South American Publishing

SAP Transport, Mobility & Society. 2024;3:126
doi: 10.62486/tms2024126

ORIGINAL

Growth of mapped cycling infrastructure in Latin American capitals, 2014-2024

Crecimiento de la infraestructura ciclista mapeada en las capitales latinoamericanas, 2014-2024

Luis Alejandro Orocio Garza[1]
Carlos Alberto Gómez Cano[2]

[1] Instituto Técnico en Ciencias Computacionales de Reynosa A.C., Reynosa, México
[2] Corporación Universitaria de Asturias. Bogotá, Colombia

Submitted: 06-05-2024 | Revised: 03-07-2024 | Accepted: 11-09-2024 | Published: 15-09-2024

Corresponding Author: Carlos Alberto Gómez Cano

ABSTRACT

Introduction: Latin American capitals have expanded their cycling networks over the past decade, yet comparable longitudinal measures of that expansion remain scarce. OpenStreetMap history allows reconstruction of mapped cycling infrastructure at past dates. Methods: This ecological longitudinal study compared 20 Latin American capitals between 2014 and 2024. Mapped cycling infrastructure was measured with the ohsome API at 1 January of each year, and population with the United Nations World Urbanization Prospects 2018 revision. Growth was summarised with compound annual growth rates and provision in metres per 1,000 inhabitants. Results: Mapped infrastructure increased from 1,276.90 km in 2014 to 2,101.20 km in 2024, a pooled growth of 64.6%. The median city length rose from 6.20 to 23.20 km. Fifteen of 20 capitals grew, three declined and two remained essentially unmapped. Pooled provision rose from 13.80 to 20.10 m per 1,000 inhabitants. Conclusions: Mapped cycling infrastructure in Latin American capitals grew over the decade but was concentrated in a few cities. Apparent declines in three capitals are consistent with OpenStreetMap retagging rather than physical removal, which cautions against reading mapped length as a purely physical measure.

Keywords: bicycling; city planning; OpenStreetMap; Latin America; urban transport.

RESUMEN

Introducción: Las capitales latinoamericanas ampliaron sus redes ciclistas en la última década, pero faltan medidas longitudinales comparables de esa expansión. El historial de OpenStreetMap permite reconstruir la infraestructura ciclista mapeada en fechas pasadas. Métodos: Estudio ecológico longitudinal que comparó 20 capitales latinoamericanas entre 2014 y 2024. La infraestructura ciclista mapeada se midió con la API ohsome al 1 de enero de cada año y la población con la revisión 2018 de World Urbanization Prospects de Naciones Unidas. El crecimiento se resumió con tasas de crecimiento anual compuesto y provisión en metros por 1.000 habitantes. Resultados: La infraestructura mapeada aumentó de 1276,90 km en 2014 a 2101,20 km en 2024, un crecimiento agregado de 64,6%. La mediana por ciudad pasó de 6,20 a 23,20 km. Quince de 20 capitales crecieron, tres decrecieron y dos permanecieron prácticamente sin mapear. La provisión agregada subió de 13,80 a 20,10 m por 1.000 habitantes. Conclusiones: La infraestructura ciclista mapeada en las capitales latinoamericanas creció en la década, pero se concentró en pocas ciudades. Las caídas aparentes en tres capitales son compatibles con recambios de etiquetas en OpenStreetMap más que con remoción física, lo que advierte contra leer la longitud mapeada como una medida puramente física.

Palabras clave: ciclismo urbano; planificación urbana; OpenStreetMap; América Latina; transporte urbano.

© 2024; The Authors. This Open access article is distributed under CC BY 4.0 licence.

INTRODUCTION

Urban cycling has consolidated as a central component of transport policy in Latin American capitals. Bogotá built its first segregated cycle network in the late 1990s and later framed the bicycle as a democratic instrument of mobility, a position Epting(1)reconstructs as the Peñalosa principle.

Gomez et al.(2)documented how urban environment interventions, including cycleways, were promoted across the region as levers for physical activity.

Buenos Aires, Santiago, Mexico City and Bogotá have since announced successive network expansions, and Bogotá continues to combine hard infrastructure with commuting incentives.(3)

The rationale for these investments is documented beyond the region as well: Yang et al.(4) reviewed the association between built environment features and cycling behaviour, and Wali et al.(5)linked bicycle infrastructure to chronic disease risk at the ecological scale in the United States.

The length of cycling infrastructure became a headline indicator of progress for municipal governments and transport advocates alike, even though comparable figures for the region as a whole have been difficult to assemble. The pandemic then accelerated a second wave of interventions, as cities from Bogotá to Zapopan converted road space to temporary cycleways.(6)

Two positions structure the regional debate. The first holds that the measured expansion of cycle networks signals real progress toward active mobility, a reading that rests on network extensions being followed by rising ridership, as Macedo Filho and Cunquero(7)estimated for São Paulo.

