STRANDED INFRASTRUCTURE

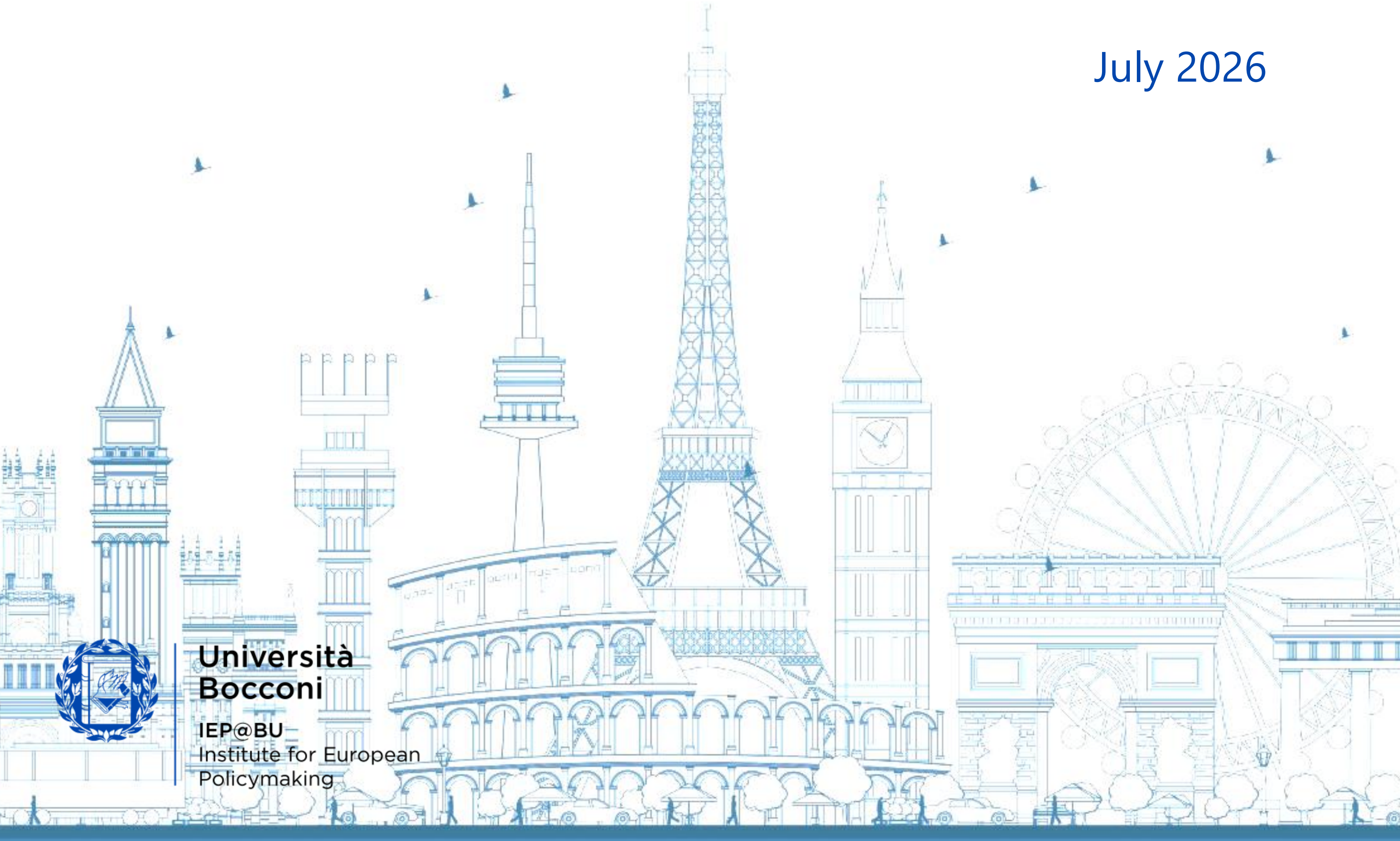
A PNRR CASE STUDY ON MILAN'S CYCLING NETWORK

Why Kilometer-Based Reporting Is Not Enough For Cycling Policy

VLADIMIR **SIMIĆ**

IEP@BU Policy Brief

July 2026



Università Bocconi
IEP@BU
Institute for European Policymaking

Executive Summary

As the PNRR approaches its 2026 closure, the evaluation of Italy’s largest national recovery plan financed under NextGenerationEU is moving from disbursement tracking toward an assessment of what the funded investment has achieved. That assessment will depend heavily on which indicators are chosen, a point already raised within the IEP@BU policy-brief series (Boeri and Perotti, 2026; Leonardi, 2026). Boeri and Perotti (2026) identify formalism over substance as one of the principal flaws of the plan, describing how milestones and targets can foster a “spreadsheet culture” in which numerical compliance substitutes for the policy outcomes the indicators were meant to capture. This brief takes that diagnosis down to the level of a single measure. The PNRR urban cycling sub-investment (M2C2, Investment 4.1.2), governed by MIT Decree 509/2021, ties funding to kilometer-based delivery targets together with corridor-level requirements linking universities to interchange nodes. While the framework makes construction progress visible and auditable, it does not show whether the wider network being built is cohering into a usable system, and Milan provides a case where that gap can be measured directly against municipal data.

Using official municipal geospatial data classified under the Italian Codice della Strada, the brief isolates Milan's dedicated cycling infrastructure and assesses how far it functions as a connected network. The results show severe fragmentation. Of 202.9 km of dedicated cycling infrastructure, 88.2% lies outside the largest connected component. District-level analysis shows that this fragmentation is not evenly distributed, with several outer districts combining substantial provision with high stranded shares. A comparison with Barcelona and Paris indicates that this outcome is not an inevitable consequence of network scale. The indicator gap is therefore empirical, and, in Milan, under this measure, it is observable in the data.

