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Was the low-fare public transport in Bonn a success? An evaluation of the climate ticket users and lessons for transportation companies

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ABSTRACT

The transport sector is a major source of air pollution and thus a major contributor to the changing climate. As a result, in the recent past, driving bans have been imposed on cars with critical pollutant groups. As an international UN campus and self-proclaimed climate capital, the Federal City of Bonn declared a climate emergency in 2019 and participated in a federally funded "Lead City" project to optimise air quality. A key goal of the project is to reduce private motorised transport and strengthen public transport. Among the implemented measures, a "climate ticket" was introduced in 2019 whereby consumers could purchase an annual 365 € ticket for all local public transport. This paper reports on an analysis of that ticket's changes in travel behavior.

A quantitative survey (n = 1,315) of the climate ticket users as well as the multiple regressions confirm that the climate ticket attracted more customers to the buses and trams and that a modal shift for the period of the measure was recognisable. The multiple regressions showed that the ticket was perceived significantly more positively by full-time employed users than by unemployed people. The results also show that, in addition to the price, it is essential that travel time and reliability are ensured. Furthermore, the eligible groups of people, the area of coverage, and good connecting services should be extended. To sustainably improve air quality, this type of mobility service must be optimised and introduced on a permanent basis.

1. Introduction

Human-made climate change and the development of sustainable environmental strategies are fundamental challenges of the 21st century, with the transport sector playing a central role (Cepeliauskaite et al., 2021; Matthias et al., 2020). At the same time, the current debate in Germany on introducing free or heavily discounted public transport tickets is politically highly topical and poses great challenges for transport companies, that have to implement the requirements of political decision-makers in the best possible way (SZ, 2022).

In addition to the CO2 emissions of motorised individual transport (MIT), car traffic in Germany leads to EU-wide pollutant limits being exceeded in many cities and to court-ordered driving bans in the affected cities (Representation of the European Union in Germany 2018). As a measure to reduce pollutant emissions, the Federal City of Bonn introduced a discounted ticket in 2019 under the name 365 €-ticket (the climate ticket) as part of the "Lead City" model cities programme funded by the German government (BAV, 2019).

Low-cost or free public transport has been predominantly based on socio-economic motivations, e.g., in Brussels (De Witte et al., 2013), in Tallinn (Cats et al., 2014), in Vienna (Buehler, 2017) and in Luxembourg (Carr, 2019). By comparison, in Bonn, low-cost public transport was carried out as an air pollution control measure, in particular to avoid the threat of judicial driving bans at main pollution axes.

As the former federal capital and a centre of United Nations organisations, and with 338,396 inhabitants (as of 01.01.2023), Bonn is considered one of the economically strongest cities of the state of North Rhine-Westphalia. It covers an area of over 141 km2 (30.06.2022) and has a working population of 188,930 individuals. The surrounding area of the Rhein-Sieg district with its more than 600,000 inhabitants is economically highly interwoven. The local transport services primarily serve the entire Bonn city area but also parts of the Rhein-Sieg district and outskirts of the city of Cologne. As a former federal capital, Bonn's transport infrastructure is well developed. In the past, the Bonn public transport company has attracted international attention, particularly with its "Zweiterstellung"(second life) project, which involved the sustainable and resource-saving restoration of old trams to modern ones, a project that was so successful that it has been expanded.

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The "Lead City" project essentially consisted of three pillars: First, the introduction of a "climate ticket". Bonn citizens who had not had a public transport subscription in the 12 months before the measure could purchase an annual ticket for the city of Bonn at a discounted price of 365 € and so use all of Bonn's public transport. The motivation for the introduction was that the price is one of the most important factors for a modal shift to public transport. A large number of past studies, including those by Belgiawan et al., 2019, Hergesell & Dickinger, 2013, show the effects of price on the choice of transport mode. Therefore, the citizens of Bonn were to be given the opportunity to test public transport for one Euro per day for a period of one year at a low cost, in the hope that the travel behaviour would change in favour of public transport. This discounted annual ticket was available for two years. The last issued climate tickets expired on December 31, 2020.

Since the ticket was expected to attract more customers to the buses and trains, the second pillar was to expand the range of transport services. The expansion of services included increased frequency in bus and train schedules and improved public transport connections through additional bus stops, especially in rural areas (Hahn et al., 2023). As well as the aspect of cost-effective public transport, the expansion of services was also expected to make public transport more attractive. According to the Downs-Thomson paradox, a journey using public transport should only take approximately as long as one by car (Mogridge et al., 1987; Zhang et al., 2014). The third pillar was the expansion of the "job ticket" scheme– a specific offer that employees can be granted by their employers. However, this pillar played a subordinate role in the overall Lead City project, both in monetary terms and in terms of impact. The Lead City project was funded by the federal government for a total of €39.34 million over two years (Federal City of Bonn, 2018), with the subsidy for the climate ticket amounting to €18.31 million, the expansion of services to €18.79 million, and the expansion of the job ticket service to €2.24 million.

The climate ticket was an opportunity for the transport company to convince new users to switch from MIT to public transport and thereby promote a permanent change - even after the projects end. However, sales of the climate tickets were slow at the beginning. When it became clear that the climate ticket was not going to be a guaranteed success, extensive information and marketing campaigns were organised. Despite this advertising, the quota of tickets available was not exhausted. The project was originally designed with 17,000 tickets in mind but during the two years, only, 6,000 tickets were sold (RP Online, 2019). The outbreak of the Covid 19 pandemic at the beginning of 2020 further reduced public transport use (Gkiotsalitis & Cats, 2021).

The pilot project of the Lead City initiative makes it possible to learn from the experience gained in order to support transport operators when they implement similar concepts in the future and to advance the transport turnaround towards climate-friendly mobility in cities. This paper is based on the accompanying evaluation of the pilot project. The evaluation reveals more detailed information about the ticket users, as well as information about a future design of an optimised ticket for transport companies. For the evaluation and interpretation of the results, we used Kaufmann's theoretical motility model (Kaufmann et al., 2004; 2016). In an online survey, 1,315 people from the Bonn/Rhein-Sieg region and neighbouring municipalities were asked about the climate ticket in a three-part series of surveys. The first two survey stages took place in February 2020 and August 2020. It should be noted that in the third and final part, a response to the questionnaire was possible until the end of February 2021 and that this survey took place during the Covid 19 pandemic. Using Kaufmann's model, the survey provided insights into the travel behaviour of climate ticket users. The results were tested for statistical significance using multiple regression. The significant predictors in the evaluation of the climate ticket allow for targeted optimisations for future tickets of the public transport companies.

