

The causal effects of protected bike lane improvements on cycling behaviours: A quasi-experimental study in London, UK

Working paper

Dongsheng He¹, Nik Lomax¹, Ed Manley¹

1 School of Geography, University of Leeds

In submission to *Transportation Research Part A*

Abstract: Governments in different countries increasingly invest in protected bike lanes, yet credible causal evidence on their impacts remains limited. Using longitudinal Strava Metro data and a synthetic difference-in-differences (SDID) design, this study estimates the causal effects of four recently created protected bike lane projects on street-segment cycling activity in London, UK (2020–2025). To strengthen treatment–control comparability and reduce local contamination from diversion and spillovers, we construct donor pools from comparable main roads outside exclusion buffers around the interventions. Staggered SDID estimates indicate statistically significant post-intervention increases in recorded cycling activity (travelled distance) for three of the four projects, with project-specific effects ranging from 14% to 90% relative to synthetic controls. However, evidence on heterogeneous effects is inconsistent. Apart from age differences (18–34 vs. 35+), we find no consistent differential impacts by trip purpose, gender, or time of day across projects. Robustness checks support the validity of the Strava-based measures and the causal identification strategy. Overall, the findings suggest that expanding connected protected-lane networks can increase recorded cycling activity in a high-cycling city with a rapidly growing network, while impacts vary substantially across schemes and population groups.

Keywords: bike lane; cycling behaviour; causal inference; transport infrastructure; London;

1. Introduction

Cycling is an environmentally, socially and economically sustainable travel mode (Millard-Ball et al., 2025). Its benefits have drawn extensive attention recently, such as relieving overreliance on cars and reducing carbon emissions, increasing physical activity (Ding et al., 2024), and improving population-level health outcomes (e.g., lower risk of chronic diseases and mental health outcomes) (Oja et al., 2011; Schwarz et al., 2024). As a result, creating cycling-friendly cities has been widely advocated by policymakers and urban planners (Pucher et al., 2010). Protected bike lanes have become an important component of these investments because physical separation from motor traffic may improve both actual and perceived safety (Kraus & Koch, 2021). However, reallocating road space to protected bike lanes can be costly and

politically contested, particularly where schemes affect parking and motor vehicle capacity (Rein-Sapir & Hickman, 2026; Wild et al., 2018). Therefore, it is essential to understand the actual impact of bike infrastructure on cycling behaviours for both investment appraisal and scheme design.

The investment, design, and effects of bike lanes have attracted much attention. Several studies have investigated the association between bike infrastructure (e.g., bikeway networks) distribution, improvements in these networks, and cycling behaviours (Buehler & Dill, 2016; Hong et al., 2020). The common approach involves using survey data or cyclist counts to examine spatial variations in cycling behaviour in relation to bike lane proximity (Heesch et al., 2016; Skov-Petersen et al., 2017). Most of the cross-sectional evidence indicated a positive association between bike lane networks and a higher propensity to cycle (Parker et al., 2013). However, cross-sectional research designs limit their ability to provide compelling evidence. This limitation is primarily attributable to the difficulties in measuring cycling behaviours across large geographical areas over an extended period (Ito et al., 2024). Recently, crowdsourced cycling flow data have enabled the measurement of population-level changes in cycling activity, offering new opportunities to evaluate the longitudinal impacts of bicycle infrastructure (Kraus & Koch, 2021; Pellicer-Chenoll et al., 2025).

