

Low-fare public transport and modal shift – Lessons from Bonn, Germany

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ABSTRACT

The air quality in many German cities does not comply with EU-wide standards. Vehicle emissions, in particular, have been identified as an important cause of air pollution. As a result, driving bans for diesel vehicles with critical pollutant groups have been imposed by courts in many places in recent history. Against the backdrop of the growth of major German cities over the last few years, the question has become whether and how a change in the modal split in favor of more environmentally and climate-friendly public transport sector can be achieved. The Federal City of Bonn is one of five model cities that is testing measures to reduce traffic-related nitrogen dioxide emissions through a Climate Ticket as a mobility flat rate for one year for 365 €, which is part of the two-year "Lead City" project funded by the federal government. A quantitative survey ($n = 1,315$) of Climate Ticket users as well as the logistic regression carried out confirm that a change in individual mobility behavior in favor of public transport is possible by subsidizing the ticket price. The results show that individual traffic could be saved on the city's main congestion axes. In order to achieve a sustainable improvement in air quality, such a Climate Ticket must be granted on a permanent basis, with a well-designed mobility offer and must be generous in terms of the group of authorized persons and the area of validity.

1. Introduction

Life in the 21st century is fundamentally shaped by human-induced climate change and the development of more sustainable environmental strategies (Dubois et al., 2019). In order to limit global warming, in accordance with the Paris Climate Agreement, to well below 2° (and preferably to 1.5°), far-reaching changes are required, both for individual sectors and every individual on Earth. (Climate protection in figs., 2020). The transportation sector, which is a major source of global greenhouse gas emissions, has a central role to play in any climate-related strategy (Cepeliauskaite et al., 2021; Matthias et al., 2020). In certain major European cities such as Madrid, Barcelona, Athens and Rome, restrictions in the form of driving bans have already been implemented and further comparable measures will follow. In Germany, too, exceeding EU-wide pollutant limits has resulted in court-ordered driving bans in select cities. To avoid possible consequences, the Federal Republic of Germany launched the "Lead Cities" concept in February 2018 and submitted an alternative proposal for improving general air quality to the EU commissioners via its Model Cities Plan. The Federal City of Bonn participated as one of the five model cities in the project that was funded by the Federal Government,

which works to improve CO2 emissions through targeted ecological measures and supports essential building blocks for a traffic turnaround vis-a-vis public transport (PT) and supports key building blocks for a traffic transformation centered on public transport.

A comprehensive urban concept with climate-friendly measures has been developed, which includes measures to cut down on car traffic, such as reducing parking spaces, increasing parking fees, closing lanes for cars and promoting more bicycle traffic. In addition to these measures, it is also important to work towards a switch to emission-friendly public transport system. Key factors in this vein include travel time, access to public transport, flexibility and economic considerations that must be designed intentionally.

These factors were the basis for the design of the contents of the Lead City project in Bonn. As a result, a total funding of € 39.34 million (Bundesstadt Bonn 2018), for a cost-effective use of a Climate Ticket (€ 18.31 million), an expansion of the transport offer (€ 18.79 million) and an operational connection of companies as major customers (€ 2.24 million) was approved.

In Bonn, the Lead City project includes expanding transport services, low-cost access to public transit through a so-called Climate Ticket, and an operational connection of companies as major customers. Now that

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the Federal City of Bonn has officially declared a climate emergency in 2019, these measures have taken on new significance and shed light on possible contributions that the transportation sector could make to achieving climate neutrality. In this article, we analyzed the introduction of the Climate Ticket and listed lessons policymakers can draw from the temporary measure.

In political and scientific discussions alike, price is often identified as one of the most important factors for a modal shift. To this end, the citizens of Bonn should be given the opportunity to test the PT at the relatively low cost of 365 € for a whole year (i.e., one Euro every day). Through such a Climate Ticket, it is hoped that travel habits will change in favor of PT. One of the main aims of this attractive pricing scheme is to make car drivers, in particular, more aware of the urgent need to switch to PT.

The subsidy was designed for a total of 17,000 tickets. This number was based upon the previous income from monthly tickets as a basis for calculation. Initially, the measures were advertised only cautiously, as a quick sell-out was expected. After a slow start, extensive information and marketing campaigns occurred. In total, 6000 tickets were sold over the course of the initiative (cf. [RP Online., 2019](#)).

Previous key studies addressed changes in mobility behaviour through low-cost or free public transport. A major commuter survey in the Belgian capital Brussels showed that a modal shift from car to public transport is possible by reducing the price of public transport ([De Witte et al., 2013](#)). In addition to this economic approach, there were also studies that tested a modal shift for social reasons. In the Estonian capital Tallinn, free public transport was implemented for locals. The aim of this measure was to make public transport affordable for all residents regardless of their income level ([Hess, 2017](#)). Luxembourg was the first country in the world to introduce free public transport for everyone. The main focus was also on making mobility accessible to people with low incomes and reducing congestion on the roads as a result ([Carr & Hesse, 2019](#)). Even if the motivation for the individual studies has very different focuses, the main focus is on socio-economic factors. The framework conditions have changed due to the challenges of climate change and ecological issues have moved into the public discussion.

Our 2020 study in Bonn differs from earlier studies in its fundamental focus. Here, low-cost public transport is understood as a means of both regulating air pollution and as a measure to avoid judicial driving bans on main pollution axes ([Hahn et al., 2023](#)). Indeed, as the negative ecological consequences of climate change are ever more visible, extensive countermeasures are essential. Therefore, this study offers a first attempt at analysing individuals' travel patterns based on an individual survey focused on the mobility behaviour of Climate Ticket users. This study is a unique opportunity to analyse the effects of this climate-oriented ticket and to identify far-reaching implications for future pricing. Thus, this study seeks to understand how the Bonner Climate Ticket contributes to air pollution control or mobility behaviour in the transport sector. We believe the findings of this study are relevant both from a scientific and a practical point of view.

