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RESEARCH ARTICLE

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Do hard traffic measures produce hard changes? A case study of individuals' changing mobility behaviour and environmental concern following the implementation of a modal filter in Aachen, Germany

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ABSTRACT

In the transition to sustainable mobility, many cities aim to reduce motorised transport and promote active modes of travel. In June 2021, the city of Aachen, Germany, together with citizen and student associations closed a section of the inner-city ring street 'Templergraben' to individual motorised transport (IMT) by implementing a modal filter for IMT through traffic as a 'hard measure'. The street section and its surrounding infrastructure were transformed into a living lab. This paper aims to assess the impact of the hard measure on individuals' mobility behaviour as pro-environmental behaviour (PEB) in relation to their environmental concern (EC). We conducted a survey ($N = 1243$) in autumn 2021 to measure the respondents' acceptance of the modal filter, their EC, and their mobility behaviour. We operationalise cost through transport equity and perform various linear regression models to enable empirical validation of the low-cost hypothesis within high-cost subgroups. Our findings demonstrate how inequitable burdens disrupt the connection between environmental concern, acceptance of a modal filter, and PEB in high-cost mobility situations. We conclude that hard measures alone fail to induce PEB in high-cost contexts, but equity-centred soft measures could facilitate the translation of EC into PEB via increased acceptance.

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Hard measure; environmental concern; mobility behaviour; equity; sustainable mobility transition; quantitative

1 Introduction

The changes in mobility behaviour arising during the COVID-19 pandemic have prompted European cities to temporarily test new infrastructural measures and changes in traffic regulations. In recent years, these so-called 'hard measures', i.e. infrastructural barriers or changes in traffic regulations, have become increasingly popular in the transport context because they seemingly help to not only reduce emissions and air and noise pollution but may also increase active travel modal share (e.g. Bamberg et al., 2011; Weiand et al., 2019).

Following a citizen motion[1], the city of Aachen, Germany, together with citizen and student associations, closed a section of the city's inner ring street 'Templergraben' to individual motorised transport (IMT) via a modal filter for IMT through traffic[2] in June 2021. This street section and its surrounding infrastructure were referred to as 'living lab Templergraben'[3].

As a first step in evaluating the relevance of this project for a sustainable transition in the context of mobility, this paper focuses on the implementation of a modal filter for IMT through traffic as a hard measure. Recent transport research has focused on whether temporary hard measures lead to changes in mobility behaviour and on whether the distribution of costs and benefits of hard measures is equitable (Aldred et al., 2021; Thomas et al., 2022) and therefore suitable for an inclusive sustainable mobility transition. In environmental social science research, however, there is an ongoing debate on how pro-environmental behaviour (PEB) relates to environmental concern (EC) and whether PEB and EC accurately predict environmental impact (Bruderer Enzler & Diekmann, 2019; Csutora, 2012; Huddart Kennedy et al., 2015; Moser & Kleinhückelkotten, 2018). Synthesising these strands of research, we

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evaluate the effects of the modal filter as a hard measure on the mobility behaviour of respondents in relation to their EC and in relation to whether the hard measure was a low-cost (LC) or high-cost (HC) intervention for the respondent.

We conducted a survey ($N = 1243$) to elicit the EC and mobility behaviour of individuals in Aachen following the implementation of the modal filter. Using multiple linear regression, we evaluate the following two research objectives (ROs):

RO1 Determining the predictive power of the LC/HC categorisation and EC for the acceptance of the modal filter.
RO2 Determining the predictive power of the acceptance of the modal filter and EC for mobility behaviour change as impact-oriented PEB.

A better understanding of these ROs will aid in advancing sustainable changes in mobility behaviour and thus in a sustainable transformation of the transport sector.

2 Theoretical background

2.1. Hard and soft policy measures

In the context of transport policies and their impact, the terms 'hard measures' and 'soft measures' are used to describe different approaches to influence individual behaviour and attitudes related to mobility. While hard measures often refer to coercive structural interventions, including vehicle bans, street closures, or vehicle charges, soft measures are always noncoercive.

Hard measures are implemented to encourage people to shift from car use to using other modes of travel that are more environmentally friendly (Aldred & Goodman, 2020; Weiand et al., 2019). In general, their aim can be summarised as increasing the costs for travel options with negative environmental impact, thus making environmentally friendly travel mode choices the more economical ones (Bamberg et al., 2011). However, the public acceptance and political feasibility of hard measures is often low (Eriksson et al., 2008; Gärling & Schuitema, 2007), as exemplified in the case of road pricing (Schade & Schlag, 2003). Ultimately, the coerciveness of hard measures may be subjective and therefore not equitable (Gärling & Schuitema, 2007).

Contrary to hard measures, soft measures focus on nudging individuals' behaviours towards choosing environmentally friendly travel modes voluntarily. Soft measures include so-called psychological interventions, such as providing information on car use and travel alternatives (Graham-Rowe et al., 2011). They also include public awareness campaigns or funding of marketing measures for public transport (Bamberg et al., 2011; Möser & Bamberg, 2008). Compared with hard measures, soft measures are less costly and may have a higher level of public acceptance (Gärling & Schuitema, 2007; Graham-Rowe et al., 2011). Thus, a combination of hard and soft measures may be more politically feasible because it may increase public acceptance (Gärling & Schuitema, 2007; Möser & Bamberg, 2008; Weiand et al., 2019).

One well-studied example of the combined implementation of hard and soft measures in European cities is the Low Traffic Neighbourhood (LTN) scheme in the UK (Aldred et al., 2021; 2024; Furlong et al., 2025; Goodman et al., 2023; Jones & Meriçliler, 2025; Xiao et al., 2023). For LTNs in London, road safety improvements are well-documented (Furlong et al., 2025), as are air quality improvements in both LTNs and boundary areas (Yang et al., 2022). For Birmingham, mixed results on air pollution were reported (Whelan et al., 2024). Although air quality measurements showed improvements within LTN areas, residents living on boundary roads reported perceived increased pollution, leading to a perception of inequity and divergent acceptance (Whelan et al., 2024).

Strong evidence for a modal shift comes from the longitudinal five-year Mini-Hollands study, which demonstrated that LTNs increased active travel and reduced car ownership in London's Outer boroughs (Aldred et al., 2024; Goodman et al., 2020). Public acceptance of LTNs varied. For London, implementation of LTNs proved equitable at city and micro levels, but not necessarily at district level (Aldred et al., 2021). Public acceptance was highly polarised in Birmingham (Whelan et al., 2024) and 27 of 113 London LTNs have been removed by 2025 due to public opposition or political changes (Furlong et al., 2025).

2.2. Environmental concern and pro-environmental behaviour

Studies in environmental social science research have generally been concerned with the relationship between EC and PEB (Miller et al., 2022). EC is 'the degree to which people are aware of problems regarding the environment and support efforts to solve them and/or indicate a willingness to contribute personally to their solution' (Dunlap & Jones, 2002) and PEB is generally understood as 'behavior that consciously seeks to minimize the negative impact of one's actions on the natural and built world (e.g. minimize resource and energy consumption, use of non-toxic substances, reduce waste production)' (Kollmuss & Agyeman, 2002).

PEB, however, does not necessarily accurately depict environmental impact (Huddart Kennedy et al., 2015). First, numerous studies that measured environmental impact as greenhouse gas emissions have found little to no explanatory power of PEB on environmental impact (Bruderer Enzler & Diekmann, 2019; Csutora, 2012; Huddart Kennedy et al., 2015; Moser & Kleinhückelkotten, 2018; Tabi, 2013). Second, socio-demographic variables such as income and household size have been found to be more accurate predictors of environmental impact (Bruderer Enzler & Diekmann, 2019; Csutora, 2012; Moser & Kleinhückelkotten, 2018). For example, Bruderer Enzler and Diekmann (2019) argue that for PEB to be a reliable measure of environmental impact, it would have to include all individual behaviours with environmental impact. Additionally, behaviours would need to be weighed accordingly (Bruderer Enzler & Diekmann, 2019).

Finally, PEB may be high while household carbon footprints may be large if cumulated behaviours are not weighed according to their carbon emissions (Diekmann & Jann, 2000; Huddart Kennedy et al., 2015). Thus, we follow Bruderer Enzler and Diekmann (2019) and Stern (2000) in differentiating between impact-oriented PEB and intent-oriented PEB. We also understand personal mobility behaviour as part of private impact-oriented PEB.

2.3. Mobility behaviour, attitudes and environmental impact

A variety of studies have analysed travel behaviour in relation to sustainability, for example, drawing on psychological concepts (Gehlert et al., 2013 for an overview). Studies assessed mobility behaviours in relation to hard and soft measures (Bamberg et al., 2011; Gärling & Schuitema, 2007). It has been argued that instead of clustering according to socio-demographic factors, eliciting attitudes in relation to travel behaviours as well as perceived behavioural control improves the accuracy of attitude-behaviour relations in the context of mobility behaviour and environmental attitudes (Anable, 2005; Haustein & Hunecke, 2013; Hunecke et al., 2007; Prillwitz & Barr, 2011). In this context, Hunecke et al., (2007) argue that psychological factors and attitudes also influence impact-oriented behaviour and that attitudinal variables are therefore relevant to accurately measure environmental impact of mobility behaviour. Their findings support the necessity for soft measures in order to ensure that transport policy measures are environmentally impactful (Hunecke et al., 2007).

2.4. Low-cost hypothesis

Many studies have shown attitudes to be less environmentally impactful in higher cost situations. Costs not only include economic capital, but also social and cultural capital, for example in the context of cycling (Bosen et al., 2023). The LC hypothesis suggests that EC is often consistent with PEB in LC situations, but not in HC situations (Diekmann & Preisendörfer, 1998; 2003). Recycling waste is an example for LC behaviour, as it does not require a lot of time or effort. Switching from IMT to public transport daily is an example for HC behaviour, as personal costs are higher for this behavioural change (Del Saz Salazar & Pérez Y Pérez, 2021; Diekmann & Preisendörfer, 2003).

One possible explanation for this divergence of EC and PEB is the 'defensive denial hypothesis', which aims to explain why attitudes have less explanatory power for behaviours in HC than in LC situations. Individuals show a 'defensive denial' mechanism in order to avoid having to adapt their behaviour in HC situations, even when their environmental attitudes would predict behavioural change. They invalidate the environmental impact of their behaviour in HC situations to prevent cognitive dissonance, while maintaining their HC behaviour with negative environmental impact, even though their individual EC is high (Diekmann &

Preisendörfer, 2003). The validity of the LC hypothesis has been challenged, with some studies supporting it (Best & Kroneberg, 2012; Diekmann & Preisendörfer, 1998; 2003) and others contesting it (Best, 2008; Liebe & Preisendörfer, 2007). We argue that the LC hypothesis is relevant in the context of transport equity and inclusion, however, as the definition of costs is directly related to equity.

2.5. Transport equity and inclusion

Over the past decade, there has been a growing emphasis on equity and inclusion in transport research, both generally (e.g. Buehler & Pucher, 2021; Umweltbundesamt, 2020) and specifically in the context of temporary hard measures (for example in Aldred et al., 2021; Thomas et al., 2022). Main research concerns are whether groups of people are disproportionately impacted by hard measures and whether the potential positive impacts, including environmental impacts, are equally distributed.

Concerns are that hard measures negatively impact individuals with less social, cultural, and economic capital and social status, while these groups do not profit as much from the measures' positive impacts.

