moderate level of consensus (IQR = 10); * low level of consensus (IQR > 10)

[a]Referred to as socio-cultural factors in the Delphi study

[b]No score assigned as only one element included i.e. weight = 100.00

'infrastructure-pull factors', and 21% to 'infrastructure-push factors'. This represents a significant divergence from the equal share (17%). Programmes and governance were also attributed relatively low scores with means of 11 and 15% respectively, though the latter is close to equal share. A moderate level of importance was placed on exogenous factors, with a combined score of 27%. Within this figure, a far greater proportion corresponds to policy amenable aspects (19%) than to non-policy amenable aspects (9%). Levels of consensus at this highest level of the framework were generally high, with four of the six features' scores having an interquartile range (IQR) of below 10 and two equal to 10.

As shown in Fig. 4, within each feature, the mean scores generally demonstrate some divergence from equal share.

Under infrastructure-pull factors, there was notable emphasis on 'linear components' (A1) and 'network quality, completeness and integration' (A4) and a notably lower score
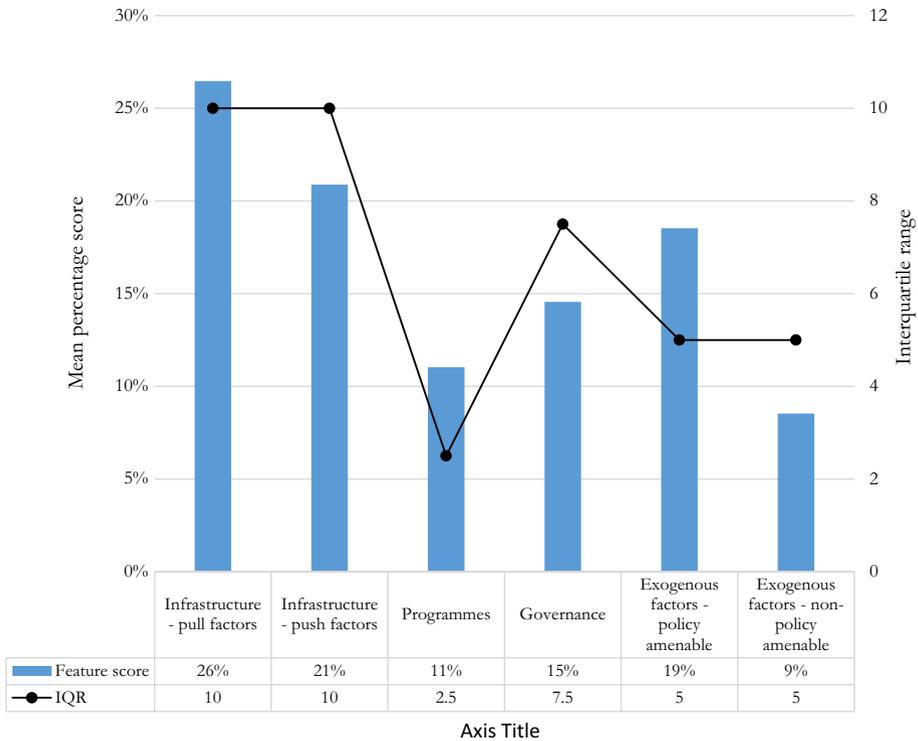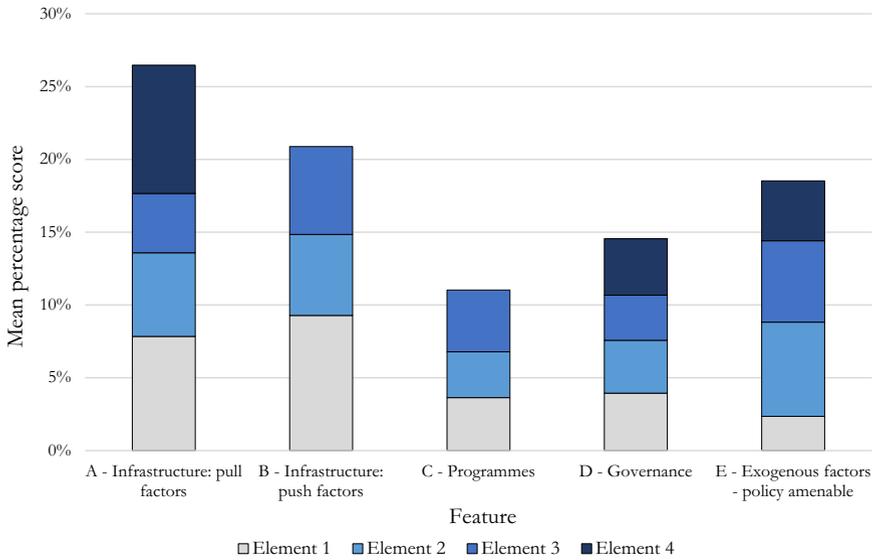
Fig. 3 Mean percentage score and interquartile range versus theoretical policy framework features for Delphi study expert panel