In this article, we first present the current state of research on the fare-free public transport (FFPT) in a comprehensive literature review and then present the case of Bonn/Rhein-Sieg. We conducted an online survey among Climate Ticket users to analyse the added value for the traveller. We used statistical methods to process the findings from a total of 1315 people from Bonn, the Rhein-Sieg area and neighbouring municipalities. In the results section, we present and discuss the effects of the measure, a logistic regression and the mobility practices. Finally, we summarise the main contents in a conclusion and provide implications for further research approaches arising from the topic.

The results of the present study are addressed to policymakers and are intended to provide lessons learned from Bonn for a sustainable follow-up ticket. It is likewise intended to contribute to the current debate on the succession of a ticket offer for local transport that is valid nationwide but limited. These optimizations point to continuing the

initiative in Bonn, as well as in other cities.

2. Literature review

Despite global climate protection movements, individual transport remains the primary mode of transport, though traffic jams, excessive consumption of energy and resources, negative environmental impacts such as noise, vibrations, and emissions of various pollutants, as well as global warming are all known to be negative consequences resulting from individual transport ([González et al., 2019](#)). In Germany, taking local transport is considered to be an act of public service and in many municipalities, such as in Bonn, is loss-making and dependent on state subsidies to run their public transportation systems.

For several years, there has been a lively debate across Europe about the abolition of PT fares ([Urbanek, 2019](#)). Critics argue that, from the perspective of utility, efficiency, and economic growth ([Storchmann, 2003](#)), eliminating fares harm PT financially and may lead to useless mobility ([Baum, 1973](#); [Duhamel, 2004](#)). Moreover, scholars and practitioners alike see the mobility problems in sustainable development ([Kębłowski & Bassens, 2018](#)) and point to the weaknesses of PT in driving a modal shift from private vehicles to PT ([Cats et al., 2014](#); [o., 2017](#); [Cervero, 1990](#); [Fearnley, 2013](#)).

This sentiment has been countered by advocates for free PT from divergent fields of academia, including mobility ([Briche, 2017](#)), policy ([Larrabure, 2016](#)), urbanists ([Brown et al., 2003](#)), and communications ([Santana & Silva 2013](#)). Low-cost PT is also praised in non-scientific publications by political activists and public representatives ([Prince & Dellheim, 2018](#)). They assume that PT not only generates operational savings, induces a modest modal shift from cars to PT, and reduces the externalities of car use, but contend that it also works toward social, environmental, and political change.

Despite the controversy surrounding fare abolition, few studies have attempted to examine the issue in a systematic, in-depth way ([Kębłowski & Bassens, 2018](#)). We view this controversial consideration as an opportunity in our study aimed at assessing the impact through the Bonn Climate Ticket.

In the past, there have been many model-based attempts around the world to manage modal shift by increasing the attractiveness of mass transit ([Grzelec & Jagiello, 2020](#)). The design of these models and the ensuing results and consequences vary greatly; the central measure of most projects is a price reduction or free use of PT. In their study, [Kębłowski et al. \(2019\)](#) distinguished between "partial" FFPT and "full" FFPT. As our study concerns fully subsidized PT and not about individual groups of people like pensioners, students, etc., we only consider these nearly 100 different field trials worldwide.

The topic of FFPT is widespread and of the utmost importance worldwide. The reasons for the movement toward FFPT, however, vary strongly between economic, ecological, and social considerations.

The world's first known FFPT case dates back to 1962, when FFPT was introduced in the city of Commerce, a small suburb of Los Angeles, due to social benefits. In the following decades, other FFPT programs were added and the global pioneering role of North America was consolidated.

Further examples of known cases from Mercer County (New Jersey) and Denver (Colorado) date back to the 1970s. As a result, both cities saw a sharp increase in passenger numbers. Ultimately, however, there was not enough political support to sustain the investment in infrastructure, capacity and in increased safety requirements. As a result, both projects were only temporary and were not extended ([Volinski 2012](#)).

What is striking about the cases in the USA is that most of them involve small municipalities and counties, of which only three cities have more than 100,000 inhabitants. Unlike our ecological study in Bonn, the field trials in the USA are often aimed at social and economic goals. Government subsidies for public transport are intended to counter socio-political concerns about the effects of the economic recession. The

aim of the FFPT is to ensure mobility, particularly for unemployed people and the working poor (Kębłowski, 2020).

Unlike in North America, FFPT programs in South America, Australia and Asia were tested much later and only in small numbers (Kębłowski, 2020).

There have been recent notable FFPT cases in Brazil, most of which are social policy measures that contribute to combating imbalances and sustainable development (Aftimus & Santini, 2018; Gomes, 2016). There were also FFPT cases in the three Chinese cities of Changning (Hunan), Gaoqing (Shanxi) and Kangbashi (Inner Mongolia) in the 2000s (Shen & Zheng, 2015), as well as in the Australian city of Manly. According to the few media reports, the focus is on socio-political improvement of the population and relief from increasing traffic congestion.

As our study was conducted in Germany, we believe that field trials in the European region offer the greatest comparability and useful lessons.

In Germany, for example, the small eastern cities of Templin (population: 16,000) were able to offer free local public transport between 1997 and 2003 and Lübben (population: 15,000) between 1998 and 2002. Prior to the introduction of this measure, ridership was so low that buses were threatened with discontinuation, but transferring to a full cost absorption model among the cities led to a reduction of motorised private transport (MPT) towards PT (Fearnley, 2013). Funding could not be sustained by the city in the long term, so tickets are no longer free today. Nevertheless, services remain inexpensive compared to price levels in comparable cities, and the number of trips has remained above the original level.