For example, as found in a recent study by Preisendörfer et al. (2022), income affects road traffic annoyance negatively. Additionally, costs have historically not always been measured equitably in research, as has been shown for the lack of data on care-related trip purposes by Sánchez de Madariaga, (2013a, 2013b). Since care-related trips are still mostly conducted by people identifying as women (Sánchez de Madariaga & Zucchini, 2019), eliciting care work as a trip purpose also contributes to improving the data basis on gendered mobilities, and provides for data better suitable for policies fostering transport equity and inclusion by accounting for diversity.

3 Hypotheses

Bringing together transport research and environmental social science research, we combine results from environmental behaviour and -attitude research with results from transport behaviour and -attitude research, as well as transport equity and inclusion, in six hypotheses.

Our first hypothesis is that EC is positively correlated with the acceptance of the modal filter. Our second hypothesis is that respondents for whom the modal filter is a HC intervention have a lower acceptance, compared to the respondents for whom the modal filter is a LC intervention. Our third hypothesis is that the correlation of EC and the acceptance of the modal filter of the HC category is positive but lower compared to the correlation of EC and the modal filter acceptance of the complete sample. Our fourth hypothesis is that the categorisation into LC or HC is a stronger predictor for the acceptance of the modal filter than EC. Our fifth hypothesis is that individuals of the HC category with high EC (>4), who have reportedly not reduced their IMT, show a higher defensive denial score than individuals who reportedly reduced their IMT. Our sixth hypothesis is that EC is the stronger predictor for a change in transport modes towards more active travel modes than acceptance of the modal filter. Table 1 delivers an overview of our hypotheses and the corresponding variables.

Table 1. Overview of the hypotheses.

	Hypotheses	Variables
H 1	EC and the acceptance of the modal filter are positively correlated	Dependent variable: Acceptance of the modal filter Independent variable: EC
H 2	The mean of the acceptance of the LC category is higher than the mean of the HC category	Test variable: Acceptance of the modal filter Grouping variable: LC/HC categorisation
H 3	The correlation between EC and the acceptance of the modal filter in the HC category is positive but smaller compared to the whole sample	Dependent variable: Acceptance of the modal filter Independent variable: EC
H 4	LC/HC categorisation is the stronger predictor than EC for the acceptance of the modal filter	Dependent variable: Acceptance of the modal filter Independent variables: EC and LC/HC categorisation, control variables
H 5	Individuals of the HC category with a high EC who have not reduced their IMT behaviour have a lower mean of the defensive denial item than the ones who reduced their IMT behaviour	Test variable: Defensive denial item Grouping variable: Only HC category and high EC (>4); change in motorised individual traffic behaviour
H 6	EC is the stronger predictor for a change in impact-oriented PEB than acceptance	Dependent variable: Change in impact-oriented PEB Independent variables: EC and acceptance modal filter; control variables

4 Materials and method

4.1. Street section and modal filter

A section (170 metres) of the inner-city street Templergraben has been closed to IMT through traffic via a modal filter since June 18th 2021, by the city of Aachen, as a result of a citizen motion filed in June 2020 by the student association Uni.Urban.Mobil, the transport association Germany (VCD), and the German cycling association (ADFC)[4].

The Templergraben is part of Aachen's inner ring street, circling the historic city centre. It is a single carriageway with one traffic lane for each direction. The closed section of the Templergraben runs between and along main university buildings, making it a busy pedestrian area with many pedestrians crossing and dwelling, as well as a frequented street for IMT through traffic (see Figure 1). Approximately 7330 cars per day used to pass through the Templergraben section in June 2021, before the implementation of the modal filter[5] (Stadt Aachen, 2023). Even with the modal filter in place, buses are still allowed to pass through the street section to reach bus stops in front of the main university building. Additionally, approximately 150 cars per day (approximately 3% of total cars per day) pass through the street section, as drivers ignore the modal filter (Stadt Aachen, 2021).

The modal filter and the newly used public spaces are compendiously called 'living lab' (German: 'Reallabor') and are a joint project of the student association Uni.Urban.Mobil, the AStA (the university-wide representation of interests of all students at RWTH Aachen University), the VCD and the ADFC, and the city (Stadt Aachen, 2023). Since its implementation, different activities have been organised to reshape and enliven the freed-up urban space, such as sports events or a temporary open-air pub (AStA RWTH, 2021) (see appendix A for pictures).

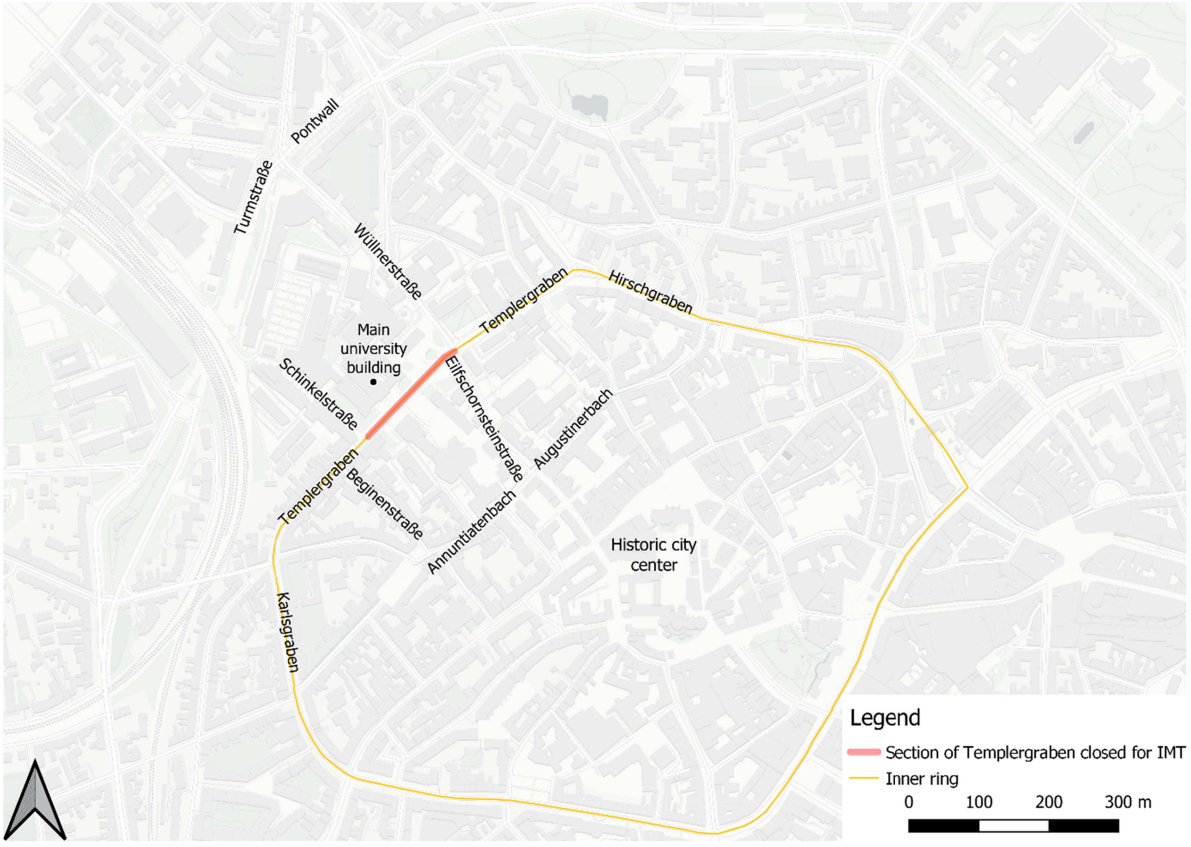


Figure 1. Map of the historic city centre of Aachen and the section of the Templergraben closed for IMT created using map tiles by CartoDB, under CC BY 3.0. Data by OpenStreetMap, under ODbL.

4.2. Survey and sample

To gain information on opinions on the modal filter and its value for a mobility transition, a survey was conducted by a team at RWTH Aachen University led by the paper's first author, in cooperation with the city of Aachen, the student association Uni.Urban.Mobil, the VCD, the AStA, and the ADFC (Stadt Aachen, 2023).

The survey took approximately ten minutes to answer. We pretested the completion time and possible question ambiguities among colleagues, members of the involved associations, and employees of the city of Aachen. The survey was run online via the survey tool SoSci-Survey from mid-September (17.09.2021) until mid-November (15.11.2021), and in addition, the same survey on paper was distributed to households in streets surrounding the Templergraben street section (see appendix B for a full list of survey questions). All participants gave informed written consent, in accordance with European and German data protection laws.

The survey contained 24 questions in total, including questions concerning the evaluation of living lab activities that were relevant for the city and the associations, but are not evaluated in this paper. For the analysis in this paper, we implemented items on mobility behaviour pre- and post-implementation of the modal filter, attitudes concerning the acceptance of the modal filter, as well as the EC scale as developed by Diekmann and Preisendörfer (2001) (see appendix A). Response rate on paper was low with only 23 paper surveys returned and 1629 surveys completed online. We assume this was because online survey completion was more convenient, as a QR-code was printed on the paper surveys. 1652 persons participated in total. Not all respondents answered all items evaluated in this paper. Thus, the sample used in this paper only contains the $N = 1243$ respondents who answered all items relevant to our analysis completely.

4.3. Measuring acceptance

To assess the acceptance of the modal filter, the survey contained four Likert-scaled items that asked for the attitudes towards the change in IMT through traffic at the Templergraben, and the possible wider implications for traffic and active travel in the surrounding areas and the city (see appendix A, Table A4 for an overview of the items translated into English). We used these items to calculate a scale for the acceptance of the modal filter. The four items were, if necessary, reverse coded, and the average was calculated. This resulted in a scale ranging from 1 to 5. High values indicate high acceptance (M = 4.31, 95% CI [4.25, 4.38]) (see Table 4). The reliability of the scale is high with $\alpha = 0.952$ (mean of Cronbach's alpha across M = 17.26, $n = 1243$). A factor analysis revealed that a one-dimensional solution could explain 87.77% of the variance of the scale (principal components: $\chi 2(6) = 5718.34$, $p = .000$; KMO = 0.852; $n = 1243$).

4.4. Measuring environmental concern

EC was measured following the approach of Diekmann & Preisendörfer, (2001, 2003), which was also utilised in recent studies by Bruderer Enzler and Diekmann (2019) and Preisendörfer et al. (2022). The EC-scale of Diekmann and Preisendörfer (2001) is widely established, and has been empirically tested in various German surveys (Best, 2011; Franzen, 2023). Based on 9 Likert-scaled items, which cover the three theoretical dimensions affective, cognitive, and conative, an average scale is constructed (Diekmann & Preisendörfer, 2001). Conducting a factor analysis on the 9 items, delivered a one-dimensional solution (principal components: $\chi 2(36) = 6079.89$, $p = .000$; KMO = 0.931; 58.59% of variance explained, $n = 1243$) which is in line with Diekmann and Preisendörfer (2001) and Bruderer Enzler and Diekmann (2019). If necessary, the items were reverse coded and the mean value was calculated resulting in a scale that ranges from 1 to 5 with high values indicating high EC (M = 4.02, 95% CI [3.98, 4.07]) (see Table 4). The reliability of the scale is high, as $\alpha = 0.91$ (mean of Cronbach's alpha across M = 36.22, $n = 1243$) (see appendix A, Table A5 for an overview of the items translated into English).