was attributed to 'discrete components' such as bicycle parking at end-of-trip facilities. The lack of importance placed on nodal components (A2) is not consistent with several interview responses, which emphasised the importance of intersections in cycling safety. The levels of consensus for 'linear components' and 'nodal components' were relatively high and relatively low for the 'discrete components' and 'network quality, completeness and integration'.

Elements scores for the infrastructure-push factors feature were weighted toward 'relative network speed interventions', such as motor traffic calming and localised prohibition of motor traffic. Levels of consensus for this feature were low relative to other features.

Under the programmes and governance features, mean elements scores were close to equal share. Governance demonstrated very high levels of consensus in scoring its four constituent elements, while overall very low levels of consensus were reached under programmes.

Elements that make up the 'exogenous factors-policy amenable' feature diverged somewhat more from equal share and had varying and generally high levels of consensus. 'Media and social dynamics' and especially 'socio-demographic and household characteristics' were attributed lower scores than 'spatial characteristics' and 'quality of provision and cost of alternatives to cycling'. The latter two elements are related to the spatial environment and are influenced by transport and urban planning policy, which is an area of expertise of a number of the panellists, which could in part explain this characteristic.

Fig. 4 Mean percentage scores versus theoretical policy framework features and elements for Delphi study expert panel

Feature	Element 1	Element 2	Element 3	Element 4
A - Infrastructure: pull factors	Linear components	Nodal components	Discrete components	Network quality, completeness and integration
B - Infrastructure: push factors	Relative network speed interventions	Private motor vehicle 'system' supply	Changes to the cost of travel by car	-
C - Programmes	Education	Information and promotional campaigns	Traffic laws and police presence	-
D - Governance	Policy formation	Policy implementation	Involvement of stakeholders	Strong leadership
E - Exogenous factors - policy amenable	Socio-demographic and household characteristics	Spatial characteristics	Quality of provision and cost of alternatives to cycling	Media and social dynamics
F - Exogenous factors - non-policy amenable	Physical environment and climate	-	-	-

Effect of country and professional background

Scoring of the framework varied according to both the country in which the panel members are based, as well as their professional background. The level of variation is generally minor to moderate, with some notable exceptions.

Results by country

Figure 5 summarises responses at the features level according to the location of the expert panel members (the Netherlands or NZ). Overall, most of the patterns in responses could be at least in part explained by the comprehensive, consistent nature of municipal cycling policies in the Netherlands. Dutch participants may regard this as a baseline situation and therefore allocated lower scores to the policy output components of the system. Conversely, participants in NZ placed greater importance on those policy outputs which are not necessarily common place.

Significantly more importance was placed on infrastructure-pull factors by NZ participants (mean score of 29%) than Dutch participants (24%). This could be at least partly explained by the lack of cycle specific infrastructure in NZ contrasting with its ubiquity in the Netherlands.

NZ participants (mean score of 17%) scored the governance feature notably higher than Dutch participants (13%). Again, this could be explained by the fact that comprehensive, consistent municipal cycling policies are commonplace in the Netherlands, where they are much less so in NZ.