In Belgium, free public transport was introduced in the city of Hasselt in 1997. The city, which at the time had a population of 70,000, is a destination for many commuters and was developed with an extensive route network even before the introduction of the zero fare. Due to massive cost increases, ticket sales had to be reintroduced in 2013 (Fearnley, 2013). Here again, ridership has subsequently declined but nonetheless remains above its original levels. A study of commuting behavior in Brussels demonstrated a modal shift resulting from the introduction of free public transport (De Witte et al., 2006; De Witte et al., 2008). Brussels, which is the capital of Belgium, has a well-developed route network, but its costs did not make permanent free public transport feasible.

The Estonian capital of Tallinn (population: 425,000) introduced free public transport for locals in 2013 and is the first European capital (as well as the largest city) to have implemented a free public transport system (Cats et al., 2014). The main focus of the measure in Estonia is not to reduce air pollution (as is the case in Bonn), but to address certain social concerns. The goal here is to make public transport affordable for all residents, regardless of their income level (Hess, 2017). The use of public transport increased from 55 % to 63 %, which was below the expected changes (Prause & Tuisk, 2020).

In Vienna, the share of car journeys was reduced by a third between 1993 and 2014: from 40 % to 27 %. The key to Vienna's success was a coordinated package of mutually reinforcing transport and spatial planning policies. These policies made car use slower, less convenient and more expensive, while increasing the safety, convenience and feasibility of walking, cycling and public transport (Buehler R., 2017). Another important measure was the increase in car parking charges, which supported the willingness to a modal shift to public transport (Bühler, 2017). The City of Vienna's future growth plans also included the expansion of infrastructure and the introduction of a heavily subsidised public transport ticket. The sales figures for this 365 € ticket for public transport doubled in the first five years.

Luxembourg, a small European country, is the first country in the world to have made its public transport free for all people since the Summer of 2020. The initiative's goal is to reduce congestion and mitigate air pollution, but also to make collective mobility accessible to people with lower incomes (Carr & Hesse, 2019). Due to the Covid-19-pandemic, it is difficult to assess commuter adoption, but

recently released figures show a positive trend. According to the report, an average of 31,000 riders per day used the streetcar in February 2020. In February 2021, a peak of 42,000 passengers was reached, though the situation has not yet returned to normal due to the continued use of work-from-home options in various sectors.

The introduction of a 9 € ticket for public transport for a limited period of three months (01.06.2022–31.08.2022) was the first Germany-wide field experiment in the mobility sector. This special offer was intended to relieve the burden on regular public transport customers, but also to focus on a modal shift to emission-friendly public transport, which would not have taken place without the ticket (Krämer & Korbutt, 2022). The intended modal shift succeeded to a limited extent - market research from across Germany shows that the number of public transport users increased significantly as a result of the 9-euro ticket. After the end of this special promotion, the measure's lasting effect appeared to be jeopardized without an attractive follow-up offer (Dietl & Reinhold, 2022).

After far-reaching political deliberations, it was decided to launch a 49 € ticket, the so-called Germany Ticket, for nationwide public transport use from 01.05.2023. According to a study by the German Institute for Transport Research on the potential of the 49 € ticket, respondents use a mobility mix and predominantly prefer a flexible monthly ticket. Furthermore, the study advises that a nationwide area of validity should be maintained (Nobis, 2022). Moreover, discussions about special regulations for social tickets, for students or job tickets, clarify that the price of 49 € was set too high to achieve greater acceptance in society and sustainable effects for the transport transition (Krämer et al., 2023). It is to be expected that the modal shift effects will be less pronounced among people with little affinity for public transport. Rather, existing public transport users with a more expensive ticket can be expected to switch (Krämer, 2023). Finally, to appeal to all customer groups, a digitalization offensive is required to gain long-term social acceptance (Krämer, 2023).

The effects of free or greatly subsidized public transport on people's mobility behavior were highly differentiated in the field tests, but they were able to show inflows to public transport and a reduction in private car usage. However, urban planning measures, such as an expansion of the route network or the purchase of new buses and trains, were often necessary. In many cities, the framework conditions for a successful implementation without high investments were not evident and therefore, in many cases, the public transport system was overloaded. The main issue, however, is the cost and the question of how to finance such a project over the long term. The case of Bonn as a former federal capital is interesting, as the city has a well-developed route network and optimal framework conditions.

3. The case of Bonn/Rhein-Sieg

With a population of 330,769 (as of January 1, 2020), the former federal capital of Bonn is considered one of the economically strongest cities in the state of North Rhine-Westphalia (NRW) and offers 176,689 employees a job on an area of more than 141 km² (as of 30.06.2018) (State Office NRW, 2020; Statistics Bonn in figures 2020). A large number of the people employed in Bonn live in the neighboring municipalities of the Rhein-Sieg area. This includes almost all of Bonn and represents an important business site that has more than 600,000 inhabitants.

