Comparing municipal progress in implementing temporary cycle lanes during the Covid-19 pandemic

Ariane Kehlbacher*, Kerstin Stark, Laura Gebhardt, Julia Jarass, Julia Schuppan

DLR German Aerospace Center, Institute of Transport Research, Berlin, Germany

Abstract

This study investigates whether the Covid-19 pandemic opened a policy window of opportunity for the implementation of temporary cycle lanes, and how German municipalities differed in their implementation progress. The Multiple Streams Framework is used to guide the data analysis and interpretation of the results. A survey of staff working in German municipalities is conducted. The extent to which municipal administrations progressed in the implementation of temporary cycle lanes is estimated using a Bayesian sequential logit model. Our results show that of the administrations who responded to the survey most did not consider implementing temporary cycle lanes. The Covid-19 pandemic positively affected implementation progress of temporary cycle lanes, but only the first implementation stage, which was the decision to consider implementing this type of measure. Administrations are more likely to report progress if they already had plans for and experience with implementing active transport infrastructure and were located in areas with high population density.

Keywords: temporary cycle lanes, Covid-19, administration, Multiple Streams Framework, Bayesian sequential logit model

*Corresponding author: ariane.kehlbacher@dlr.de, DLR Institute of Transport Research, Rudower Chaussee 7, 12489 Berlin, Germany

1. Introduction

Walking and cycling play a key role in developing sustainable transport systems by reducing cost, noise, road traffic and emissions (Woodcock et al., 2009; WHO, 2018) whilst at the same time being affordable and providing health benefits (Kelly et al., 2014). For local administrations this means a redistribution of street space away from cars. In Germany, the promotion of active transport is an expressed goal at all political levels modes as part of the "mobility transition". However, the process of expanding active transport infrastructure is slow or stalling. As an example, as of yet the city state of Berlin has managed to build only a small percentage of the required 2,700 km of cycle lanes that should be completed by 2030 according to its Mobility Act (Sueddeutsche Zeitung, 2022; Changing Cities, 2023). The Covid-19 pandemic has shown that increasing active transport infrastructure can also increase society's resilience to disruptive events. During the pandemic, active transport measures (ATMs) were implemented at an unprecedented pace and level in cities all over the world. Cycle lanes were built in Bogotà and Paris, a provisional pedestrian zone was created in Brussels, temporary car-free streets and terraces for restaurants and social projects on former parking spaces were set up in Berlin (Jarass and von Schneidemesser, 2021). A reason for the construction of temporary cycle lanes was heightened demand for safe cycling and walking infrastructure as people avoided shared and public transport to lower their risk of infection (Abdullah et al., 2020; Kolarova et al., 2021). This mean that disruptive events like the Covid-19 pandemic can open a window of opportunity for a change in transport policies, something which this research investigates. The focus is on temporary cycle lanes, a type of provisional cycling infrastructure that is built on existing roads where riders are protected from car traffic through bollards or lines. They are used to extend existing cycle lanes or to create new ones, and can potentially become part of the permanent infrastructure, thereby making a long-lasting contribution to improving cycling infrastructure. This makes it important to better understand what drives the implementation of ATM during the Covid-19 pandemic. Understanding the effects of disruptive events on administrations' behaviour is also important to help administrations become more resilient to future pandemics or extreme weather events as the climate gets warmer.

This study uses the Covid-19 pandemic as an occasion to compare implementation progress of temporary cycle lanes in German municipalities. It thereby adds to the literature in several ways. Unlike previous research on ATMs and the Covid-19 pandemic, which uses qualitative methods and focuses on urban areas (e.g. Stark et al., 2021), this study delivers a more complete picture by including all types of areas and quantifying differences in implementation progress. Also, different to other studies on implementation progress like Weber (2017), it explicitly accounts for the sequential nature of the implementation progress by estimating a sequential logistic regression model. Uncertainty about model parameters is accounted for using Bayesian inference in the estimation of the model. Like Weber (2017), we use the Multiple Streams Framework (MSF) (Kingdon, 1995) as a theoretical framework to guide our analysis of administrative behaviour, thereby adding to the limited literature on the applicability of the MSF to transport policy implementation.

Our results show that the MSF is well suited to connect data on administrations' behaviour to general concepts explaining how transport policy implementation works. Different to predictions made by the MSF, we find no evidence of policy decision-makers influencing transport policy implementation at the municipal level. In line with the MSF, there is evidence of the Covid-19 pandemic opening a policy window of opportunity. Its effect is limited to the earliest implementation stage, so that overall most administrations ended up not implementing temporary cycle lanes. Having plans for and experience with measures to improve cycling infrastructure, as well as factors relating to population density are important to implementation progress. The implications are that temporary cycle lanes are unlikely to be a panacea for quicker active transport policy implementation, but administrations that are located in a conducive environment are more likely to at least consider their implementation.

2. Active transport measures and their determinants

This section briefly explains ATMs and factors that determine whether a municipality decides to implement them. There are long-term and short-term ATMs. Examples of long-term ATMs are complete streets policies, which require consideration of the needs of all transportation modes in street design and planning (Carlson et al., 2017), or land use planning policies that promote mixed-use developments, or infrastructure developments. Another example is the concept of the 15-minute-city, which highlights the idea that everyday activities should be reachable from every home within 15 minutes on foot or by bike. Examples of ATMs that can be implemented by communities at relatively short notice are bike and e-scooter sharing schemes, the integration of active transportation with public transport, or the creation of play streets or temporary cycling infrastructure.

From a policy perspective, there are soft and hard policies that can be used to support active transport. Soft policies focus on influencing individuals and changing habits using, for example, marketing, cycle training or special events. Hard policies involve measures such as signposting and safe cycle parking, but also changes to the infrastructure such as improved footpaths, substitution of car parking spaces with bicycle spaces and dedicated pedestrian or cycle lanes Magginas et al. (2019). Thus, temporary cycle lanes, which are the focus of this research, can be seen as part of a hard policy. As such, temporary ATM are a relatively new type of measure, which can both short- or long-term. They can be implemented for a limited amount of time or in provisional way, tested, adjusted and they can also be turned into permanent structures. Most of research on temporary ATMs is in relation temporary cycle lanes or "pop-up bike lanes". They became popular during the Covid-19 pandemic and their impact on mobility behaviour has been investigated. For example, Kraus and Koch (2021) look at the impact of the introduction of temporary cycle lanes during the Covid-19 pandemic on cycling traffic in 106 European cities. They find that within four months, an average of 11.5 km of provisional pop-up cycle lanes were built per city and that this ATM increased cycling by between 11 and 48% on average. This suggests that temporary bike lanes can lead to a substantial rise in cycling, which makes them interesting to municipalities wishing to increase cycling.

Looking at different factors that are important to the implementation of ATMs, evidence suggests that success depends on support or opposition by policy experts and interest groups. According to Baumann and White (2012) there are typically two stakeholder groups that may try to influence policy outcomes: those who prioritise values such as material growth and individual freedom and often support motorised road transport and those who prioritise values such as environmental health and social equity and often support active and public transport solutions. Baumann and White (2012) identify potential mechanisms in which these two groups affect policy change such as a shift in stakeholder perceptions, the identification of a lowest common denominator or a shift in the amounts of influence that groups have on policy making. This means that when considering the implementation of ATMs, it is important to consider the influence of interest groups or other stakeholders and whether or not they are supportive of this type of measure.