However, several limitations hinder the current understanding of the relationship between bike lane provision and cycling behaviours. First, cross-sectional research designs can only answer the question of the association between bike lane distributions and cycling behaviours (Winters et al., 2016). Such designs cannot address the cause-and-effect question (Goodman et al., 2013), as non-random infrastructure placement and people who prefer to cycle may intentionally choose to live near bike infrastructure, resulting in potentially spurious statistical associations (Heinen et al., 2018). To provide more solid evidence, recent studies have used longitudinal aggregated flow data to investigate the causal effects of bike lane improvement or installation on cycling behaviours (Pellicer-Chenoll et al., 2025). However, the challenge is that increased cycling activity on an improved corridor does not necessarily represent an equivalent increase in cycling across the wider area (Skov-Petersen et al., 2017). If the latter is the case, claims about the presumed benefits of bike lane investments should be interpreted more cautiously. Second, protected bike lanes have become the default design for new cycle infrastructure in the UK since the 2020s, implemented with either plastic wands or elevated kerbs to physically separate vehicles from cyclists. Despite the increase in protected bike lane interventions in the UK, there have been very few evaluations. The investment in protected bike lanes is much higher than painted ones, with 1 million pounds per kilometre (Taylor & Hiblin, 2017), necessitating the need for more rigorous impact assessment in project and investment appraisals. Third, the effects of protected bike lanes may also vary across cyclists and trip contexts. For instance, protected cycling environments may encourage females to cycle more. However, there is very limited evidence regarding the impacts of bike lane interventions across different sub-groups (Pellicer-Chenoll et al., 2025).

Using Strava Metro data and a synthetic difference-in-differences (SDID) design, this study estimates the causal effects of four protected bike lane interventions on recorded cycling distance in London, UK, from 2020 to 2025. The paper makes three contributions. First, it provides evidence on the causal impacts of protected bike lanes in a UK setting using a quasi-experimental design, where such infrastructure has expanded rapidly since the early 2020s. Second, it improves treatment–control comparability by constructing weighted synthetic controls from similar main road segments and by using exclusion buffers to reduce local contamination from diversion and spillovers. Third, it examines heterogeneous responses by trip purpose, cyclist characteristics (gender and age), and time of day, offering a more nuanced assessment of which groups benefit and when effects emerge.

2. Discussion

Protected bike lanes have become the default cycling intervention in the UK since the early 2020s, yet their real impact remains understudied. Using Strava Metro data, this study provides evidence of the causal effects of protected bike lanes on cycling uptake across four projects in London, UK. Overall, three of the four treated projects experienced statistically significant increases in recorded cycling travelled distance of Strava users, with average treatment effects ranging from 14% to 90% after the bike lanes opened. However, aside from age group (18–34 vs. 35+), we found no consistent differential effects by trip type (commute vs. non-commute), gender (male vs. female), or time of day (e.g., morning vs. evening) compared to the synthetic control groups across projects. Taken together, these results suggest that continuous networks of protected bike lanes can facilitate recorded cycling activity on Strava in London. However, heterogeneous treatment effects exist on different groups, and relying solely on infrastructure may not be sufficient to broaden participation of underrepresented cyclists.

Appraisals of the effects of bicycle infrastructure interventions matter, as they reflect the cost-effectiveness of the investment. Displacement in cycling flow data can bias impact estimates, and most of the observed increase in cycling on treated corridors is likely due to route diversion from nearby roads (Skov-Petersen et al., 2017). Using credible treatment–control comparisons, our results point to induced cycling activities of Strava users for most newly constructed bike lanes in London relative to their synthetic control groups. Although this study does not systematically identify the drivers of these project-level effects, we offer several plausible interpretations linking bike lane improvements to changes in cycling behaviour. First, scale may matter for short-term impacts. Except for C23, the other three projects include multiple segments delivered during the study period. Expanding a well-connected network, together with timely project delivery, may have contributed to their success. Second, C4 appears to have generated larger effects, potentially because it was implemented on a corridor with high baseline cycling demand and was followed by timely upgrades to the cycling environment within two to three years. Third, our findings underscore the importance

of network effects. Although not all segments of C9 received substantial physical upgrades during the study period, we still observed treatment effects after delivery, highlighting the role of area-level connectivity and network completeness.