4.5. Measuring change in impact-oriented PEB

The respondents stated their mobility behaviour before the implementation of the modal filter for various modes of transport (see Table 4). For each mode of transport, the frequency of use was assessed with a

Likert-scaled item, with 1 as 'never' and 5 as 'always'. Respondents also reported their frequency change of each mode of transport after the implementation of the modal filter, by answering a Likert-scaled item for each mode of transport, with 1 as 'much rarer' and 5 as 'much more frequently'. To compute the change in impact-oriented PEB, the mean of the frequency change items was calculated. The items for IMT as a passenger and for Carsharing were not used, as their environmental impact is context specific. The IMT item was reversed coded. A high scoring in the change in impact-oriented PEB variable signals a switch towards more environmentally friendly mobility patterns. A score of 3 signals no change while a low scoring indicates a reduction of environmentally friendly mobility patterns (M = 3.11, 95% CI [3.09, 3.13]) (see Table 4).

Analogous, we calculated the mean for the mobility patterns before the modal filter to use this variable as a further control variable. The resulting scale ranges from 1 to 5. A higher score indicates the more frequent use of environmentally friendly modes of transport (M = 3.15, 95% CI [3.11, 3.18]).

4.6. Low-cost categorisation and defensive denial

Respondents were categorised into the LC or the HC category. The categorisation is based on items eliciting the means of transport and trip purposes for the street section the modal filter applies to. Items were developed considering items on means of transport and trip purposes used in the Mobility in Germany surveys (see Eggs et al., 2018).

Since the street section is only closed for IMT through traffic, we differentiate between IMT as higher-cost, concerning the modal filter, whereas public transport and active modes of travel, such as cycling and walking, are not impacted by the modal filter and therefore lower-cost behaviours in this context. We also include trip purposes in our categorisation.

The HC category consists of respondents who stated that their frequency of using any kind of motorised means of transport (including car sharing) as a driver or passenger is 'often' or 'always', or for being a driver and a passenger was 'occasionally', and who selected at least one of the HC trip-purposes (see Table 4 and appendix A, Table A2). We categorise care-related trips as a HC trip purpose, to contribute to transport research that aims to make care-related trip purposes more visible, as argued for by Sánchez de Madariaga and Zucchini (2019). Everyone who is not allocated to the HC category ($n = 307$) is part of the LC category ($n = 936$). We also asked for limitations in mobility due to health issues and used this as a control variable to better account for equity and inclusion.

To test the defensive denial hypothesis (H 5), we included a defensive denial item in the survey ('In principle, I think the individual's choice of mode of transport has no impact on the state of the environment') (see appendix A, Table A6).

5 Results

5.1. Descriptive statistics

All results were calculated using the software SPSS. A descriptive overview of the socio-demographic variables can be found in Table 2. About one third of the participants identified as women. The majority of the participants were between 16 and 34 years old (76.1%). About one quarter were direct residents of the Templergraben area[6] while 5.1% did not live in Aachen. The majority of the participants were students (university) or employees, with 56.9% and 37.9%, respectively. Consequently, the most frequent trip purpose is the use of the Templergraben to go to work, school, or university, with 64% (see Table 3). A share of 2.7% reported being limited in mobility due to health issues.

The overall acceptance of the modal filter is high, with a mean value of 4.31 (95% CI [4.25, 4.38]) and a median of 5 (see Table 4). The high mean acceptance may be indicative of the fact that the hard measure was introduced following a citizen motion, which is likely to have led to an increase in public support. In the HC category the average acceptance is lower, with a mean value of 3.14 and a median of 3. The mean value and the median of the LC category is higher, with 4.7 and 5, respectively.

On average, the respondents have high EC, indicated by a mean value of 4.02 (95% CI [3.98, 4.07]) and a median of 4.22 (see Table 4). For EC, a difference between the LC and HC categories can be observed.

Table 2. Descriptive statistics of socio-demographic variables.

Variable	Category	*n* (N = 1243)	%
Gender	Women	415	33.4
	Men	822	66.1
	Diverse	6	0.5
Age	Between 16 and 24	475	38.2
	Between 25 and 34	471	37.9
	Between 35 and 44	106	8.5
	Between 45 and 54	72	5.8
	Between 55 and 64	79	6.4
	Older than 65	40	3.2
Direct Resident of the Templergraben area	Yes	316	25.4
	No, lives somewhere else in Aachen	864	69.5
	No, does not live in Aachen	63	5.1
Occupation	Student (School)	2	0.2
	Student (University)	707	56.9
	Apprentice	9	0.7
	Employed	471	37.9
	Retired	39	3.1
	Others	15	1.2
Limited in mobility due to health issues	Yes	33	2.7
	No	1210	97.3

Table 3. Trip purpose variables.

Trip purpose to use Templergraben as an everyday traffic/transport route before the change in traffic routing	n	%
To work, school, university	795	64
Other job-related trips	198	15.9
To leisure activities	758	61
To do shopping for bigger items	261	21
Taking people somewhere and picking up people (including children)	117	9.4
To provide for relatives, people in need	26	2.1
Other purposes	28	2.3
Did not use Templergraben as an everyday traffic route	260	20.9

Table 4. Descriptive overview of variables.

				95% Confidents interval	
Variable	N	Median	Mean	Lower limit	Upper limit
Mobility behaviour before the modal filter:					
IMT as driver	1243	2	2.29	2.22	2.36
IMT as passenger	1243	2	2.08	2.03	2.13
Carsharing	1243	1	1.4	1.36	1.44
Bicycles, electric bikes, pedelecs	1243	4	3.62	3.54	3.69
Bus, train, public transport	1243	3	3.03	2.97	3.09
E-Scooter	1243	1	1.43	1.39	1.48
By foot	1243	4	3.94	3.9	3.99
PEB before the modal filter	1243	3.2	3.15	3.11	3.18
Change of mobility behaviour:					
IMT as driver	1243	3	2.88	2.85	2.91
IMT as passenger	1243	3	2.87	2.84	2.9
Carsharing	1243	3	2.94	2.92	2.96
Bicycles, electric bikes, pedelecs	1243	3	3.23	3.19	3.26
Bus, train, public transport	1243	3	2.99	2.97	3.02
E-Scooter	1243	3	2.96	2.94	2.98
By foot	1243	3	3.26	3.23	3.3
Change in impact-oriented PEB	1243	3	3.11	3.09	3.13
Environmental Concern	1243	4.22	4.02	3.98	4.07
Acceptance of the modal filter	1243	5	4.31	4.25	4.38

Respondents allocated to the HC category show an average EC of 3.41 (median = 3.56) while members of the LC category show an average EC of 4.23 (median = 4.33).

5.2. Analysis

To test for hypotheses one and three, we conducted a Pearson-correlation between EC and the acceptance of the modal filter for the whole sample and for the HC category only. The analysis of the correlation of the complete sample reveals that higher levels of EC are connected to higher levels of acceptance, as a positive

Table 5. Multiple linear regression model for acceptance of the modal filter.

	Acceptance of modal filter				
	Unstandardised coefficient		Standardised coefficient		
Variable	B	Std Error	β	t-value	*p*-value
EC (1-5)	0.874***	0.122	0.581***	28.35	<0.001
LC/HC category (0/1)	0.752***	0.059	0.264***	12.86	<0.001
Women (0/1)	−0.213***	0.048	−0.082***	−4.44	<0.001
Direct resident of the Templergraben (0/1)	−0.208***	0.052	−0.074***	−4.03	<0.001
Limited in mobility due to health issues (0/1)	−0.087	0.143	−0.011	−0.61	0.543
Between 16 and 24	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
Between 25 and 34 (0/1)	0.029	0.06	0.011	0.47	0.636
Between 35 and 44 (0/1)	0.057	0.108	0.013	0.53	0.594
Between 45 and 54 (0/1)	−0.113	0.12	−0.022	−0.94	0.346
Between 55 and 64 (0/1)	−0.266*	0.119	−0.053*	−2.24	0.025
Older than 65 (0/1)	−0.824**	0.26	−0.118**	−3.17	0.002
Student (University)	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
Student (School) (0/1)	−0.322	0.556	−0.011	−0.58	0.563
Apprentice (0/1)	−0.697**	0.264	−0.048**	−2.64	0.008
Employed (0/1)	−0.15*	0.07	−0.059*	−2.15	0.032
Retired (0/1)	0.36	0.261	0.051	1.38	0.167
Other (0/1)	−0.389	0.212	−0.035	−1.83	0.067
Constant	0.449***	0.122		3.69	<0.001
Number of observations	1243		1243		
Adjusted R^2	0.6		0.6		

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

correlation is observed ($r(1241) = 0.71$, $p < 0.001$ (one-sided); 95% CI [0.68, 1]). Therefore, hypothesis 1 is supported.

The correlation of the HC category is similar to that of the complete sample. A significant ($p < 0.001$ (one-sided)) positive Pearson-correlation of 0.72 ($df = 305$; 95% CI [0.67, 1]) is confirmed. We expected the correlation between EC and the acceptance of the HC category to be positive, but lower compared to the correlation of the complete sample, however, this hypothesis has to be rejected, as the correlations are on a similar level (for the HC category, it is 0.01 higher).

The acceptance of the HC ($M = 3.14$, $SD = 1.64$) is lower compared to the LC category ($M = 4.7$, $SD = 0.72$). To test if the difference is significant an adjusted t-test was conducted as the Levene's test for the two samples revealed a difference in the variance of the samples ($p < 0.001$). The null-hypothesis is: There is no significant difference between the mean acceptance of the HC and the LC category. The t-test proved a significant difference in the mean acceptance of the modal filter between the two categories, $t(345.92) = 16.2$, $p < 0.001$. Consequently, the null-hypothesis is rejected. A high effect size is observed (Cohen's $d = 1.03$). Thus, the difference between the two categories is not only significant but can be considered relevant. This proves hypothesis two to be valid as the mean acceptance of the modal filter of the LC category is significantly higher than of the HC category.

Additionally, concerning EC a lower mean value is observed for the HC category ($M = 3.41$, $SD = 1$) compared to the LC category ($M = 4.23$, $SD = 0.63$). Analogous to the mean acceptance, an adjusted t-test was applied to test the null-hypothesis: There is no significant difference between the mean EC of the HC and the LC category. Again, an adjusted t-test was utilised, as the Levene's test showed a difference in the variance of the two samples ($p < 0.001$). A significant difference of the mean values is proven, $t(387.44) = 13.46$, $p < 0.001$. Consequently, the null-hypothesis is rejected. Additionally, the effect size was estimated. With a Cohen's d of 0.74, it is medium.

As EC and the acceptance of the modal filter correlate positively, and due to the significant difference in the means of the HC and the LC category, and as the acceptance is a metric variable, a multiple linear regression was conducted to examine which variable is the better predictor for the acceptance of the modal filter. The variables gender, direct resident of the Templergraben, limitation in mobility due to health issues, age, and occupation were additionally integrated into the model as predictors to control for their potential effects. Table 5 illustrates the results of the multiple linear regression.

The explanatory power of the model is 0.6 as the adjusted R^2 indicates (see Table 4). The model indicates a significant positive correlation between EC and the acceptance as well as a positive correlation between the LC/HC categorisation and the acceptance. However, the impact of EC is stronger as the

standardized β coefficient is higher compared to the LC/HC categorisation, with 0.581 and 0.264, respectively (see Table 4).

Looking at the control variables, gender (women) and local resident are significant predictors, having a standardized β coefficient of −0.082 and −0.074, respectively. Hence, both control variables have a smaller impact compared to EC and the LC/HC categorisation. Participants of the age categories 55-64 and 65 + show on average a significantly lower acceptance compared to the reference category 16-24 with a difference of 0.266 and 0.824, respectively. Respondents who are employed or are doing an apprenticeship have, on average, a significantly lower acceptance compared to the reference category of students (university). The differences are 0.15 and 0.697, respectively. Contrary to the assumption of hypothesis four, EC is found to be the stronger predictor for the acceptance than the LC/HC categorisation is. Consequently, hypothesis four is rejected.