Milan's latest Möves plan recognizes the underlying issue, framing the cycling network qualitatively in terms of continuity and recognizability. The operationalization gap, however, remains. Milan has the strategic vision yet lacks the indicator framework to act on it, and this is precisely the kind of indicator-design gap that performance-based EU funding will need to address if it is to deliver on the institutional advance Leonardi (2026) attributes to it. The same pattern extends well beyond Milan. Kilometer-based delivery targets are the dominant monitoring standard across EU and national cycling-funding instruments, which means the indicator gap identified here is structural rather than local. On this basis the brief advances three recommendations, developed in full at the end. First, EU and national funding frameworks should complement kilometer-based delivery targets with standardized network-cohesion indicators capable of registering whether funded segments are assembling into a coherent system. Second, municipal and metropolitan authorities should incorporate fragmentation diagnostics into project appraisal, giving explicit weight to interventions that close gaps and reinforce the main connected spine. Third, in already fragmented networks, investment should be sequenced toward consolidation before further outward expansion.

KEY FINDINGS

- **Milan's headline cycling figure does not describe a coherent cycling network.** Of the 336 km reported by the city, only 203 km qualifies as dedicated cycling infrastructure under the Codice della Strada, and within that dedicated network 88.2% lies outside the city's main connected spine. The issue is therefore not only how much infrastructure Milan reports, but how much of it functions as part of a continuous system.
- **The gap between reported provision and functional coherence is evaluative as much as physical**. The PNRR's urban cycling measure verifies kilometers delivered and the completion of specified university-to-interchange corridors. **Beyond these two levels, however, the decree contains no requirement or mechanism for registering how the kilometers counted against the target relate to one another or to the wider municipal cycling network**.
- **EU and national funding frameworks should complement kilometer-based delivery targets with standardized network-cohesion indicators.** Kilometer-based delivery targets are the standard form of performance-based funding under the Recovery and Resilience Facility, and the Commission's July 2025 proposal for the 2028–2034 Multiannual Financial Framework extends the same milestone-and-target logic to the successor Cohesion Policy architecture. The next programming cycle therefore offers a concrete opportunity to specify network-cohesion indicators at the outset, where they can shape both allocation and closure assessment.
- **At the municipal and metropolitan level, fragmentation diagnostics should inform project appraisal and investment sequencing.** Project appraisal should give explicit weight to whether interventions close gaps, connect existing segments, and reinforce the main connected spine, and in already fragmented networks, investment should be sequenced toward consolidation before further outward expansion.

Introduction

The PNRR is the largest national recovery plan financed under NextGenerationEU, and as its 2026 closure approaches, the debate is shifting from disbursement and milestone compliance toward an assessment of what the funded investment has produced (Boeri and Perotti, 2026; Leonardi, 2026). That assessment is structured by the PNRR's milestone-and-target architecture, under which disbursement and compliance are tied to numerical indicators agreed in advance with the European Commission. While standard, any framework constructed under this methodology carries the inherent risk that compliance attaches to indicator delivery rather than to the substantive outcome the indicator was meant to capture. The choice of indicator is therefore not a neutral measurement question and is instead a key determinant of which conclusions about the effectiveness of a measure can be drawn. This brief examines that question under one specific PNRR sub-investment, the urban cycling measure (M2C2, Investment 4.1.2), governed by MIT Decree 509/2021, which assigns municipalities binding kilometer-based delivery targets together with corridor-level requirements linking universities to interchange nodes.

Cycling infrastructure is a compelling case for the broader question because the policy stakes are substantial and the indicator paradigm is well established. Cycling has become a major pillar of sustainable urban mobility policy across the European Union, supported by the European Green Deal's emphasis on carbon neutrality and reinforced by post-pandemic shifts in travel behaviour (European Commission, 2021; Buehler and Pucher, 2021). As public investment has grown, so has the pressure to demonstrate progress, justify expenditure, and compare outcomes across jurisdictions, and in this context total network length has become one of the standard benchmarking metrics. It translates infrastructure investment into a single figure legible to budget reports, press releases, and EU funding applications. The simplicity is also the limitation, as the rest of the brief illustrates, since the relationship between kilometers delivered and a functioning network is more demanding than the indicator allows.

Length is a reasonable indicator for infrastructure whose value scales with quantity delivered, however, cycling infrastructure is a more nuanced case. A property of networked infrastructure is that its value derives both from individual components and from the complementarities between them, and the effect is particularly pronounced for cycling, where a single unsafe or missing segment can compromise the usability of an entire route. Indeed, a route that terminates without connection, forcing cyclists back into mixed traffic, offers a differing experience compared to a connected one. A segment that does not join the wider network supports fewer trips than its length alone may initially suggest. The literature on cycling uptake is consistent with this intuition, even if the precise magnitude of the continuity-ridership relationship remains laborious to isolate empirically (Schön, Heinen & Manum, 2024; Buehler & Dill, 2016; Schoner & Levinson, 2014). What this means in essence for monitoring is that two networks of identical length can differ substantially in the mobility they enable, depending on how their segments are assembled.

In the Italian PNRR cycling measure, this limitation is institutionalized in the way the physical target is operationalized. The monitoring architecture tracks financial, procedural, and implementation progress, yet the binding physical indicator for the infrastructure itself is expressed in kilometers delivered, with no explicit indicator of connectivity, fragmentation, or network integration. The framework can therefore confirm that investment has occurred while saying much less about whether that investment is producing the networked good it was intended to produce.

Milan provides an instructive case for examining what this blind spot can leave unaddressed in practice. The city has invested substantially in cycling infrastructure under its Sustainable Urban

Mobility Plan (PUMS), parts of which are financed through the PNRR, and it shows high latent demand for active mobility, with walking and cycling together accounting for 35% of daily trips, ahead of both private cars and public transport (AMAT, 2025). Prior research has also identified Milan as one of the most fragmented cycling networks in Europe (Szell et al., 2022). Milan is therefore useful not because it proves that kilometer-based frameworks produce fragmentation, a causal claim this analysis cannot support, but rather because it illustrates that substantial reported provision, delivered within a framework that monitors delivery effectively, can nonetheless coexist with a network that does not function as one.