The local PT system primarily serves the entire Bonn metropolitan area, including parts of the Rhein-Sieg area and the surrounding area of Cologne. Bonn's subway network consists of two main lines and one branch line. The city's subway system is supplemented by streetcars, which run above ground. In addition, Bonn has a comprehensive bus network that connects all of the outlying areas to the city center. (Figs. 1,2,3, and 4)

The Bonn Climate Ticket can be used for one year within a limited validity period of two years. As part of the "Lead City Bonn" project,

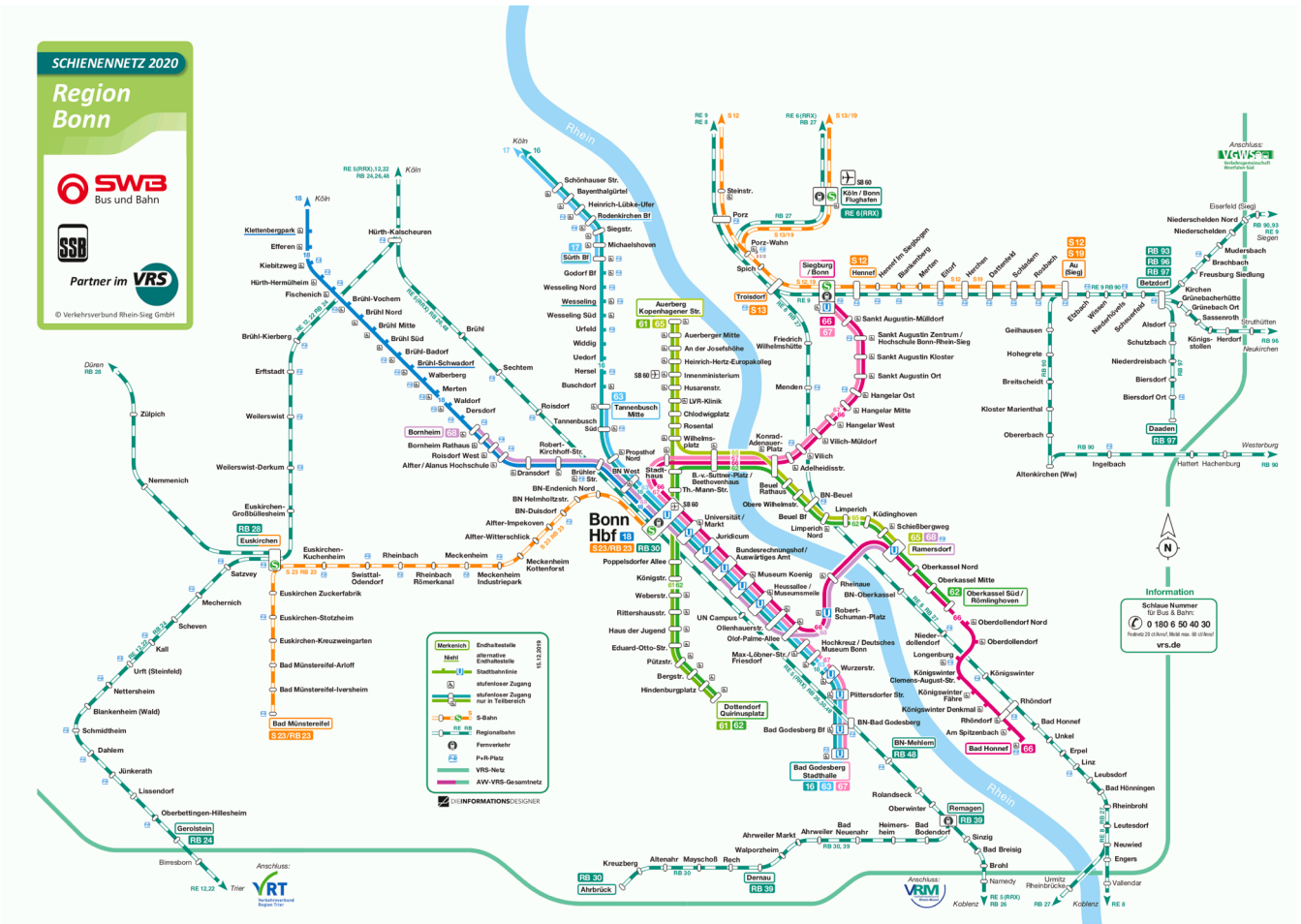


Fig. 1. Official network map of the public utility company Bonn.

1. The climate ticket has increased my use of public transport.
2. Without the climate ticket I will make as many trips with buses & trains as with the climate ticket.
3. Without the climate ticket I will use the car more.
4. The regular fares of the transport company is a sufficient substitute for me in case of loss of the climate ticket.
5. I only bought the climate ticket because of the price advantage compared to the regular fare.
6. My attitude to driving with buses and trains has improved by the climatic ticket.
7. The climate ticket should be introduced permanently.

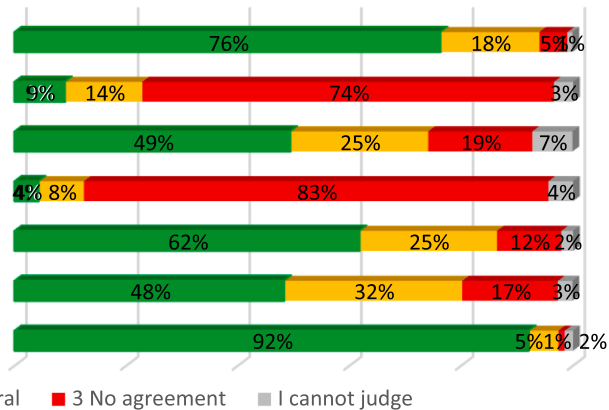


Fig. 2. Statements on the climate ticket Own representation.

people who did not have a PT subscription in the 12 months prior to the measure were offered the opportunity to purchase an annual ticket that would allow them to access the city of Bonn at a discounted price of 365 €/year. The total amount is divided over 12 months (for comparison, a regular monthly ticket would cost 1021 € for 12 months). The last Climate Tickets expired on December 31, 2020. The Climate Ticket is not transferable and could only be purchased by people who were not subscription customers during the project period. This mandatory criterion caused some controversy, but was nonetheless retained despite

the disadvantage to subscription customers. The Climate Ticket includes further comprehensive take-away options. From Monday to Friday after 7 p.m., as well as on weekends and public holidays, up to three children from 6 to 14 years of age, one person over 14 years of age, and one bicycle can ride on the ticket free of charge all day long. Furthermore, Climate Ticket were also able to use the local bicycle rental system (Nextbike) with 30 free minutes per day.