The second position qualifies that reading: mapped length is distributed unevenly. Mora et al.(8)showed that cycleway accessibility in Santiago favours higher income areas, Parra et al.(9)

found the Bogotá network concentrated in higher socioeconomic strata, and Tiznado-Aitken et al.(10)argued that structural inequalities and weak quality standards limit the usable value of Latin American cycling infrastructure.

Torres-Barragan et al.(11)added that public representation of cycling safety in Bogotá is itself spatially skewed.

Perceptual studies reinforce the second position: Márquez et al.(12)showed that safety and theft risk shape infrastructure preferences in Colombia, and Márquez et al.(13)found that the characteristics of bike lanes condition the intention to use cycling as a feeder to bus rapid transit. These studies measure levels at one point in time, so the disagreement over progress turns partly on whether growth, not only the current stock, is also uneven.

Part of the reason the debate persists is that no common, longitudinal measure of infrastructure exists across the region. Official inventories use different definitions and appear irregularly, which frustrates cross city comparison and retrospective analysis. OpenStreetMap offers an alternative: a volunteer maintained, openly licensed road network whose edit history can be reconstructed at any past date.

Barrington-Leigh and Millard-Ball(14)estimated the global road network to be more than 80 percent complete, Herfort et al.(15)documented that completeness nonetheless varies systematically with city size and income, and Minghini and Frassinelli(16)showed that the version history of the map supports intrinsic quality assessment. This source has been used to measure pedestrian street provision across hundreds of cities,(17)to build national bicycle infrastructure inventories from open data,(18)and to monitor changes in bicycle volumes from crowdsourced traces.(19)

The decisive advantage for the present question is temporal: because the full edit history is stored, the same definition can be applied consistently to every year, which no administrative inventory of the region currently permits. The trade off is familiar from volunteered geographic information research: the map is extensive but heterogeneous, and its cycling tags depend on the conventions of local editors.(20,21)

Both properties matter for the present question: completeness determines whether a low value means little infrastructure or little mapping, and tag conventions determine whether the same label means the same thing across the twenty capitals.

What remains open is whether the mapped cycle networks of Latin American capitals actually grew over the last decade, how much of that change is real, and how the change compares with population.

This study aimed to quantify the length of mapped cycling infrastructure in 20 Latin American capitals between 2014 and 2024 and to express that length relative to population. National capitals were chosen because they concentrate the documented cycling programmes of the region and because their administrative boundaries are better represented in OpenStreetMap than those of secondary cities. The hypothesis, aligned with the equity critique, was that capitals with lower per capita provision in 2014 grew faster than those that already mapped more infrastructure.

METHODS

Design and period

An ecological longitudinal design compared 20 national capitals of Latin America across yearly snapshots from 2014 to 2024. The units of analysis were the capital cities, the outcome was the length of mapped cycling infrastructure, and the exposure was calendar time. The study used only public geospatial and demographic data, with no participants and no primary collection, and it followed the reporting logic of observational studies of routinely available data. The ecological level of analysis was chosen deliberately: the research question concerns cities as units, and the available open data do not support within city disaggregation for the full set of capitals.

Cities and inclusion criteria

All national capitals of Latin American countries were eligible if they had an OpenStreetMap administrative boundary and a population record in the United Nations World Urbanization Prospects 2018 revision. Twenty capitals met both criteria: Buenos Aires, La Paz, Brasília, Santiago, Bogotá, San José, Havana, Santo Domingo, Quito, San Salvador, Guatemala City, Tegucigalpa, Mexico City, Managua, Panama City, Asunción, Lima, Montevideo, Caracas and Port-au-Prince. No eligible capital was excluded. Each city was delimited by the bounding box of its administrative boundary obtained from the Nominatim geocoder of OpenStreetMap; the bounding box approximates the municipal area and can include adjacent territory in some cases, a limitation addressed in the discussion.

Data sources

Mapped cycling infrastructure was obtained from the ohsome API of the Heidelberg Institute for Geoinformation Technology, which computes aggregate statistics from the full OpenStreetMap history database.(22,23)The API rests on the OSHDB, a spatio temporal index of the complete edit history, so the state of the map can be reconstructed retrospectively without downloading the planet file. For each city, two queries were run at 1 January of each year from 2014 to 2024, yielding eleven yearly observations per city. Snapshots were taken at 1 January so that each year is measured at a fixed point of the map history and the two endpoints span a full decade.

The primary measure counted the length of ways tagged highway=cycleway or carrying one of the tags cycleway=lane, cycleway=track, cycleway=opposite_lane, cycleway=opposite_track or cycleway=shared_lane. This definition treats dedicated cycleways and on road cycle lanes together as mapped cycling infrastructure. The tag selection follows the convention used in open bicycle inventories, in which a dedicated cycleway is mapped as a highway=cycleway way and an on road lane as a cycleway tag on the carriageway; ways tagged highway=path with bicycle=designated were excluded because that combination is applied inconsistently and would blend cycleways with shared recreational paths.