Using official municipal geospatial data classified under the Italian Codice della Strada, this brief examines whether Milan's reported cycling infrastructure corresponds to a functionally connected network. It distinguishes dedicated cycling facilities and other road environments where cycling is permitted, assesses connectivity within the dedicated network, disaggregates results to the district level, and compares Milan with Barcelona and Paris. The contribution is twofold. Firstly, the brief shows what the indicator gap identified at the macro level by Boeri and Perotti (2026) resembles at the level of a single PNRR measure, in a case where network coherence, a necessary condition for the cycling mobility the measure was funded to produce, is directly measurable from municipal data. Secondly, the brief advances three recommendations addressing both the assessment of the PNRR's urban cycling measure at closure and the design of the cycling-funding instruments that will succeed it.

Data and Methodology

The analysis draws on official geospatial data from Milan's municipal open data portal. The primary source is the Itinerari ciclabili dataset (DS60), which contains 4,154 line segments representing reported cycling infrastructure. District-level analysis uses the Nuclei d'Identità Locale (NIL) dataset, which defines Milan's 88 official planning districts. Both shapefiles include the field tipologia, which records infrastructure type under the Codice della Strada. All spatial calculations were performed in EPSG:32632 (UTM zone 32N).

Infrastructure Classification

Italian transport law provides clear definitional criteria for cycling infrastructure. The Codice della Strada (D.Lgs. 285/1992) and (DM 557/1999) distinguish between dedicated cycling facilities and other road configurations where cycling may be permitted.

Category	Legal Status	Length	Share	Classification
Ciclabile sede propria	Separated bike path	123.0 km	36.6%	**Dedicated**
Ciclabile segnaletica	Marked bike lane	79.8 km	23.8%	**Dedicated**
Promiscuo pedoni	Pedestrian zone	62.4 km	18.6%	Non-dedicated
Promiscuo veicoli	Traffic-calmed zone	70.8 km	21.1%	Non-dedicated

Table 1: Classification of Milan's reported cycling infrastructure according to Italian transport law

This classification shows that Milan’s official 336 km figure includes 133 km (40%) of facilities that do not constitute dedicated cycling infrastructure under Italian law. While pedestrian zones and speed-limited roads may accommodate cycling, they do not provide dedicated cycling space and are therefore analytically distinct from bike lanes and separated cycle paths.

Connectivity Analysis

Network connectivity was assessed by treating two infrastructure segments as connected if they satisfied any of three conditions. One, endpoint proximity within 5 metres, two, a T-junction configuration (where one segment's endpoint falls within 5 metres of another segment's interior), three, a direct segment overlap. The 5-metre tolerance accounts for positional imprecision typical of digitised municipal records. The primary connectivity indicator is the Largest Connected Component (LCC) ratio, defined as the length of the largest single connected cluster divided by total network length, following Szell et al. (2022). A ratio of 1.0 indicates a fully connected network while values approaching 0 indicate severe fragmentation. The complement metric, the stranded ratio (1 − LCC), captures the share of infrastructure lying outside the network's main connected spine. To test whether findings depend on infrastructure definition, the analysis was repeated under three specifications: dedicated infrastructure only, dedicated plus shared pedestrian paths, and all reported cyclable segments. A separate replication using the OpenStreetMap-based pipeline of Szell et al. (2022) was also conducted for cross-validation. This methodology was then consolidated in a repository named infragap (Simić, 2026), an open-source library developed by the author for standardised infrastructure connectivity diagnostics.

To contextualize Milan's results, the same methodology was applied to Barcelona and Paris. Barcelona's network was sourced from the Ajuntament de Barcelona open data portal (Carril bici dataset; Ajuntament de Barcelona, 2025); Paris's from the Base Nationale des Aménagements Cyclables, December 2025 snapshot, filtered to Paris commune boundaries (Geovelo, 2025). Both comparator datasets are restricted at source to dedicated cycling infrastructure, making them broadly comparable to Milan's filtered dedicated network of 203 km, though differences in local classification practices introduce a degree of measurement uncertainty that should be acknowledged when interpreting cross-city comparisons.

Findings

City-Wide Connectivity

Restricting the analysis to 202.9 km of dedicated cycling infrastructure, the clustering algorithm identifies 330 distinct connected components. The average component length is 615 meters, with the largest connected component spanning 23.9 km, yielding an LCC ratio of 11.8%. In other words, 88.2% of Milan’s dedicated cycling infrastructure lies outside the network’s main connected spine.

This diagnosis is robust to broader infrastructure definitions. Across all three specifications, the stranded ratio ranges from 84.5% to 90.2%. Adding shared pedestrian paths increases total network length by more than 62 km yet reduces components by three and the LCC ratio from 11.8% to 9.8%. Adding all reported cycling infrastructure raises the LCC ratio to 15.5%, though only alongside a substantial increase in the number of disconnected components. The diagnosis is also insensitive to the tolerance parameter. Re-running the analysis at 10m, 15m, and 20m yields stranded shares of 87.2%, 87.2%, and 87.0% respectively, indicating that the result is not an artefact of the 5m threshold. Overall, across all definitions, Milan remains highly fragmented.

Definition	Segments	Length	Components	LCC	Stranded
Strict dedicated (Main Analysis)	3464	202.9 km	330	11.8%	88.2%
+ shared pedestrian	3880	265.2 km	327	9.8%	90.2%
Overall cycling infrastructure	4154	336 km	407	15.5%	84.5%

Table 2: Milan network connectivity under alternative infrastructure definitions.

These results are consistent with and extend the findings of Szell et al. (2022). A direct replication with their published computational pipeline and current OpenStreetMap data yields a separate count of 361 components with an LCC ratio of 4.8%, confirming that fragmentation remains severe. The two approaches diverge in coverage and geometric detail. They converge, however, on the same substantive diagnosis.