Use during and after the climate ticket

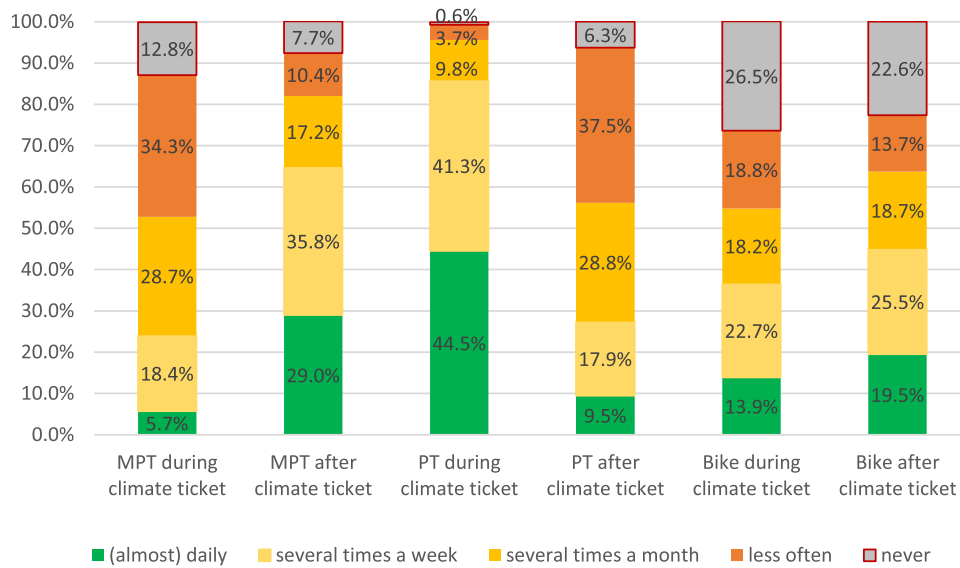


Fig. 3. Mobility behavior during and after Climate Ticket. Own representation.

Use of transport after the end of the measure

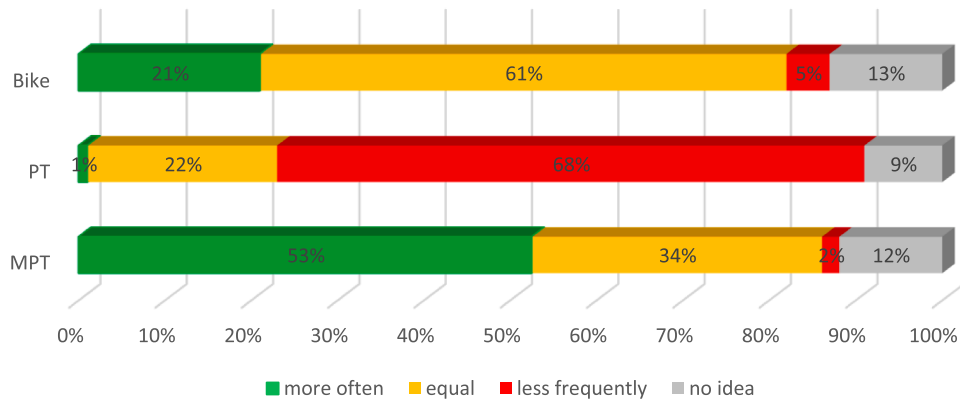


Fig. 4. Use of transport after the end of the measure. Own representation.

4. Data and methods

4.1. Survey design

In addition to participants’ socio-demographic such as age, gender and place of residence, the primary contents of the questionnaire included an evaluation of the Climate Ticket and seven key statements. The aim of the questionnaire was to determine, on the basis of seven key statements regarding the use of the ticket and the price, how the users assess the short- and long-term contribution that was made by the Climate Ticket to the modal shift to PT and whether a sustainable improvement in the environment had been achieved. The evaluation as well as the seven statements about the Climate Ticket were presented in a metric scale. Subsequently, the use of the mobility options MPT (car/motor/cycle), PT (buses/trains), as well as bicycle could be compared before and after the expiration of the Climate Ticket initiative. Based upon the changes in use, the aim was to find out whether and to what extent car trips could be avoided.

Due to the complexity of the questionnaire, a large number of data sets were collected, and the conclusions drawn from the survey were based on various statistical analyses.

4.2. Data collection and participants

The aim of this study is to determine the effects of the Climate Ticket in order to take further measures on the basis of the survey. The evaluation was carried out as a written quantitative survey online in the form of an initial survey during the use of the Climate Ticket, as well as a follow-up survey following the end of the Climate Ticket program. The questionnaires were the same in the initial survey and the follow-up survey in order to be able to compare the results across surveys. The different survey dates ensured that there was no duplication of respondents in the initial survey and the follow-up survey. In the initial survey, we wanted participants to reflect upon their own mobility habits. The initial survey took place during the use of the Climate Ticket at two different survey times. The first survey wave took place in May

2019. Of 2200 people contacted, 1045 people returned a completed questionnaire, resulting in a response rate of 48 %. The second wave of the initial survey began in January 2020 and the questionnaire response included 476 questionnaires (response rate: 43 %). The different waves vis-a-vis the start date of the Climate Ticket were intended to ensure that participants were surveyed promptly at the start of the Climate Ticket. To check the results of the initial survey, a follow-up survey was carried out via a new questionnaire. The results of the re-examination were done in three waves. The aim was to compare the results during the use of the Climate Ticket with the assessment following the end of the program. The evaluation was carried out via a written quantitative survey online as a post-evaluation following the end of the Climate Ticket at three different points in time, which corresponded to the starting time of the ticket use. Thus, it involved a completely new selection of respondents. This makes it possible to derive information about the overall impact of the measure. In the end, a total of 3430 Climate Ticket users from the Bonn metropolitan area were contacted via mail and invited to participate in the online follow-up survey.