A secondary measure counted the subset tagged highway=cycleway, interpreted as dedicated cycleways, and served as a sensitivity check against the on road lane tags. Because the construct is mapped infrastructure, differences across cities and years partly reflect mapping activity and tag conventions rather than built infrastructure, a distinction returned to when interpreting the declines. Ways that carry both a highway=cycleway tag and a cycleway lane tag are counted once, because the query evaluates way membership rather than tag combinations. The underlying geodata are distributed by OpenStreetMap contributors under the Open Database License,(24)and reuse requires attribution to those contributors.

City population was taken from the annual file of urban agglomerations with 300,000 inhabitants or more of the United Nations World Urbanization Prospects, 2018 revision.(25)Values for 2014 are estimates and values for 2024 are projections from that revision. The 2018 revision was preferred over later releases because it was published within the study window and still projects population to 2035, which avoids mixing map history with demographic data published after the period under study. Each capital was matched to its agglomeration by name and country, and population was expressed in thousands of inhabitants.

Variables

The outcome was expressed in kilometres. Absolute growth was computed as the difference between the 2024 and the 2014 length. The compound annual growth rate was computed as the tenth root of the ratio of the 2024 to the 2014 length, minus one, and is undefined for cities with a

zero baseline. Provision relative to population was expressed in metres of mapped infrastructure per 1,000 inhabitants, calculated as the length in metres divided by the population in thousands.

The two measures, total mapped infrastructure and dedicated cycleways, were kept separate because they respond to different tag conventions. The total includes on road lanes whose presence depends on whether mappers tag the carriageway, whereas the dedicated measure depends only on whether a way is classified as a cycleway. Divergence between the two therefore flags tagging artefacts rather than physical change, and the comparison between them was treated as a quality signal for the primary estimate.

Statistical analysis

Distributions were summarised with medians and interquartile ranges because city lengths were strongly right skewed. The pooled compound annual growth rate was computed from the sum of lengths across cities rather than from the mean of city rates, so that small capitals do not receive the same weight as large ones. Because the growth rate is undefined for a zero baseline, the median city rate was computed only over capitals with a positive 2014 length, while all capitals were retained in the length and provision summaries. Spearman rank correlation tested the association between per capita provision in 2014 and the 2014 to 2024 growth rate, and between length in 2024 and population in 2024.

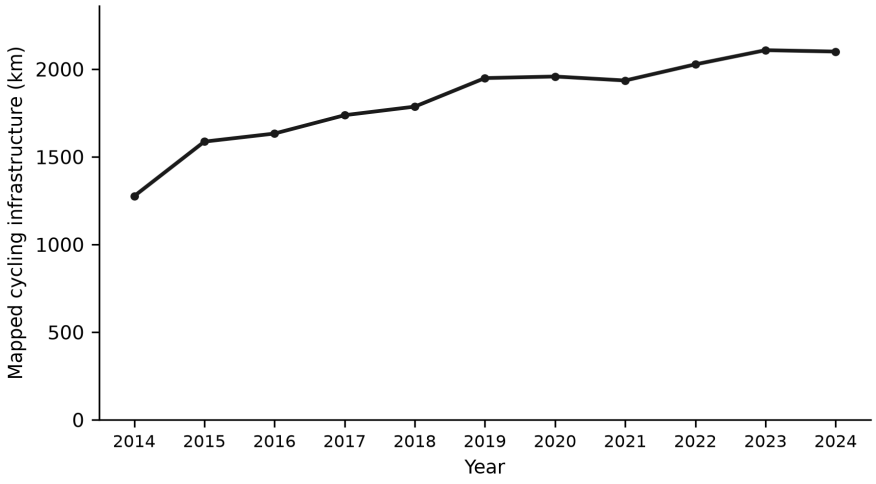
A two sided significance level of 0.05 was used, and correlations are reported with their p value because a confidence interval for a rank correlation on 20 units is wide and uninformative. No imputation was applied: cities with no mapped infrastructure were recorded as zero rather than dropped. The dedicated subset served as a sensitivity analysis: the pooled estimates were recomputed with the narrow definition and compared with the primary results to confirm that no conclusion depended on the on road lane tags. The Spearman coefficient was chosen over the Pearson coefficient because the length distributions were strongly skewed and contained zeros, which violates the assumptions of the parametric test.

RESULTS

Overall growth

Mapped cycling infrastructure in the 20 capitals increased from 1,276.90 km on 1 January 2014 to 2,101.20 km on 1 January 2024, a gain of 824.40 km (64.6%) (Figure 1). The pooled compound annual growth rate was 5.1 percent per year. The median capital held 6.20 km of mapped infrastructure in 2014 and 23.20 km in 2024, and the median city level growth rate was 7.3 percent per year, with an interquartile range of 0.9 to 12.7 percent. Fifteen of the 20 capitals (15) recorded a net increase over the decade.

Figure 1. Mapped cycling infrastructure in 20 Latin American capitals, 2014-2024.



Note: Sum of the length of ways tagged highway=cycleway or with a cycleway lane or track tag, measured at 1 January of each year.