In terms of exogenous factors, the Dutch participants scored the policy amenable and non-policy amenable features considerably higher than the NZ participants. The explanation for this characteristic is not obvious. One hypothesis is that Dutch experts are more attuned to the influence of exogenous factors due to the recent research which has been carried out on this matter in the Netherlands (for example Harms et al. 2014;
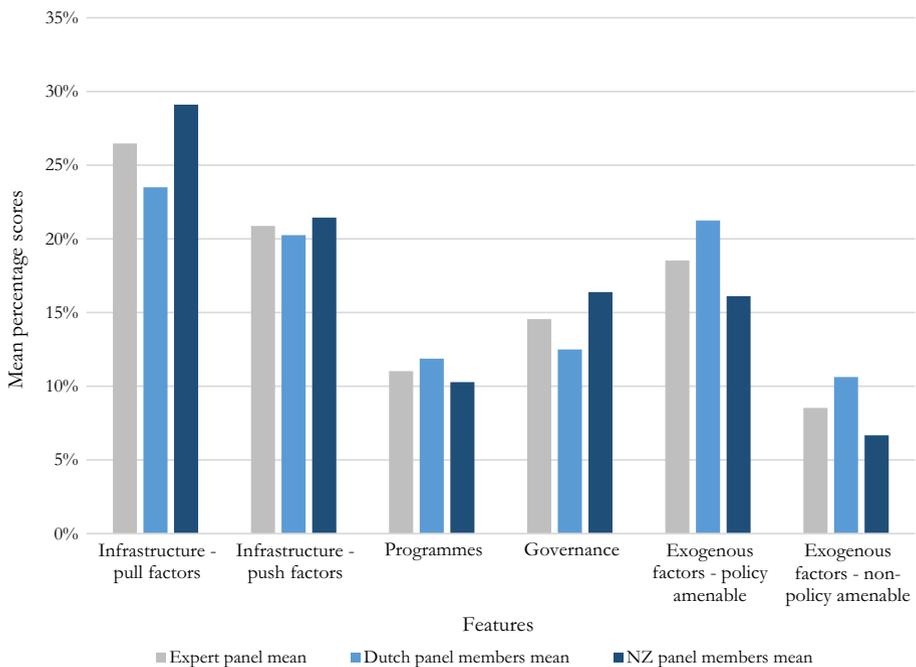

Fig. 5 Mean percentage scores versus theoretical policy framework features for Delphi study expert panel's Dutch and NZ members

Rietveld and Daniel 2004). The ubiquity of the Dutch cycling system may also allow experts to more easily examine variations in cycling numbers according to external factors such as land use mixing, age and ethnicity.

Results by professional background

Figure 6 describes differences according to the professional background of respondents. Here the small sizes of the subsamples must be recognised, which reduce the significance of the patterns identified. The number of responses received and therefore scores analysed are: research—7, practice—3, policy—2 and advocacy—5. The following characteristics are noted:

- Those participants who work in policy placed a markedly higher score on infrastructure-pull factors.
- Participants in professional practice emphasised the importance of programmes.
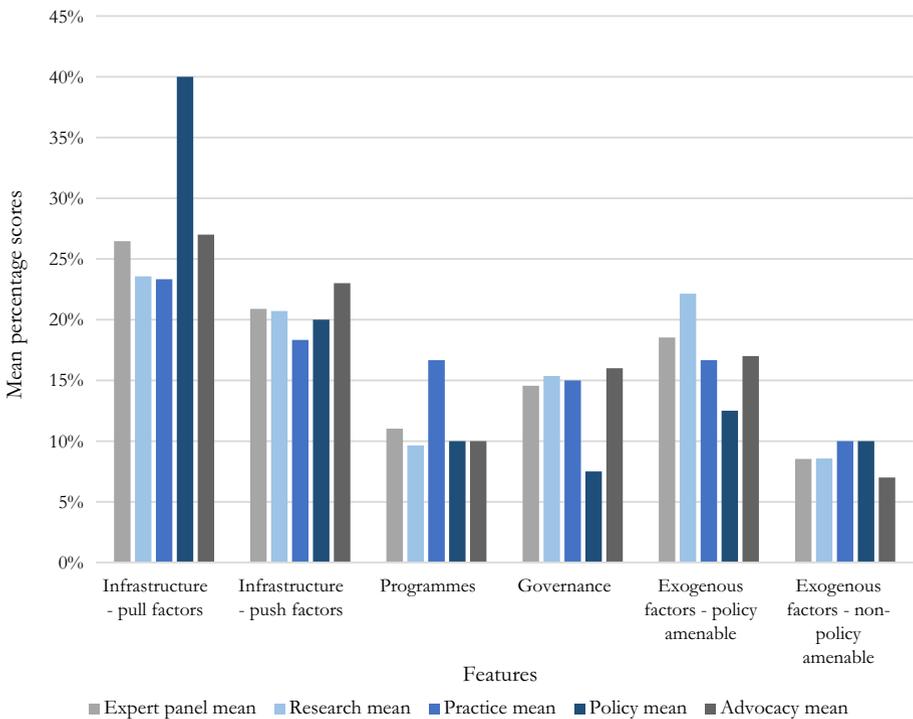- Governance received notably less attention from those working in policy.