The evaluation of mobility patterns on the basis of an individual survey on the travel behaviour of climate ticket users offers the unique opportunity to analyse the effects of this climate protection-oriented ticket and to provide essential insights for operational optimisation from the ticket users' perspectives. For this reason, both from a theoretical and a practical point of view, the question is relevant as to which added values the Bonn climate ticket can provide for the operational design of future tickets and how the attitudes, abilities, and accesses of the climate ticket users are connected.

2. Theoretical background

2.1. Literature review

MIT is one of the most important modes of transport worldwide. In Germany, for example, the car is the most popular main mode of transport (Nobis & Kuhnimhof, 2018). This remains true even though congestion, excessive energy and resource consumption, negative environmental impacts such as noise, vibration, and emissions of various pollutants, and global warming are known to be negative consequences of MIT (González et al., 2019).

In addition, public transport plays another fundamental role in people's mobility. In Germany, for example, public transport is a component of public services of general interest even though, without subsidies, in most cases public transport is loss-making (Hörcher & Tirachini, 2021). Subsidies for public transport systems have traditionally been used to reduce negative externalities, minimise user costs, increase ridership (Hahn et al., 2020), as well as address social inequalities, as public transport is more often used by low-income people (Guzman et al., 2021).

In addition to the two main modes of transport: private and public, the bicycle is becoming increasingly important (Nobis & Kuhnimhof, 2018). This increase can be attributed to the surging price increases for mineral oil since the outbreak of the war in Ukraine early 2022 and also to the technical development of e-bikes. Furthermore, the contact restrictions during the Covid 19 pandemic have boosted bicycle usage (Schaefer et al., 2021), and long-term policy decisions to expand roadways and redesign cities to be bicycle-friendly have the effect of promoting bicycle-oriented mobility routines.

A choice in favour of a mode of transport is usually a permanent decision that is not reconsidered on a daily basis and is associated with a purchase decision (Aarts & Dijksterhuis, 2000). This permanency is especially true for a car purchase, which is often a long-term decision in favour of MIT mobility, and one that cannot be reverted without economic losses (Al-Busaidi, 2019). Buying a season ticket such as a job ticket also incurs costs coupled with a long-term contract with cancellation periods, and can only be judged as worthwhile by using public transport as often as possible.

Even if the choice of means of transport is highly path-dependent, there are occasions that favour a willingness to switch (e.g., scrapping a car, changing residence, etc.). People's short-term willingness to switch depends largely on monetary aspects (Litman, 2017), especially in urban areas (Grzelec & Jagiello, 2020). The willingness to use public transport can change if the ticket is not only cheaper but also available without increasing the costs for alternative means of transport. Travel passes are organised very differently both nationally and internationally. Targeted subsidies are used to motivate different groups of people to use public transport. In the past, in addition to job tickets, student tickets and school tickets, there were often social tickets for senior citizens, low-income groups and the unemployed. Studies such as that by Hörcher et al., 2018 take a critical view of the economic significance of travel passes. According to them, a marginal price of zero after an initial entrance fee can lead to unavoidable overconsumption and disproportionately strain resources (Hörcher & Tirachini, 2021).

Cools et al. (2016) distinguish between the effects of reduced and zero fares on transport. When there is no cost for a product or service, demand increases significantly compared to a reduced price. Furthermore, no costs also instigate mental transaction costs. Here customers ask themselves whether the price for a product or service corresponds

subjectively to its value. This question leads to the paradox that customers are more easily convinced by a free product, but at the same time they do not value such a free product as much as one for which they have paid (Shampaner et al., 2007). Therefore, Cools et al. (2016) maintain there is a no cost effect in their study on stated preferences in Flanders. After several experiments to better understand the overreaction to no cost conditions, Ariely and Shampaner (2006) attribute the no cost effect to an affective response of individuals. They argue that "options with no downside (no cost) elicit a more positive affective response than options that include both benefits and costs" (p. 20).

In the past, there have been over 100 different field trials around the world to establish a low-cost or free public transport system (Keblowski et al., 2019). The design and motivations of these field trials vary widely between economic, environmental, and social aspects. The early studies were predominantly economic and social in nature. In the meantime, ecology represents a significant factor that has been brought into focus by the negative consequences of climate change.

Particularly relevant for our study is the Vienna 365 € ticket, which was introduced in 2012. As a European metropolis of millions, the Austrian capital Vienna reduced the price of its citywide public transport flat rate to 365 € per year, financed by increased parking fees in the city (Sommer & Bieland, 2018), and its use is being increased as part of a larger package of sustainable transport policies (Buehler et al. 2016). Furthermore, areas of short-stay parking zones have been continuously expanded and cooperation agreements have been arranged with surrounding municipalities and cities to promote commuting. The measure resulted in 928,000 Viennese (Statista, 2023) using such a ticket in 2022 and reduced the share of car trips by one third (from 40 % to 27 %) between 1993 and 2014 (Buehler et al., 2017). In addition to its expanded infrastructure, future growth plans, and heavily subsidised tickets, Vienna is ensuring that other measures such as an increase in parking prices will lead to a modal shift to public transport.

Other European cities such as Tallinn (Estonia) and Hasselt (Belgium), as well as small countries (Luxembourg), have implemented free public transport. In the case of Tallinn, Cats et al. (2017) showed that attitudes toward public transport improved significantly when the free ticket was introduced and used. In addition, the share of public transport trips increased. Contrary to hopes for more sustainable transport, Cats et al. (2017) attributed some of this modal shift to changing from previous walking habits. Notably, the total number of car trips did not decrease (see van Goeverden et al., 2006 for similar results in Hasselt).

2.2. *Access, skills and appropriation as drivers for mobility*

In the design of the Lead City project, the price of the Bonn climate ticket was considered to be the focus of the model test. However, Kaufmann et al. (Kaufmann et al., 2004; Kaufmann, 2016) showed that other factors besides the price play a role in the individual choice of means of transport. To be able to analyse the complexity of individuals' mobility behaviour through a structured approach, we have employed Kaufmann's theoretical concept.

In their research, Kaufmann et al. (2004) examined the conceptual and theoretical relationships between spatial and social mobility. This construct, known as "motility," describes the potential and actual ability of goods, information, or people to be both geographically and socially mobile. In their qualitative study, Kaufmann et al. (2004) operationalised the concept of motility under three dimensions of (1) *access*-the range of all possible mobilities according to time, place, and other contextual constraints; (2) *competence*-the skills and abilities directly or indirectly related to mobilities; (3) *cognitive appropriation*-how individuals interpret and use their access and abilities (see Fig. 1).