The increase was front loaded rather than linear. The pooled network reached 1,587.60 km by 2015, and that initial jump already accounted for 37.7 percent of the decade's net gain. The series then dipped to 1,936.20 km in 2021, peaked at 2,109.10 km in 2023 and ended at 2,101.20 km in 2024. The annual increments after 2015 were small in relation to the initial jump, and the network stagnated around the years of the pandemic before a modest recovery.

Divergence across capitals

The expansion was concentrated in a few cities (Table 1). Bogotá held the longest mapped network in 2024 (562.70 km), ahead of Brasília (494.60 km) and Lima (309.10 km). Brasília recorded the largest absolute addition, 426.60 km, and Bogotá the second largest, 346.10 km. Asunción grew fastest in relative terms, at 36.8 percent per year, from 1.90 km in 2014 to 43.80 km in 2024.

Five capitals mapped no cycling infrastructure in 2014 (5) and grew from a zero baseline. Three capitals registered a net decline in mapped length: Quito fell −342 km (−9.0 percent per year), Buenos Aires −85.20 km (−7.7 percent per year) and Santiago −8.10 km. Managua and Port-au-Prince remained effectively without mapped infrastructure in both years. The three largest networks accounted for 65.0 percent of the pooled length in 2024, a smaller share than in 2014 (73.0 percent). Five capitals mapped more than 100 km in 2024(5), eight between 10 and 100 km (8) and seven 10 km or less(7). Of the 15 capitals with a positive baseline in 2014, 8 at least doubled their mapped length by 2024.

Trajectories of growth and decline

The leading capitals followed different paths. Bogotá grew steadily, from 274.60 km in 2016 to 431.80 km in 2020 and 562.70 km in 2024. Brasília expanded abruptly in the first two years, reaching 294.50 km by 2016, and then slowed. Lima grew continuously, passing 133.60 km in 2020. Among the declining capitals, Quito fell progressively across the decade, from 476.50 km in 2016 to 381.20 km in 2020.

Table 1. Mapped cycling infrastructure in 20 Latin American capitals, 2014 and 2024.

Capital	Length 2014 (km)	Length 2024 (km)	Change 2014-2024 (km)	CAGR (%/year)
Bogota	216.6	562.7	346.1	10.0
Brasilia	68.0	494.6	426.6	22.0
Lima	49.8	309.1	259.2	20.0
Quito	561.6	219.7	-342.0	-9.0
Mexico City	140.3	214.0	73.7	4.3
Buenos Aires	154.1	68.9	-85.2	-7.7
Montevideo	16.0	59.0	43.0	13.9
Asuncion	1.9	43.8	41.9	36.8
Santiago	39.5	31.4	-8.1	-2.3
Guatemala City	0.0	24.2	24.2	
Panama City	7.6	22.3	14.7	11.4
Havana	6.0	12.2	6.1	7.3
Caracas	4.9	11.7	6.8	9.2
Santo Domingo	6.4	8.7	2.3	3.1
San Jose	4.1	7.3	3.3	6.1
La Paz	0.0	6.5	6.5	
San Salvador	0.0	4.3	4.3	
Tegucigalpa	0.0	0.9	0.9	
Port-au-Prince	0.1	0.1	-0.0	-1.3
Managua	0.0	0.0	0.0	

Note: CAGR = compound annual growth rate 2014-2024. Empty cells indicate that the rate is not computable when the 2014 length is zero.

Buenos Aires rose to 173.90 km in 2016 before falling to 110.80 km in 2020, and Mexico City increased to 272 km in 2020 before falling to 214 km in 2024. Santiago fluctuated without a clear direction and ended close to its starting value. The intermediate capitals, Montevideo, Asunción and Panama City among them, expanded from low or moderate baselines and did so without the reversals seen in the larger declining cities.

Provision relative to population

Pooled provision rose from 13.80 to 20.10 metres per 1,000 inhabitants, an increase of 45.6% (Table 2), and the median capital rose from 3 to 5.30 m per 1,000. Quito retained the highest provision in 2024 (110.60 m per 1,000 inhabitants), followed by Brasília (100.20) and Bogotá (48.30). Five capitals exceeded 25 m per 1,000 inhabitants in 2024(5), and ten remained at 5 m or fewer per 1,000(10).

Provision increased in 15 capitals, decreased in 4 and did not change in 1. The correlation between provision in 2014 and the subsequent growth rate was negative and not statistically significant (rho = −0.13, p = 0.648), whereas longer mapped networks in 2024 were associated with larger populations (rho = 0.70, p = <0.001). Dedicated cycleways tagged highway=cycleway grew from 1,063.30 km in 2014 to 1,911.60 km in 2024, and their share of the mapped total rose from 83.3 to 91.0 percent. On road lane tags contributed a smaller proportion of the mapped stock in 2024 than in 2014.

Table 2. Mapped cycling infrastructure per 1,000 inhabitants in 20 Latin American capitals, 2014 and 2024.