This study also examines domain-specific treatment effects by trip type (e.g., commute vs. non-commute) and cyclist characteristics (e.g., gender and age), enabling a more nuanced understanding of behavioural responses to bike lane interventions. Our results show no consistent gender-specific treatment effects across four bike lane projects in London, UK. By contrast, recent studies suggest that protected bike lanes may encourage female cycling participation more than male cycling in Valencia, Spain (Pellicer-Chenoll et al., 2025). The possible explanation for the inconsistency was that London has higher baseline cycling activity and a more diverse population composition. Similarly, we find no consistent effects by trip type or time of day. These findings highlight the complex local contexts of London that shape varied treatment effects on different groups in varied regions. However, we observed higher increases in cycling activity among younger cyclists. The results suggest that protected bike lanes may not affect all groups in the same way and that local context may shape who changes more from a particular intervention, although we are not able to confirm whether the results can be generalised to broader projects.

Despite its contributions, this study has several limitations. First, we could not determine whether the induced cycling demand came from existing or new cyclists, limiting our ability to identify the complex mechanisms through which bike lane interventions affect cycling uptake. Second, the Strava dataset has limitations. Although we conducted validation tests to assess the association between Strava Metro data and official counter data and to calculate the capture rate, we acknowledge limitations in the representativeness of Strava users and potential capture rate variations across areas. Also, the data may be biased with respect to user composition (e.g., gender and age) and cycling trip purpose because they are either self-reported or inferred and may be missing for some activities. Consequently, more group-specific validation of the Strava trips is needed for future studies. Third, we have methodological limitations in estimating treatment effects. The intervention dates were identified at the quarterly level, which may introduce measurement error, particularly where schemes were implemented gradually or upgraded from temporary to permanent infrastructure. Furthermore, although the synthetic control strategy improves comparability and the exclusion zones reduce local contamination, the identifying assumptions may still be affected by wider network spillovers, concurrent transport interventions, and spatially heterogeneous changes.

This study offers several policy implications for bike lane interventions in the UK. First, our study suggested that recent investments in protected bike lanes can generate significant increases in recorded cycling uptake for Strava users in London. Given the potential benefits, these findings support continued investment in future delivery rounds. At the same time, policymakers should avoid assuming uniform benefits and consider scheme selection more carefully and prioritise corridors with strong latent demand and good network connectivity. Second, we did not find consistent evidence of

larger effects for women or older riders across projects. This suggests that protected lanes alone may be insufficient to broaden participation of underrepresented groups without complementary measures. Bike lane design should further prioritise the safety and needs of these vulnerable and underrepresented cyclists to generate more targeted benefits, such as segregation continuity and intersection design. Furthermore, monitoring of cycling flow should also extend beyond aggregate corridor counts to examine whether schemes broaden cycling participation across population groups.

3. Conclusion

Using Strava Metro data and synthetic difference-in-differences models, this study applies a quasi-experimental design to estimate the causal effects of protected bike lane interventions on cycling activity in London between 2020 and 2025. We find that cycling activity increased on most treated street segments after opening, with segment-level effects on average travelled distance ranging from 14% to 90% relative to synthetic controls. However, evidence of heterogeneous treatment effects is limited. Aside from age differences (18–34 vs. 35+), we do not observe consistent differences by trip type, gender, or time of day across projects. Overall, the results indicate that protected bike lanes can increase recorded cycling activity among Strava users in a high-cycling city with a rapidly expanding network like London. Future research should test the extent to which these findings generalise to other cities and what complementary measures are needed to broaden participation among underrepresented groups.