Fig. 6 Mean percentage scores versus theoretical policy framework features for Delphi study expert panel's professional groups

Interpretation of findings

This section examines the findings of this study in the context of the literature, presents a theoretical example of the application of the study's findings and reflects on research problems and limitations.

Summary of findings

The results of this study demonstrate a number of themes in municipal cycling policy and go some way to quantifying the relative effectiveness of various strategies for increasing cycling mode share in low-cycling urban centres.

The Delphi study demonstrated the order of most effective policy measures, as shown in Table 5.

Key themes in the qualitative analysis include:

- *Safety* strong emphasis was placed on real and perceived safety and the importance of physical infrastructure in influencing safety in both interviews and the Delphi study.
- *Infrastructure* it was mostly agreed that a basic level of infrastructure is a prerequisite for inducing utility cycling mode share. This included facilities segregated from motor traffic where traffic speeds and volumes necessitate and low speed, shared streets elsewhere. Effective implementation strategies were discussed.
- *Context dependency* the importance of responding to local conditions was emphasised, particularly the physical characteristics of urban centres, such as topography, local variations population density and degree of land use mixing. Generalisation in formulating and implementing cycling policy, for example the simple copying of infrastructure design, was cautioned against.
- *Political dimensions* the expert panel demonstrated strong awareness to the political aspects of cycling policy formulation and outputs, although this was not reflected in the scoring of the framework. A holistic view which sought to improve the attractiveness of cycling relative to travel by car and is integrated with other policy areas was agreed to be the optimal approach.
- *Cycling cultures and sub-cultures* the majority view was that the cycling system needs to be shaped around the needs and sensitivities of those who do not currently cycle for utility purposes in order to encourage more diversity in cycling.

Relevance to the research question, literature and conceptual framework

This study broadly reinforces findings in the literature but uses a seldom-used methodology for cycling policy research which allows for generalisation in the dispersed city setting. It achieves this by eliciting the views of a diverse panel of utility cycling experts on a theoretical basis on all aspects of municipal cycling policy and quantifying their views by ranking policies.

The findings suggest there is optimism over the potential to encourage cycling in car-oriented urban environments. The single most effective measure to increase cycling mode share and improve real and perceived cycling safety was judged to be the provision of infrastructure. In combination with measures to improve conditions for cycling, the potential benefits of disincentivising travel by car was also recognised. The participants all

Table 5 Hierarchy of effectiveness of municipal cycling policy

Rank	Feature	Definition	Examples
1	Infrastructure-pull factors	Physical infrastructure interventions that increase the attractiveness of cycling	Cycle lanes and paths, intersection treatments, bicycle parking
2	Infrastructure-push factors	Physical infrastructure interventions that decrease the attractiveness of alternatives to cycling	Modal filtration devices restricting movement by car, restrictions on car parking supply
3	Exogenous factors-policy amenable	Socio-spatial contextual factors that can be influenced by some level of public policy	Population density, degree of land use mixing, level of public transport service
4	Governance	Governmental setting in which policy is formulated, funded and delivered	Policy coherence with regional and national levels, authoritative/charismatic leaders, involvement of external actors
5	Programmes	Providing education, awareness-raising, information and promotion of cycling at different scales to induce psychological changes in individuals and encourage positive social interaction and learning associated with the bicycle	Cycling education for children, promotional events, traffic laws
6	Exogenous factors-non-policy amenable	Physical environment and climate variables that cannot reasonably be impacted by any public policy	Topography, rainfall, average temperatures

demonstrated a belief that people's modal choices are made in response to their physical environments, and hence have scope to change based on modifications to transport infrastructure and urban form. This was evident in that a high degree of influence is also perceived to be exerted by policy amenable exogenous factors. This belief was grounded with caveats relating to the political setting in which they are proposed, as demonstrated in the interviews and the medium weighting placed on governance (policy inputs) in the Delphi study. Interview results also suggest that socio-cultural and individual factors have a moderate degree of influence on policy outcomes. Measures aimed at changing behaviour through non-infrastructural means (programmes) and non-policy amenable exogenous factors were suggested to have a low degree of influence.