Capital	Population 2014 (thousands)	Population 2024 (thousands)	Provision 2014 (m/1,000)	Provision 2024 (m/1,000)	Change (m/1,000)
Quito	1705.9	1986.7	329.2	110.6	-218.7
Brasilia	4072.4	4935.3	16.7	100.2	83.5
Bogota	9434.8	11658.2	23.0	48.3	25.3
Montevideo	1697.7	1781.4	9.4	33.1	23.7
Lima	9627.3	11361.9	5.2	27.2	22.0
Asuncion	2887.1	3568.8	0.7	12.3	11.6
Panama City	1637.9	2015.7	4.6	11.1	6.4
Mexico City	21093.5	22505.3	6.7	9.5	2.9
Guatemala City	2701.6	3159.6	0.0	7.6	7.6
Havana	2119.5	2152.5	2.8	5.6	2.8
San Jose	1277.5	1482.5	3.2	5.0	1.8
Santiago	6471.6	6951.0	6.1	4.5	-1.6
Buenos Aires	14619.5	15618.3	10.5	4.4	-6.1
Caracas	2915.2	2991.7	1.7	3.9	2.2
San Salvador	1096.5	1123.4	0.0	3.8	3.8
La Paz	1722.8	1965.6	0.0	3.3	3.3
Santo Domingo	2872.3	3587.4	2.2	2.4	0.2
Tegucigalpa	1192.4	1609.3	0.0	0.5	0.5
Port-au-Prince	2375.9	3060.2	0.0	0.0	-0.0
Managua	1019.5	1107.1	0.0	0.0	0.0

DISCUSSION

The mapped network of the region expanded over the decade, but the increase was slower and more concentrated than the growth narrative of Latin American cycling policy implies. The hypothesis of convergence was not confirmed: capitals that began with the lowest provision did not grow systematically faster, and three capitals recorded net declines. This reading contrasts with accounts that present network expansion as a uniform regional advance, and it extends the equity critique from the distribution of infrastructure at one point in time to the distribution of its growth. The finding that growth did not close the initial gap is the central result, because it answers the question that the equity literature poses.

The concentration of growth in Bogotá, Brasília and Lima is consistent with the association between network extension and ridership that Macedo Filho and Cunquero(7)estimated for São Paulo, and with interrupted time series evidence that new cycle infrastructure raises cycling levels in French cities.(26)

Rérat and Schmassmann(27)report a comparable pattern in Switzerland, where new infrastructure changed cycling practices but did so gradually and selectively. Bogotá, the leading capital in absolute length, has been described as combining infrastructure with commuting incentives, a pairing Márquez et al.(3)analyse for workplace trips.

The near zero baselines in the Central American capitals and the continued absence of mapping in Managua are consistent with the structural inequalities and institutional limitations that Tiznado-Aitken et al.(10)describe for the region, and with the opportunistic, pandemic era infrastructure documented in Zapopan.(6)

The concentration of provision also mirrors the equity evidence assembled for individual cities. Mora et al.(8)found cycleway accessibility in Santiago uneven, Parra et al.(9)found the Bogotá network concentrated in higher socioeconomic strata, and Torres-Barragan et al.(11)showed that the safety discourse around Bogotá is itself spatially skewed.

Barón(28)documents the same logic of priority setting in Mendoza, where observed and potential cyclist trips, rather than social need, guide the identification of cycle lanes. This study adds the longitudinal dimension: even where the stock grew, the growth accrued disproportionately to the cities that already led, so the gap between the leading capitals and the rest of the region widened rather than closed.

Even so, the declines in Quito, Buenos Aires and Santiago are unlikely to reflect physical removal. Minghini and Frassinelli(16)and Raifer et al.(22)show that volunteer editing and tag reclassification can shrink a mapped network without any change on the ground, and completeness varies with city size and income.(14,15)

Ferster et al.(18)and Vierø et al.(20)document the dependence of open bicycle inventories on tag conventions, and Harvey et al.(21)show that data sources classify bicycle infrastructure inconsistently.

The high share of dedicated cycleways in the mapped total indicates that the primary measure is dominated by a single tag, which makes the series sensitive to exactly the reclassification events that these studies describe. The gradual, decade long decline of Quito fits this reading better than any demolition scenario, and the oscillating path of Santiago points to repeated reclassification rather than to a single loss.

A further reason for caution is that part of the recorded growth is mapping catch up rather than construction. In cities where the map was sparse in 2014, the observed increase reflects both new infrastructure and the progressive recording of infrastructure that already existed, a distinction Herfort et al.(15)and Barrington-Leigh and Millard-Ball(14)document for the global archive, and one that Al-Ramini et al.(19)face when tracking bicycle volumes from crowdsourced traces.

The stagnation of the pooled series around 2021 is ambiguous for the same reason: the map cannot separate a pause in construction from a pause in mapping activity.(6)Any reading of the pooled curve therefore requires the caveat that the y axis measures recorded length, not built length.

The front loaded shape of the curve carries a further implication: a jump of the size recorded in the pooled series between 2014 and 2015 is difficult to attribute to construction, which proceeds more slowly, and easier to attribute to the retroactive mapping of networks that already existed, plausibly driven by organised import and mapping campaigns of the kind documented for other regions.(16)The slower increments that follow are closer to the pace at which infrastructure is actually delivered.