To test the defensive denial hypothesis, we conducted an adjusted t-test to compare the means of the defensive denial item for the respondents of the HC category with high EC, who reportedly reduced their IMT mobility behaviour, to the respondents who reportedly did not reduce their IMT mobility behaviour.

The group that did not reduce their IMT mobility behaviour consists of 86 respondents and has a mean for the defensive denial item of 2.01, while the group that reduced their IMT consists of 24 respondents and has a mean value of 1.46. The Levene's test revealed a difference in the variances of the two samples ($p = 0.049$). The null-hypothesis for the adjusted t-test is that no difference in the means of the defensive denial item of the two samples exists. Conducting the adjusted t-test results in rejecting the null-hypothesis, $t(71.45) = -3.28$, $p < 0.001$. Thus, a difference in the means is observed. A high effect size (Cohen's $d = 1.01$) is observed, which indicates a relevant difference of the means. This finding strongly supports hypothesis five, which predicted that participants who reduced their IMT mobility behaviour have a higher EC, compared to the ones who did not reduce their IMT mobility behaviour.

We analysed the predictive power of EC and the acceptance of the modal filter for the metric variable 'PEB' with a multiple linear regression model to examine which of the two variables is the better predictor for PEB. The variables gender, direct resident of the Templergraben, limitation in mobility due to health issues, 'PEB before', age, and occupation were additionally integrated into the model as predictors to control for their potential effects. The results of these multiple regression models relevant for hypothesis six are displayed in Table 6. The explanatory power of the regression models is acceptable, with a R^2 of 0.162.

The model indicates a significant positive correlation between EC and PEB, as well as a positive correlation between the acceptance of the modal filter and PEB. However, the impact of the acceptance is stronger, as the standardized β coefficient is about 3 times higher compared to acceptance, with 0.261 and 0.084, respectively (see Table 6). Consequently, hypothesis four is rejected.

Looking at the control variables, gender (women) has a significant ($p = 0.047$) negative effect on change in impact-oriented PEB, with a comparably minor effect of −0.053 (standardized β coefficient). PEB before the modal filter has the second highest impact, with a standardized β coefficient of 0.171 ($p < 0.001$). Therefore, PEB before the modal filter is a better predictor than EC. Participants of the age category 25-34 have, on average, a significantly lower change in impact-oriented PEB compared to the reference category 16-24 with a minor difference of 0.055, suggesting that the effect is rather negligible. The different occupational groups do not show any significant effects, nor do the variables direct resident of the Templergraben and limitation in mobility due to health issues. Lastly, the LC/HC categorisation is slightly above of the significance level of $p < 0.05$ with a p-value of 0.051. As the effect is on a minor level ($\beta = -0.064$), it is negligible anyway.

As EC and acceptance of the modal filter are highly correlated, we checked for multicollinearity, calculating the Variance Inflation Factor (VIF) for both variables. The results show that there is no problematic multicollinearity (VIF < 5), as EC has a VIF of 2.136 and the acceptance of the modal filter a VIF of 2.64. All other variables also have a VIF of below 5 (see Table 6).

Given the strong correlation observed between EC and acceptance of the modal filter in the regression analysis, an additional mediation analysis was conducted to ascertain whether the relationship between EC and PEB functions indirectly through acceptance. Prior diagnostics indicated no problematic multicollinearity between EC and acceptance of the modal filter (VIF < 5), suggesting that both variables could be included in the same model. The mediation analysis was therefore performed using the

Table 6. Multiple linear regression model for change in impact-oriented PEB.

	Change in impact-oriented PEB					
	Unstandardised coefficient		Standardised coefficient			
Variable	B	Std Error	*β*	t-value	*p*-value	VIF
EC (1-5)	0.033*	0.015	0.084*	2.201	0.028	2.136
Acceptance (1-5)	0.069***	0.011	0.261***	6.178	<0.001	2.64
LC/HC category (0/1)	−0.049	0.025	−0.064	−1.956	0.051	1.609
Women (0/1)	−0.037*	0.018	−0.053*	−1.99	0.047	1.061
Direct resident of the Templergraben (0/1)	−0.013	0.02	−0.017	−0.655	0.513	1.047
Limited in mobility due to health issues (0/1)	0.044	0.054	0.022	0.802	0.423	1.072
PEB before the modal filter (1-5)	0.097***	0.2	0.171***	4.885	<0.001	1.817
Between 16 and 24	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
Between 25 and 34 (0/1)	−0.055*	0.023	−0.083*	−2.408	0.016	1.741
Between 35 and 44 (0/1)	−0.058	0.041	−0.05	−1.407	0.16	1.85
Between 45 and 54 (0/1)	−0.074	0.046	−0.053	−1.605	0.109	1.612
Between 55 and 64 (0/1)	0.035	0.046	0.026	0.772	0.44	1.734
Older than 65 (0/1)	0.031	0.1	0.017	0.31	0.757	4.339
Student (University)	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
Student (School) (0/1)	0.044	0.213	0.005	0.206	0.837	1.017
Apprentice (0/1)	0.069	0.101	0.018	0.682	0.495	1.022
Employed (0/1)	0.008	0.027	0.012	0.291	0.771	2.406
Retired (0/1)	−0.03	0.1	−0.016	−0.304	0.761	4.212
Other (0/1)	−0.098	0.081	−0.033	−1.209	0.227	1.099
Constant	2.452***	0.065		37.989	<0.001	
Number of observations	1243		1243			
Adjusted R^2	0.162		0.162			

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 7. Mediation model for change in impact-oriented PEB with acceptance as mediator.

					95% Confidents interval	
	Estimate	se	t	*p*	Lower limit	Upper limit
Mediator: Acceptance						
a: EC → Acceptance	0.809	0.031	26.085	<.001	0.748	0.869
Outcome: change in PEB						
c′: EC → change in PEB (direct effect)	0.052	0.023	2.294	0.022	0.008	0.096
b: Acceptance → change in PEB	0.091	0.017	5.482	<.001	0.058	0.124
Indirect effect (a x b)	0.074	0.014			0.047	0.102
Total effect (c)	0.129					

Note: N = 1243; Indirect effect CI based on 5000 bootstrap samples.
Model for mediator: $R^2 = 0.600$, $F(15, 1227) = 122.66$, $p < .001$; Model for outcome: $R^2 = 0.104$, $F(16, 1226) = 8.90$, $p < .001$.

PROCESS macro for SPSS (Model 4; Hayes, 2022), with EC specified as the independent variable, acceptance of the modal filter as the mediator, and PEB as the dependent variable. The same control variables as in the regression analysis, namely gender, direct resident of the Templergraben, limitation in mobility due to health issues, PEB before, age, and occupation, were included as covariates to control for their potential effects.

The results show that EC significantly predicts acceptance of the modal filter (b = 0.81, $p < .001$) (see Table 7 and Table A7). In turn, acceptance of the modal filter is positively associated with PEB (b = 0.09, $p < .001$). Additionally, EC retains a small but statistically significant direct association with PEB when acceptance is included in the model (b = 0.05, $p = .022$). Furthermore, the indirect effect of EC on PEB via acceptance of the modal filter is significant, as indicated by the bootstrapped 95% confidence interval, which does not include zero (b = 0.074, 95% CI [0.047, 0.102]). This finding suggests that the relationship between EC and PEB is partially mediated by acceptance of the modal filter. Overall, the results indicate that higher levels of EC are associated with higher acceptance of the modal filter, which in turn is associated with higher levels of PEB, while a small direct association between EC and PEB remains. Given that the analysis is based on cross-sectional data, the findings should be interpreted as associations rather than causal effects.

To address the imbalanced demographic composition of the sample with respect to gender and age, additional mediation analyses were conducted separately for these groups (see Appendix A, Tables A8–A15). The gender-specific models yielded results consistent with the overall model, indicating no substantial differences. Similarly, the age groups 16–24, 25–34, and 35–44 showed comparable patterns. In

contrast, the models for the older age groups (45–54, 55–64, and 65+) were not statistically significant but suggest deviations from the overall mediation pattern.

5.3. Limitations

Our sample is not representative of Aachen's general population, as it includes a disproportionately higher share of respondents identifying as men as well as a disproportionately higher share of respondents under the age of 35 and students. The survey was distributed with the support of student associations and the Templergraben is surrounded by university buildings. In addition, many of the living lab activities were aimed at students. These factors likely increased participation among students who are mainly under 35 years old. Furthermore, the gender distribution of the university in Aachen is highly imbalanced with 65.5% men and 33.5% women (RWTH Aachen University, 2025), which explains the disproportionately high share of respondents identifying as men in our study. The mediation analysis clustered by age suggests that there is age difference in the mediating role of acceptance but as the mediation models for the age groups above 55 are not significant, interpretation is limited (see appendix A, table A8-A13). Our data aligns with the local conditions and reflects the local mobility culture, but our results may therefore not be fully generalisable to other contexts.

We measured defensive denial with a single-item scale. This was necessary to ensure brevity of the survey which covered multiple topics to include all transdisciplinary partners' interests. However, limitations include higher measurement error and lack of internal consistency measures.

Furthermore, assessing data through self-reported measures may introduce information biases, such as recall bias and social desirability bias, which can lead to overreporting by respondents (Althubaiti, 2016). However, self-reported measures are widely used in environmental behaviour research, and are considered a practical and established approach for assessing attitudes and pro-environmental behaviours in survey-based studies (Kormos & Gifford, 2014). While self-reporting facilitates the assessment of impact-oriented PEB, it is subjective and does not directly translate into a comparable degree of environmental impact, which limits the precision of the inquiry. Calculating impact-oriented PEB by forming the mean of the reported behaviour changes cannot predict quantitatively the environmental impact, in terms of e.g. greenhouse gas emissions. However, it is an indication of the actual impact, as switching to active modes of transport and reducing IMT reduces greenhouse gas emissions emitted by an individual. As this analysis aims to investigate the connections between the predictors EC, the acceptance of the modal filter, socio-demographic variables, and change in impact-oriented PEB, this simplification remains appropriate.

6 Discussion & conclusion

When the suitability of transport policy measures for a mobility transition towards sustainability is discussed, identifying factors that influence individuals to change their mobility behaviour as impact-oriented PEB in a way that is environmentally impactful is a key concern. Hard measures such as modal filters aim to force people to adapt their behaviour to increase impact-oriented PEB. The current evidence base on modal filters in European cities derives mainly from UK implementations, for example of LTNs (Aldred et al., 2021; 2024; Furlong et al., 2025; Goodman et al., 2023; Jones & Meriçliler, 2025; Xiao et al., 2023). Our study adds to this body of work by providing results for another European city with a different mobility culture.

In the case of the Templergraben modal filter, more respondents stated that they reduced any kind of IMT than respondents who stated that they increased it after the implementation of the modal filter. Furthermore, more people stated that they increased environmentally friendly modes of transport compared to the ones who stated that they reduced these modes after the modal filter implementation. Although the behavioural data are self-reported, the analysis enables the examination of correlations between EC, PEB, acceptance, and cost. Consistent with the established use of self-reported measures in environmental behaviour research (Kormos & Gifford, 2014), this approach helps to address a research gap by integrating perspectives from transport research and environmental social sciences. Our study advances the theoretical understanding of the LC hypothesis by integrating transport equity as a critical dimension of cost, thereby resolving a key limitation in prior research.