ATMs are more commonly implemented in more densely populated spaces. The extent to which this is driven by demand or supply side factor is difficult to establish, but correlations can be observed. Feuillet et al. (2015) find that relationships between the environment and walking or cycling for commuting purposes vary spatially. Weber (2017) finds that populous cities in the US are more likely to have considered and implemented bicycle facilities. Saelens et al. (2003) find that neighbourhoods with higher population density, greater connectivity, and more land use mix report higher rates of walking or cycling for utilitarian purposes than low-density, poorly connected, and single land use neighbourhoods. Moreover, urban design and quality of the urban environment can influence the use of active transport modes as they tend to move slower than public transport or cars and are more in physical contact with their surroundings. For example, Cao et al. (2009) find that in northern California, people walk more often or ride a bike if the living environment is well-groomed, attractive with varied buildings and green streets. Busy roads, on the other hand, reduce the quality of stay, so that consequently fewer distances are covered on foot (Cao et al., 2006). This highlights that both socio-economic as well as spatial differences need to be considered when investigating differences in municipalities' implementation of ATMs.

There is a recognition that in addition to political and structural factors, mobility culture may influence the extent to which active transport modes are used in a given municipality. The term mobility culture refers to the collective values, beliefs, behaviours, and attitudes of a community towards transportation and mobility. Bamberg et al. (2020) conceptualise mobility culture as injunctive normative beliefs that comprise the priorities of a local transport system and are acquired through communication within social networks. Accordingly, Bamberg et al. (2020) suggest differences in mobility culture as a possible explanation for why two similar, neighbouring cities may have very different transport systems and mobility patterns. It is likely that mobility culture influences policymakers, urban planners, and local administrations when deciding if and what type of ATM to implement.

Lastly, administrations themselves may influence ATM implementation. For example, Sowa and Selden (2003) finds evidence of administrations' discretion in determining appropriate policy implementation behaviour, which is why the prevailing perceptions of and views on temporary ATMs need to be considered when analysing their implementation.

3. Theoretical Framework

This study applies the MSF by Kingdon (1995) as an organising concept when analysing differences in temporary bicycle infrastructure implementation progress between German municipalities during the focusing event that is the Covid-19 pandemic. It is therefore different to Weber (2017) who focuses on agenda setting and decision-making in his application of the MSF to cycling policy making. In the MSF, "problem stream" refers to conditions that are non-ideal and draw attention from policymakers. Problems rise to attention due to changes in indicators, previous policies failing to improve indicators, or a focusing events. The problem of insufficient cycling infrastructure was known to German policy makers prior to the pandemic as reflected in discussions on the stalling of the "mobility transition". The question is whether the Covid-19 pandemic opened a "window of opportunity", that made the implementation of cycling policy measures more likely. In the MSF a "window of opportunity" is a limited time period during which a policy is more likely to be adopted given that the problem receives sufficient attention from policymakers, a policy solution is feasible, and politics are amenable to change. During the pandemic, parts of the German public as well as some politicians advocated for more and safe cycling lanes. This was in response to increasing numbers of people avoiding public transportation, which was associated with a higher risk of infection. Instead of people switching to cars, they would be provided with a safe cycling infrastructure that is also attractive to less experienced cyclists. Thus, a "window of opportunity" opened in the "politics stream", which refers to legislators and administrators who have their own ideas and preferences whilst making decisions based on solutions developed in the "policy stream". The latter refers to competing policy interpretations (Fowler, 2021) or ideas that are debated and evaluated by experts in terms of their technical feasibility, value acceptability, or visibility. An example is the notion to build temporary cycling infrastructure so as to increase space for cycling at short notice, which was seen as being in principal technically feasible and politically acceptable. As a result, "policy entrepreneurs" in German municipalities, as actors who couple streams together while a policy window is open, adopted the view that the creation of temporary cycling infrastructure helps address the problem of insufficient, climate friendly transport infrastructure. Their views were enacted by "implementers" which Fowler (2021) describes as "a swath of people with some capacity to impact policy outputs through public service delivery". Like policy entrepreneurs, implementers' interpretation of policies constitutes the norms of policies in practice where ideas translate into action. Policy entrepreneurs therefore attempt to influence the implementers' interpretations, something which is also investigated in this study.

4. Survey Design

The survey design draws on the MSF, literature on ATM implementation and on information obtained from an expert interview study, which was conducted by the authors during the Covid-19 pandemic. Its aim was to investigate how transport and urban planning measures changed during the pandemic and whether temporary measures were seen to offer potential to accelerate the mobility transition. The results can be found in Stark et al. (2021).

Self-reported progress in implementing temporary cycle lanes in a given municipality has a sequential nature. It is measured using a 5-point Likert scale. Its levels are "not considered", "considered, but not investigated", "investigated, but not implemented", "implementation started", and "implementation completed". The decision to assign these stages is based on knowledge gained during the expert interviews in Stark et al. (2021). They suggest that implementation progress often stalls for differing reasons at different stages. For example, a lack of interest is expected to result in implementation not being considered, whereas a lack of street space is expected to result in the measure being investigated, but not implemented.

In addition to the dependent variable for implementation progress, we include five sets of covariates in the model. Their summary statistics are reported in Table 2. First, we expect spatial or structural differences to be important in explaining differences in implementation progress. For example, municipalities in urban regions and/or in city states like Hamburg or Berlin, may find it easier to reallocate street space to cycling than municipalities in rural areas do. We therefore include state level and RegioStaR7 (BMDV, 2022) level group effects. The latter groups municipalities in Germany into seven categories according to their spatial and urban development characteristics and captures differences in the centrality and size of cities and towns in terms of infrastructure.

Second, we expect the socio-economic environment of a municipal district to play a role because of the demand for cycling that it can create, but also the supply of cycling infrastructure. For example, municipalities in less densely populated regions, are less likely to have experienced public demand for better cycling infrastructure in the past, which is why they may be less disposed to implement cycling measures also during the Covid-19 pandemic. Or, municipalities in more densely populated areas may have more resources to allocate to building cycling infrastructure. To approximate these differences, we include population density as a covariate. This is in line with Saelens et al. (2003) who identify it as an important determinant of active transport mode usage. We also considered including car density and degree of urbanisation as covariates, but both variables are highly correlated with population density. The data on population density are obtained from the German Statistics Agency German Federal Statistical Office (2019). They are mean-centred in the model to facilitate interpretation of the categorical variables in the model.

Third, the administrative environment in which a municipality operates can facilitate or hinder its implementation of cycling infrastructure. We assume that a municipality with an existing well-developed cycling infrastructure, is a sign of its administrative environment being conducive to the implementation of temporary bike lanes during the pandemic. Similarly, the PRESTO guidance distinguishes between "Starter", "Climber" and "Champion" cities to account for differences in the initial preconditions (Dufour, 2010). Expertise and experience in building cycling infrastructure are more likely to be present if this has been done in the past. Because it is difficult to measure existing cycling infrastructure at a municipal level, the survey includes statements on the perceived need for additional and quality of cycling infrastructure prior to the pandemic. The survey also asks which mode of transport respondents most strongly associate with their municipality. This is intended to measure the prevailing "mobility culture" (Bamberg et al., 2020), which as explained above, is the perceived consensus of a community what priorities should guide the design and further development of the local transport system.