The primary goal of a journey is to get from Point A to Point B and to do so as closely aligned as possible to one's travel patterns and one's

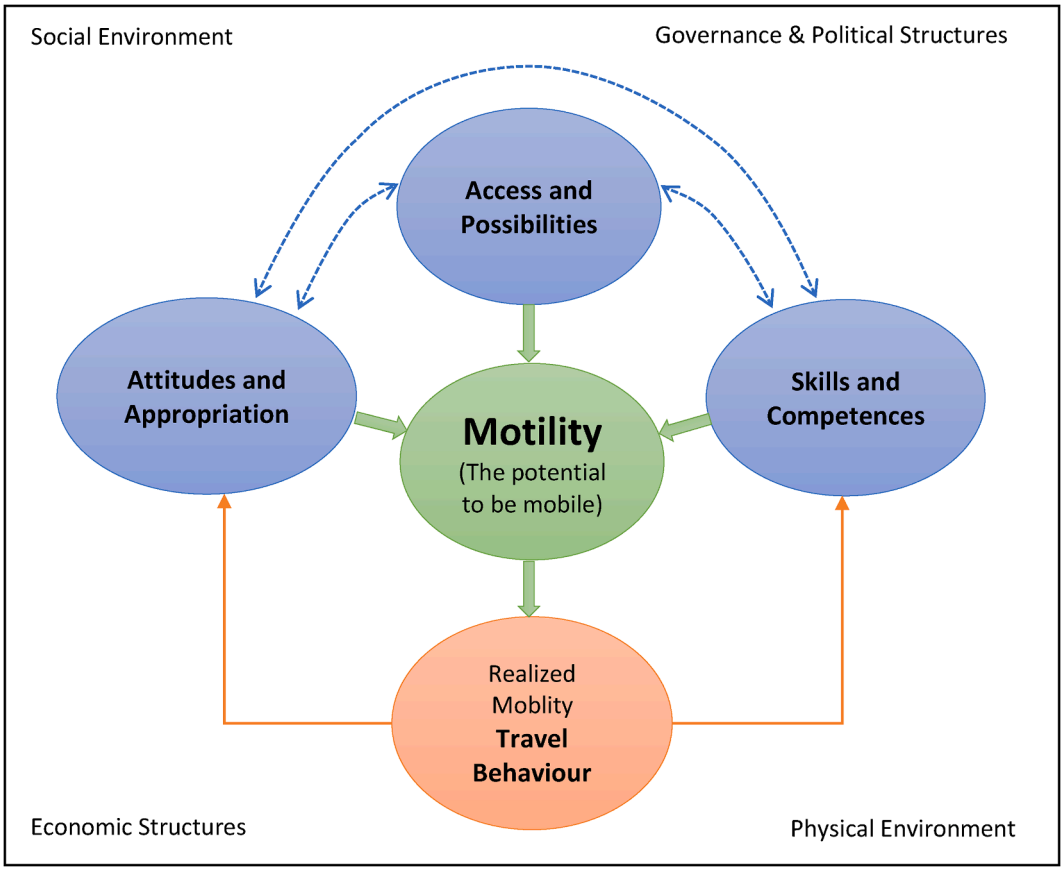

Fig. 1. The Motility Concept developed by Kaufmann (2004), representation based on Hamidi & Zhao (2020).

derived eudaemonic well-being (Shliselberg et al. 2020). According to Kaufmann, the goal is to determine what potential factors lead an individual to make or refrain from making a particular journey. The factors are divided into the three categories (access, skills, and cognitive appropriation) that represent an individual's travel potential. The main advantage of the theoretical framework is that it provides a broader view of the phenomenon, which shows that several factors are crucial for the travel decision and the choice of transport mode (De Witte et al., 2013). It is the situational interaction of the different factors that results in the actual travel behaviour (Hamidi & Zhao 2020).

The application of the motility concept has been tested as a theoretical basis in various empirical studies. Among others, research on understanding migration (Ofer, 2017), identity (Arp et al., 2013) and gender (Akyelken, 2013; Didero et al., 2021) has been conducted.

In terms of mobility use, studies on cycling (Aldred, 2015), method development (Tyfield & Blok, 2016), and in a survey of commuters in Brussels (De Witte & Macharis 2013) were examined. Hamidi and Zhao (2020) used Kaufmann's mobility concept to understand travel behaviour from a subjective user perspective. Hahn et al. (2023) were able to investigate the effects of an expansion of public transport services in a large-scale household survey in the Bonn/Rhein-Sieg region. Accordingly, the applicability of the model is considered applicable for analysing the acceptance of climate ticket users.

2.3. The climate ticket Lead City Bonn

Bonn was selected as a Lead City alongside four other cities as part of the federal Clean Air funding program (Federal Government, 2017). The Lead City project, which is limited to two years, includes several measures with which the federal government, as the funding body, wants to examine whether innovative fare offers, improved public transport services and company mobility management can encourage people who have never or rarely used public transport to use public transport instead of their cars (Federal City of Bonn, 2018).

In our study, we focused on the users of the climate ticket as an innovative fare offer. The climate ticket gives people, who have not had a subscription with a transport company in the transport association in the last 12 months, the opportunity to purchase a discounted climate ticket at a price of 365 € instead of 1,021 € for one year. The climate ticket cannot be transferred to other people and is only valid within the city limits of Bonn. However, it is possible to take up to three children aged 6 to 14, one person over 14 and a bicycle with you free of charge from 7p.m. on Mondays to Fridays and all day on weekends and public holidays (Federal City of Bonn, 2018).

After the project was approved and the funding was granted, the schedule was as follows (see Fig. 2). It can be seen that the majority of climate ticket users opted for the ticket directly in the first quarter: a total of 44 % of users decided to start on 01.01.2019. The number of new users decreased with each subsequent month. The main reasons for purchasing a climate ticket were the attractive price, the contribution to environmental protection and being able to travel in a relaxed manner.

3. Data and methods

3.1. Research design

The basis for this study was to find out in which areas the climate ticket could bring about the most far-reaching improvements from the users' points of view and whether the climate ticket represents a sustainable option for transitioning transport. For this purpose, the attitude to the climate ticket was first surveyed using a metric scaling.

In our Study, the userś evaluation of the climate ticket is the dependent variable, the influence of which is analysed by several independent factors. The measure was evaluated on a Likert scale from 1 (very good) to 5 (very bad).