We found that EC correlates with the acceptance of the modal filter (Hypothesis 1), and that EC is even a stronger predictor than LC/HC categorisation (H 4), but that EC does not necessarily correspond to a considerable environmental impact, that is, reducing IMT mobility behaviour and increasing active modes of travel (H 6). When EC and acceptance of the model are combined in one model, acceptance has a higher effect than EC on change in impact-oriented PEB (H 6). As EC is a strong predictor for the acceptance (H 4), a conclusion we propose is that strengthening EC potentially increases acceptance, which would have a positive impact on impact-oriented PEB (H 6). This interpretation is corroborated by the mediation analysis, which indicates that the relationship between EC and impact-oriented PEB is primarily indirect through acceptance of the modal filter. While the direct effect of EC on PEB is not significant when acceptance is included in the model, the indirect effect via acceptance is significant. This suggests that acceptance acts as a mediating mechanism, linking EC to behavioural change.

Previous research has shown that EC predicts PEB (Bruderer Enzler & Diekmann, 2015) but that PEB does not necessarily translate into environmental impact (Huddart Kennedy et al., 2015). Thus, researchers have argued that EC does not directly predict environmental impact, as it is more strongly influenced by socio-demographic variables (Bruderer Enzler & Diekmann, 2019; Csutora, 2012; Moser & Kleinhückelkotten, 2018). In our data, some socio-demographic control variables showed a significant effect, but no pattern could be discovered. Furthermore, these significant effects have minor effect sizes, which limits their interpretational potential (H 6). Nevertheless, it is particularly important to address costs in the context of transport equity and inclusion. Our data showed that individuals for whom a modal filter is a HC situation have a lower acceptance (H 2). Furthermore, individuals over 55 years of age, as well as individuals who are working or doing an apprenticeship, show a lower acceptance of the modal filter. In the HC category, EC is lower than in the complete sample (H 3), and correlates with acceptance (H 3). The correlation between EC and acceptance in the HC category is similar to the correlation between EC and acceptance in the complete sample (H 3). Furthermore, we found that individuals in the HC category with high EC that have not reduced IMT have a higher defensive denial score than those who reduced IMT (H 5).

While the LC hypothesis posits that EC aligns with PEB in LC contexts, but not HC ones (Diekmann & Preisendörfer, 2003), our findings demonstrate that cost is inherently multidimensional, encompassing not only economic, but also social and cultural barriers tied to equity. Our data confirm that HC groups exhibit lower EC (H 3), lower acceptance of modal filters (H 2), and higher defensive denial among high-EC individuals who failed to reduce car use (H 5). Thus, we argue that, for modal filters to achieve equitable environmental impact, they must be coupled with participatory soft measures that reduce social and cultural costs.

This extends the LC hypothesis by showing that EC's predictive power for environmentally impactful behaviour is contingent on equitable cost structures. Our theoretical contribution lies in reframing the LC/HC framework through an equity lens: Hard measures alone fail to bridge the EC-PEB gap in HC contexts, but equity-centred soft measures (e.g. participatory EC-building, reimagining public space as a 'living lab') could potentially reduce social and cultural costs, mitigate defensive denial, and facilitate the translation of EC into impact-oriented PEB via increased acceptance. Thus, we propose that sustainable mobility transitions require simultaneously deploying hard measures and soft measures designed to address equity-specific costs.

That reporting on the positive effects of hard measures can increase public acceptance has been shown in a study on acceptability and acceptance of congestion charges in Stockholm, by Schuitema et al. (2010). The acceptance of the congestion charge was higher after its implementation than the acceptability beforehand. Schuitema et al. (2010) conclude that, along with positive experiences of the 'hard effects' of the congestion charge, such as increased availability of parking space, the positive reporting by the council and the mass media (i.e. the soft measures) also increased the acceptance of the hard measure. In this specific case of congestion pricing, other studies have also shown that the public framing and perceived public status quo of the acceptability of hard measures influences public acceptance (e.g. Börjesson et al., 2016; Eliasson, 2014; Schade & Schlag, 2003).

Similarly, concerning LTNs in Europe, several studies identified community engagement as a critical factor in LTN success. Whelan et al. (2024) highlighted how lack of consultation led to significant negative sentiment among residents, particularly those outside LTN boundaries, and emphasised the importance of collaborative decision-making and consultation of the local communities to foster higher acceptance. In

Oxford, there was moderate support for LTNs among residents, but opinions were varied and acceptance mostly correlated with household circumstances (Jones & Meriçliler, 2025). The political sensitivity of LTNs is reflected in their removal in some cases. Of the 113 London LTNs, 27 were removed due to public opposition or changes in political administration (Furlong et al., 2025).

Framing the Templergraben street section as a living lab and inviting citizen associations to creatively transform the section into public space was an initiative aimed at fostering more community engagement in the context of hard transport measures. In line with research suggesting that factors such as connectedness and diversity should play a bigger role in mobility and transport planning (Bosen & Leicht-Scholten, 2020; te Brömmelstroet et al., 2017) and challenging the systemic hegemony of automobilities (e.g. Cox, 2022), we argue that conducting participatory events that foster individuals' EC, along with lowering the social and cultural costs for switching from IMT to active travel, could increase the positive environmental impact of the modal filter long-term, by fostering acceptance and thereby encouraging impact-oriented PEB.

We therefore suggest that a participatory approach with a mobility- and EC-educational focus could lower the barriers to taking up active travel more frequently across all social strata, age groups, and occupations, reduce IMT, and increase positive environmental impact along with transport equity and inclusion. The relatively low explanatory power of the change in impact-oriented PEB model suggests that, in addition to the mechanisms identified in this study, other underlying factors, including accessibility and infrastructural factors, may influence behavioural change and should be explored in future research. It is recommended that future studies investigate potential differences in age groups and gender further. Ideally, such future research should be conducted using representative samples and employ a longitudinal study design.

Combining transport research and environmental social science research in our study yielded multi-faceted results that contribute to understanding how environmental attitudes are connected with mobility behaviours in the context of the acceptance of hard transport measures. The further development of the EC concept in the context of mobility, with a dedicated focus on transport equity and inclusion, will be useful in ensuring that policy interventions yield long-lasting effects and facilitate an equitable mobility transition towards greater sustainability.

Endnotes

1. The citizen motion pursuant to section 25 of the North Rhine-Westphalia (NRW) Municipal Code gives citizens and associations of citizens the opportunity to influence matters of concern or issues within a municipality by handing a written request including a justification to the council (Gemeindeordnung für das Land Nordrhein-Westfalen, 1994).
2. A modal filter is an infrastructural element (e.g. a gate, traffic sign, bollard) that stops or filters motorised traffic. Modal filters are most commonly implemented to reduce motorised through traffic. In our case, the modal filter is a non-permanent red-white beacon on one side of the single-lane carriageway and a traffic sign prohibiting IMT through traffic on both sides of the street closure (see appendix A for pictures).
3. Note that the city of Aachen and the associations used the term 'living lab' (German: 'Reallabor') in their communication to the public as an umbrella term for the combination of street-section closure to IMT through traffic via the modal filter and events. Their use of the term and its use in some of the survey questions therefore differs from our use in this paper. For the sake of definitory clarity and analytical rigour in this paper, the term 'living lab' is used to designate the events organised around the Templergraben street-section, and the term 'modal filter' is used to describe the traffic measures (beacon and change in traffic regulations, see note 2). We have ensured that the survey questions we use for our calculations are clearly consistent with the distinction we provide in this paper.
4. The motion to implement a modal filter for IMT through traffic at the Templergraben also included the surrounding streets 'Annutiatenbach' and 'Jakobstraße', in order to prevent a strain on local residents through overflow traffic. The 'Annutiatenbach' was only closed for IMT through traffic via bollards in May 2022. The motion to implement modal filters in the inner city had been part of a more comprehensive citizen motion filed in 2017 by the ADFC that also included propositions on how to redirect through traffic, parking, and improve cycling infrastructure. It was perceived favourably by the citizen forum in 2017 but never executed by the city.
5. Averaged daily number of cars on the weekdays Tuesday, Wednesday, Thursday in weeks outside school holidays. Included COVID-19 pandemic, lecture-free periods at the university, and temporary construction sites. Numbers are therefore not fully representative but nevertheless a valid indicator for traffic volume on the Templergraben street section closed by the modal filter (Stadt Aachen, 2023).

6. A list of 26 streets that surround the Templergraben section were provided by the city of Aachen (see appendix B).

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Disclosure statement

The authors report there are no competing interests to declare.

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Appendices

Appendix A

Pictures of the Templergraben street section and the modal filter.

Table A1. Means of transport items; developed considering means of transport used in the Mobility in Germany surveys (Eggs et al., 2018).

How often do you use the following means of transport or mobility services in your everyday life?
Cars, motorcycles as driver (including estate cars/vans/minibuses/mopeds)
Cars, motorcycles as passenger (including estate cars/vans/minibuses/mopeds/)
Bicycles, electric bikes, pedelecs
E-Scooter
Carsharing
Bus, train, public transport
By foot (including with walkers or wheelchair)
Other:

Response scale: '1 never', '2 rarely', '3 occasionally', '4 often', '5 always'.

Table A2. Change of mobility behaviour items.

How has your usage of means of transportation changed since the beginning of the Templergraben living lab?
Cars, motorcycles as driver (including estate cars/vans/minibuses/mopeds)
Cars, motorcycles as passenger (including estate cars/vans/minibuses/mopeds/)
Bicycles, electric bikes, pedelecs
E-Scooter
Carsharing
Bus, train, public transport
By foot (including with walkers or wheelchair)
Other:

Response scale: '1 much rarer', '2 rarer', '3 unchanged', '4 more frequently', '5 much more frequently'.

Table A3. Trip purpose items; developed considering trip purposes used in the Mobility in Germany surveys (Eggs et al., 2018).

For what trip purpose did you mainly use the Templergraben as an everyday traffic/transport route before the change in traffic routing?
I did not use the Templergraben as an everyday traffic route.
Trips to work, school, university[a]
Other job-related trips (excluding trips to work, school, university)[a]
Trips to leisure activities
Trips to do shopping for bigger items[a]
Taking people somewhere and picking up people (including children)[a]
Trips to provide for relatives, people in need[a]
Other purpose:

Notes: Multiple selection possible.
[a] high-cost trip purpose

Table A4. Acceptance scale of the modal filter items.

The living lab should provide insights into how the inner ring road ('Grabenring') and mobility in Aachen could be redesigned. To what extent do you agree with the following statements?
Overall, I support the test of a closure to car traffic on the Templergraben.
Overall, I would be in favour of a permanent closure of the Templergraben to car traffic.
I **don't** like the idea of the Grabenring becoming a distribution ring for safe and convenient cycling priority lanes to all boroughs.[a]
I think it's good to have less through traffic downtown so that buses, bicycles, and pedestrians have more space.
Response scale: '1 do not agree at all', '2 do rather not agree', '3 agree partially', '4 rather agree', '5 agree fully', '6 I do not know'
a reverse-scored

Notes: We used the term 'car traffic' in the survey because it is more intuitive than the term individual motorized transport.
[a] reverse-scored.

Table A5. Environmental concern scale items taken from Diekmann and Preisendörfer (2001); translation taken from Bruderer Enzler and Diekmann (2019).