The association between mapped length and population was strong and positive, which is what demand driven network models predict. Paulsen and Rich(29,30)model welfare optimal bicycle networks in which investment follows density, and Bonsma-Fisher et al.(31)describe the equity efficiency trade off that planners face when allocating scarce infrastructure.

Cunha and Silva(32)and Zhao et al.(33)likewise show that allocation rules determine who benefits. In this light, the persistence of near zero provision in several capitals reflects the absence of mapping, of investment and of the technical capacity that mapping records, rather than a shortcoming of the map alone.

The failure of convergence has a direct interpretation within these models. If investment and mapping both follow density and institutional capacity, the capitals that began with the least provision are also the least able to add infrastructure, so gaps persist rather than close on their own. The negative but non significant correlation is therefore best read as weak evidence that laggards did not catch up, not as evidence that they did. This matters for the equity debate, because a policy

that rewards past progress will widen the gap that the equity literature describes.

The comparison with administrative inventories gives the map based measure its place. Ferster et al.(18)built a national Canadian bicycle dataset from open sources and reported that tag based extraction is practical but requires harmonisation, Vierø et al.(20)proposed tools for exactly that harmonisation, and Harvey et al.(21)warned that alternative sources classify traffic stress differently.

Bartzokas-Tsiompras et al.(17)applied a similar logic to pedestrian streets worldwide. The present study shows that the same infrastructure can be assembled for Latin America, but that the result must be read as an upper bound of what a city has mapped and a lower bound of what it has built. The same pipeline, rerun annually, would produce a comparable time series at marginal cost, which is the kind of longitudinal monitoring that official inventories rarely sustain.

The two positions set out in the introduction can be reconciled through this distinction. The first position, which reads expansion as progress, is correct about the direction of change in the leading cities and about the association with ridership. The second position, which stresses uneven distribution, is correct that the map overstates what exists and that the stock is concentrated. The present data support the second reading for the region as a whole: the aggregate grew, but the growth reproduces the existing hierarchy of provision, and part of the recorded increase is an artefact of the recording itself.

Open map monitoring also has a governance dimension that the comparisons above only touch on. The completeness of the map depends on volunteer communities whose size and activity differ across cities,(15)so a low value can reflect a weak mapping community as much as weak infrastructure.

Municipalities that publish their own inventories create a feedback loop: official data feed the map, and the map in turn becomes a check on the official data, as the Canadian experience shows.(18)Where neither exists, as in several Central American capitals, the absence of measurement itself becomes a form of invisibility in the regional debate.

This study has several strengths. It reconstructs a decade of mapped cycling infrastructure for all Latin American capitals from a single openly licensed source whose history can be audited.(22,23)

It separates dedicated cycleways from on road lane tags, transforms length to a per capita scale, and reports declines rather than discarding them as anomalies. Covering the complete set of national capitals also removes the selection bias of single city case studies. The deterministic pipeline makes every number reproducible, and the population source was deliberately chosen to remain inside the study window. Because the method is agnostic to city size, it can be applied unchanged to smaller cities and to future years.

The results should also be read as specific to national capitals. Capitals concentrate institutional capacity and international attention; secondary cities, where Barón(28)documents a different priority setting logic, may show slower and less complete mapping. Their exclusion here is deliberate, and it means the estimates describe the best resourced tier of the region rather than its average. Extending the method to secondary cities would test whether the pattern observed here, growth concentrated where capacity already exists, generalises below the capital tier.

Several limitations qualify these findings. First, mapped length is not built length; the measure captures what volunteers have recorded, and its growth conflates construction with mapping activity.(15)

Future monitoring should triangulate OpenStreetMap with official inventories, as Ferster et al.(18)and Vierø et al.(20)recommend. Second, city boundaries were approximated by the bounding boxes of administrative units, so some lengths include adjacent territory; boundary polygons would refine the estimates. Third, the population figures are projections for 2024 from the 2018 revision,(25)and per capita provision is sensitive to the agglomeration definition adopted.

Fourth, the rank correlations have limited power with 20 units, and the null convergence result should be read with caution. Fifth, the zero baselines for several cities prevent the computation of a growth rate there, which removes exactly the cities of greatest equity interest from the convergence test. Sixth, the ecological design treats each city as a single unit, so the within city distribution of infrastructure, which the equity literature treats as central, remains invisible in these estimates.

For transport policy, the findings suggest that monitoring cycling infrastructure with open map data is feasible across the region, provided that mapping artifacts and boundary definitions are corrected.

Economic evaluations of active transport investment favour schemes that are selected on measurable outcomes,(34)and assessment instruments such as the one proposed by Ángel et al.(35)could incorporate the per capita indicators used here. What remains open is whether the leading capitals convert their mapped advantage into sustained modal shift, and whether lagging capitals receive the technical and financial support needed to close the gap.