Fourth, the political environment may influence how responsive administrations were to demands for increased cycling infrastructure during the Covid-19 pandemic. If cycling aligns well with governing political parties' overall agenda, it is expected that implementation of temporary bike lanes is more likely. The "political environment" in our study corresponds to the policy and politics streams in the MSF, which are predicted to influence policy agenda-setting and implementation. Relevant covariates include questions on whether the implementation of the "mobility transition" is perceived as being a priority for policy makers, and whether and in what direction political parties and interest groups are perceived to have influenced ATM policy decision-making. The survey also asked about the perceived influence of the public and whether it seems to be in favour of cycling measures, but both variables were highly correlated with the respective questions on the influence of interest groups, which is why they were omitted from the final model specification.

Fifth, temporary ATMs were little known in Germany prior to the Covid-

19 pandemic and their implementation was often demanded by pro-cycling activist groups, which may have influenced how they were perceived by municipal staff. The expert interviews that we conducted as part of Stark et al. (2021) also suggested that administrators' views and perceptions of temporary ATMs can affect to what extent administrative personnel engage with these measures. This is in line with predictions by the MSF. According to Fowler (2019), implementers can have "problematic preferences" which may affect their work. Accordingly, the survey asks for the perceived benefits of temporary ATMs. Since these measures were largely unknown at the time of the survey, we see responses to this question as an indication how favourably temporary ATMS are perceived by respondents. Concretely, respondents were asked if temporary ATMs are perceived as beneficial, and if their implementation is expected to require a lot of resources. The survey also asks if there are plans to have the temporary ATMs become part of the permanent cycling infrastructure. We would expect that municipalities who respond yes to this question have made bigger efforts to successfully complete the implementation process. It is important to note that the survey questions do not differentiate between walking in cycling when talking of ATMs. However, this seems reasonable as all active transport modes require the reduction or absence of motorised transport as a precondition (Cao et al., 2006).

Finally, addressing our research question on the effects of the Covid-19 pandemic on administrative behaviour, the survey asks whether the Covid-19 pandemic created additional demand for cycling infrastructure. Also, based on the notion of a policy window in the MSF, the survey asks whether the Covid-19 pandemic opened a window of opportunity for the implementation of temporary ATMs. Our assumption is that those municipalities that agree with this statement, will report higher levels of implementation progress, as they are more likely to have experienced support from actors representing politics, policy or problem stream.

5. Data

Data collection took place from January to March 2021. Circa 5,000 emails containing a link to the online survey were sent out to publicly available email addresses of German municipalities. In total, 382 individuals completed the survey. After removing incomplete responses, the sample size is $N = 230$. Looking at who responded, 169 persons (85%) are part of the administration and 30 persons (15%) consider themselves to be part of the political leadership. In total, 59% of respondents state that they have managerial authority; out of those 37% are responsible for 10 or less members of staff, 45% are responsible for 11 to 50 members of staff and 17% are responsible for 51 to 300 members of staff. One person is responsible for 2,800 members of staff. In terms of field of work, 69% of respondents are responsible for cycling in their municipality, 47% are involved in traffic management and 54% in urban development.

The distribution of responses to the question on implementation progress ranges from "not considered" (n=157), "considered, but not investigated" (n=23), to "investigated, but not implemented" (n=24), "implementation started" (n=10), and to "implementation completed" (n=16). Table 1 reports responses to selected survey items by implementation stage. Overall, it is apparent that most municipalities did not consider implementing temporary cycling infrastructure. At lower levels of implementation there is no difference in the proportion of those who see the mobility transition as an important policy goal and those who do not. But at higher implementation stages the proportion of municipalities that see the mobility transition as an important policy goal is slightly higher. Regarding the need for ATM before the Covid-19 pandemic, the proportion of those who state no need, is consistently higher than that of those who report a need. Regarding mobility culture, which is approximated by the question about which transport mode is most associated with the municipality, we find that the proportion of car is always larger than that of bike, but the difference decreases at as municipality report to have reached higher implementation stages.

To check the representativeness of our data, we compare our sample to rep-

implementation stage	mobility trans. is priority	%	need for ATM before Covid-19	%	mobility culture*	%
not considered	no	34.9	no	59.2	bike	5.5
	yes	32.7	yes	14.0	car	62.1
considered, but not investigated	no	4.8	no	7.7	bike	1.5
	yes	4.8	yes	3.3	car	7.0
investigated, but not implemented	no	2.6	no	6.3	bike	2.2
	yes	7.7	yes	4.8	car	7.4
implementation started	no	1.8	no	3.3	bike	0.7
	yes	3.7	yes	2.6	car	3.3
implementation completed	no	1.1	no	4.4	bike	2.9
	yes	5.9	yes	2.9	car	2.6

Table 1: Proportion of responses to selected survey items by implementation stage.
*depicts only responses for car and bike, other options were walking and public transport

resentative data in terms of RegioStaR7 membership (Figure 1) and federal state membership (Figure 2). In our sample, small urban towns are under-represented, and urban towns, cities and metropolises are over-represented. Towns in rural areas are also over-represented, whilst towns and cities in urban areas are under-represented. Looking at the sample distribution over states, we find that Bavaria and Saxony are over-represented, as relatively more administrations in these states took part. On the other hand, Rhineland-Palatinate, which has a total of 2,303 municipalities and is second highest number of municipal districts in Germany, is under represented. By design, the number of municipalities in city states like Bremen, Hamburg and Berlin is very small, so only few observations arose for Berlin and none for Bremen and Hamburg. The fact that administrations in some states or regions are over- or under-represented in our sample highlight the importance of including variables capturing state and regional difference in our model specification to ensure that valid inferences can be made.

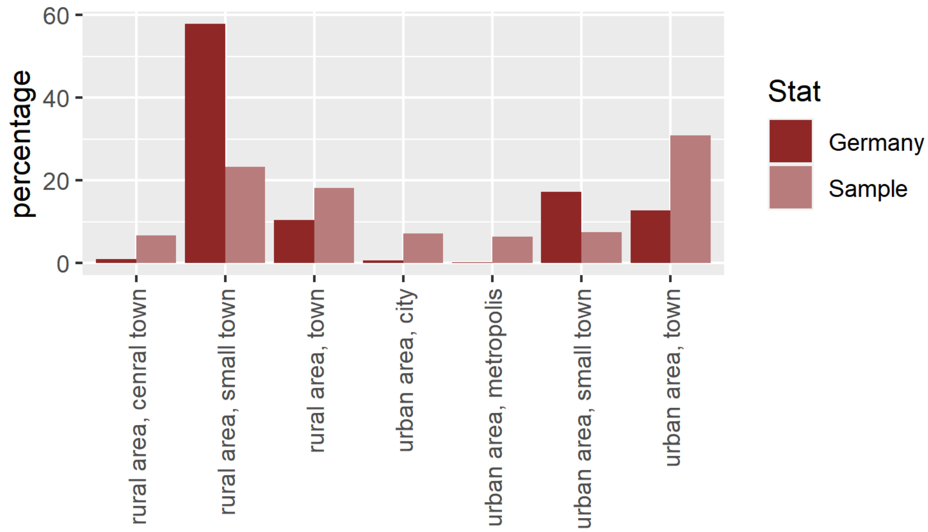

Figure 1: Comparing our sample distribution of RegiostaR7 to representative data (Federal Ministry for Digital and Transport, 2020)