To what extent do you agree with the following statements:
It bothers me when I think about the environmental conditions in which our children and grandchildren will probably have to live.
If we continue down the same path, we are heading toward an environmental catastrophe.
If I read news or watch TV news reports about environmental problems, I often become outraged and angry.
There are limits on growth that our industrialized world has already exceeded or will soon reach.
Most people in this country still do not act in an environmentally conscious way.
In my opinion, many environmentalists exaggerate claims about environmental threats.[a]
Politicians still do not do enough to protect the environment.
In order to protect the environment, we should all be willing to reduce our current standard of living.
Actions to protect the environment should be implemented even if they cause job losses.

Response scale: '1 do not agree at all', '2 do rather not agree', '3 agree partially', '4 rather agree', '5 agree fully'.
[a] reverse-scored

Table A6. Defensive denial item.

To what extent do you agree with the following statement:
In principle, I think the individual's choice of mode of transport has no impact on the state of the environment.
Response scale: '1 do not agree at all', '2 do rather not agree', '3 agree partially', '4 rather agree', '5 agree fully'

Table A7. Overall mediation model for change in impact-oriented PEB with acceptance as mediator including all covariates.

						95% Confidents interval	
Outcome	Predictor	B	SE	t	*p*	Lower limit	Upper limit
Mediator: Acceptance							
	Constant	−0.641	0.310	2.070	0.039	−1.248	−0.033
	EC (1-5)	0.809	0.031	26.085	<.001	0.748	0.869
	LC/HC category (0/1)	0.561	0.061	9.139	<.001	0.441	0.682
	Women (0/1)	−0.207	0.047	−4.43	<.001	−0.299	−0.115
	Direct resident of the Templergraben (0/1)	−0.228	0.050	−4.541	<.001	−0.327	−0.130
	Limited in mobility due to health issues (0/1)	0.072	0.139	0.521	0.602	−0.200	0.345
	PEB before the modal filter (1–5)	0.409	0.049	8.314	<.001	0.313	0.506
	Between 16 and 24	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
	Between 25 and 34 (0/1)	0.039	0.059	0.663	0.508	−0.076	0.154
	Between 35 and 44 (0/1)	0.111	0.105	1.060	0.29	−0.095	0.317
	Between 45 and 54 (0/1)	−0.047	0.117	−0.400	0.689	−0.277	0.183
	Between 55 and 64 (0/1)	−0.160	0.116	−1.378	0.169	−0.389	0.068
	Older than 65 (0/1)	−0.623	0.254	−2.452	0.014	−1.122	−0.125
	Student (University)	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
	Student (School) (0/1)	−0.622	0.543	−1.146	0.252	−1.687	0.443
	Apprentice (0/1)	−0.65	0.257	−2.532	0.012	−1.154	−0.146
	Employed (0/1)	−0.051	0.069	−0.732	0.464	−0.186	0.085
	Retired (0/1)	0.385	0.254	1.518	0.129	−0.113	0.883
	Other (0/1)	−0.276	0.207	−1.332	0.183	−0.682	0.130
Outcome: change in PEB							
	Constant	2.637	0.18	14.641	<.001	2.284	2.991
	EC (1-5)	0.052	0.023	2.294	0.022	0.008	0.096
	Acceptance (1-5)	0.091	0.017	5.482	<.001	0.058	0.124
	LC/HC category (0/1)	−0.019	0.037	−0.523	0.601	−0.092	0.053
	Women (0/1)	−0.101	0.027	−3.674	<.001	−0.154	−0.047
	Direct resident of the Templergraben (0/1)	0.025	0.03	0.862	0.389	−0.032	0.083
	Limited in mobility due to health issues (0/1)	−0.048	0.081	−0.591	0.555	−0.206	0.111
	PEB before the modal filter (1-5)	−0.013	0.029	−0.452	0.651	−0.071	0.044
	Between 16 and 24	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
	Between 25 and 34 (0/1)	−0.042	0.034	−1.221	0.222	−0.109	0.025
	Between 35 and 44 (0/1)	0.005	0.061	0.086	0.931	−0.115	0.125
	Between 45 and 54 (0/1)	−0.041	0.068	−0.596	0.551	−0.174	0.093
	Between 55 and 64 (0/1)	0.074	0.068	1.091	0.276	−0.059	0.207
	Older than 65 (0/1)	−0.137	0.148	−0.924	0.356	−0.427	0.154
	Student (University)	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
	Student (School) (0/1)	−0.923	0.316	−2.925	0.004	−1.542	−0.304
	Apprentice (0/1)	0.067	0.150	0.449	0.654	−0.226	0.361
	Employed (0/1)	0.048	0.040	1.186	0.236	−0.031	0.126
	Retired (0/1)	0.314	0.148	2.125	0.034	0.024	0.603
	Other (0/1)	−0.033	0.120	−0.277	0.782	−0.270	0.203
Indirect, direct and total effect							
	Indirect effect	0.074	0.014			0.047	0.102
	Direct effect	0.052	0.023	2.294	0.022	0.008	0.096
	Total effect (c)	0.129					

Note: N = 1243; Indirect effect CI based on 5000 bootstrap samples.
Model for mediator: $R^2 = 0.621$, $F(16, 1226) = 125.7$, $p < .001$; Model for outcome: $R^2 = 0.104$, $F(17, 1225) = 8.386$, $p < .001$.

Table A8. Subgroup 16-24: mediation model for change in impact-oriented PEB with acceptance as mediator including all covariates.

						95% Confidents interval	
Outcome	Predictor	B	SE	t	*p*	Lower limit	Upper limit
Mediator: Acceptance							
	Constant	1.326	0.723	1.834	0.067	−0.095	2.746
	EC (1–5)	0.671	0.049	13.828	<.001	0.575	0.766
	LC/HC category (0/1)	0.672	0.097	6.901	<.001	0.481	0.864
	Women (0/1)	−0.109	0.067	−1.628	0.104	−0.240	0.023
	Direct resident of the Templergraben (0/1)	−0.188	0.073	−2.566	0.011	−0.332	−0.044
	Limited in mobility due to health issues (0/1)	−0.498	0.349	−1.426	0.154	−1.185	0.188
	PEB before the modal filter (1–5)	0.289	0.076	3.817	<.001	0.140	0.437
Outcome: change in PEB							
	Constant	2.603	0.453	5.746	<.001	1.713	3.493
	EC (1–5)	0.081	0.036	2.263	0.024	0.011	0.152
	Acceptance (1–5)	0.097	0.029	3.376	<.001	0.041	0.154
	LC/HC category (0/1)	−0.033	0.064	−0.517	0.605	−0.159	0.093
	Women (0/1)	−0.093	0.042	−2.220	0.027	−0.175	−0.011
	Direct resident of the Templergraben (0/1)	0.023	0.046	0.495	0.621	−0.068	0.114
	Limited in mobility due to health issues (0/1)	−0.080	0.219	−0.368	0.713	−0.510	0.349
	PEB before the modal filter (1–5)	−0.026	0.048	−0.550	0.583	−0.121	0.068
Indirect, direct and total effect							
	Indirect effect	0.065	0.019			0.031	0.103
	Direct effect	0.081	0.036	2.263	0.024	0.011	0.152
	Total effect (c)	0.146					

Note: N = 475; Indirect effect CI based on 5000 bootstrap samples.
Model for mediator: $R^2 = 0.541$, $F(6, 468) = 91.894$, $p < .001$; Model for outcome: $R^2 = 0.095$, $F(7, 467) = 7.03$, $p < .001$.

Table A9. Subgroup 25-34: mediation model for change in impact-oriented PEB with acceptance as mediator including all covariates.

						95% Confidents interval	
Outcome	Predictor	B	SE	t	*p*	Lower limit	Upper limit
Mediator: Acceptance							
	Constant	−2.062	0.635	−3.251	0.001	−3.309	−0.816
	EC (1–5)	0.817	0.049	16.705	<.001	0.720	0.913
	LC/HC category (0/1)	0.510	0.096	5.331	<.001	0.322	0.698
	Women (0/1)	−0.288	0.073	−3.930	<.001	−0.431	−0.144
	Direct resident of the Templergraben (0/1)	−0.245	0.077	−3.185	0.002	−0.396	−0.094
	Limited in mobility due to health issues (0/1)	0.633	0.307	2.061	0.040	0.029	1.238
	PEB before the modal filter (1–5)	0.520	0.072	7.191	<.001	0.378	0.662
Outcome: change in PEB							
	Constant	3.214	0.332	9.684	<.001	2.562	3.867
	EC (1–5)	0.036	0.032	1.114	0.266	−0.027	0.099
	Acceptance (1–5)	0.068	0.024	2.809	0.005	0.020	0.115
	LC/HC category (0/1)	−0.049	0.051	−0.955	0.340	−0.149	0.052
	Women (0/1)	−0.107	0.039	−2.788	0.006	−0.183	−0.032
	Direct resident of the Templergraben (0/1)	0.052	0.040	1.293	0.197	−0.027	0.131
	Limited in mobility due to health issues (0/1)	−0.283	0.160	−1.769	0.078	−0.596	0.031
	PEB before the modal filter (1–5)	0.004	0.039	0.105	0.917	−0.073	0.082
Indirect, direct and total effect							
	Indirect effect	0.055	0.026			0.005	0.107
	Direct effect	0.036	0.032	1.114	0.266	−0.027	0.099
	Total effect (c)	0.091					

Note: N = 471; Indirect effect CI based on 5000 bootstrap samples.
Model for mediator: $R^2 = 0.606$, $F(6, 464) = 119.107$, $p < .001$; Model for outcome: $R^2 = 0.072$, $F(7, 463) = 5.116$, $p < .001$.

Table A10. Subgroup 35-44: mediation model for change in impact-oriented PEB with acceptance as mediator including all covariates.

						95% Confidents interval	
Outcome	Predictor	B	SE	t	*p*	Lower limit	Upper limit
Mediator: Acceptance							
	Constant	−0.669	0.998	−0.671	0.504	−2.649	1.310
	EC (1–5)	−0.669	0.998	−0.671	0.504	−2.649	1.310
	LC/HC category (0/1)	0.408	0.223	1.825	0.071	−0.036	0.851
	Women (0/1)	−0.411	0.212	−1.934	0.056	−0.832	0.011
	Direct resident of the Templergraben (0/1)	0.075	0.201	0.375	0.708	−0.323	0.473
	Limited in mobility due to health issues (0/1)	−0.017	0.485	−0.035	0.972	−0.980	0.946
	PEB before the modal filter (1–5)	0.273	0.170	1.605	0.112	−0.065	0.612
Outcome: change in PEB							
	Constant	3.102	0.552	5.619	<.001	2.007	4.198
	EC (1–5)	−0.072	0.081	−0.888	0.377	−0.232	0.089
	Acceptance (1–5)	0.164	0.056	2.950	0.004	0.054	0.274
	LC/HC category (0/1)	0.100	0.125	0.796	0.428	−0.149	0.349
	Women (0/1)	0.015	0.119	0.128	0.899	−0.222	0.253
	Direct resident of the Templergraben (0/1)	−0.070	0.111	−0.633	0.529	−0.290	0.150
	Limited in mobility due to health issues (0/1)	−0.014	0.268	−0.051	0.960	−0.545	0.518
	PEB before the modal filter (1–5)	−0.150	0.095	−1.569	0.120	−0.339	0.040
Indirect, direct and total effect							
	Indirect effect	0.162	0.065			0.062	0.316
	Direct effect	−0.072	0.081	−0.888	0.377	−0.232	0.089
	Total effect (c)	0.091					

Note: N = 106; Indirect effect CI based on 5000 bootstrap samples.
Model for mediator: R^2 = 0.619, F(6, 99) = 26.816, p < .001; Model for outcome: R^2 = 0.139, F(7, 98) = 2.261, p = 0.036.