Furthermore, socio-demographic user data such as income, residential situation, educational level, age, gender, but also information about household size, cars in the household and their availability were collected.

Using the theoretical basis according to Kaufmann, we derived the

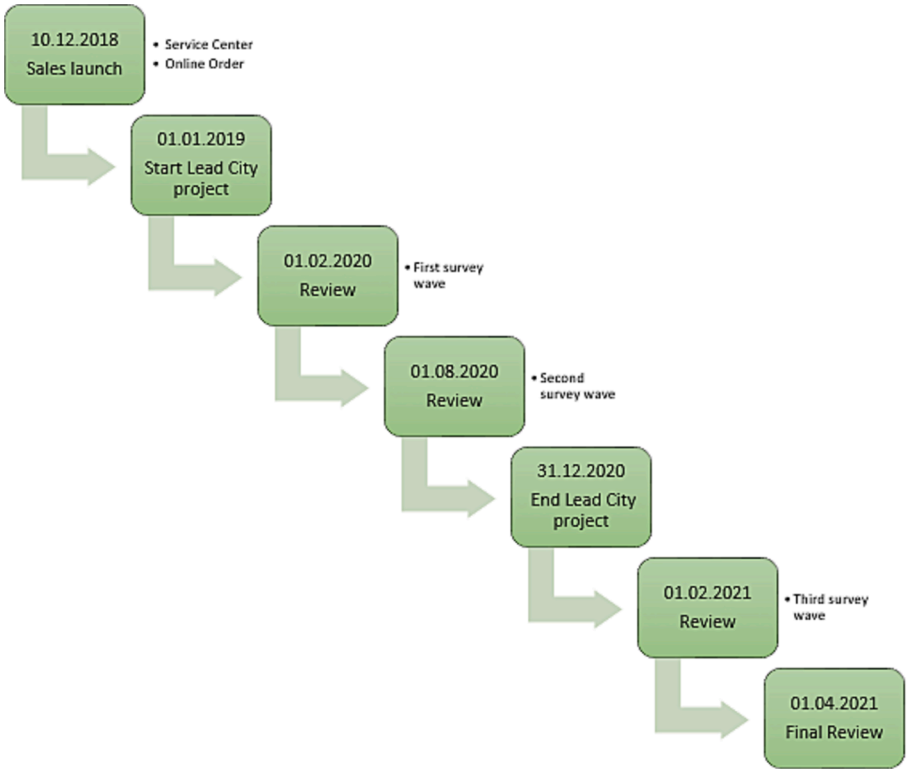

Fig. 2. Timeline of the Lead City measure.

subcategories relevant for our study from previous studies. Table 1 shows how the individual factors measured were assigned to Kaufmann's three main categories of access, skills, and cognitive appropriation.

The Access category includes the variables Income, Household size (Hamidi & Zhao 2020), Car availability in the household, and Residential situation, analogous to the operationalisation of Kaufmann's model in the studies by de Witte (2006, 2008, 2013) and Macharis (2006). In addition, we added the variable Car in the household in line with the study by Hahn et al. (2023) and so asked the participants whether they were owners of no car, one car, or several cars.

The Skills category includes Professional status and Age, analogous to the operationalisation of Kaufmann's model in the studies by de Witte (2006, 2008, 2013), Macharis (2006) and Hamidi and Zhao (2020). Analogous to the studies by Akyelken (2013), Turdalieya and Edling (2018) and Hamidi and Zhao (2020), we included the variable Gender in our model. In the Appropriation domain, we were able to consider Attitudes and Travel habit variables, analogous to the studies by de Witte (2006, 2008, 2013) and Macharis (2006); for more precise operationalisation, we measured the two constructs using three and four statements, respectively.

Attitudes.

- My attitude towards riding buses & trains has improved with the climate ticket.
- I only bought the climate ticket because of the price advantage compared to the regular fare.
- The climate ticket should be introduced permanently.

Travel Habits.
Relatively compared to the time before of the climate ticket.

- Due to the climate ticket, I travel more by bus & train.
- Due to the climate ticket, one or more car journeys were avoided.

Absolutely within the time of the climate ticket.

- Frequency of MIT use.
- Frequency of public transport use.
- Frequency of bicycle use.

Prospectively regarding the time after the climate ticket.

- Without the climate ticket, I would make as many trips with buses & trains.
- Without the climate ticket, I would use the car more.

Furthermore, we were interested in the general preference for the different transport modes. Therefore, we asked the participants to rank the model choice for the modes car, public transport, and bicycle during and after the climate ticket offer according to their personal frequencies of use.

Table 1
Assignment of the independent variables to the three motility categories.

Access	Skills	Appropriation
Income	Profession	Attitudes towards public transport/climate ticket
Size of the household	Age	
Car availability in the household	Gender	Travel habits (before, within, and after the climate ticket period)
Cars of the household		
Residential situation		

3.2. Data collection

The evaluation used data from a follow-up survey in which 3,430 climate ticket users from the Bonn city area and relevant neighbouring municipalities were contacted by mail after the climate ticket expired and invited to participate in the online survey.

The implementation periods for evaluating the climate ticket users took place in a three-part series, in line with the end of the original ticket contracts. The first survey took place at the end of February 2020. At this time, 1,530 people were contacted, of which 699 respondents (response rate = 46 %) returned the completed questionnaire. The response rate for the second wave was significantly lower at 30 %: In August 2020, 900 people were surveyed, of whom 270 took part in the survey. In the third wave in January 2021, 1,000 users were contacted, of whom 346 completed the survey. A response rate of 35 % was recorded here. It should be noted that responses were possible until February 2021.

A total of 1,315 respondents took part in the evaluation. The data records of this sample of n = 1,315 surveys were statistically evaluated in order to draw conclusions about the user profiles and the effectiveness of the measure as well as the resulting mobility behaviour of people from the region (Table 2).

The total sample size was n = 1,315. The differences to the population can be attributed to "don't know" or invalid answers. Accordingly, there were non-valid responses for the predictors age (22), gender (18), and profession (17). The percentages refer to the valid response for each predictor and always add up to 100 %.

3.3. Data analysis

Before starting the data evaluation, the survey data was cleaned or processed to be able to guarantee error-free results. For the evaluation of the collected data and to obtain an overview, descriptive statistics methods were applied, such as the calculation of frequencies and mean values. The exploratory data analysis procedure was used to sift through data to identify unusual values, extreme values, and gaps in the data or other anomalies (Döring & Bortz, 2016).