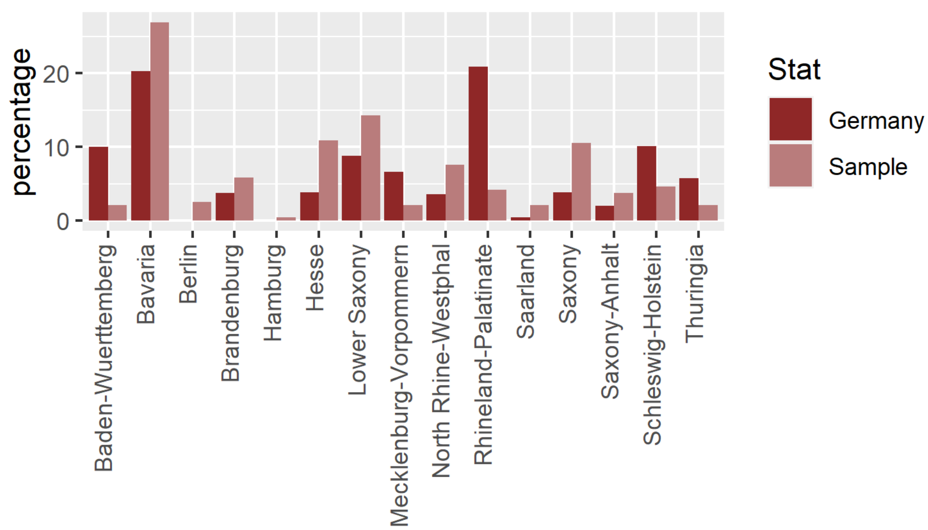

Figure 2: Comparing our sample distribution of states to representative data (German Federal Statistical Office, 2019)

Type	covariate	median	mean	std.dev.
socio-economic env.	population density (1000 pers./km^2)	0.33	0.65	0.92
administrative env.	cycling strongly associated with municipality (yes=1/no=0)	0	0.11	0.31
	need for ATM before Covid-19 (high=1/low=0)	1	0.90	0.30
	quality of cycling infrstr. before Covid-19 (good=1/poor=0)	0	0.27	0.45
political env.	mobility transition is priority (yes=1/no=0)	1	0.56	0.50
	infl. of political parties on ATM decision-making (high=1/low=0)	1	0.80	0.40
	political parties in favour of ATM (yes=1/no=0)	1	0.86	0.35
	infl. of interest groups on ATM decision-making (high=1/low=0)	1	0.90	0.30
	interest groups in favour of ATM (yes=1/no=0)	1	0.93	0.25
temporary measures	benefits of temporary ATMs overestimated (yes=1/no=0)	0	0.22	0.42
	temporary ATMs made permanent (yes=1/no=0)	0	0.18	0.39
	temp. cycling infrastructure is resource intensive (yes=1/no=0)	0	0.21	0.41
Covid-19 pandemic	Covid-19 increased need for cycling infrstr. (yes=1/no=0)	0	0.26	0.44
	Covid-19 opened window of opp. for ATM (yes=1/no=0)	0	0.44	0.50

Table 2: Summary statistics of covariates by group. ATM=active transport measures

6. Model specification and estimation

As outlined in section 4, information about an administration's progress in implementing temporary cycle lanes in its municipality is elicited via a 5-point Likert scale with categories "not considered" (1), "considered, but not investigated" (2), "investigated, but not implemented" (3), "implementation started" (4), and "implementation completed" (5). We specify a conditional ratio model (Cox, 1972; Agresti, 1984; Tutz, 1990) where at each stage an administration faces the binary choice between continuing or terminating the implementation process, provided that the decision to continue was made in all earlier stages. This is different to Weber (2017) who uses the cumulative logit model with 7-point Likert scale data ranging from "no consideration" to "substantial implementation". In this type of model, the probability of reaching a given category is unconditional of the probability of reaching previous categories. Instead, the conditional ratio model accounts for the fact that an administration can only get to the next implementation stage if the preceding implementation stages have been reached. Because of specifying progress as a sequence of binary choices, the model allows for covariates to have varying levels of association at different stages. This is done for variables relating to the Covid-19 pandemic the effect of which is the focus of this research. For every category k of implementation there is a latent continuous variable y^*_{isrk} that determines the transition between the kth and the $k+1$th category of administration i in state s in RegiostaR7 region r. Categories are separated by threshold parameters τ_k. If $y^*_{isrk} > \tau_k$ the sequential process continues, otherwise it stops at stage k. The latent variable y^*_{isrk} can be interpreted as a continuous measure of the administration's preference for implementing temporary cycle lanes and specified as follows

$$\begin{aligned} y^*_{isrk} &= \eta_{isrk} + \varepsilon_{ik} \\ &= \alpha + \alpha_{s[i]} + \alpha_{r[i]} + \beta' x_i + \gamma_k z_i + \varepsilon_{ik} \end{aligned} \tag{1}$$

where α is the overall intercept, $\alpha_{s[i]}$ are state-level deviations from the intercept where $s[i]$ denotes the federal state s that administration i belongs to and $S = 14$ as Bremen and Hamburg have no data; $\alpha_{r[i]}$ are also regional deviations with $R = 7$ levels where $r[i]$ denotes the Regiostar7 region that administration i is located in. The varying intercepts capture differences in local conditions pertaining to federal state and RegiostaR7 regions and their variances in (3) and (4) therefore represent variation in implementation progress between states and RegiostaR7 regions beyond what is explained by variation in the covariates x_i and z_i. The parameter vector β captures constant-over-categories effects of x_i on the probability of continuing the implementation process and includes covariates for the socio-economic, administrative and political environment, the perception of temporary measures and the Covid-19 pandemic as explained in section 4. The parameters γ_k capture category-specific effects of covariates in vector z_i. Because we are interested in whether the Covid-19 pandemic opened a window of opportunity, we estimate category-specific effects only for this variable. The error term ε_{ik} is distributed i.i.d. Extreme Value (EV). The likelihood of administration i falling into category k is equal to the probability of it not falling in any of the preceding categories 1 to $k - 1$, and when deciding whether to stop at k or to continue the administration decides to continue (see also Buerkner and Vuorre, 2019). Thus, the probability of the sequential implementation process to continue beyond category k is given by

$$Pr(y_{ik} = k|\eta) = (1 - F(\eta - \tau_k)) \prod_{j=1}^{k-1} F(\eta - \tau_j)) \tag{2}$$

where F is a logistic distribution, η is the set of parameters as defined in (1) and τ are threshold parameters. To obtain the joint posterior distribution of all parameters, which is our object of inference, we combine the likelihood in

(2) with the following prior distributions for each parameter

$$\alpha_{s[i]} \sim N(0, \sigma^2_{\alpha_s}) \; \forall \; s = 1, ..., S \tag{3}$$

$$\alpha_{r[i]} \sim N(0, \sigma^2_{\alpha_r}) \; \forall \; r = 1, ..., R \tag{4}$$

$$\beta \sim N(0, 5) \tag{5}$$

$$\tau_k \sim t(3, 0, 2.5) \tag{6}$$

$$\gamma_k \sim N(0, 5) \tag{7}$$

$$\sigma_s \sim t^+(3, 0, 2.5) \tag{8}$$

$$\sigma_r \sim t^+(3, 0, 2.5) \tag{9}$$

where the group standard deviation parameters σ_s and σ_r capture variation between states and RegiostaR7 regions, respectively. These parameters are restricted to be non-negative and have a half student-t prior with 3 degrees of freedom and a scale parameter that depends on the standard deviation of the response after applying the link function. Minimally, the scale parameter is 2.5. This prior is weakly informative in order to influence results as little as possible, while providing some regularisation to improve convergence and sampling efficiency (Buerkner, 2017). All group level parameters, α_s or α_r, share a standard deviation parameter, respectively. This way information on the group level intercept estimates is regularised meaning the estimate of one group's intercept is partially informed by estimates of other groups. This way, a group with few observation has its estimate "pulled" towards the mean based on information on other groups. This effectively weights down groups for which less information is available, whilst still allowing the estimation of all groups.