Table A11. Subgroup 45-54: mediation model for change in impact-oriented PEB with acceptance as mediator including all covariates.

						95% Confidents interval	
Outcome	Predictor	B	SE	t	*p*	Lower limit	Upper limit
Mediator: Acceptance							
	Constant	−2.117	0.869	−2.435	0.018	−3.853	−0.381
	EC (1–5)	1.151	0.164	7.018	<.001	0.823	1.478
	LC/HC category (0/1)	0.482	0.276	1.747	0.085	−0.069	1.033
	Women (0/1)	0.015	0.224	0.067	0.947	−0.432	0.462
	Direct resident of the Templergraben (0/1)	−0.642	0.240	−2.678	0.009	−1.121	−0.163
	Limited in mobility due to health issues (0/1)	0.624	0.383	1.629	0.108	−0.141	1.390
	PEB before the modal filter (1–5)	0.067	0.260	0.259	0.796	−0.451	0.586
Outcome: change in PEB							
	Constant	2.275	0.592	3.840	<.001	1.092	3.459
	EC (1–5)	0.376	0.142	2.648	0.010	0.092	0.659
	Acceptance (1–5)	0.043	0.081	0.529	0.599	−0.119	0.204
	LC/HC category (0/1)	0.089	0.184	0.481	0.632	−0.279	0.457
	Women (0/1)	−0.223	0.146	−1.528	0.131	−0.515	0.069
	Direct resident of the Templergraben (0/1)	0.070	0.165	0.425	0.672	−0.259	0.399
	Limited in mobility due to health issues (0/1)	−0.152	0.255	−0.594	0.555	−0.661	0.358
	PEB before the modal filter (1–5)	−0.216	0.169	−1.274	0.207	−0.554	0.123
Indirect, direct and total effect							
	Indirect effect	0.049	0.09			−0.102	0.255
	Direct effect	0.376	0.142	2.649	0.01	0.092	0.659
	Total effect (c)	0.425					

Note: N = 72; Indirect effect CI based on 5000 bootstrap samples.
Model for mediator: R^2 = 0.704, F(6, 65) = 25.753, p < .001; Model for outcome: R^2 = 0.274, F(7, 64) = 3.458, p = 0.003.

Table A12. Subgroup 55-64: mediation model for change in impact-oriented PEB with acceptance as mediator including all covariates

Outcome	Predictor	B	SE	t	*p*	95% Confidents interval Lower limit	Upper limit
Mediator: Acceptance							
	Constant	−0.628	0.900	−0.697	0.488	−2.421	1.166
	EC (1–5)	0.908	0.132	6.871	<.001	0.644	1.171
	LC/HC category (0/1)	0.408	0.270	1.510	0.136	−0.131	0.947
	Women (0/1)	−0.215	0.216	−0.994	0.323	−0.646	0.216
	Direct resident of the Templergraben (0/1)	−0.708	0.245	−2.886	0.005	−1.198	−0.219
	Limited in mobility due to health issues (0/1)	−0.449	0.359	−1.251	0.215	−1.165	0.267
	PEB before the modal filter (1–5)	0.640	0.247	2.597	0.011	0.149	1.131
Outcome: change in PEB							
	Constant	2.638	0.588	4.487	<.001	1.466	3.810
	EC (1–5)	0.004	0.111	0.031	0.975	−0.217	0.224
	Acceptance (1–5)	0.091	0.077	1.190	0.238	−0.062	0.244
	LC/HC category (0/1)	0.046	0.179	0.254	0.800	−0.311	0.402
	Women (0/1)	−0.042	0.142	−0.298	0.766	−0.325	0.240
	Direct resident of the Templergraben (0/1)	−0.117	0.169	−0.694	0.490	−0.454	0.220
	Limited in mobility due to health issues (0/1)	0.009	0.236	0.040	0.969	−0.462	0.481
	PEB before the modal filter (1–5)	0.054	0.168	0.320	0.750	−0.281	0.388
Indirect, direct and total effect							
	Indirect effect	0.083	0.081			−0.057	0.267
	Direct effect	0.004	0.111	0.031	0.975	−0.217	0.224
	Total effect (c)	0.087					

Note: N = 79; Indirect effect CI based on 5000 bootstrap samples.
Model for mediator: R^2 = 0.718, F(6, 72) = 30.475, p < .001; Model for outcome: R^2 = 0.12, F(7, 71) = 1.388, p = 0.224.

Table A13. Subgroup 65+: mediation model for change in impact-oriented PEB with acceptance as mediator including all covariates.

Outcome	Predictor	B	SE	t	*p*	95% Confidents interval Lower limit	Upper limit
Mediator: Acceptance							
	Constant	−0.678	1.137	−0.596	0.555	−2.990	1.635
	EC (1–5)	0.779	0.203	3.831	<.001	0.365	1.192
	LC/HC category (0/1)	0.557	0.416	1.339	0.190	−0.289	1.402
	Women (0/1)	−0.192	0.356	−0.540	0.593	−0.917	0.532
	Direct resident of the Templergraben (0/1)	−0.099	0.549	−0.180	0.858	−1.215	1.017
	Limited in mobility due to health issues (0/1)	−0.491	0.438	−1.121	0.271	−1.382	0.400
	PEB before the modal filter (1–5)	0.747	0.370	2.019	0.052	−0.006	1.500
Outcome: change in PEB							
	Constant	1.900	0.885	2.147	0.040	0.097	3.704
	EC (1–5)	−0.010	0.189	−0.053	0.959	−0.396	0.376
	Acceptance (1–5)	0.200	0.135	1.485	0.147	−0.074	0.475
	LC/HC category (0/1)	−0.369	0.331	−1.116	0.273	−1.042	0.305
	Women (0/1)	−0.061	0.277	−0.218	0.829	−0.625	0.504
	Direct resident of the Templergraben (0/1)	−0.139	0.425	−0.326	0.747	−1.005	0.728
	Limited in mobility due to health issues (0/1)	0.259	0.346	0.749	0.459	−0.445	0.964
	PEB before the modal filter (1–5)	0.123	0.304	0.406	0.687	−0.496	0.742
Indirect, direct and total effect							
	Indirect effect	0.156	0.143			−0.118	0.441
	Direct effect	−0.010	0.189	0.053	0.959	−0.396	0.376
	Total effect (c)	0.146					

Note: N = 40; Indirect effect CI based on 5000 bootstrap samples.
Model for mediator: R^2 = 0.695, F(6, 33) = 12.552, p < .001; Model for outcome: R^2 = 0.160, F(7, 32) = 0.872, p = 0.539.

Table A14. Subgroup men: mediation model for change in impact-oriented PEB with acceptance as mediator including all covariates.

Outcome	Predictor	B	SE	t	*p*	95% Confidents interval	
						Lower limit	Upper limit
Mediator: Acceptance							
	Constant	−0.329	0.428	−0.769	0.442	−1.170	0.511
	EC (1–5)	0.792	0.037	21.573	<.001	0.720	0.864
	LC/HC category (0/1)	0.579	0.074	7.828	<.001	0.434	0.724
	Direct resident of the Templergraben (0/1)	−0.260	0.062	−4.189	<.001	−0.382	−0.138
	Limited in mobility due to health issues (0/1)	0.017	0.198	0.084	0.933	−0.371	0.404
	PEB before the modal filter (1–5)	0.358	0.059	6.106	<.001	0.243	0.473
	Between 16 and 24	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
	Between 25 and 34 (0/1)	0.125	0.073	1.704	0.089	−0.019	0.268
	Between 35 and 44 (0/1)	0.200	0.125	1.602	0.110	−0.045	0.445
	Between 45 and 54 (0/1)	−0.025	0.146	−0.168	0.867	−0.311	0.262
	Between 55 and 64 (0/1)	−0.130	0.148	−0.884	0.377	−0.420	0.159
	Older than 65 (0/1)	−0.314	0.307	−1.021	0.308	−0.917	0.290
	Student (University)	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
	Apprentice (0/1)	−0.275	0.341	−0.808	0.419	−0.944	0.394
	Employed (0/1)	−0.097	0.086	−1.130	0.259	−0.265	0.072
	Retired (0/1)	−0.012	0.329	−0.037	0.971	−0.657	0.633
	Other (0/1)	−0.624	0.282	−2.211	0.027	−1.179	−0.070
Outcome: change in PEB							
	Constant	3.033	0.266	11.423	<.001	2.512	3.554
	EC (1–5)	0.050	0.029	1.744	0.082	−0.006	0.106
	Acceptance (1–5)	0.101	0.022	4.640	<.001	0.058	0.144
	LC/HC category (0/1)	−0.024	0.048	−0.500	0.618	−0.117	0.070
	Direct resident of the Templergraben (0/1)	0.001	0.039	0.013	0.990	−0.076	0.077
	Limited in mobility due to health issues (0/1)	−0.224	0.123	−1.831	0.067	−0.465	0.016
	PEB before the modal filter (1–5)	−0.037	0.037	−0.989	0.323	−0.110	0.036
	Between 16 and 24	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
	Between 25 and 34 (0/1)	−0.033	0.045	−0.720	0.472	−0.122	0.056
	Between 35 and 44 (0/1)	−0.011	0.078	−0.146	0.884	−0.164	0.141
	Between 45 and 54 (0/1)	−0.010	0.090	−0.109	0.914	−0.187	0.168
	Between 55 and 64 (0/1)	0.068	0.091	0.739	0.460	−0.112	0.247
	Older than 65 (0/1)	−0.264	0.191	−1.385	0.167	−0.638	0.110
	Student (University)	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
	Apprentice (0/1)	−0.112	0.211	−0.530	0.597	−0.527	0.303
	Employed (0/1)	0.035	0.053	0.665	0.506	−0.069	0.140
	Retired (0/1)	0.463	0.204	2.274	0.023	0.063	0.863
	Other (0/1)	−0.069	0.176	−0.395	0.693	−0.414	0.275
Indirect, direct and total effect							
	Indirect effect	0.080	0.019			0.045	0.119
	Direct effect	0.050	0.029	1.744	0.082	−0.006	0.106
	Total effect (c)	0.130					

Note: N = 822; Indirect effect CI based on 5000 bootstrap samples.
Model for mediator: $R^2 = 0.618$, $F(14, 807) = 93.505$, $p < .001$; Model for outcome: $R^2 = 0.089$, $F(15, 806) = 5.238$, $p < .001$.
Covariates that were constant within either the men or women subgroup were removed from the analyses for both groups.

Table A15. Subgroup women: mediation model for change in impact-oriented PEB with acceptance as mediator including all covariates.