The analysis showed that our data deviated from the normal distribution of the residuals. However, due to the size of our population, our analysis is sufficiently robust against violations of the normal distribution of the residuals assumption and can be continued (Lumley et al., 2002). Therefore, we also used multiple regression to investigate the influence of the individual factors on users' climate ticket ratings. For this purpose, the data was structured and analysed according to Kaufmann's categories. The statistical calculations were prepared and performed in the data analysis software SPSS 27.

Table 2
Sociodemographic data of climate ticket users.

Characteristics	Count	Percent
Survey participants by age		
up to 18 years	8	0.6 %
18–29 years	94	7.3 %
30–49 years	486	37.6 %
50–64 years	430	33.3 %
65 and older	275	21.3 %
Gender		
Women	859	65.3 %
Men	434	33.0 %
Diverse	4	0.3 %
Profession		
Full-time employed	542	41.2 %
Working part-time	289	22.0 %
School/study/training	40	3.1 %
Head of household	46	3.5 %
Parental leave / Maternity leave	49	3.7 %
Not employed	29	2.2 %
Retired	297	22.6 %

4. Results

4.1. Satisfaction/Evaluation of the climate ticket

Overall, the users of the climate ticket were very satisfied with the offer and rate the project as very successful with an average grade of 1.43. The measure was evaluated on a Likert scale from 1 (very good) to 5 (very bad) (see Fig. 3).

4.2. Multiple linear regression analysis

Multiple regression analysis tests for a systematic relationship between several independent factors and a dependent variable. In our study, the users evaluation of the climate ticket is the dependent variable, the influence of which is analysed by several independent factors.

Here, four different regression models were examined, in which the individual factors were included in the regression block-wise, corresponding to the blocks Access, Skills, Appropriation, and Travel Behavior (Table 3).

The multiple regression model shows that it can significantly contribute to explaining the variance ($F(36, 580)$ is equal to 9.424, $p = 0.001$, $R^2 = 0.384$, $f^2 = 0.62$). In the corresponding model, 38.4 % of the variance in the study's assessment can be explained by the variables included in the model (Eid et al., 2017). According to Cohen (1992), this percentage represents to a strong effect. Using the mobility concept allows the results of the individual categories to be interpreted and placed in context.

4.3. Application of the motility concept

Data analysis based on Kaufmann's motility model can be used to gain insights into discounted public transport tickets according to the main characteristics of access, skill, and appropriation. This structuring of the analysis according to the model helps to interpret the data and draw conclusions for the future mobility behaviour arising from the developed transport offer.

4.3.1. Access

In our study access refers to the framework conditions that make it possible for the individual to use the mobility. Access to public transport goes hand in hand with income and financial means and the ability to afford mobility. In turn, the use of transport services depends on factors such as the accessibility of transport networks. Other access factors lie in the size of households, the number of cars in the household, and the resulting availability of cars.

The multiple regression shows that there are no significant correlations between the four variables in this category and the dependent criterion variable "assessment of the measure". Nevertheless, it is worth taking a closer look at the individual variables.

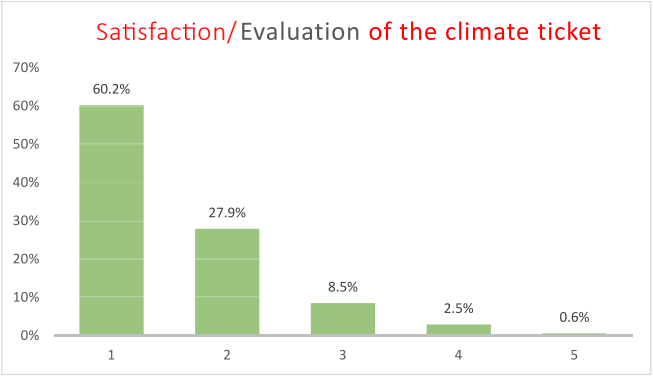

Fig. 3. Satisfaction/Evaluation of the climate ticket.

Table 3
Multiple regression for the entire model.

Modell	*Variable*	*b*	*β*	*t*	*p*	*VIF*
(Constant)		*−0,15*		*−0,21*		
Access						
	Income	−0,04	−0,05	−1,31		1,219
	Number of persons in the household	−0,03	−0,05	−1,13		1,561
	Number of cars in the household	−0,03	−0,02	−0,48		1,2
(ref category: none)	Car availability	−0,01	−0,01	−0,15		1,202
Skills						
Age	30–49 years	−0,04	−0,03	−0,36		5,247
(ref category: 18–29)	50–64 years	0,007	0,005	0,06		5,138
	65 and older	−0,03	−0,01	−0,15		7,613
(ref category: male)	Gender	0,137	0,088	2,327	*	1,263
(ref category: urban)	Residential situation	−0,11	−0,03	−0,78		1,085
Profession	Working part-time	−0,03	−0,02	−0,39		1,463
(ref category: no. of full-time employed)	School/study/ training	0,279	0,06	1,663		1,155
	Head of household	−0,15	−0,04	−1,1		1,241
	Parental leave / Maternity leave	−0,01	−0	−0,03		1,195
	Not employed	−0,65	−0,1	−2,8	**	1,108
	Retired	0,059	0,032	0,422		4,972
Appropriation						
Attitudes	Purchase because of price advantage	0,032	0,032	0,929		1,066
	Improved attitude towards public transport	0,221	0,231	5,963	***	1,321
	Climate ticket permanent	0,365	0,196	5,115	***	1,293
Travel habits						
Relatively compared to the time before of the climate ticket						
	Increased PT usage	0,351	0,245	6,154	***	1,397
(ref category: none)	≥ 1 MIV trip avoided	−0,35	−0,07	−1,87	0,06	1,116
Absolutely within the time of the climate ticket						
MIV	daily	0,016	0,005	0,082		2,785
Usage	several times a week	0,098	0,055	0,598		7,463
(ref category: never)	several times a month	0,002	0,001	0,011		8,867
	less often	−0,09	−0,06	−0,55		8,925
PT	daily	0,147	0,097	0,235		149,26
Usage	several times a week	0,396	0,258	0,632		146,89
(ref category: never)	several times a month	0,279	0,106	0,441		50,965
	less often	0,426	0,092	0,658		17,231
MIV	daily	0,214	0,083	2,031	*	1,468
Usage	several times a week	−0,03	−0,02	−0,33		1,759
(ref category: never)	several times a month	0,032	0,018	0,407		1,642
	less often	−0,02	−0,01	−0,21		1,548
Prospectively regarding the time after the climate ticket						
	Unchanged public transport use	0,063	0,047	1,2		1,364

(*continued on next page*)

Table 3 (*continued*)

Modell	*Variable*	*b*	*β*	*t*	*p*	*VIF*
	Increased car use	−0,04	−0,04	−1,06		1,325
	Load axes	0,043	0,027	0,751		1,149
	*p < 0.05, **p < 0.01, ***p < 0.001					
	model1: F(df, df2)=, R^2, p, f^2					
	model1: F(df, df2)=, R^2, p, f131					
	model1: F(df, df2)=, R^2, p, f132					

Income. Climate ticket users are mostly coping very well 367 (28.6 %) or well 556 (43.3 %) with their financial means. 314 (24.5 %) of the participants rate their income as somewhat satisfactory. This contrasts with 38 participants (3 %) with poor or 8 participants (0.6 %) with very poor financial means.