The revised conceptual framework is shown in Fig. 7 based on the results of the study.

Policy outputs

The framing of this study is centred on policy outputs, as evident in the research question and objectives and methodology. Interview responses as well as the results of the Delphi study indicate a strong degree of consensus at the highest level of the hierarchy of policy levers.

The provision of physical infrastructure, for example, physically protected cycle paths and intersections, is emphasised as an indispensable starting point for inducing increases in cycling mode share. This functions principally through improving the real and perceived safety of cycling, and also increasing the level of convenience and comfort of the facilities (pull factors), especially as a means of increasing competition with the automobile. It was broadly agreed that in parallel, disincentives for car use need to be put in place (push factors) to induce substantial modal shifts to alternative modes. Actions that discourage car use by limiting traffic volumes or speeds, such as traffic calming and modal filtration devices that restrict movement by car, are seen to automatically incentivise cycling. Many cycle network developments require the reallocation of road space away from automobiles, such as a protected cycle path requiring the removal of on-street parking.

Effective policy strategies were, however, conceived to be a more complex interplay than a simple balancing of incentives and disincentives. Cycling policy should be formulated and implemented to be responsive to the broader policy context, including urban planning policy, such as degree of mixing facilitated in land use planning. The combination of 'carrot' and 'stick' approaches are seen as both necessary and effective.

Broadly speaking, these findings are aligned to the literature, which shows a bias toward physical interventions through the breadth, depth and frequency of the coverage of such considerations. Cycling policy overviews such as Pucher and Buehler (2008), Buehler and Dill (2015) and Pucher et al. (2010) demonstrate this trend. Harms et al. (2016) also emphasise the importance of cycling infrastructure in combination with policies that discourage car use.

Participants were asked about their position on a spectrum with 'vehicular cycling' at one end and a fully segregated cycle network at the other. This references the Forester versus Pucher debate on whether efforts should be focused on promoting vehicular cycling (i.e. through 'effective' cycle training) on the existing transport network (as Forester advocates) or to build segregated bike specific infrastructure to protect cyclists and cater for a wider range of cycling abilities (as Pucher advocates) (Pucher 2001). The participants unanimously supported Pucher's promotion of segregated infrastructure, although there was some variation in positions. Assessments of the historical development or maintenance
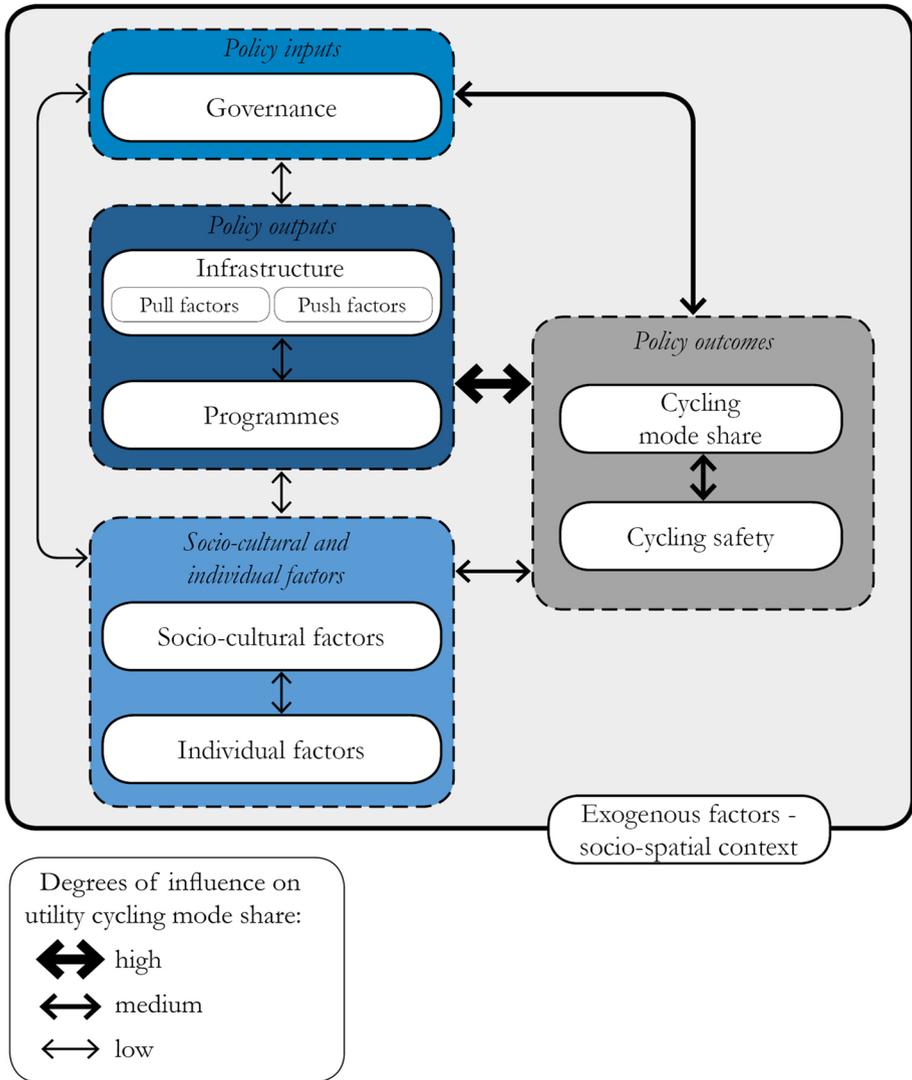
Fig. 7 Revised conceptual framework