Equity oriented planning should address that gap explicitly rather than treating network length alone as progress. A monitoring system built on this source could be repeated annually at low cost, and its indicators, provision per 1,000 inhabitants and the share of dedicated cycleways, are simple enough to be reported by municipalities alongside mode share. For lagging capitals, the practical implication is that mapping capacity itself is part of the gap and may need to be funded before infrastructure can be compared on equal terms.

CONCLUSIONS

Between 2014 and 2024 the mapped cycling infrastructure of the 20 Latin American capitals expanded, but the growth was concentrated in a few cities and was not faster in those that started with the lowest provision. Provision per 1,000 inhabitants rose in most capitals yet remained low or absent in several. The declines observed in three capitals were consistent with retagging of OpenStreetMap elements rather than with physical removal, which limits the direct comparison of mapped length with built infrastructure over time.

REFERENCES

1. Epting S. The Peñalosa Principle of Transportation Democracy: Lessons from Bogotá on the Morality of Urban Mobility. Sci Eng Ethics. 2017;23(4):1085-1096. doi: 10.1007/s11948-016-9839-1
2. Gomez LF, Sarmiento R, Ordoñez MF, Pardo CF, de Sá TH, Mallarino CH, et al. Urban environment interventions linked to the promotion of physical activity: A mixed methods study applied to the urban context of Latin America. Social Science & Medicine. 2015;131:18-30. doi: 10.1016/j.socscimed.2015.02.042
3. Márquez L, Cantillo V, Paternina-Arboleda CD. Hard and soft measures for motivating workers to commute by bicycle: The case of Bogota. Case Studies on Transport Policy. 2024;18:101299. doi: 10.1016/j.cstp.2024.101299
4. Yang Y, Wu X, Zhou P, Gou Z, Lu Y. Towards a cycling-friendly city: An updated review of the associations between built environment and cycling behaviors (2007–2017). Journal of Transport & Health. 2019;14:100613. doi: 10.1016/j.jth.2019.100613
5. Wali B, Frank LD, Chapman J, Fox EH. Role of walkability, bike infrastructure, and greenspace in combatting chronic diseases: A heterogeneous ecological analysis in the United States. Sustainable Cities and Society. 2024;113:105550. doi: 10.1016/j.scs.2024.105550
6. Ohlund H, El-Samra S, Amezola D, Soto Morfín JC, López Zaragoza C, Aguilar Gónzalez S. Building Emergent Cycling Infrastructure During the COVID-19 Pandemic: The Case of Zapopan, México. Front Sustain Cities. 2022;4:805125. doi: 10.3389/frsc.2022.805125
7. Macedo Filho FE, Cunquero C. City-wide cycling network extension and bicycle ridership in São Paulo: A causal analysis. Latin American Transport Studies. 2024;2:100021. doi: 10.1016/j.latran.2024.100021
8. Mora R, Truffello R, Oyarzún G. Equity and accessibility of cycling infrastructure: An analysis of Santiago de Chile. Journal of Transport Geography. 2021;91:102964. doi: 10.1016/j.jtrangeo.2021.102964
9. Parra DC, Gomez LF, Pinzon JD, Brownson RC, Millett C. Equity in cycle lane networks: examination of the distribution of the cycle lane network by socioeconomic index in Bogotá, Colombia. Cities & Health. 2018;2(1):60-68. doi: 10.1080/23748834.2018.1507068
10. Tiznado-Aitken I, Mora R, Oyarzún G, Vergara J, Vecchio G. A bumpy ride: structural inequalities, quality standards, and institutional limitations affecting cycling infrastructure. Transportation Research Part D: Transport and Environment. 2022;110:103434. doi: 10.1016/j.trd.2022.103434
11. Torres-Barragan CA, Cottrill CD, Beecroft M. Spatial inequalities and media representation of cycling safety in Bogotá, Colombia. Transportation Research Interdisciplinary Perspectives. 2020;7:100208. doi: 10.1016/j.trip.2020.100208
12. Márquez L, Soto JJ. Integrating perceptions of safety and bicycle theft risk in the analysis of cycling infrastructure preferences. Transportation Research Part A: Policy and Practice. 2021;150:285-301. doi: 10.1016/j.tra.2021.06.017
13. Márquez L, Cantillo V, Arellana J. How do the characteristics of bike lanes influence safety perception and the intention to use cycling as a feeder mode to BRT?. Travel Behaviour and Society. 2021;24:205-217. doi: 10.1016/j.tbs.2021.04.005
14. Barrington-Leigh C, Millard-Ball A. The world's user-generated road map is more than 80% complete. PLoS ONE. 2017;12(8):e0180698. doi: 10.1371/journal.pone.0180698
15. Herfort B, Lautenbach S, Porto de Albuquerque J, Anderson J, Zipf A. A spatio-temporal analysis investigating completeness and inequalities of global urban building data in OpenStreetMap. Nat Commun. 2023;14(1):3985. doi: 10.1038/s41467-023-39698-6
16. Minghini M, Frassinelli F. OpenStreetMap history for intrinsic quality assessment: Is OSM up-to-date?. Open geospatial data, softw stand. 2019;4(1):9. doi: 10.1186/s40965-019-0067-x
17. National Technical University of Athens, Greece. Utilizing OpenStreetMap data to measure and compare pedestrian street lengths in 992 cities around the world. EJG. 2022;13(2):127-141. doi: 10.48088/ejg.a.bar.13.2.127.138
18. Ferster C, Nelson T, Manaugh K, Beairsto J, Laberee K, Winters M. Developing a national dataset of bicycle infrastructure for Canada using open data sources. Environment and Planning B: Urban Analytics and City Science. 2023;50(9):2543-2559. doi: 10.1177/23998083231159905
19. Al-Ramini A, Takallou MA, Piatkowski DP, Alsaleem F. Quan tifying changes in bicycle volumes using crowdsourced dat a. Environment and Planning B: Urban Analytics and City Science. 2022;49(6):1612-1630. doi: 10.1177/23998083211066103
20. Vierø AR, Vybornova A, Szell M. BikeDNA: A tool for bicycle infrastructure data and network assessment. Environment and Planning B: Urban Analytics and City Science. 2024;51(2):512-528. doi: 10.1177/23998083231184471
21. Harvey C, Rodríguez DA, Fang K. Comparing methods and data sources for classifying bicycle level of traffic stress: How well do their outcomes agree?. Sustainable Cities and Society. 2024;101:105151. doi: 10.1016/j.scs.2023.105151
22. Raifer M, Troilo R, Kowatsch F, Auer M, Loos L, Marx S, et al. OSHDB: a framework for spatio-temporal analysis of OpenStreetMap history data. Open geospatial data, softw stand. 2019;4(1):3. doi: 10.1186/s40965-019-0061-3
23. Heidelberg Institute for Geoinformation Technology (HeiGIT). ohsome API: OpenStreetMap history data analytics [Internet]. 2019. Available from: https://api.ohsome.org/
24. OpenStreetMap contributors. OpenStreetMap geodatabase (history data, Open Database License) [Internet]. 2024. Available from: https://www.openstreetmap.org/
25. United Nations, Department of Economic and Social Affairs, Population Division. World Urbanization Prospects: The 2018 Revision (annual population of urban agglomerations with 300,000 inhabitants or more) [Internet]. 2018. Available from: https://population.un.org/wup/