This high degree of availability of financial means is due, among other things, to the fact that Bonn, as the former federal capital, is still the headquarters of several federal ministries as well as the location of the DAX corporations Deutsche Post and Deutsche Telekom. Accordingly, the use of the climate ticket was spread across all groups of people, independent of their economic circumstances.

From previous studies (Guzman et al., 2021, Tirachini & Proost, 2021), it can initially be assumed that users with low financial means increasingly use public transport. These findings are not reflected amongst our climate ticket users. One explanation for this could be that groups of people with lower incomes already had a public transport customer ticket and were therefore excluded from obtaining a climate ticket.

Household size. Our sample of 473 couples (36.5 %), 356 singles (27.5 %), 202 families with one child (15.6 %) and 199 with two children (15.4 %) reflects figures from the Federal Statistical Office, which show that single-person households and couples predominate in Bonn and the Rhein-Sieg area. These target group account for just under 64 % of respondents. Larger families with three children 50 (3.9 %), four children 9 (0.7 %), or five children (0.5 %), and one family of 8 people, are represented comparatively rarely.

The families live predominantly in the areas around Bonn or in the surrounding countryside. The decision to live rurally is not only based on the wish to save money by avoiding higher expenses but also on a conscious lifestyle choice. Larger households often have more than one car at their disposal. The number of cars depends on the total household wealth, which is higher due to adult children living with their parents. In turn, such a situation creates multiple drivers and often, due to geography, MIT mobility and less public transport. Thus, an increase in household income has a positive impact on mobility (Dargay, 2007).

Number of cars in household. 801 (61.1 %) of the participants own one car, while 234 (17.8 %) respondents have multiple cars. The remaining almost 21 % of our subjects did not have a car.

The number of cars in the households is consistent with the reported car availability. Although the inner-city region of Bonn in particular is densely populated and offers a wide range of mobility options (e.g., e-scooters, rental bicycles, car sharing, and carpooling), the temporary climate ticket measure has not led to any change in behaviour. However, future mobility could reduce the attractiveness of the car through a shortage of parking spaces and driving bans in urban areas.

Car availability in the household. A car is available to 900 (68.8 %) of the climate ticket users at any time. 314 (24 %) of the users can either use a car if they coordinate their travel arrangements with someone else or occasionally. The remaining 95 (7.2 %) of the participants of our study have no continuous access to a car.

The car availability shows that, due to not only the good economic conditions but also to company cars from the two DAX corporations in Bonn and the surrounding region, the MIT transport mode predominates. A wide mobility range with e-scooters, rental bikes, and ride-sharing opportunities is offered through the local transport company in Bonn, in addition to other car-sharing providers. Especially in the inner-city areas, numerous opportunities exist for a demand-oriented and targeted mobility, detached from the car.

Initially, it cannot be assumed that the car availability has changed as a result of the temporary expansion of services and the climate ticket. Purchasing a car represents a long-term decision in favour of MIT (Al-Busaidi, 2019) and a reduction of cars in households can only be achieved through a permanently attractive public transport offer.

4.3.2. Skills

In the transport context, the skills of each individual are shaped by the mobility they experience, coupled with their knowledge of the subject and their attitude toward the available modes of transport. Decisions on the means of transport must correspond to an individual's lifestyle and life cycle. In our climate ticket survey, analogous to the study by De Witte (2008) in Brussels and Hahn et al. (2022) in Bonn, the skills of the participants were linked to their professional status and to factors such as age and gender. The multiple regression shows a significant correlation with gender and the professional status of the participants.

Age. Increased use of the climate ticket occurred across all five defined age groups (Table 2). The under-30 s are the smallest group of climate ticket users. This can be explained by the fact that similar ticket offers exist for a large part of this age group. Pupils and students, in particular, fall into these age groups and with this status, are able to obtain a public transport flat rate and are therefore not the main addressees of this climate ticket. Between the ages of 30 and 49, a central residential location is often preferred due to the living situation. When people start a family, the priority often change to buying a house and living in suburban areas. Mobility behaviour shifts and, accordingly, longer journeys are made from a place of residence that is often poorly connected in terms of infrastructure.

It can be seen that in the age group between 50 and 64, there are adult offspring in the household and, accordingly, more cars are needed and also available. Particularly in the outlying areas, public transport is used less frequently because the distances to work are too long (Porru et al., 2020).

In the target group over 65 years of age, a contrary picture emerges. Since many of the offspring have started their own families and no longer live with their parents, people in this age group sell their only houses, which are now oversized, and prefer to live in the inner cities. According to Dargay (2007), increasing car ownership and vehicle use can be observed among the older generation. However, this use changes again when declining eyesight due to age makes driving no longer an option for many pensioners.

A comparison of age groups shows that the 30–49 age group rated the measure 0.357 units lower and the over-65 age group rated it 0.150 units lower than young participants up to the age of 29.

Gender. The climate ticket users are predominantly female (66.2 %), with 33.5 % identifying as male and the other four participants defining themselves in the diverse category. These differences cannot be explained by the gender distribution of the population. Bonn has a total population of 332,769, of which 51.7 % are female and 48.3 % male. Instead, the survey reflects the fact that women generally have a higher propensity to use public transport than men (Beirão & Cabral, 2007).

The different perception of the offer is also reflected in the evaluation of the climate ticket. Thus, compared to men, women rated the offer slightly better with 0.137 units. This observed relationship is statistically significant ($t = 2.327$, $p < 0.05$).

Place of residence. 1,239 (95.5 %) of our study participants came from Bonn. The remaining 59 (4.5 %) climate ticket users lived in the

surrounding area of Bonn, predominantly in the Rhein-Sieg district.