of high levels of utility cycling in high-cycling countries underline this view, however, it is cast as one important element in the development of a comprehensive, integrated cycling system as opposed to the only prerequisite. Oldenziel et al. (2016) provide a comprehensive review of the European experience of cycling policy. Hence, constructing a network of cycle infrastructure is seen as crucial, however the recipe for progress contains further key ingredients, so the adage 'build it and they will come' cannot be applied in an unqualified manner.

Programmes also received significant attention in the literature but in contrast to infrastructure were given relatively little weight in the results of this study. The majority of

studies conclude that programmes have a role to play in successful cycling policy packages (refer Pucher et al. 2010; Pucher and Buehler 2012a). The success of such programmes is, however, not often systematically evaluated and some authors conclude that they only have a modest potential to induce utility cycling (refer Forsyth and Krizek 2010; Pucher et al. 2011 and Pucher et al. 2010). Programmes received the second-lowest score behind non-policy amenable exogenous factors at the features level of the Delphi study. This is perhaps related to the commentary in the above referenced literature as the participants may have experienced or had insight into real-world examples of where programmes have not made a significant lasting impact.

Exogenous factors

The socio-spatial context of municipal cycling policy is given significant weight in the results of the Delphi study with a high level of consensus, with those defined as being amenable to wider public policy scoring particularly highly. Similarly, interview responses showed strong awareness of the context dependent nature of cycling policy. Among elements under the exogenous factors features, spatial characteristics and quality of provision and cost of alternatives to cycling received the highest scores. Awareness of such factors is also notable in part of the literature, as is evident in selected recent studies such as Harms et al. (2014), Pucher and Buehler (2006) and Heinen et al. (2010), which point to the significance of factors such as socio-demographics and the built and natural environments. This evidence suggests that an understanding of the local context in which municipal cycling policies are implemented is crucial to their success.

Policy inputs

Policy inputs or governance is recognised as having some influence in selected areas of the literature (see Pucher et al. 2011; Pucher and Buehler 2008). The governmental setting of cycling policy and political strategies were a common theme in interview responses and were given moderate weight in the Delphi study with a high degree of consensus within the expert panel. The elements under the governance feature scored relatively evenly, which aligns to findings in the literature which emphasise the need for comprehensive, consistent cycling policy. The results of this study reinforce the need for municipal cycling policies to be formulated and implemented in a politically strategic manner and that they benefit from strong leadership and community and stakeholder involvement. This is seen both in wider conversations about cycling policy as well as through this study as being a core issue. The critical obstacle to implementing cycling infrastructure in the low-cycling environment is seen as principally political in nature rather than technical.

Socio-cultural and individual factors

Socio-cultural and individual factors received significant attention during the interviews and have been focused on in selected previous studies, notably Heinen and Handy (2012). Due to the indirect nature of the influence of municipal cycling policies on these factors, they were not included in the Delphi study. The results of this study suggest that a thorough understanding of local socio-cultural conditions and prevalent norms, attitudes and beliefs forms an essential part of the formulation of cycling policy.