Estimation of the joint posterior distribution is done using RStan (Stan Development Team, 2021) via the R package brms version 2.16 (Buerkner, 2017). The model is estimated using Markov Chain Monte Carlo (MCMC) method with four independent Markov chains, with 5,000 warmup iterations and 5,000 sampling iterations each. To ensure that the sampler has converged, stationarity of the Markov chains is checked via the split potential scale reduction factor (Rhat), which measures the ratio of the average variance of samples within each of the four chains to the variance of the pooled samples across chains. A Rhat value of 1 indicates that the four chains for a parameter are comparable to each other and therefore have converged to the same level. The reliability of the estimates is further verified by looking at bulk and tail effective sample sizes, which when large indicate that estimates are reliable as they are based on a large number of independent samples from the posterior distribution.

Model comparison

Different model specifications are estimated with different sets of covariate blocks included as outlined in Table 2. Model fit is compared using Pareto smoothed importance sampling leave-one-out cross-validation (PSIS-LOO CV) (Vehtari et al., 2017, 2021), which we implement using the R package loo (Vehtari and Gelman, 2016). In Bayesian inference, model comparison is done using the posterior predictive distribution, which is given by

$$p(\tilde{y} \mid y) = \int_{\Theta} p(\tilde{y} \mid \theta)\, p(\theta \mid y)\, d\theta \tag{10}$$

where $\theta = \{\eta, \tau_k, \sigma_s, \sigma_r\}$. It is the distribution of future data, $\tilde{y}$, given the estimated posterior distribution, $p(\theta|y)$, which in turn is the result of the prior distributions in (3) to (9), the likelihood in (2), and observed data, y. To define a measure of predictive accuracy for the n observations, they are taken one at a time using leave-one-out (LOO) cross-validation (CV). The Bayesian LOO estimate of out-of-sample predictive fit, which is called the expected log predictive density (ELPD), is given by

$$ELPD = \sum_{i=1}^{n} \log\, p(y_i|y_{-i}) \tag{11}$$

where $p(y_i|y_{-i})$ is the leave-one-out predictive density given the data without the ith observation. Exact CV would require re-estimating the model with different data sets. Vehtari and Gelman (2016) show how approximate LOO-CV can be computed using Pareto smoothed importance sampling (PSIS) such that

$$\widehat{ELPD} = \sum_{i=1}^{n} \log \frac{\sum_{s=1}^{S} w_i^s p(y_i|\theta^s)}{\sum_{s=1}^{S} w_i^s} \tag{12}$$

where w_i^s is the importance weight of observation i at posterior draw s. The best model is the model with the highest ELPD because its predictions are the closest to the ones of the true data generating process. ELPD differences reported in Table 3 are computed by making pairwise comparisons between one model at the time and the preferred model that has the largest ELPD.

7. Results

The results of the comparison of different model specifications are reported in Table 3. It shows the posterior means of the parameters β and γ alongside the PSIS-LOO CV results. Differences in ELPD values are computed by making pairwise comparisons between each model and the model with the best ELPD. A negative value indicates that the expected predictive accuracy is higher for the best model. The most preferred model is $\mathcal{M}_5$. This is also the only model specification with category-specific effects specified for the variable "Covid-19 opened window of opp. for ATM", which are of particular interest in this research. The ELPD difference of zero for $\mathcal{M}_5$ arises because it is compared with itself. $\mathcal{M}_5$ is closely followed by $\mathcal{M}_3$ and given the standard error of the ELPD difference of 4.4, it could be argued that from the perspective of PSIS-LOO CV both models are indistinguishable. The fact that $\mathcal{M}_2$ is least preferred is notable. It means that there is no evidence to suggest that covariates related to the political environment help explaining differences in implementation progress of temporary cycle lanes.

The following inference is based on the results for $\mathcal{M}_5$. Estimates are reported in Table A1, which shows that potential scale reduction factors, Rhat,

	$\mathcal{M}_1$	$\mathcal{M}_2$	$\mathcal{M}_3$	$\mathcal{M}_4$	$\mathcal{M}_5$
population density (1000 pers. $/km^2$)	1.102 *	1.085 *	0.811*	0.803*	0.833*
cycling strongly associated	0.824 *	0.832 *	1.051*	1.065*	0.917*
needs for ATM before Covid-19	0.440	0.499	0.972*	0.959	0.973
quality of cycling infrstr. before Covid-19	0.082	-0.014	-0.135*	-0.134	-0.036
mobility transition is priority		0.374			
infl. of parties		0.370			
political parties in favour of ATM		0.942			
infl. of interest groups		1.598			
interest groups in favour of ATM		0.618			
pol.parties infl:in favour		0.156			
inter. group infl:in favour		-1.585			
temp. ATM benefits are overest.			1.527*	1.609*	1.607*
temp. ATM made permanent			1.641*	1.549*	1.681*
benefit overestimated:made permanent			-0.252	0.306	-0.263
temp. cycling infrastr. resource intensive			0.490	0.531	0.497
Covid-19 increased need for cycling infrstr.				0.021	0.034
Covid-19 opened window of opp. for ATM				0.478	
Covid-19 window[k=1]					1.261*
Covid-19 window[k=2]					-0.283
Covid-19 window[k=3]					-0.764
Covid-19 window[k=4]					-2.156*
ELPD difference	-13.3	-15.2	-0.7	-3.1	0.0
sd(ELPD difference)	7.7	8.5	4.4	4.7	0.0
Rank	4	5	2	3	1

*95% credible interval excludes zero

Table 3: Results of model comparison using PSIS LOO-CV as indicated by the ELDP difference from best model, and posterior means of parameters β and γ_k. ATM=active transport measures

are 1 for all parameters. This indicates that the MCMC estimation procedure has converged. Bulk and tail effective sample sizes (ESS) are large, indicating that estimates are reliable as they are based on large numbers of independent draws from the posterior distribution. Model fit is evaluated by plotting 100 draws from the posterior distribution against the smoothed data in Figure 3. It shows that the model generally predicts the data well, albeit

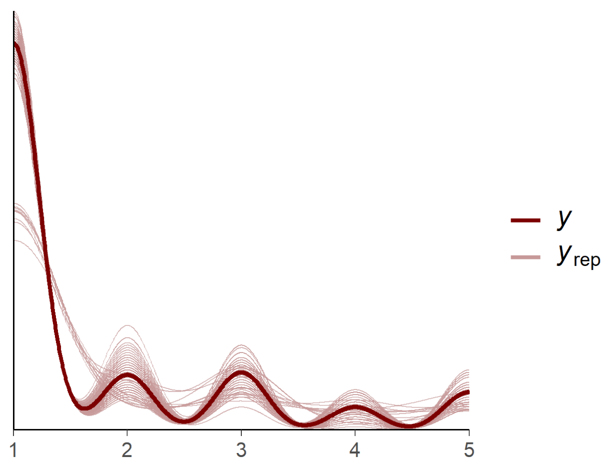

Figure 3: Plot of 100 samples from the posterior distribution (y_{rep}) against the smoothed data y.