The climate ticket was introduced as a measure for the federal city of Bonn and, accordingly, predominantly usable by people living in urban areas. The place of residence as an influential component of access is a decisive factor for people when using public transport. Accordingly, people from Bonn's surrounding area did not evaluate the measure more positively than Bonn citizens. This fact shows that the climate ticket was considered useful for all stakeholders.

Especially in rural regions, commuters have to cover long distances to their work place and depend on reliable and flexible mobility (Chatterjee et al., 2020). Especially for these groups of people, long trips can be avoided and CO2 can be reduced. Both the scope and the groups of people are crucial for the acceptance of a permanent modal shift.

People in rural areas scored 0.784 units lower on the measure compared to urban residents. However, the difference is not significant.

Professional status. In our sample, 542 (41.4 %) were full-time employed, 289 (22.1 %) were part-time employed, and 29 (2.2 %) were not employed. Furthermore, 95 (7.2 %) were homemakers/ parental leave (homemakers 46 (3.5 %), parental leave 49 (3.7 %)), another 40 (3.1 %) were in education, and 297 were retired (22.7 %).

Among the status groups, climate ticket users who were not gainfully employed rated the offer the lowest. Compared to full-time employees, this status group rated the climate ticket 0.645 units lower. The regression analysis shows that this effect is significant. One explanation is that employed people often have to travel to work every day and depend on reliable mobility. People who are not employed are not necessarily dependent on daily mobility and may also be able to take advantage of low-cost tickets specific to other groups of people, such as the Bonn "Sozialticket".

4.3.3. Appropriation

Appropriation refers to attitudes towards mobility options and the corresponding travel habits.

Attitudes towards public transport. The survey shows that the climate ticket was purchased primarily because of the price advantage over the standard fare. Almost 62 % of the participants fully agree with this statement and 25 % partially agree. Only 12 % do not see the subsidised price as a decisive factor in their decision to use the climate ticket. However, the regression analysis does not show that this primarily monetary incentive has a significant influence on the assessment of the measure ($t = 0.929$, $p > 0.05$).

The climate ticket enabled the citizens of Bonn to obtain a comprehensive impression of the public transport system and to gain new experiences. In this context, 1,046 (80.2 %) of the respondents stated that the climate ticket had led to an improved attitude towards public transport. The remaining 258 (19.8 %) were not able to gain an improved perception by using public transport. An improved attitude towards public transport also had a positive effect on the evaluation of the measure. Where this perception was improved, the evaluation of the measure increased by 0.221 units. This observed relationship is statistically significant ($t = 5.963$, $p < 0.001$).

The vast majority of 1,205 (97.4 %) respondents also expressed the wish to have a permanent climate ticket. This desire did not exist for 15 (1.1 %) respondents, and the remaining 19 (1.5 %) respondents did not answer this question. The desire for a permanent introduction goes hand-in-hand with a more positive assessment of the measure. Among people who were positive about a permanent climate ticket, the assessment of the measure was 0.365 units higher. This correlation is statistically significant ($t = 5.115$, $p < 0.001$).

Travel habits. The travel habits can be analysed relative to time before using the ticket, during the use, and after the end of the project.

Relatively compared to the time before using the ticket. With regard to the change in mobility behaviour as a result of the ticket, a total of 94.1 % of respondents indicated that they had increased their use of public transport at least in part as a result of the climate ticket. This figure contrasts with 5 % who have not intensified their use of public transport, despite having the climate ticket. The remaining 0.9 % of the participants abstained from evaluating this statement. The analysis shows that people who said they used public transport more, rated the climate ticket measure 0.351 units better. This increase is statistically significant ($t = 6.154$, $p < 0.001$).

Increased public transport use is less associated with a reduction in MIT trips. While 94.1 % stated they used more public transport, only 73.7 % of the respondents stated avoiding one or more journies per week due to the climate ticket. 49.0 % of respondents were able to save three or more car journies per week.

The regression analysis shows no significant correlation between the avoidance of MIT trips and the assessment of the measure. The p-value here is 0.063. The respondents who saved one or more MIT journies assessed the climate ticket on average 0.353 units worse.

Absolutely within time before using the ticket. We also asked about the frequency of use of the various modes during the validity of the climate ticket. Here, 24.1 % of the respondents indicated they use the car daily or several times a week (mean = 2.70). 85.8 % of the respondents use public transport daily or several times a week (mean = 4.25), and 27.4 % of respondents use bicycles daily or several times a week (mean = 2.87). This use is also reflected in the preferences for the three main means of transport MIT, public transport, or the bicycle.

Mobility habits do not seem to influence the assessment of measures. Thus, the regression analysis shows a statistically significant influence only in the case of daily bicycle use ($t = 2.031$, $p < 0.05$). Thus, daily bicycle users rated the measure 0.214 units better than participants who did not ride a bicycle. Car and public transport users, on the other hand, did not show a significant result either in the frequencies of use or in the choice of the preferred main mode of transport.

Prospectively regarding the time after the climate ticket. In the survey, we also asked respondents to assess their mobility behaviour after the project had been discontinued. Almost 23 % of the respondents stated that they would use public transport more even without the climate ticket. The remaining 77 % used public transport solely because of the climate ticket, and a total of 83.2 % did not consider the traditional pricing models to be competitive with MIT before the introduction of the climate ticket. Accordingly, 74 % of respondents also indicated that they would increase their use of cars if the climate ticket was not continued.

However, the prospective assessment of mobility behaviour does not seem to influence the assessment of the measures. The regression analysis showed no significant correlation with the assessment of the measure.

Since the survey was carried out in three parts, we were able to survey the mode of transport preference during and after the use of the climate ticket (see Fig. 4).

With regard to transport preference, it can be seen that, in terms of the daily use of the main means of transport during the use of the climate ticket, public transport was ahead of the car and the bicycle. After the end of the measure, the ranking shifted again, and the car led the ranking ahead of the bicycle and public transport.

From this result, it can be concluded that there was a real modal shift in favour of public transport among the climate ticket users during the period of the measure, but that this shift was not long-lasting. After the end of the measure, the use of public transport dropped sharply and car use increased again.

This finding suggests that the price plays a stronger role than the desire to permanently use public transport and acquire competences to organise one's mobility with the help of public transport. These competences, nevertheless, certainly remained even after the price advantage of the 365 € ticket had been discontinued. However, the acquisition of the new competences is not sufficient to compensate for the increase in the price of public transport due to the end of the measure. These findings coincide with the wish of the climate ticket users for a permanent introduction of a low-cost public transport.