To verify that algorithmically identified breaks correspond to genuine on-street discontinuities, selected disconnection points were cross-referenced with street-level imagery and on-site validation. Figure 2 shows a representative example at Via Zurigo, in the Forze Armate district, where the clustering algorithm identified a break between two components. Street-level inspection confirms that the gap is physical. Bike-lane markings terminate at the intersection, requiring cyclists to merge into mixed traffic without signage, markings, or a protected crossing to reach the next segment.

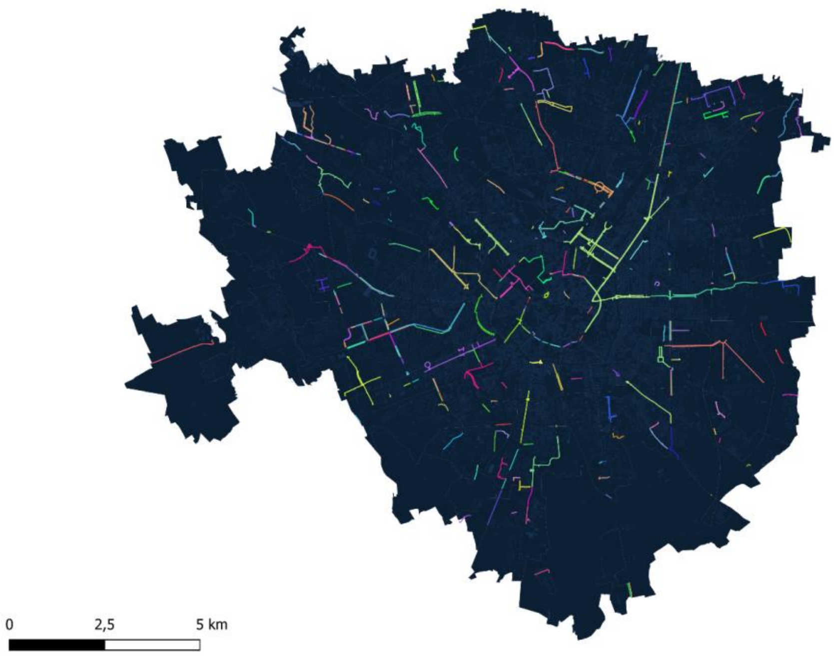


Figure 1: Milan cycling network coloured by cluster membership. Each colour represents a distinct disconnected component.

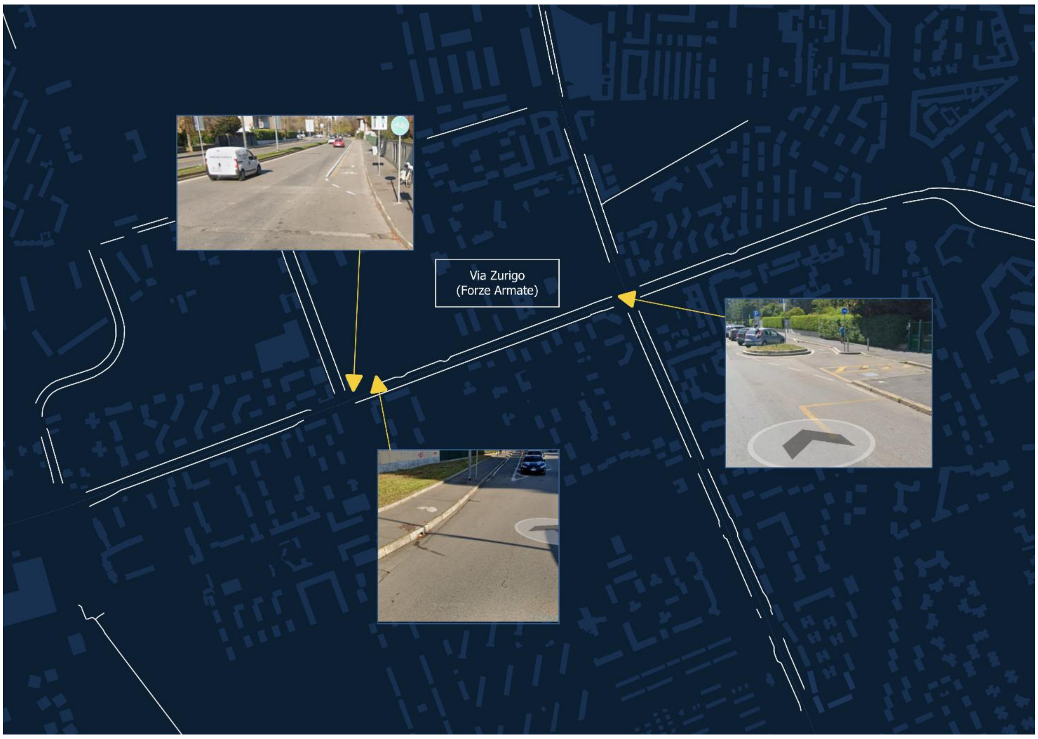


Figure 2: Forze Armate district. Cycling network (white lines) overlaid on satellite imagery. Source: Google Street View, January 2026.

District-Level Fragmentation

District-level analysis shows that fragmentation is systemic rather than confined to a small number of isolated areas. Of Milan's 88 districts, 21 contain less than 1 km of cycling infrastructure and 6 contain none. Among the remaining districts, the median LCC ratio is 0.50, meaning that in the typical district only around half of the local network forms a single connected system. Thirty districts fall below this threshold, and five record LCC ratios below 0.30 despite substantial infrastructure provision. Figure 3 maps these results across the city. The most fragmented districts are concentrated in the western and northern periphery, while the few highly connected districts tend to be either small central zones or peripheral areas where a single short segment constitutes the entire local network.