Policy outcomes

Utility cycling mode share and cycling safety were conceptualised as coupled policy outcomes for the purposes of this study, with reference to Harms et al. (2016). The results of the interviews and Delphi study support this decision in the sense that improving safety was a constant theme. Generally, the view among panellists was that municipalities cannot expect to see improvements in utility cycling numbers until real and crucially perceived safety is increased to such a level that safety is no longer the main barrier to cycling for the majority of the population. The idea of 'safety in numbers'; that crashes involving motorists and pedestrians or cyclists are less likely as levels of walking and cycling increase (Jacobsen 2003). This concept was questioned by some respondents, who proposed that the concept of 'numbers in safety' is equally as relevant. These findings support the pattern of safety being the most important consideration in cycling policy in low-cycling urban centres.

Theoretical example of findings

The findings of this study have been applied to a theoretical example to illustrate a possible physical manifestation of a selection of the most effective municipal cycling policies. Figure 8 represents a street and land use pattern typical of mid-late 20th century suburbs in developed countries. It features a motorway and a dendritic pattern of arterial and collector roads and residential crescents and culs-de-sac. Three types of intervention are shown: infrastructure-pull and push factors and changes to exogenous factors.

The infrastructure-pull factors make cycling more attractive by improving the real and perceived safety of travelling by bicycle and by modifying the street network. More direct trips by bicycle are facilitated by new connections which complete street blocks, go through public open spaces and cross the motorway. A long distance cycle path or 'cycle superhighway' allows for commuting trips or trips to the next centre. Intersection treatments improve conditions for cyclists at key points in the network ranging from subtle changes to side street junctions to complete restructuring of major signalised intersections with regard to geometry and signal phasing. The bicycle network is integrated with a rapid transit network. Bicycle parking and end of trip facilities are provided at the train station, and transition between the two modes is facilitated in the station's design.

The infrastructure—push factors make driving less attractive by restricting the movement of motor vehicles and through pricing of parking. Traffic calming and filtration devices, coupled with a 30 km/h zone simultaneously discourage driving for local trips and make the street environment safer for all street users and more pleasant for vulnerable street users, including cyclists.

Changes to exogenous factors such as road pricing and mixed use urban intensification could have a positive impact on cycling levels, although these measures would realistically not be implemented for the purpose of inducing demand for cycling exclusively. Road pricing disincentivises driving and dense urban development increases the demand for short trips, which are more likely to be taken on foot or by bicycle.
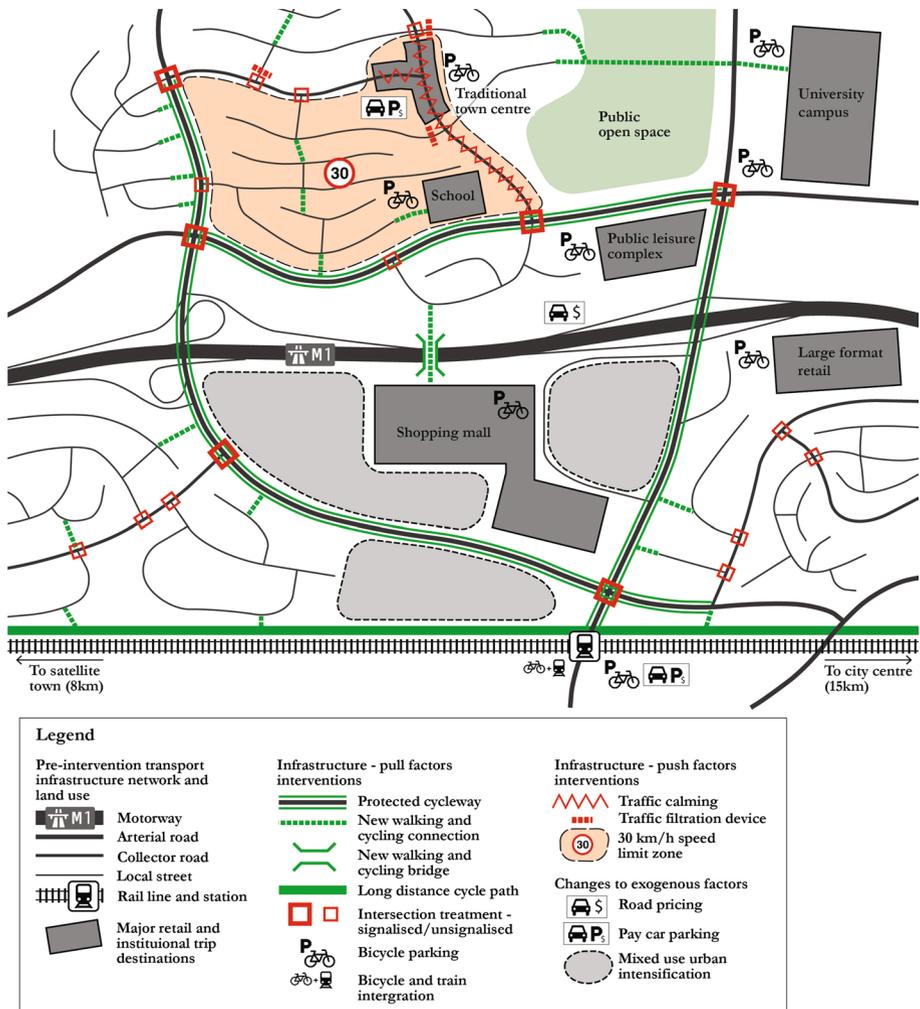
Fig. 8 Map showing theoretical example of findings