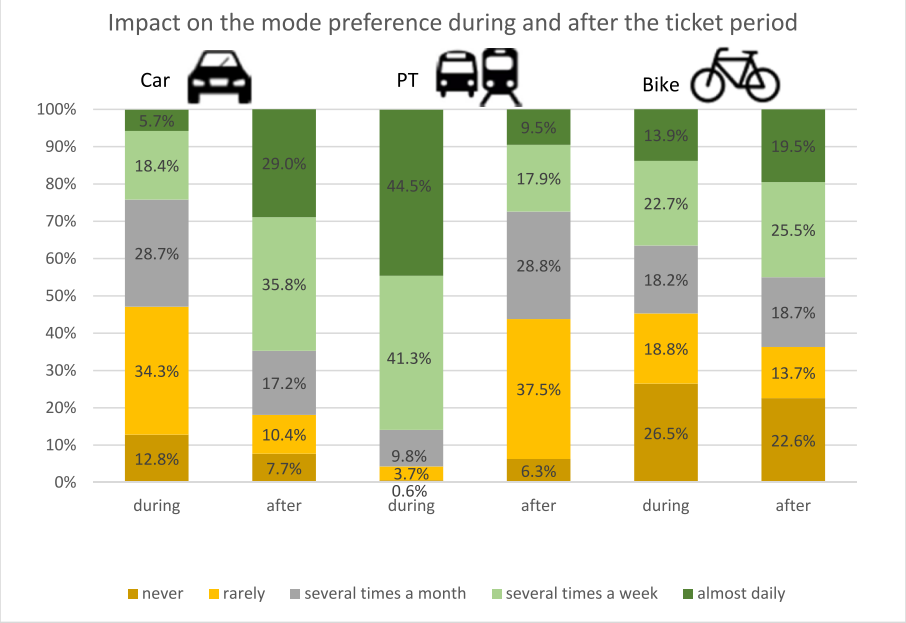

Fig. 4. Reported travel behaviour during and after climate ticket (own representation).

5. Discussion

Our survey of climate ticket users was conducted in three stages and, since the "corona shut-down" occurred unexpectedly after the questionnaire was sent out in Stage 1, a "corona influence" in this stage cannot be completely ruled out. However, most of the questionnaires from Stage 1 were completed and returned before the shut-down. Stage 3 took place during the hard "Corona shut-down" at the beginning of 2021, but the event only had only a minor influence in isolated cases on the survey results. The significantly lower response rate in Stage 2 and 3 (30 % and 35 %, respectively) compared to Stage 1 (46 %) could be due to possibly more widespread information that the ticket would not be continued but could also be a result of the Corona situation and less interest in the ticket or public transport overall.

At the time of the final part of the survey, it was not clear how public transport would be used in the future, due to the recommended contact restrictions and subsequently uncertainty over a climate ticket would continue to be a meaningful measure. After the passenger numbers in public transport returned to normal, the war in Ukraine broke out, which led to far-reaching severe economic consequences. Inflation in Germany rose to well over 5 % and required optimised economic management for each individual with scarce financial resources. The decision to either buy fuel or food shows the severity of the situation. The population has less money for mobility and also the transport companies are faced with higher fuel prices without passing these costs on to the long-suffering customers. In the current turmoil, the focus is shifting, at least temporarily, away from climate towards the economy. However, climate change still exists and cannot be ignored.

The Lead City project has caused a split between policymakers and transport companies. Politicians have set the funding for such projects and reaffirmed the basic directions. The transport companies have to deal with challenges such as lack of infrastructure, lack of buses and trains, higher fuel prices, and staff shortages. Even if subsidies are available for the project period, these other factors must be managed for a long-term switch. In particular, rising operating costs and staff shortages resulting from a demographic change will have to be managed.

Since mobility is acrucial factor in reaching the workplace and is dictated by the employer, it will remain essential. Even though the Corona pandemic and the lock-down, as well as the resulting changes in the working world, led to an increased proportion of people working from home, the use of public transport was, at least temporarily, associated with health obstacles for too many people. Transport companies, like the rest of the economy, have had to contend with enormous declines in revenue as a result of the pandemic. Transport companies have relied in part on federal funds to maintain operations.

6. Conclusions

Our study in Bonn was initiated in 2020 and differs from earlier studies in that low-cost public transport is understood in the context of air pollution control and as a measure to avoid the threat of judicial driving bans at main pollution axes. The novelty of this study is that the advancing climate change and the negative ecological consequences are becoming increasingly visible and far-reaching countermeasures are essential.

In the opinion of the users, the current standard tariffs of the transport companies cannot compensate for the financial advantage of the climate ticket. The willingness to switch to public transport can only be generated by the transport companies offering a long-term low-cost ticket. Vienna is a good example of a well-functioning low-cost annual public transport ticket. The ticket was introduced there more than 10 years ago and resulted in more people having a ticket than cars being registered in the city. However, supra-regional agreements for a connection ticket with other transport associations for the tariff zone transitions must be created.

The multiple regression results reveal significant characteristics of ticket users. The climate ticket project was rated particularly well by people with high public transport usage or those whose attitudes toward public transport had improved as a result of the ticket. People who were not employed rated the measure lower than those who were employed full-time. This circumstance suggests that the climate ticket does not appear attractive for this group of people. In Bonn, there is a so-called social ticket for non-employed persons that can be purchased for 19 € per month and is equivalent to the climate ticket in terms of scope (Federal City of Bonn, 2022). Furthermore, women rate the climate ticket better than men. One explanation is that women generally have a more positive attitude toward public transport and are more willing to use it. The assessment of the measure by daily bicycle users is significantly more positive than for those participants who do not use a bicycle. The significant result suggests that cycling is often used as a

complementary form of mobility in conjunction with public transport.

The authors believe the transport sector is a key driver of climate change, and ticketing adopted by the population is a reason for a change in travel behavior. As the operational implementers of decisions by political decision-makers, the transport companies must be involved in the decision-making process when designing a future ticket, and the lessons learned from Bonn must be taken into account in the public debate. A few municipalities are considering introducing a 365 € ticket at the regional level. Our study is particularly interesting for these cities and the resulting implications in Bonn should be taken into account in the design. It should be noted however, that our observations refer to Bonn and neighbouring municipalities. A blanket replicability of the results to other cities, regions, or even countries should not be assumed to be always achievable and can only be made with caution.

CRediT authorship contribution statement

Andreas Hahn: Conceptualization, Data curation, Formal analysis, Investigation, Visualization, Writing – original draft. **Christina Pakusch:** Methodology, Supervision. **Gunnar Stevens:** Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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