The first survey took place at the end of February 2020. At that time, 1530 people were contacted, 699 of whom returned the completed questionnaire. This corresponds to a response rate of 46 %. It is important to note here that the questionnaire could be returned until April 2020, but that most initial respondents answered before the Covid-19 shutdown, suggesting that the Covid-19-pandemic hardly had any effect on the first wave. The response rate for the second wave was significantly lower at 30 %. There were 900 respondents in August 2020, 270 of whom participated in the survey. In the summer period, the incidences due to the Covid-19-pandemic were significantly lower than in the shutdown period; however, the mobility behavior of users is significantly altered by the Covid-19-pandemic and its effects on the results of the survey cannot be excluded. The third wave in January 2021 was for 1000 subjects who were contacted, 346 of whom completed the questionnaire. A response rate of 35 % was thus recorded here. It should be noted that the responses were possible until February 2021 and took place in the Covid-19 shutdown.

Thus, a total of 1315 different users participated in the evaluation in the three survey waves. The data sets of this population of $n = 1315$ surveys were statistically evaluated in order to draw conclusions about the effectiveness of the measure, as well as its effects on the resulting mobility behavior of people from the region. (Tables 1–4)

The total population is $n = 1315$. The differences to the total population can be attributed to "don't know" or invalid answers. Accordingly, there were non-valid responses for the predictors age (22), gender (18), as well as place of residence (17) and non-valid responses. The percentages refer to the valid response for each predictor and add up to 100 %.

4.3. Data analysis

For the evaluation of the collected data –and to obtain an overview – methods of descriptive statistics were first applied, such as calculating frequencies and mean values. The exploratory data analysis procedure

Table 1
The evolution of full FFPT cases worldwide.

Year	Full FFPT cases Total	Worldwide				
		Europe	North America	South America	Australia	Asia
1970	1	–	1	–	–	–
1980	6	2	4	–	–	–
1990	13	4	9	–	–	–
2000	27	8	17	2	–	–
2010	60	29	25	5	–	1
2017	99	57	27	11	1	3

Adopted from: [Kebłowski \(2020\)](#).

Table 2
Demographics of survey participants.

Characteristic	Number	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 %
Divers:	4	0.3 %
Place of residence:		
Bonn:	1239	94.2 %
Adjacent municipalities:	59	4.5 %

was used to sift through data so as to identify unusual values, extreme values, as well as gaps in the data or other anomalies (Döring & Bortz, 2016). In addition to descriptive statistics, inductive statistics were also used in the analysis of the research question, which could be utilized to draw conclusions about the entire sample (Eid et al., 2017). Furthermore, correlations were calculated to determine the relationships between relevant variables.

As part of the results, we compared the mobility practices between the mode of transport used during the Climate Ticket use as well as the mobility behavior after the end of the measure. The measure impact uses seven core statements to show how ticket users evaluated the measure. Using logistic regression, we examined the binary dependent variable of car trip avoidance for these seven core statements. This constituted a nominal variable that required people to answer simply yes or no. The answer options of the seven core statements could be answered via metric scaling.

To statistically answer the research question, we first examined the ecological contribution of the study by using logistic regression. Here, we examined the predictor car avoidance for the main core statements of the survey. The evaluation of the mobility practices shows the effects of the transport modes car, PT, as well as bicycle with or without Climate Ticket. The statistical calculations were prepared and performed in the data analysis software SPSS 27.

5. Results and discussions

5.1. Effect of measures

In the past, there were similar projects that focused on low-cost PT with the aim of leveraging a modal shift in favor of PT. Oftentimes, socio-economic factors have been used in the foreground as well as the financing of the measures. The present study showed that the users of the Climate Ticket are very satisfied with the offer and on average rate the project as very good (1.43). The majority of respondents are in favor of extending the offer. However, to initiate a permanent switch to PT, further framework conditions must be created beyond just the attractive price.

The aim of the present evaluation is to draw further conclusions about the people who used the Bonn Climate Ticket offer so as to inform the design of future mobility. A total of 1315 respondents took part in the survey; when one subtracts the 160 invalid answers, this leaves 1155 appropriately given answers. This corresponds to almost 88 % of all answers to the survey. The respondents are predominantly very satisfied (52.9 %) or satisfied (24.5 %) with the Climate Ticket. A far smaller share assessed the initiative as balanced (7.5 %), bad (2.5 %), or very bad (0.5 %).

Based upon the question about the assessment of the measure, users were able to assess the benefit as well as the price of the Climate Ticket on the basis of seven essential core statements included in the survey. These statements are intended to examine the use of the Climate Ticket

Table 3
Results of logistic regression analysis for the dependent variable car avoidance.

Statement	Variable	b	S.E.	Wald	p	OR	CI 0.025	CI 0.975
1	Increased use of PT	-0,763	0,167	20,959	***	0,466	0,336	0,646
2	Trips during and after Climate Ticket	0,188	0,136	1898		1206	0,924	1575
3	Return to the car	-1535	0,117	171,671	***	0,215	0,171	0,271
4	Regular fare as substitute	-0,074	0,185	0,159		0,929	0,646	1336
5	Price advantage Climate Ticket	-0,031	0,129	0,056		0,970	0,753	1250
6	Attitude towards PT	-0,282	0,131	4669	*	0,754	0,584	0,974
7	Permanent Climate Ticket	0,016	0,213	0,005		1016	0,669	1541
	Evaluation Climate Ticket	-0,064	0,148	0,188		0,938	0,702	1253

*p<.05, **p<.01, ***p<.001.