District (NIL)	Infra. (km)	Clusters	LCC Ratio	Stranded
Forze Armate	6.1	27	0.12	88% (5.4 km)
Padova-Turro-Crescenzago	2.8	8	0.21	79% (2.2 km)
Quarto Oggiaro-Vialba	6.4	9	0.27	73% (4.6 km)
Cimiano-Rottole-Q.re Feltre	3.7	7	0.27	73% (2.7 km)
Q.re Gallaratese	5.9	28	0.29	71% (4.2 km)
De Angeli-Monte Rosa	3.8	1	1.00	0% (connected)
Taliedo-Forlanini	3.2	1	1.00	0% (connected)

Table 3: District-level fragmentation analysis. Highest and lowest connectivity areas

The districts at the top of Table 3 are notable due to substantial provision and low functionality as a network. Forze Armate contains 6.1 km of dedicated cycling infrastructure, more than many better-connected districts, yet 88% lies outside the largest connected component. Gallaratese shows a similar pattern, with 5.9 km of infrastructure fragmented across 28 disconnected clusters. These are districts where relatively limited linking interventions may yield higher returns than further outward expansion of already fragmented provision.

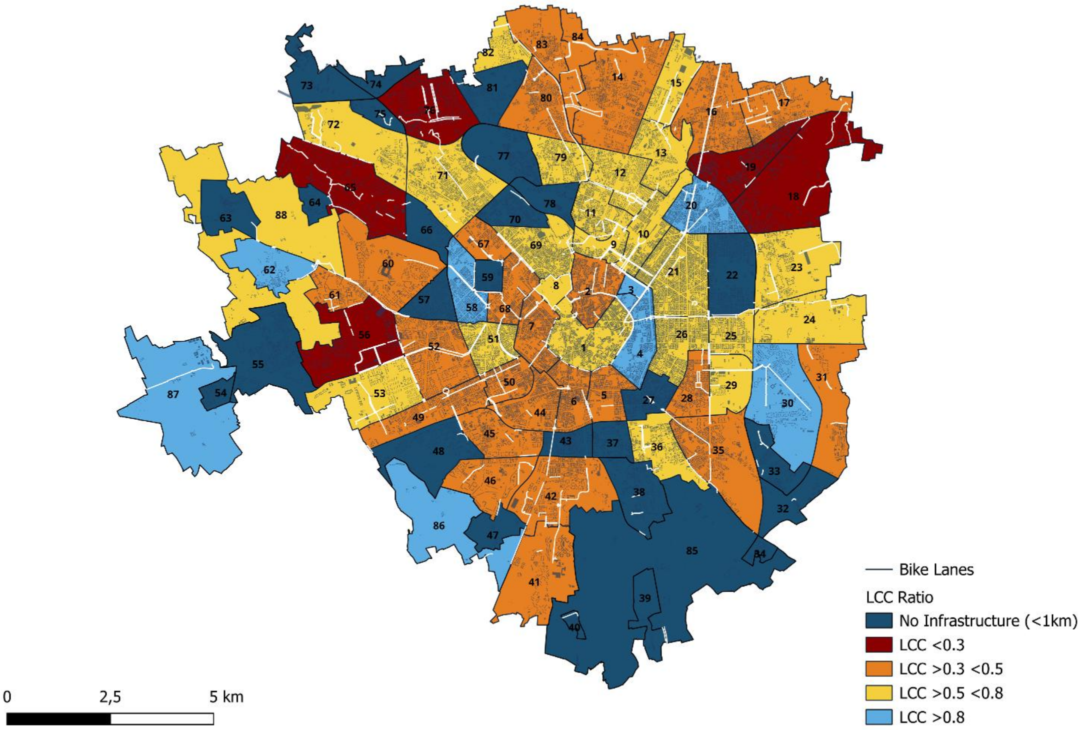


Figure 3: Milan districts colored by LCC ratio and infrastructure presence. White lines represent the cycling network.

Comparative Context

Barcelona's dedicated cycling network, while only marginally longer than Milan's (233.6 km over 202.9 km), achieves an LCC ratio of 86.0%, meaning that most of its infrastructure forms a single connected system. Paris, despite having approximately three times Milan's infrastructure length and 350 disconnected components, nevertheless concentrates 86.4% of its network in one dominant connected spine. A high component count, in other words, is not in itself evidence of dysfunction. What matters is whether the largest component captures enough of the network to function as a citywide system. By that measure, both comparator cities perform on a fundamentally different scale from Milan, whose LCC ratio remains 11.8%.

It must be noted that these comparisons should be interpreted with appropriate caution. Although the same connectivity method was applied across all three cases, the underlying datasets originate from different administrative sources and are shaped by local classification practices that are thus not perfectly identical. The comparison therefore does not establish strict equivalence, nor does it isolate the effects of urban form, governance, or investment strategy which are beyond the scope of this brief. Its value is instead twofold. Firstly, it shows that Milan's fragmented outcome is not an unavoidable consequence of network scale alone. Secondly and most importantly, it also shows that no single metric, taken in isolation, adequately captures network performance. Kilometers, component counts, and even connectivity ratios each describe only one dimension of a cycling network. Read together, however, they illustrate that Milan differs from its comparators in both provision and function of its system.

City	Total length	Components	LCC Ratio	Stranded
Milan	202.9	330	0.118	88.2%
Paris	619.2	350	0.864	13.6%
Barcelona	233.6	48	0.860	14.0%

Table 4: Comparative connectivity metrics for Milan, Barcelona, and Paris, calculated using the same Union-Find algorithm and 5-metre tolerance on dedicated cycling infrastructure datasets.

Discussion

The PNRR Cycling Measure and the Architecture of Delivery-Centered Monitoring

The PNRR's urban cycling measure (M2C2, Investment 4.1.2) was originally structured through MIT Decree 509/2021, which allocated €150 million of new PNRR funds to 40 Italian university cities and made disbursement conditional on the delivery of at least 365 additional kilometers of piste ciclabili urbane e metropolitane by June 2026. The 2024 PNRR revision has since adjusted the kilometric target for the urban sub-investment to approximately 570 km against an essentially unchanged financial envelope of €200 million. For the purposes of this brief, DM 509/2021, itself unchanged, remains the foundational instrument establishing the monitoring architecture that the rest of this section examines.