with some uncertainty as would be expected given the small numbers of observations at higher implementation stages. Next, the posterior means of the hierarchical standard deviations of the random effects for federal states and RegioStaR7 regions are 0.7 (u-95% CI: 1.7) and 0.9 (u-95% CI: 1.6), respectively (see Table A1). The data are therefore consistent with both standard deviations having sizes of up to 1.6 and 1.7, respectively, which suggests that differences in implementation progress is to some extent associated with differences in unobserved state and RegioStaR7 specific factors. Estimates for the posterior means of the regional and state level effects are depicted in Figures 4 and reported in Table A2. The credible intervals provide 50% and 95% certainty that conditional on the data the estimated parameters' true values lies within these bounds. Figure 4 shows that whilst uncertainty is high, of the administrations who chose to participate in the survey, those in Lower Saxony and in North Rhine-Westphalia are more likely to report higher levels of implementation progress, while those in Thuringia are more likely to report to have made little progress. Looking at differences in terms of RegioStaR7, we find that of the administrations who chose to participate urban areas in towns are more likely to report higher implementation levels, whilst urban areas in cities tend to report less progress in the implementation of temporary cycle lanes. The effect of increases in population densities on

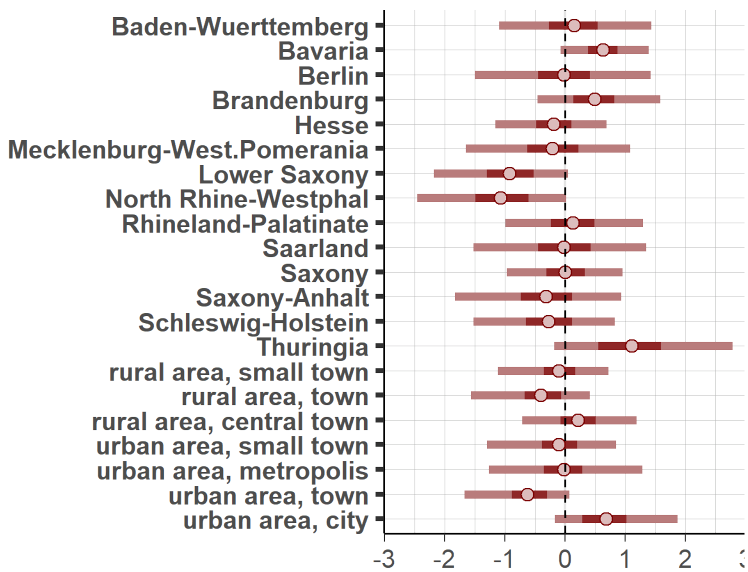

Figure 4: Posterior distributions of the parameters state and Regiostar7 level deviations, α_s and α_r, with means and 50% (dark red) and 95% (light red) credible intervals

predicted probability of making implementation progress is as expected positive (see Table A1). This means administrations that are located in areas with higher population densities are more likely to report of implementation progress.

Figure 5 shows the conditional effects of relevant covariates at each stage of the implementation process. They are obtained by computing for each variable the difference of the expected values of the posterior predictive distributions with the variable of interest set to 0 and 1, respectively. All other variables are set to 0, which implies that population density takes its mean value. To obtain conditional effects for Germany overall, we integrate over state and regional effects, thereby including uncertainty arising from differences in these factors in our conditional effect estimates. When interpreting these effects the reader is reminded that inferences can only be made in terms of comparisons between administrations. Nothing can be said about changes within administrations over time as causality cannot be established given the observational and cross-sectional nature of the data. Looking at the administrative environment, Figure 5 shows that administrations in municipalities where cycling first comes to mind (cycling assoc.) or where there was a need for active transport measures (need for ATM) prior to the pandemic, tend to report higher implementation progress, compared to municipalities where this is not the case. By contrast, differences in the quality of the existing active transport infrastructure (AIT quality high), make no difference in terms of predicted probability of implementation progress. When it comes to factors relating to temporary ATMs, we find that administrations who intend to make temporary cycle lanes permanent (permanent) are predicted to report higher levels of implementation progress, than those who do not intend to do so, although the effect size is uncertain. The same applies to administrations who believe that the benefits of temporary cycle lanes are overestimated (benef. overest.). Administrations who view the implementation of temporary cycle lanes as requiring a lot of resources (resource int.) are also predicted to have a higher probability of reporting more implementation progress, albeit to a lesser extent than it is the case of the two previously mentioned factors.

Looking at the effect of the Covid-19 pandemic, we find that differences in the need for extra active transport infrastructure due to the Covid-19 pandemic (C-19 demand) do not lead to differences in predicted implementation progress. This suggests that this factor is less relevant when a municipality decides to begin and continue the process of implementing temporary cycle