Outcome	Predictor	B	SE	t	*p*	95% Confidents interval	
						Lower limit	Upper limit
Mediator: Acceptance							
	Constant	−1.323	0.464	−2.852	0.005	−2.236	−0.411
	EC (1–5)	0.862	0.059	14.709	<.001	0.747	0.977
	LC/HC category (0/1)	0.493	0.112	4.394	<.001	0.272	0.714
	Direct resident of the Templergraben (0/1)	−0.166	0.087	−1.915	0.056	−0.336	0.004
	Limited in mobility due to health issues (0/1)	0.126	0.198	0.638	0.524	−0.263	0.515
	PEB before the modal filter (1–5)	0.480	0.091	5.275	<.001	0.301	0.658
	Between 16 and 24	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
	Between 25 and 34 (0/1)	−0.109	0.098	−1.112	0.267	−0.303	0.084
	Between 35 and 44 (0/1)	−0.146	0.200	−0.731	0.466	−0.540	0.247
	Between 45 and 54 (0/1)	−0.098	0.202	−0.482	0.630	−0.495	0.300
	Between 55 and 64 (0/1)	−0.337	0.194	−1.741	0.082	−0.718	0.044
	Older than 65 (0/1)	−1.214	0.496	−2.451	0.015	−2.188	−0.240
	Student (University)	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
	Apprentice (0/1)	−1.080	0.398	−2.716	0.007	−1.862	−0.298
	Employed (0/1)	0.047	0.116	0.403	0.687	−0.182	0.275
	Retired (0/1)	0.995	0.425	2.344	0.020	0.160	1.830
	Other (0/1)	0.709	0.358	1.981	0.048	0.006	1.412
Outcome: change in PEB							
	Constant	2.085	0.241	8.652	<.001	1.612	2.559
	EC (1–5)	0.059	0.037	1.577	0.116	−0.015	0.133
	Acceptance (1–5)	0.079	0.026	3.086	0.002	0.029	0.130
	LC/HC category (0/1)	0.005	0.059	0.088	0.930	−0.111	0.121
	Direct resident of the Templergraben (0/1)	0.060	0.045	1.341	0.181	−0.028	0.148
	Limited in mobility due to health issues (0/1)	0.095	0.102	0.931	0.352	−0.105	0.295
	PEB before the modal filter (1–5)	0.036	0.048	0.735	0.463	−0.060	0.131
	Between 16 and 24	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
	Between 25 and 34 (0/1)	−0.056	0.051	−1.105	0.270	−0.156	0.044
	Between 35 and 44 (0/1)	0.029	0.103	0.279	0.781	−0.174	0.231
	Between 45 and 54 (0/1)	−0.137	0.104	−1.312	0.190	−0.341	0.068
	Between 55 and 64 (0/1)	0.104	0.100	1.036	0.301	−0.093	0.300
	Older than 65 (0/1)	0.038	0.257	0.146	0.884	−0.467	0.542
	Student (University)	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
	Apprentice (0/1)	0.295	0.206	1.431	0.153	−0.110	0.701
	Employed (0/1)	0.091	0.060	1.517	0.130	−0.027	0.208
	Retired (0/1)	0.130	0.220	0.592	0.554	−0.302	0.562
	Other (0/1)	−0.031	0.185	−0.169	0.866	−0.395	0.332
Indirect, direct and total effect							
	Indirect effect	0.068	0.024			0.024	0.120
	Direct effect	0.059	0.037	1.578	0.116	−0.015	0.133
	Total effect (c)	0.127					

Note: N = 415; Indirect effect CI based on 5000 bootstrap samples.
Model for mediator: $R^2 = 0.642$, $F(14, 400) = 51.297$, $p < .001$; Model for outcome: $R^2 = 0.136$, $F(15, 399) = 4.194$, $p < .001$.
Covariates that were constant within either the men or women subgroup were removed from the analyses for both groups.



Figure A1. South-west entrance of the Templergraben street section with modal filter.



Figure A2. Close view of the modal filter at the south-west entrance of the Templergraben street section.



Figure A3. View on the north-east entrance of the Templergraben street section from the intersection in front of it.



Figure A4. Close view of the modal filter at the north-east entrance of the Templergraben street section with bus.



Figure A5. Rear view of the modal filter at the north-east entrance of the Templergraben street section.



Figure A6. Bus stop in front of the main university building at the Templergraben street section.

Appendix B

Survey Questions.

1. Please enter your age.
16–24
25–34
35–44
45–54
55–64
65+
Prefer not to disclose
Response scale: Single choice
2. Please enter your gender.
Female
Male
Diverse
Prefer not to disclose
Response scale: Single choice
3. Are you a direct resident of the Templergraben?
Yes, I live in one of the following streets:
Annutiatenbach
Augustinerbach

3. Are you a direct resident of the Templergraben?

Bärenstraße
Beginenstraße
Eilfschornsteinstraße
Friesenstraße
Hirschgraben
Jakobstraße
Johanniterstraße
Judengasse
Junkerstraße
Karlsgraben
Kármánstraße
Königstraße
Lindenplatz
Malteserstraße
Marienbongard
Paulusstraße
Pontwall
Pontdriesch
Pontstraße
Schinkelstraße
Templergraben
Trichtergasse
Turmstraße
Wüllnerstraße
No, I live elsewhere in Aachen
No, I don't live in Aachen
Prefer not to disclose
Response scale: Single choice

3. What is your current occupation?

Student in school
Student at university
Apprentice
Employed
Retired
Other:
Prefer not to disclose
Response scale: Single choice

5. Are you limited in your mobility due to health issues?

Yes
No
Prefer not to disclose
Response scale: single choice

6. To what extent do you agree with the following statements on the quality of stay at the Templergraben? Please check the matching boxes.

I enjoyed spending time in the Templergraben area before the launch of the living lab Templergraben.
Since the start of the living lab Templergraben, I have spent more time in the Templergraben area.
I don't feel any safer crossing the street since the start of the living lab Templergraben.
Response scale: 'do not agree at all', 'do rather not agree', 'agree partially', 'rather agree', 'agree fully'

7. To what extent has your length of stay at Templergraben changed with regard to the following purposes since the start of the living lab Templergraben? Please check the matching boxes.

To meet up with friends
To dwell (e.g. to read, sit, etc.)
For studying or learning (e.g. group work, etc.)
Other:
Response scale: 'much rarer', 'rarer', 'no change', 'more frequent', 'much more frequent', 'do not use'

8. How do you rate the following offers of the living lab Templergraben? Please check the matching boxes.

Beergarden

Benches

'Travelling tree avenue'

Sports activities (e.g. Zumba, Fitness, etc.)

Clothes swap

Response scale: 'very bad', 'bad', 'neutral', 'good', 'very good', 'I don't know it'

9. What would you like to see as an additional offer?

(open text)

10. To what extent do you agree with the following statements about the perception of the living lab Templergraben? Please check the matching boxes.

The media reports positively on the living lab Templergraben

In my opinion, the living lab Templergraben is perceived negatively by Aachen's citizens.

I feel sufficiently informed about the purpose of the living lab Templergaben.

Response scale: 'do not agree at all', 'do rather not agree', 'agree partially', 'rather agree', 'agree fully', 'I do not know'

11. What has most strongly shaped your own image of the Templergraben living lab? (Multiple selection possible) Please check the matching boxes.

Own experience on site

Newspaper

Website of the city Aachen

Website of ASTA of RWTH

Website U.U.M., VCD or ADFC

Social Media

Friends or Family

Other: (open text)

None of the above

Response scale: Multiple choice

12. How often do you use the following means of transport or mobility services in your everyday life? Please check the matching boxes.

Cars, motorcycles as driver (including estate cars/vans/minibuses/mopeds)

Cars, motorcycles as passenger (including estate cars/vans/minibuses/mopeds)

Bicycles, electric bikes, pedelecs

E-Scooter

Carsharing

Bus, train, public transport

By foot (including with walkers or wheelchair)

Other:

Response scale: 'never', 'rarely', 'occasionally', 'often', 'always'

13. How has your usage of means of transportation changed since the beginning of the Templergraben living lab? Please check the matching boxes.

Cars, motorcycles as driver (including estate cars/vans/minibuses/mopeds)

Cars, motorcycles as passenger (including estate cars/vans/minibuses/mopeds)

Bicycles, electric bikes, pedelecs

E-Scooter

Carsharing

Bus, train, public transport

By foot (including with walkers or wheelchair)

Other:

Response scale: 'much rarer', 'rarer', 'unchanged', 'more frequently', 'much more frequently'

14. For what trip purpose did you mainly use the Templergraben as an everyday traffic/transport route before the change in traffic routing? Please check the matching boxes.

I did not use the Templergraben as an everyday traffic route.

Trips to work, school, university

Other job-related trips (excluding trips to work, school, university)

Trips to leisure activities

Trips to do shopping for bigger items

14. For what trip purpose did you mainly use the Templergraben as an everyday traffic/transport route before the change in traffic routing? Please check the matching boxes.

Taking people somewhere and picking up people (including children)

Trips to provide for relatives, people in need

Other:

Response Scale: Multiple choice

15. To what extent do you perceive that the following factors have changed in the surrounding streets since the closure of the Templergraben? Please check the matching boxes.

The volume of motorised traffic has

The noise level in the surrounding streets has

Response scale: 'strongly decreased', 'rather decreased', 'not changed', 'rather increased', 'strongly increased', 'I don't know'

16. The living lab should provide insights into how the inner ring road ('Grabenring') and mobility in Aachen could be redesigned. To what extent do you agree with the following statements? Please check the matching boxes.

Overall, I support the test of a closure to car traffic on the Templergraben.

Overall, I would be in favour of a permanent closure of the Templergraben to car traffic.

I **don't** like the idea of the Grabenring becoming a distribution ring for safe and convenient cycling priority lanes to all boroughs.

I think it's good to have less through traffic downtown so that buses, bicycles, and pedestrians have more space.

I think that the change in traffic routing at the Templergraben positively impacts the air quality in Aachen.

Response scale: 'do not agree at all', 'do rather not agree', 'agree partially', 'rather agree', 'agree fully', 'I do not know'

17. To what extent do you agree with the following statements: Please check the matching boxes.

It bothers me when I think about the environmental conditions in which our children and grandchildren will probably have to live.

If we continue down the same path, we are heading toward an environmental catastrophe.

If I read news or watch TV news reports about environmental problems, I often become outraged and angry.

There are limits on growth that our industrialized world has already exceeded or will soon reach.

Most people in this country still do not act in an environmentally conscious way.

In my opinion, many environmentalists exaggerate claims about environmental threats.

Politicians still do not do enough to protect the environment.

In order to protect the environment, we should all be willing to reduce our current standard of living.

Actions to protect the environment should be implemented even if they cause job losses.

Response scale: 'do not agree at all', 'do rather not agree', 'agree partially', 'rather agree', 'agree fully'

18. To what extent do you agree with the following statement: Please check the matching box.

In principle, I think the individual's choice of mode of transport has no impact on the state of the environment.

Response scale: 'do not agree at all', 'do rather not agree', 'agree partially', 'rather agree', 'agree fully'

19. To what extent do you agree with the following statements on the relationship between the city (city's civil society) and the university? Please check the matching boxes.

The Templergraben living lab strengthens the spatial connection between the city and the university.

The Templergraben living lab makes RWTH Aachen University more accessible to the city's population.

I would like to see more offers where actors from the university and city's civil society can work together.

Response scale: 'do not agree at all', 'do rather not agree', 'agree partially', 'rather agree', 'agree fully', 'I do not know'

20. What offers would you like to see?

(open text)

21. To what extent do you agree with the following statements on engagement in the city of Aachen? Please check the matching boxes.

There is a great deal of civic engagement within RWTH Aachen University.

There is a great deal of civil society involvement in Aachen.

Civic engagement taking place in the city of Aachen is visible to me.

Response scale: 'do not agree at all', 'do rather not agree', 'agree partially', 'rather agree', 'agree fully', 'I do not know'

22. To what extent do you agree with the following statement: Please check the matching boxes.

All in all, I think the living lab Templergraben (traffic calming and events) is a successful concept.

Response scale: 'do not agree at all', 'do rather not agree', 'agree partially', 'rather agree', 'agree fully', 'I do not know'

23. Which aspects of the living lab Templergraben do you find particularly positive?

(open text)

24. Which aspects of the living lab Templergraben do you find particularly critical?

(open text)