The decree's monitoring architecture operates at two levels. The first is segment-level. A preambular clause states that the term piste ciclabili in the PNRR target is to be understood in senso ampio, comprising the definition of ciclovia in Article 2(2) letters a), b) and c) of Law 2/2018, together with the definition of corsia ciclabile introduced into Article 3 of the Codice della Strada by Law 120/2020. This admits separated cycle paths and marked cycle lanes, greenways, and itinerari ciclopedonali shared with pedestrians, while excluding strade 30, low-traffic streets, pedestrian zones, restricted-traffic zones, and residential zones. The framework therefore draws a clear segment-level boundary around what counts as a fundable kilometer, although infrastructure of substantially different protective quality falls inside that boundary. The classification used in this brief's main analysis is narrower than the decree's, however, the diagnosis reported previously (Table 2) remains robust to broader specifications.

The second level is corridor-level. Article 3(2) obliges each beneficiary municipality to provide a connection by means of pista ciclabile between one or more university sites on its territory and one or more rail or metropolitan interchange nodes. Article 3(3) further permits interventions that connect neighbouring municipalities or extend across the metropolitan area, where these support access to university sites and interchange nodes. Both provisions specify connections that must or may be built and allow their completion to be verified on inspection. Together, segment-level and corridor-level monitoring operationalize connectivity in a way that is auditable segment by segment. Quantified indicators tend to dominate public monitoring precisely because they travel well across jurisdictions and disbursement regimes (Porter, 1995), and the PNRR framework reflects that broader tendency.

Beyond these two levels, however, the decree contains no requirement or mechanism for registering how the kilometers counted against the target relate to one another or to the wider municipal cycling network. A municipality complies with the framework by demonstrating that the kilometers counted belong to the admissible legal categories and that the mandated university-to-interchange corridor, together with any extra-urban or metropolitan connections it has chosen to include, has been completed to specification. What happens to the rest of the network, whether the funded segments join existing infrastructure, whether they close gaps or create new ones, whether the cycling system as a whole is becoming more or less coherent as investment proceeds, is not a question the monitoring architecture is equipped to ask.

It must be noted that this is not a failure of implementation. The decree is doing what output-based conditionality is designed to do. It specifies what is being purchased with public funds and creates a verification regime that can determine, at the point of disbursement, whether that specification has been met. What the decree does not do, and what output-based conditionality is structurally less suited to do, is evaluate the cumulative effect of funded interventions on a system whose performance depends on how its parts connect.

Investment 4.1.2 is the most kilometer-bound and corridor-specific instrument in the PNRR's cycling-funding architecture, however it is not the only one. The same indicator paradigm, kilometric delivery, project counts, no formal network-cohesion measure, recurs in other PNRR streams that fund cycling infrastructure in Italian cities, including the Piani Urbani Integrati under M5C2 Investment 2.2 (which co-finances, for example, 82 km of the CAMBIO Biciplan superciclabili in the Milan metropolitan area at approximately €50 million; Città Metropolitana di Milano, 2022) and PINQuA under M5C2 Investment 2.3, where cycling infrastructure can be included within broader public-space requalification (MIMS, 2020). The limitation identified here is therefore structural, applying across the PNRR's cycling-funding instruments rather than being specific to DM 509/2021, an argument the next section develops further.

Networked Infrastructure and the Limits of Length as an Indicator

The limitation identified in the previous section is not that the PNRR framework ignores connectivity. Article 3 of the decree treats specified corridors, between universities and interchange nodes and, where relevant, across metropolitan areas, as substantive requirements, which means the framework does recognize that the spatial relationship between funded kilometers can matter. The observation is instead narrower. The decree registers connectivity at the level of discrete corridors, the completion of which can be verified on inspection, and does not register it at the level of the network into which those corridors are inserted. Why this distinction matters follows from a specific property of cycling infrastructure rather than from any general claim about networked goods.

Length is an indicator that works reasonably well for infrastructure whose network integration is largely determined at the point of construction. A new segment of water main or rail track is typically engineered, specified, and verified as part of the connections it makes to the existing system, so per-segment delivery and network integration are broadly aligned by design. Other networked infrastructures, such as electricity transmission or fiber, can also produce stranded segments when upstream or downstream connections lag, however these failure modes are generally registered through dedicated grid or capacity indicators rather than through length alone. Cycling infrastructure sits at a more demanding end of this spectrum. A cycle lane that terminates at an unsignalized intersection, or a segregated path that begins mid-block without a connection at either end, still functions as cycling infrastructure in the minimal sense that cyclists can use it. It supports some use in isolation, which is what makes it possible to fund and build cycling infrastructure segment by segment without the network topology being resolved in advance. The value of a cycling network, however, depends on whether its segments join into continuous routes, and because the usability of a route tends to be governed by its least protected segment, even a single discontinuity can substantially reduce the value of the wider corridor. A framework that registers the completion of segments will not, on that basis alone, register whether the network is cohering, and cycling is a case where the gap between the two is especially consequential. These properties have also motivated formal work on how cycling networks grow from fragmented beginnings toward more integrated forms in the first place (Natera Orozco et al., 2020; Szell et al., 2022). The applied literature on cycling uptake is broadly consistent with the expectation that network continuity matters for ridership, even if the precise magnitude of that relationship remains empirically difficult to isolate and likely depends on local context (Schön, Heinen and Manum, 2024; Buehler and Dill, 2016).

As such, for monitoring, two networks of identical length, and even two networks each satisfying the mandated corridor-level requirements, can differ substantially in the continuous journeys they are capable of supporting, depending on how their remaining segments relate to one another. A framework that records kilometers delivered and verifies specified corridor connections can establish that investment has occurred and that discrete deliverables have been completed. It cannot, however, establish whether the funded kilometers, added to those already in place, are assembling into a system that functions coherently across the city. The distinction is thus not between frameworks that see connectivity and frameworks that do not. It is between frameworks that verify the completion of specified connections and frameworks capable of registering how the network as a whole is taking shape as investment proceeds.