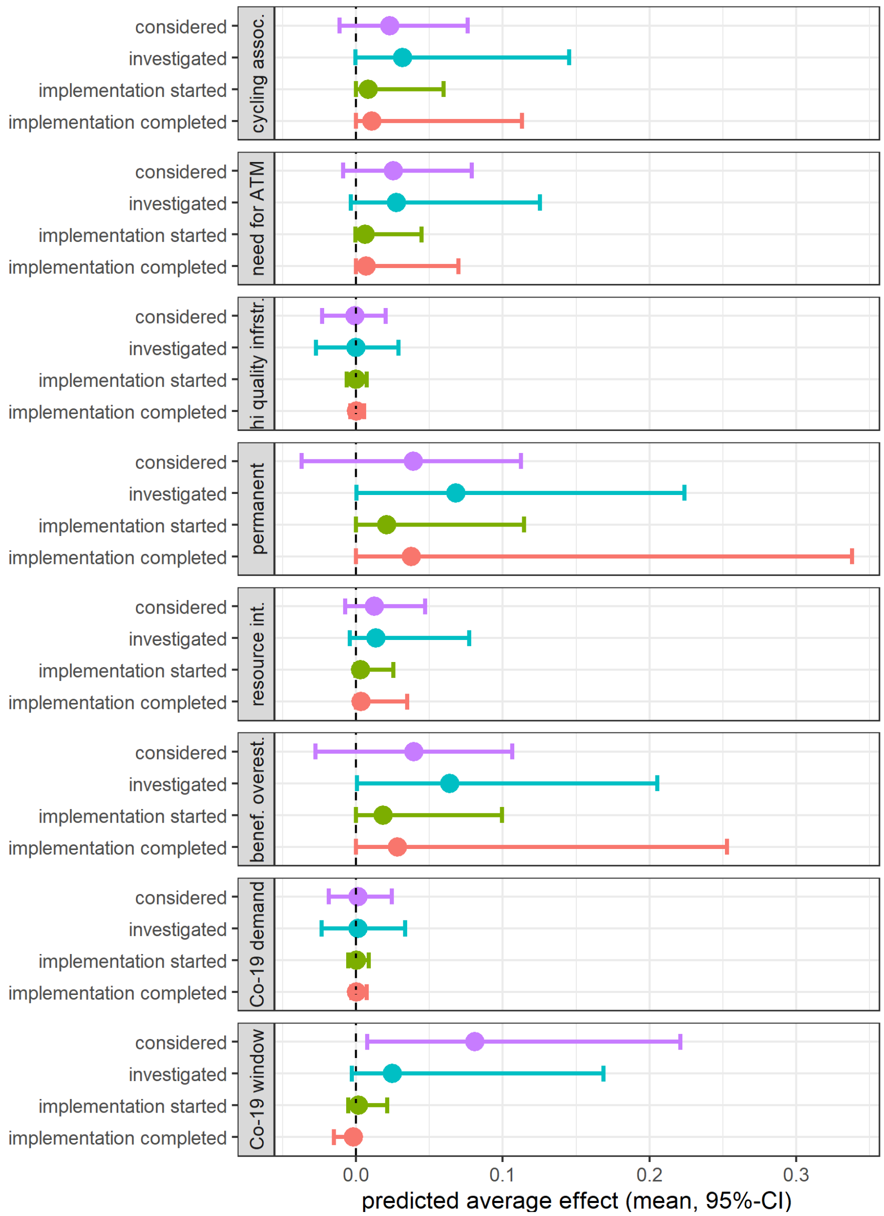

Figure 5: Estimated conditional effects (mean and 95%-CI) on the probability of administrations progressing with the implementation of temporary cycle lane

lanes. However, administrations who agreed with the statement that Covid-19 opened a window of opportunity for the implementation of temporary active transport infrastructure (C-19 window), are predicted to have made implementation progress with a higher probability than those who disagree. This applies in particular at the early stages of considering and investigating implementation. At the final stage, the effect of the Covid-19 pandemic opening a window of opportunity is negative as hardly any administration reported this level of implementation progress.

8. Discussion

This study compares German municipalities in terms of their decision to begin and continue implementing temporary cycle lanes during the Covid-19 pandemic in 2020/21. Overall, we find that the majority of administrations did not engage in the process of implementing temporary cycle lanes.

According to the MSF the Covid-19 pandemic is a focusing event, which opens a policy window to facilitate the implementation of ATMs. Based on media coverage during this time it could be argued that the Covid-19 pandemic increased public interest in cycling as a safe and healthy transport mode (Buehler and Pucher, 2021; BMDV, 2021). For example, bike sales in Germany were 17% higher in 2020 (5 mio.) compared to 2019 (4.3 mio.) (Federal Statistical Office of Germany, 2022). This could be taken as evidence of a window being opened in the problem stream. A window may also have opened in the policy stream as the concept of temporary infrastructures in the form of play-streets, gastro-streets and cycle lanes gained traction among German transport planners during the pandemic. Early adopters of these measures shared templates and guidance for the implementation of temporary cycle lanes with other municipalities via webinars or templates for planning rules (see e.g. Berlin Senate, 2022). The results of our data analysis also show some evidence that the Covid-19 pandemic opened a window of opportunity. Particularly at the first implementation stage, administrations who saw the Covid-19 pandemic as having opened a window of opportunity are more likely to report to have progressed, although there is some uncertainty about the effect size.

With regards to the politics stream, our analysis finds no evidence to suggest that differences in factors related to the political environment explain differences in predicted implementation progress. This includes variables capturing the self-reported perceived influence of interest groups and political parties. Weber (2017) looking at the influence of advocacy organisations, also finds no effect of the politics stream on cycling measure implementation levels in the US. Still, investigating the relationship between policy decision-makers and implementers is important. According to Fowler (2019), implementers may have "problematic preferences" due to uncertainty surrounding policy meanings and competing demands for attention or resources, which in turn may affect implementation. This study not finding any evidence of an association, may be an indication that the survey respondents experienced little to no political pressure, or that given the delicate nature of political influence, our approach of directly asking about it may have not have been appropriate. We therefore see potential for future research on this issue.

The conditional effect estimates show that when comparing two identical administrations, the one that intends to make temporary cycle lanes permanent is predicted to have progressed further in implementing temporary cycle lanes. This could be an indication that already before the Covid-19 pandemic the administration may have had drawn up plans and allocated resources for improvements in cycle infrastructure, which then helped making quicker implementation progress. It also suggests that temporary measures can act as a transition towards the creation of permanent cycle lanes. We also find that an administration that views the benefits of temporary active transport measures as overrated, is predicted to be more likely to have progressed further in their implementation. This seems counter-intuitive, as our expectation would be that on average a more negative perception of temporary ATMs is associated with less implementation process, and vice versa. This is based on the notion in the MSF that implementers' views affect implementation.

A potential explanation for this counter-intuitive finding is our failure to ask for information on prior experience with temporary ATMs in the survey. Administrations who made more implementation progress also have more knowledge about the potential effectiveness of ATMs. We assume that their experience taught them, that ATMs are not as effective as was proposed, for example, by advocacy groups at the start of the pandemic. This means that they would agree with the statement that the benefits of temporary ATMs are overestimated, whilst at the same time reporting a higher level of implementation progress.

Looking at the administrative environment, we find that municipalities with a mobility culture that supports cycling and municipalities with a need for better cycling infrastructure already prior to the Covid-19 pandemic made more implementation progress, compared to administrations where this is not the case. This may be an indication of path dependency in that past efforts or interest in cycling infrastructure makes it more likely that temporary cycling infrastructure is considered or implemented. Path dependence refers to a situation where past events or decisions constrain subsequent events or decisions (Arthur and Ausubel, 1988). Evidence of path dependence has been found in relation to the production of transport policies by Low and Astle (2009), and there is some evidence of path dependence in the context of transport policy implementation (Wright and Dia, 2019). Moreover, looking at differences in the socio-economic environment int terms of population density, municipalities with higher population density are more likely to report progress implementing temporary cycle lanes. This is in line with previous research. A potential explanation for this is that on the supply side higher population density may be associated with higher tax incomes or more road space that could be dedicated to cycling. On the demand side, more densely populated municipalities may face stronger pressure to improve their cycling infrastructure. Our result is in line with Weber (2017) who finds that populous cities in the US are more likely to have considered and implemented bicycle facilities. Thus, during the Covid-19 pandemic more densely populated areas were better equipped or more willing than their less densely populated counterparts to improve their bicycle infrastructure at short notice using novel measures such as temporary cycle lanes.

Overall, we conclude that the Covid-19 pandemic created an opportunity for administrations to consider implementing temporary cycle lanes. Progression beyond this stage is rare, but its likelihood increases, if administrations have a mobility culture centred around cycling, and/or plans to make temporary cycle lanes permanent and/or believe that the benefits of temporary ATMs are overestimated, which is a proxy for having experience with ATMs. Because it is central to our research question, our model specification investigates category-specific effects only in relation to the Covid-19 pandemic. Still, with a larger sample size, a more extended analysis of category-specific effects may help uncover which factors are important to different implementation progress stages.

Finally, considering the applicability of the MSF to transport policy implementation, our results, like those by Weber (2017) are mixed in terms of the uncovering relationships as hypothesised by the MSF. Predictions in relation to the window of opportunity are confirmed, albeit being limited to the first implementation stage. We notice the failure of covariates related to the political stream explaining differences in predicted municipal implementation progress. Also, our analysis is not able to establish any causal relationships, something which testing of the MSF presupposes.