Reference

- Buehler, R., & Dill, J. (2016). Bikeway networks: A review of effects on cycling. *Transport reviews*, 36(1), 9-27.
- Ding, D., Luo, M., Infante, M. F. P., Gunn, L., Salvo, D., Zapata-Diomed, B., Smith, B., Bellew, W., Bauman, A., & Nau, T. (2024). The co-benefits of active travel interventions beyond physical activity: a systematic review. *The Lancet Planetary Health*, 8(10), e790-e803.
- Goodman, A., Panter, J., Sharp, S. J., & Ogilvie, D. (2013). Effectiveness and equity impacts of town-wide cycling initiatives in England: a longitudinal, controlled natural experimental study. *Social science & medicine*, 97, 228-237.
- Heesch, K. C., James, B., Washington, T. L., Zuniga, K., & Burke, M. (2016). Evaluation of the Veloway 1: A natural experiment of new bicycle infrastructure in Brisbane, Australia. *Journal of Transport & Health*, 3(3), 366-376.
- Heinen, E., Mackett, R., van Wee, B., Ogilvie, D., & Panter, J. (2018). Residential self-selection in quasi-experimental and natural experimental studies. *Journal of transport and land use*, 11(1), 939-959.
- Hong, J., McArthur, D. P., & Livingston, M. (2020). The evaluation of large cycling infrastructure investments in Glasgow using crowdsourced cycle data. *Transportation*, 47(6), 2859-2872.

- Ito, K., Bansal, P., & Biljecki, F. (2024). Examining the causal impacts of the built environment on cycling activities using time-series street view imagery. *Transportation research part A: policy and practice*, 190, 104286.
- Kraus, S., & Koch, N. (2021). Provisional COVID-19 infrastructure induces large, rapid increases in cycling. *Proceedings of the National Academy of Sciences*, 118(15), e2024399118.
- Millard-Ball, A., Reginald, M., Yusuf, Y., & Bian, C. (2025). Global health and climate benefits from walking and cycling infrastructure. *Proceedings of the National Academy of Sciences*, 122(24), e2422334122.
- Oja, P., Titze, S., Bauman, A., De Geus, B., Krenn, P., Reger-Nash, B., & Kohlberger, T. (2011). Health benefits of cycling: a systematic review. *Scandinavian journal of medicine & science in sports*, 21(4), 496-509.
- Parker, K. M., Rice, J., Gustat, J., Ruley, J., Spriggs, A., & Johnson, C. (2013). Effect of bike lane infrastructure improvements on ridership in one New Orleans neighborhood. *Annals of behavioral medicine*, 45(suppl_1), S101-S107.
- Pellicer-Chenoll, M., Antón-González, L., Villarrasa-Sapiña, I., Devís-Devís, J., González, L.-M., & Pans, M. (2025). Effects of building cycling infrastructure on bicycle use: Differences by gender through a longitudinal natural experiment study. *Research in Transportation Economics*, 110, 101531.
- Pucher, J., Dill, J., & Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: An international review. *Preventive medicine*, 50, S106-S125.
- Rein-Sapir, Y., & Hickman, R. (2026). Controversial cycle lanes: lessons from Cycleway C9, Chiswick High Road. *Journal of Environmental Policy & Planning*, 28(2), 307-325.
- Schwarz, E., Leroutier, M., De Nazelle, A., Quirion, P., & Jean, K. (2024). The untapped health and climate potential of cycling in France: a national assessment from individual travel data. *The Lancet Regional Health–Europe*, 39.
- Skov-Petersen, H., Jacobsen, J. B., Vedel, S. E., Alexander, S. N. T., & Rask, S. (2017). Effects of upgrading to cycle highways-An analysis of demand induction, use patterns and satisfaction before and after. *Journal of transport geography*, 64, 203-210.
- Taylor, I., & Hiblin, B. (2017). *Typical Costs of Cycling Interventions: Interim analysis of Cycle City Ambition schemes*
- Wild, K., Woodward, A., Field, A., & Macmillan, A. (2018). Beyond 'bikelash': Engaging with community opposition to cycle lanes. *Mobilities*, 13(4), 505-519.
- Winters, M., Teschke, K., Brauer, M., & Fuller, D. (2016). Bike Score®: Associations between urban bikeability and cycling behavior in 24 cities. *International journal of behavioral nutrition and physical activity*, 13(1), 18.