The pattern is not specific to Italy. EU output-based funding more broadly favors indicators that are legible across member states and unambiguous at the point of verification, and the PNRR's reliance on kilometer targets reflects that broader preference. What this means for the argument of this brief is that the blind spot identified above is likely to recur wherever networked cycling infrastructure is funded through per-segment conditionality, rather than being a feature of Italian implementation alone. Barcelona and Paris, discussed previously in this brief, show that coherent cycling networks at comparable or greater scale are achievable outcomes rather than theoretical ones. The institutional conditions under which they achieved coherence, be it planning tradition, governance capacity, the structure of local cycling policy, or factors specific to each city, fall outside the scope of this analysis. What the comparison does establish is that no single metric is sufficient to assess how a cycling network is taking shape.

What Milan Illustrates, and What It Does Not

What the analysis establishes is that a monitoring framework verifying per-segment delivery and the completion of specified corridors is structurally incapable of registering whether the funded infrastructure is cohering into a network. Milan illustrates this by being a city that delivered substantial reported provision under a framework that monitored delivery effectively, and that nonetheless presents a cycling network 88.2% of which lies outside its main connected spine. The case is a worked instance of two of the principal flaws Boeri and Perotti (2026) identify in the PNRR. Monitoring gaps, in their account, prevent a proper evaluation of what worked and what did not; formalism over substance allows numerical compliance to substitute for the policy outcome the indicator was meant to capture. Both are visible in M2C2 as soon as network coherence is brought into the frame. Furthermore, Boeri and Perotti (2026) note in passing that "meeting the target of building a certain number of kilometers of railway does not automatically mean that those lines are the best use of public money", and this brief is a case of exactly that observation in the cycling domain.

This argument does not stop at Italy. The PNRR's milestone-and-target architecture is the standard form of EU performance-based funding under the Recovery and Resilience Facility, and the same logic that governs disbursement during the programme will govern the evaluation conducted after it. A framework that recorded only kilometers delivered and corridor completions can attest to those facts at closure yet cannot speak to whether the funded investment produced a functioning cycling network. The indicator-design problem this raises is therefore European in scope and structural rather than incidental.

The implication for the bilanci on the PNRR, and other similar frameworks at the EU level more broadly, is the following. DM 509/2021 did not specify network coherence as something the monitoring framework had to register, so it was not built into the assessment from the start. It can nonetheless be brought in now, since the data needed to register it is already publicly available in Milan and in comparable form across other Italian cities, as this brief demonstrates. The cycling-funding instruments that will follow the PNRR, whether under the post-2027 Cohesion Policy, the Connecting Europe Facility, or possible successor instruments to the RRF, are structured around output-based quantitative indicators that, in current form, do not register network coherence. The next programming cycle therefore has the opportunity to specify network-cohesion indicators at the outset, where they can shape both how funds are allocated and what can be assessed at closure.

Three limitations to this analysis are worth naming. The analysis cannot establish that kilometer-based monitoring caused Milan's fragmentation, since the relationship between indicator design and planning behaviour is not observable from the data used here. Nor can it establish that a connectivity indicator, had one been present in the PNRR framework, would have produced a different outcome in Milan or elsewhere, as the counterfactual is not testable within this design. The comparison with Barcelona and Paris likewise does not isolate the contribution of monitoring frameworks from other factors such as urban form, governance capacity, planning tradition, and the specific institutional history of cycling in each city. What the analysis does establish is the structural incapacity of the monitoring framework to register network coherence, which is sufficient to ground the recommendations that follow.

This point should not be read as implying that continuity is absent from Milan's own strategic vision. On the contrary, Möves (Figure 4) explicitly presents the city's cycling plan as a network that should become more extensive, more connected, and more recognizable, and it emphasizes routes that are linear, continuous, and safe. The qualitative objective is therefore already present in Milan's planning discourse. What remains weaker is its operationalization. The available public materials show that Möves contains a monitoring chapter and a broader strategic commitment to connectedness, however, no published city monitoring framework translates this objective into a formal network-cohesion diagnostic comparable to the indicators used in this brief. The contribution here is therefore to show how an acknowledged qualitative goal can be operationalized in practice, which the recommendations below take up.

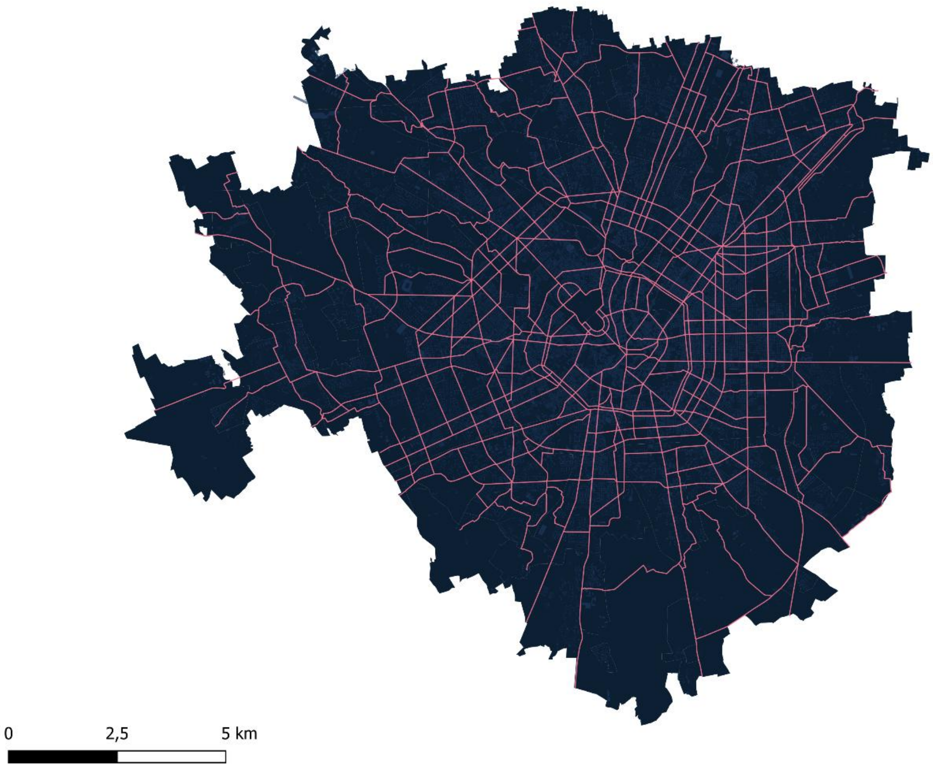


Figure 4: Möves Milan planned network with the cycling network represented by red lines.