26. Xiao CS, Sharp SJ, van Sluijs EMF, Ogilvie D, Panter J. Impacts of new cycle infrastructure on cycling levels in two French cities: an interrupted time series analysis. Int J Behav Nutr Phys Act. 2022;19(1):77. doi: 10.1186/s12966-022-01313-0
27. Rérat P, Schmassmann A. Build it and they will come? The effects of a new infrastructure on cycling practices and experiences. Transportation Research Interdisciplinary Perspectives. 2024;25:101121. doi: 10.1016/j.trip.2024.101121
28. Barón GN. Identification of cycle lane priorities based on observed and potential cyclist trips using GIS, the case of the Metropolitan Area of Mendoza, Argentina. Urban, Planning and Transport Research. 2022;10(1):412-432. doi: 10.1080/21650020.2022.2097122
29. Paulsen M, Rich J. Societally optimal expansion of bicycle networks. Transportation Research Part B: Methodological. 2023;174:102778. doi: 10.1016/j.trb.2023.06.002
30. Paulsen M, Rich J. Welfare optimal bicycle network expansions with induced demand. Transportation Research Part B: Methodological. 2024;190:103095. doi: 10.1016/j.trb.2024.103095
31. Bonsma-Fisher M, Lin B, Chan TCY, Saxe S. Exploring the geographical equity-efficiency tradeoff in cycling infrastructure planning. Journal of Transport Geography. 2024;121:104010. doi: 10.1016/j.jtrangeo.2024.104010
32. Cunha I, Silva C. Assessing the equity impact of cycling infrastructure allocation: Implications for planning practice. Transport Policy. 2023;133:15-26. doi: 10.1016/j.tranpol.2022.12.021
33. Zhao Q, Winters M, Nelson T, Laberee K, Ferster C, Manaugh K. Who has access to cycling infrastructure in Canada? A social equity analysis. Computers, Environment and Urban Systems. 2024;110:102109. doi: 10.1016/j.compenvurbsys.2024.102109
34. Bland M, Burke MI, Bertolaccini K. Taking steps toward healthy & sustainable transport investment: A systematic review of economic evaluations in the academic literature on large-scale active transport infrastructure. International Journal of Sustainable Transportation. 2024;18(3):201-220. doi: 10.1080/15568318.2023.2296952
35. Ángel A, Gómez LD, Rincón M. Cycling Assessment: A tool to inform policymakers and enhance the cyclist's travel experience, with a gender perspective. Data & Policy. 2023;5:e37. doi: 10.1017/dap.2023.35

FUNDING

No financing

CONFLICT OF INTEREST

None

AUTHORSHIP CONTRIBUTIONS

Drafting – original draft: Luis Alejandro Orocio Garza, Carlos Alberto Gómez Cano.
Writing–review and editing: Luis Alejandro Orocio Garza, Carlos Alberto Gómez Cano.