Other limitations are as follows. First, the sample size for higher implementation stages is small, and therefore uncertainty of the estimates is high, our study may have concluded too early. Nine to eleven months after start of the pandemic may not have been enough for municipalities to have completed the installation of cycle lanes, even though they are only temporary. Our analysis does not allow to differentiate between administrations who failed to progress for other reasons from those who would have needed more time.

Second, willingness to participate in our survey cannot be assumed to be independent of temporary cycle lane implementation progress. Although 68% of administrations did not consider implementing temporary cycle lanes, it is likely that administrations with a particular interest in cycling were more inclined to respond to the survey. Our results therefore apply only to this subpopulation of administrations, and a bias in the estimated effects of factors that are conducive to the implementation process may be present. Third, the sequential logit model assumes independence of the errors across all binary choices. However, in particular in smaller municipalities it is likely that implementers are the same people in the same environment doing the implementation at all stages. Thus, the assumption does not hold in this instance. Another possible model would have been the nested logit model, which does allow for correlated errors between nests. However, an important drawback of the nested logit model in the context of this research is its assumption that at the point of decision-making all possible categories are considered simultaneously, something which clearly does not apply to the multi-stage process of implementing temporary cycle lanes in a municipality.

9. Conclusion

Little quantitative research exists that investigates transport policy implementation at the municipal level. This is despite the fact that municipal administrations play an important role in making the transport system more sustainable and affordable by delivering active transport infrastructure, and by contributing to the resilience of the system in the face of disruptive events. Overall, the majority of municipal administrations did not even consider implementing temporary cycle lanes. Municipalities located in more densely populated areas reached higher levels of implementation progress, highlighting the importance of local conditions to the creation of cycle lanes. This could be factors like a higher demand for cycling, more available road space or other factors associated with higher population density. More progress is also found if administrations have plans to convert the temporary infrastructure into a permanent one, or if administrations have experience with temporary ATMs. Different to predictions made by the MSF, there is no evidence of the Covid-19 pandemic being critical to overall implementation progress. The effect is limited to the first implementation stage, which is the decision to consider implementing ATMs. Thus, given the importance of local conditions and the limited overall effect of disruptive events on progress, the opportunities for a crisis to help overcome the inertia of usual municipal administrative processes is limited. Although, a disruptive event can make it more likely for temporary ATMSs, which constitute a type of trial and error approach to planning, to be at least considered. Other potential applications where temporary measures may become more important in the future are the creation of temporary green spaces during a heatwave, or the reassignment of parking spaces as recreational spaces. Similar to previous studies using the MSF, which find no evidence of policy decision-makers influencing implementers. More research on the inter-dependencies of implementers and democratically legitimised policymakers is needed, in particular on how to measure them. Overall, we find that the MSF is useful to be used in transportation policy research. It allows to systematically comparing the impacts of different disruptive events on transport policy implementation, such as energy price hikes, pandemics or heatwaves, in different contexts, which seems important given the increased likelihood of these events in the future.

We expect our results to be most applicable to other high income countries with high levels of car ownership and where cycling is relatively popular. According to Goel et al. (2022) Japan, Finland and Switzerland are similar to Germany in terms of their cycling mode shares, and according to Pucher and Buehler (2008) the Netherlands and Denmark are similar to Germany in terms of policies to support cycling, which is why our results may be most applicable to those countries.

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Appendix

Parameter	Estimate	Est.Error	l-95% CI	u-95% CI	Rhat	Bulk ESS	Tail ESS
Intercept[k=1]	3.135*	0.763	1.655	4.643	1.00	7045	6760
Intercept[k=2]	1.672	0.919	-0.118	3.476	1.00	7287	6025
Intercept[k=3]	3.249*	0.982	1.323	5.195	1.00	7816	6863
Intercept[k=4]	2.647*	1.09	0.483	4.797	1.00	7712	6723
population density (1000 pers. /km2)	0.833*	0.267	0.312	1.36	1.00	8298	7686
cycling strongly associated with municipality (yes=1/no=0)	0.917	0.491	-0.03	1.868	1.00	9178	8437
needs for ATM before Covid-19 (high=1/low=0)	0.973	0.574	-0.1	2.147	1.00	12697	6224
quality of cycling infrstr. before Covid-19 (good=1/poor=0)	-0.036	0.367	-0.76	0.684	1.00	11025	8058
temp. measures made permanent (yes=1/no=0)	-0.263	0.73	-1.654	1.168	1.00	10378	8315
temp. cycling infrastructure is resource intensive (yes=1/no=0)	0.497	0.356	-0.209	1.193	1.00	13908	7853
benefit of temporary measures is overestimated (yes=1/no=0)	1.607*	0.415	0.8	2.443	1.00	9296	7485
benefit overestimated:made permanent	1.681*	0.494	0.723	2.657	1.00	8064	7954
Covid-19 increased need for cycling infrstr. (yes=1/no=0)	0.034	0.351	-0.661	0.728	1.00	11211	7756
Covid-19 window[k=1]	1.261*	0.405	0.487	2.072	1.00	13646	7815
Covid-19 window[k=2]	-0.283	0.675	-1.613	1.009	1.00	9294	7375
Covid-19 window[k=3]	-0.764	0.786	-2.306	0.748	1.00	10852	7187
Covid-19 window[k=4]	-2.156*	1.089	-4.365	-0.078	1.00	9938	7631
sd(RegioStaR7)	0.706*	0.423	0.097	1.766	1.00	2616	2581
sd(State)	0.847*	0.33	0.32	1.609	1.00	3388	4994

Table A1: Posterior means, 95% credible intervals, Rhat and Bulk/Tail effective sample sizes (ESS) of parameters α, β, γ_k and σ for model $\mathcal{M}_5$

*95% Bayesian confidence interval excludes 0.

Parameter	Estimate	Est.Error	l-95% CI	u-95% CI	Rhat
Baden-Wuerttemberg	0.15	0.64	-1.10	1.44	1.00
Bavaria	0.63	0.38	-0.08	1.39	1.00
Berlin	-0.02	0.71	-1.50	1.42	1.00
Brandenburg	0.49	0.52	-0.45	1.58	1.00
Hesse	-0.19	0.47	-1.16	0.69	1.00
Mecklenburg-West.Pomerania	-0.21	0.68	-1.65	1.09	1.00
Lower Saxony	-0.93	0.58	-2.18	0.06	1.00
North Rhine-Westphal	-1.08	0.65	-2.46	0.02	1.00
Rhineland-Palatinate	0.13	0.57	-0.99	1.30	1.00
Saarland	-0.02	0.70	-1.52	1.35	1.00
Saxony	0.01	0.49	-0.97	0.96	1.00
Saxony-Anhalt	-0.32	0.69	-1.83	0.94	1.00
Schleswig-Holstein	-0.28	0.60	-1.52	0.83	1.00
Thuringia	1.11	0.77	-0.18	2.79	1.00
rural area, small town	0.11	0.46	-1.12	0.73	1.00
rural area, town	-0.40	0.49	-1.56	0.42	1.00
rural area, central town	0.22	0.48	-0.71	1.20	1.00
urban area, small town	-0.10	0.53	-1.30	0.86	1.00
urban area, metropolis	-0.02	0.61	-1.27	1.29	1.00
urban area, town	-0.62	0.46	-1.67	0.07	1.00
urban area, city	0.68	0.54	-0.17	1.87	1.00

Table A2: Posterior means, 95% credible intervals and Rhat of parameters α_r and α_s for model $\mathcal{M}_5$