Model 1: X² (8) = 369.973, p<.001, R²=0.480.

Table 4
Expression of significance (p).

Variable	Total model	1 Wave	2 Wave	3 Wave
Increased use of PT	***	**		**
Trips during and after Climate Ticket				
Return to the car	***	***	***	***
Regular fare as substitute				
Price advantage Climate Ticket				
Attitude towards PT	*	*		
Permanent Climate Ticket				
Evaluation Climate Ticket				

and its effects on future scenarios. They are also intended to reflect how mobility behavior changed in the short term as a result of the measure, or how mobility behavior might change in the long term with or without the measure.

With regard to the influence of the Climate Ticket on the use of means of transport, it can be seen that the Climate Ticket had a positive effect on the use of PT; a large proportion of respondents (76 %) used PT more than they had previously. The low price was a decisive reason for 62 % of respondents to purchase the Climate Ticket. Thus, 83 % of respondents do not consider the standard fare to be a sufficient substitute for the Climate Ticket. 74 % of respondents plan to use less PT again without the Climate Ticket offer. Just 9 % of respondents say they would like to continue using PT to the same extent. At the same time, almost half of the respondents (49 %) want to increase their use of the car again following the end of the measure. Overall, 48 % of the participants reported that their attitude towards PT has improved. An overwhelming 92 % of respondents are in favor of the Climate Ticket being introduced permanently.

Overall, there is a great desire among respondents for the offer to be maintained or for a comparably favorable solution to be created. For most respondents, the current standard tariffs charged by the transport association are not a sufficient substitute in the event that the Climate Ticket is discontinued. In the opinion of the present study's participants, it was clear that the strong limitation of the circle of beneficiaries, but also of the area of validity must be extended in further considerations. Particularly with commuters from rural regions, far passenger journeys with personal vehicles can be avoided and the congestion on roads can thereby be relieved. It thus seems appropriate to extend the Climate Ticket for, among other groups, these persons and to connect further areas by continuing to develop relevant infrastructure. Especially in rural areas, PT is often not a comparable alternative.

What is critically important is the lack of information flow with regard to the offer (and accordingly, the lack of awareness about possible additional options like the possibility to take along passengers or the use of the bicycle rental system). In addition to the bicycle rental system, other forms of mobility (e.g., e-scooters or car sharing) should be integrated into the ticket regime. In addition, the above-mentioned lack of framework conditions has a meaningful impact on the sales figures of the Climate Ticket. Accordingly, a contingent of just under 17,000

Climate Tickets was offered, of which less than 50 % were sold.

5.2. Results of logistic regression analysis

De Witte et al. (2013), among others, have identified the avoidance of car trips as an essential indicator for a sustainable contribution to climate protection and examined it extensively in their studies. As the variable of car avoidance has a particularly significant importance and is highly influential for sustainable development, the data were considered in a logistic regression with respect to the basic core statements, plus the evaluation of the measure to test the research question.

The evaluation of the omnibus test of the model coefficients outputs the result of the likelihood ratio test in the form of the Chi-squared value and the associated significance level (p-value). The result of the model summary provides the values of -2log likelihood as well as the coefficient of determination according to Cox & Shell and the modified pseudo-R² according to Nagelkerkes as a measure of quality. This value shows how well the variance of the dependent variable of car avoidance can be explained by the independent variables of the four categories (Backhaus et al., 2018). The Cohen (1988) effect size can be calculated with the formula: $f^2 = R^2 / 1 - R^2$ and shows the significance of the coefficient of determination.

The output table contains information about the model, the eight independent variables, the estimated regression coefficient, the expected standard error, and the Wald test, odds ratios (OR), and confidence interval (CI) of 95 %. The results of the described analysis are included in Table 3 and the interpretation of the significant p value are formulated in the text.

The binary logistic regression model shows that the same can make a significant contribution to the variance explanation. (X² (8) = 369.973, p < .001, R² = 0.48, f² = 0.92). Accordingly, 48 % of the variance of the dependent variable can be explained by the model. According to Cohen, this value corresponds to a strong effect. The coefficients reflect that the nominally scaled dependent variable of car avoidance produces significant results. Accordingly, car trips could be saved through the measure, especially among subjects who used PT more frequently due to the Climate Ticket (Statement: 1). Subjects who will use the car more after the expiration of the Climate Ticket (Statement: 3) also show a negative and significant correlation to car avoidance. Further, the improvement of the attitude towards PT through the Climate Ticket (Statement: 6) shows a significant influence on reducing individual traffic.

An overview of all the significant expressions from the three survey waves shows that the individual surveys differ from each other and that waves 2 and 3 may have been influenced by the effects of the Covid-19-pandemic.

5.3. Mobility practices

In the model area of transport use, there is no significant influence on the evaluation of the measure due to the change in the use of cars, PT, and bicycles.

Nevertheless, the results of the survey indicate that the Climate

Ticket had a strong influence on Bonn area residents' mobility behavior. With the Climate Ticket, the mode choice behavior for MPT was just under 6 % in terms of daily use. When the Climate Ticket was discontinued, 29 % of those surveyed reported that they switched back to the car for daily use. The buyers of the Climate Ticket discontinued using PT after the expiration of the Climate Ticket approximately into their old MPT use.