Policy Recommendations

The findings suggest that Milan's cycling infrastructure challenge is one of how infrastructure coherence is measured and how investment priorities are set. If the PNRR's milestone-and-target architecture is to function, as Leonardi (2026) argues it can, as a learning experience for performance-based EU funding, the lesson available from this case is which network-level questions a successor framework must be capable of asking at the design stage in order to be capable of answering them at evaluation. The three recommendations that follow are an answer to that question for cycling infrastructure, and a template for analogous network goods:

1

EU and national funding frameworks should complement delivery targets with network-cohesion indicators.

Kilometer-based targets should be complemented by standardized indicators showing whether new infrastructure is strengthening a coherent network. Without them, monitoring can verify delivery without showing whether the system is becoming more usable.

2

Municipal and metropolitan authorities should use fragmentation analysis to prioritize high-return interventions.

Project appraisal should give explicit weight to whether an intervention closes gaps, connects existing segments, or strengthens the main network spine.

3

Municipal and metropolitan authorities should sequence investment toward consolidation before further expansion.

In fragmented networks, extending provision outward should not be treated as the default next step. Investment should first give greater weight to interventions that integrate existing infrastructure into a more continuous citywide system.

DATA AVAILABILITY AND REPLICATION

Primary data source: Comune di Milano Open Data Portal (dati.comune.milano.it). Coordinate reference system: EPSG:32632 (UTM zone 32N). Analysis date: January 2026. Network connectivity analysis was conducted via two independent pathways, both producing identical results: a custom script using Shapely, PyProj, NetworkX, and OSMnx; and infragap (Simić, 2026), an open-source Python library developed by the author for standardized infrastructure network diagnostics, available at github.com/VS-infrastructure-policy/infragap. Both replication pathways are available upon request.

References

Ajuntament de Barcelona (2025) Carril bici (Geospatial dataset). Barcelona: Open Data BCN.

AMAT (2025) Rapporto sulla mobilità a Milano 2024. Milan: Agenzia Mobilità Ambiente Territorio.

Boeri, T. and Perotti, R. (2026) An Evaluation of the Italian National Recovery and Resilience Plan, IEP@BU Policy Brief n.55. Milan: Institute for European Policymaking @ Bocconi University.

Buehler, R. and Dill, J. (2016) 'Bikeway networks: A review of effects on cycling', Transport Reviews, 36(1), pp. 9–27.

Buehler, R. and Pucher, J. (2021) 'COVID-19 impacts on cycling, 2019–2020', Transport Reviews, 41(4), pp. 393–400.

Città Metropolitana di Milano (2022) Piani Urbani Integrati — CAMBIO: 82 km di superciclabili del Biciplan della Città metropolitana di Milano.

Comune di Milano (2018) Piano Urbano della Mobilità Sostenibile (PUMS). Milan: Comune di Milano.

Comune di Milano (2025) Möves: Linee guida per la mobilità attiva. Milan: Comune di Milano.

Comune di Milano (2026) Itinerari ciclabili (Dataset DS60). Milan: Comune di Milano Open Data Portal.

Comune di Milano (2026) Nuclei di Identità Locale (NIL) – PGT 2030 (Geospatial dataset). Milan: Comune di Milano Open Data Portal.

European Commission (2021) Sustainable and Smart Mobility Strategy. COM(2020) 789 final. Brussels.

Geovelo (2025) Base Nationale des Aménagements Cyclables — Export national OpenStreetMap, December 2025 snapshot. Paris: transport.data.gouv.fr. Available at: transport.data.gouv.fr/datasets/amenagements-cyclables-france-metropolitaine.

Leonardi, M. (2026) ‘Why Italy’s NRRP Is Better Than It Looks: A response to Boeri and Perotti’s Policy Brief’, IEP@BU Commentary, 13 March. Milan: Institute for European Policymaking @ Bocconi University.

Ministero delle Infrastrutture e della Mobilità Sostenibili (MIMS) (2020) Decreto Interministeriale n. 395 del 16 settembre 2020, 'Programma innovativo nazionale per la qualità dell'abitare (PINQuA)'. Rome.

Ministero delle Infrastrutture e della Mobilità Sostenibili (2021) Decreto ministeriale n. 509 del 15 dicembre 2021, 'Modalità di utilizzo risorse Intervento 4.1 "Rafforzamento mobilità ciclistica" sub-investimento "Ciclovie Urbane" di cui alla misura M2C2 del PNRR'. Rome.

Natera Orozco, L.G., Battiston, F., Iñiguez, G. and Szell, M. (2020) 'Data-driven strategies for optimal bicycle network growth', Royal Society Open Science, 7, 201130.

Porter, T.M. (1995) Trust in Numbers: The Pursuit of Objectivity in Science and Public Life. Princeton: Princeton University Press.

Schön, P., Heinen, E. and Manum, B. (2024) 'A scoping review on cycling network connectivity and its effects on cycling', Transport Reviews, 44(4), pp. 912–936.

Schoner, J.E. and Levinson, D.M. (2014) 'The missing link: bicycle infrastructure networks and ridership in 74 US cities', Transportation, 41(6), pp. 1187–1204.

Simić, V. (2026) infragap: Infrastructure network diagnostics (Python library). Available at: github.com/VS-infrastructure-policy/infragap.

Szell, M. et al. (2022) 'Growing urban bicycle networks', Scientific Reports, 12, 6765.