Research difficulties and limitations

A number of research difficulties were identified, the most significant of which was time constraints. The time constraints imposed by the study's original purpose as a post-graduate dissertation with a fixed due date meant that interview transcripts were not provided for review and validation by participants. This may have influenced the participants' willingness to take part and the accuracy of and completeness of the data, although no feedback was received during or after the study to this effect.

The principal limitation of this study is the external validity of its findings. Firstly, as was raised by several of the study's participants, the effectiveness of many of the policies may not be able to be judged reasonably in the absence of knowledge of the context. Secondly, the 'dispersed city' as a case for the research was purposefully not precisely defined.

This may have implications for the application of the findings of the research to specific urban centres, which may not be seen universally as being dispersed or car-oriented, for example. Thirdly, data collection for this study was limited to participants from the Netherlands and NZ, two Western nations belonging to the Organisation for Economic Co-operation and Development (OECD) with high gross domestic products per capita relative to the global average. Furthermore, the Netherlands and NZ are not necessarily typical examples of OECD countries with high and low levels of cycling, respectively. It is assumed that drawing on expertise from a wider variety of nations within the OECD member states and adding participants from non-OECD countries would influence the results of this study due to differences in context. This could be overcome in future research by including experts from other OECD countries width high levels of cycling such as Denmark, Finland and Germany; and experts from low cycling countries such as the UK, USA, Canada and Australia. Other research may look into cycling policy in non-OECD countries for comparison.

Conclusion

This study contributes to addressing the discrepancy in utility cycling numbers between high and low-cycling countries. Some lessons applicable to fulfilling this aspiration have been gathered by drawing on the knowledge of Dutch and NZ cycling experts using the Delphi method, which is seldom used in cycling policy research. The Delphi technique allowed opinions to be gathered for a theoretical setting, improving the understanding of the relative merits of all municipal cycling policy options and allowing application to different dispersed city contexts. The study quantified the respondents' positions and produced a hierarchy of municipal cycling policy effectiveness.

The opinions of the panel of utility cycling experts polled reinforce the findings in the literature that the most effective measures to increase utility cycling mode share and improve real and perceived cycling safety in dispersed, low-cycling urban centres are physical infrastructure interventions. The next most influential factor is the socio-spatial environment. Cycling is unlikely to become a mainstream mode of transport without an adequate network of cycle lanes and paths, intersection treatments and bicycle parking. Measures that make driving less attractive relative to cycling such as managing car parking supply and restricting motor vehicle movements are likely to induce demand for cycling. This must, however, be balanced with the generation and maintenance of political and public support, which is also a critical success factor.

As indicated by the results of this study, the spatial characteristics which define low density, car-oriented urban environments are likely to provide limitations to the potential of cycling in dispersed urban centres (Heinen et al. 2010). In this regard, the policy shift toward the compact city model and placing greater value on place making in many cities will contribute toward creating an environment which is more conducive to non-motorised modes of transport including cycling (Harms et al. 2014). While the evolution of the urban form is likely to take considerable time in most cases, international examples show that substantial increases in cycling mode share can be reached in settings where concerted policy efforts are made to provide for it (Pucher and Buehler 2012b; Mees 2010).

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