The Climate Ticket caused a 44.5 % of test persons to use PT on a daily basis. After the ticket expired, the value dropped sharply to 9.5 %. The observations coincide, as with the MPT transport behavior. Upon expiration, the buyers tended to fall back into their old patterns or even reduced their use of PT. This suggests that at the time of the post-expiration observation, the Covid-19-pandemic caused PT to lose ridership severely, as they were detached from the Lead City project.

PT was used regularly during the initiative, which resulted in a modal shift that saved many car trips and mitigated CO₂ that would have been emitted. With regard to the use after the expiration of the Climate Ticket, it is evident that respondents will increasingly use their private cars again and that the ticket measure did not result in a lasting effect. Price is thus a decisive criterion for the choice of means of transport in our study.

The use of bicycles is relatively stable as a means of transport in the present study and is used by respondents only slightly more after the expiration of the ticket than beforehand. This finding might be related to the Covid-19-pandemic and respondents' desire to avoid contacts, meaning that the bicycle represents a suitable means of being healthy while mobile. Oftentimes, the bicycle is used to transport users from home to PT stations or on their last mile from the PT stop to their employer.

The Climate Ticket mainly appealed to occasional and infrequent riders. Only 5 % of the ticket users reported that they never used PT before the Climate Ticket and every second person already used PT several times a month before the ticket was offered. Thus, people who previously used PT on a daily basis mostly have a mobility flat rate such as tickets through their jobs, senior citizen cards, student cards, or monthly passes. From the user survey, one could therefore deduce the desire of respondents for an inexpensive season ticket with a limited number of trips, which is explicitly targeted at occasional riders.

The survey regarding the use of PT shows that a large number of users will not continue to use PT after the expiration of the Climate Ticket, but will increasingly resort to their cars (as they had done in the past). As many as 9 % of the users reported that they will continue to use PT after the end of the Climate Ticket.

6. Limitations

Our survey took place in three different waves with the last survey conducted during the Covid-19-pandemic. The pandemic and subsequent lockdown led to a reduced demand for public transport. Despite this, there was only a minor impact on our results and this was restricted to one individual case. In addition to the reduced demand for public transport, it was communicated that the climate ticket was coming to an end and would not be extended.

Following the pandemic and once contact restrictions were relaxed, passenger numbers have slowly returned to normal. The far-reaching consequences of the war in Ukraine, such as high inflation and the resulting loss of purchasing power, only materialised after the survey was completed.

It should also be noted that we focused on the 3430 Climate Ticket users in our survey. A total of 1315 complete questionnaires were included in the analysis.

7. Conclusions and implications for future research

An analysis of avoided car trips via the measure showed that this variable was influenced significantly by an increased use of PT, an

improved attitude towards the use of PT, as well as an increased use of the car after the Climate Ticket was discontinued in the Bonn area. For the period of our study, car trips on the main traffic axes facing driving bans could be reduced and nitrogen oxides could thus be saved.

In addition to financial resources, certain non-monetary factors are also relevant for the use of PT. The aim is to secure this shift over the long term through the means of high-quality PT and thus to drive forward the transport turnaround in the region. The federal city of Bonn has a modern PT network that can be designed for such an expansion. This fact should be evaluated in other cities' urban planning before such a project should be implemented. In addition to investment subsidies in the infrastructure for the expansion of the PT service, compensation for the reduced revenues compared to the standard fare was provided by way of federal subsidies.

The study has shown that such a ticket also appeals to people who have previously used their private car or not taken the bus or train. Thus, it is clear that low-cost, attractive PT is a driver for the necessary modal shift and helps reduce overall CO₂ emissions in jurisdictions in which it is implemented. In practice, however, it will be a question of financing. Politicians in Germany have recognized the need for a shift to environmentally friendly public transport and have stepped up their political efforts. After our study was completed, a temporary 9 € ticket was introduced throughout Germany to give existing MPT users the opportunity to try out public transport as an alternative. However, this public transport offer could only be financed for 3 months. After this ticket expired, it was decided to introduce a nationwide 49 € ticket. It remains to be seen how the mobility offer will be structured in the future. The findings of the present study can support the design of this nationwide climate/ transportation initiative. Due to the enormously high costs of mobility, it remains to be seen how long such a heavily subsidized public transport ticket can be made available to the general public. The German federal government sees a far-reaching shift to public transport use as essential to achieving the climate targets. However, current studies (e.g. Krämer et al., 2022) consider the price of the Deutschland Ticket to be too high and are critical of a comprehensive modal shift.

In the opinion of the study's authors, this is a forward-looking issue that is of the utmost social relevance. The Climate Ticket is considered to be very efficient but if it were to be continued, it would have to be set up under different conditions. It should be noted that our results refer to Bonn and the neighboring municipalities. A general replicability of the results to other cities, regions, or even countries would require a detailed consideration of all context-specific factors.

Our study highlights how the Climate Ticket has led to an increase in the attractiveness of public transport and thus a temporary modal shift towards public transport. The Climate Ticket was of particular interest to occasional and infrequent travellers. Essentially, users want public transport to remain affordable in the long term and do not consider the current standard fares of the transport association to be an adequate substitute. As a result, the original use of public transport was resumed following the abolition of the climate ticket. The results of our study in Bonn have implications for the future design of cost-effective and climate-friendly public transport. The recent challenges posed by the Covid-19-pandemic and the Ukraine crises have also had far-reaching consequences for the German population and are putting mobility behaviour to the test.

Following a ruling by the Federal Constitutional Court in November 2023, Germany has lost part of its financial planning and the federal government has been forced to make savings. The Deutschland-Ticket will certainly also be discussed against this backdrop. A permanent introduction does not seem feasible from a cost perspective. The findings of our study should be taken into account in the further design of future tickets.

CRedit authorship contribution statement

Andreas Hahn: Writing – original draft, Investigation, Formal

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

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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