From Static Proximity to Dynamic Accessibility: Integrating Smart-City Data into the 15-Minute City

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Abstract:
The 15-minute city has become an influential framework for proximity-based urban planning, but most operational assessments remain comparatively static: they measure whether destinations lie within a specified travel-time threshold under assumed network conditions. Smart-city infrastructures create the possibility of a more temporally responsive model. This article develops the concept of Dynamic 15-Minute Accessibility, in which neighborhood accessibility is evaluated across time using changing transit supply, congestion, operating hours, shared-mobility availability, pedestrian conditions, and other observable urban conditions. Drawing on recent research on human mobility, multimodal accessibility, GIS-based 15-minute-city measurement, smart technologies, and inclusive proximity planning, the article distinguishes potential accessibility from realized and reliable accessibility. It proposes a Dynamic Accessibility Index organized around destination availability, network travel time, service reliability, temporal availability, universal accessibility, and data confidence. Paris is used as the conceptual policy anchor, with implications for cities seeking to combine proximity planning with digital twins and real-time mobility systems. The article argues that smart-city technology is most valuable to the 15-minute-city agenda when it reveals temporal and social accessibility gaps rather than merely adding technological sophistication.

Keywords: 15-minute city; smart cities; accessibility; GIS; digital twins; urban mobility; chrono-urbanism.

1. Introduction

The 15-minute city has become one of the most recognizable planning ideas of the post-pandemic period. Its central proposition is that essential urban functions should be accessible within a short walk or bicycle trip, thereby reducing unnecessary motorized travel while improving local quality of life. Moreno et al. (2021) frame the concept through proximity, diversity, density, and digitalization, linking neighborhood accessibility to sustainability, resilience, and place identity.

Yet the practical measurement of proximity often remains static. Analysts identify amenities, construct pedestrian or cycling networks, calculate travel times, and determine the share of residents who can reach selected destinations within a threshold. These methods are useful, but they can imply that accessibility is a fixed property of urban form. In reality, accessibility changes by hour, day, season, traveler, and service condition. A clinic may be geographically close but closed. A bus route may provide excellent peak access and poor evening access. A shared-bicycle station may exist but have no available bicycles. A nominally walkable route may become difficult during extreme heat, flooding, construction, or elevator outages.

Smart-city data make these temporal differences increasingly observable. Real-time transit feeds, shared-mobility availability, traffic data, pedestrian sensing, operating-hour databases, digital twins, and environmental sensors can support a more dynamic understanding of accessibility. This article develops the concept of Dynamic 15-Minute Accessibility and asks how smart-city data can improve proximity planning without allowing technology to displace the underlying human-centered goals of the 15-minute city.

2. The 15-Minute City as an Accessibility Framework

The 15-minute city is best understood as an accessibility framework rather than a literal universal stopwatch. Moreno et al. (2021) emphasize access to essential urban functions, including living, working, commerce, healthcare, education, and entertainment. Subsequent scholarship has examined how the concept can be adapted to different urban forms and has warned against simplistic threshold-based interpretation.

Mouratidis (2024) identifies several pitfalls in the concept's use, including problems of equity, sustainability, livability, and spatial analysis. Bruno et al. (2024) similarly propose a universal framework that recognizes heterogeneity across urban contexts. These critiques are important because a binary map of 'inside' and 'outside' a 15-minute threshold can conceal meaningful variation in service quality and traveler experience.

Recent empirical work also demonstrates the difference between having nearby amenities and actually using them. Abbiasov et al. (2024), using large-scale human mobility data in the United States, found that local amenity access strongly explains variation in local trip behavior but also identified potential segregation trade-offs. This finding reinforces a basic point: spatial opportunity is not identical to realized behavior or social outcome.

3. Static Accessibility and Its Limitations

Conventional proximity analysis typically combines origins, destination points, a network, travel speeds, and a threshold. Each element contains assumptions. Point-of-interest datasets may be incomplete or inconsistent; recent research shows that POI source selection can materially affect 15-minute-city scores and inequality assessments (Niu et al., 2025). Travel speeds may be standardized even though pedestrian speed varies by age, disability, grade, crowding, and environmental conditions. Transit supply may be represented by scheduled service even when reliability varies substantially.

A second limitation is temporal availability. Urban services operate on schedules. Schools, childcare, pharmacies, clinics, grocery stores, parks, and government offices have different opening hours. Accessibility to a destination that is closed at the time of need has little functional value. The same applies to mobility supply. A transit stop is not equivalent to useful transit if headways are long or service has ended.

A third limitation is reliability. A resident may technically be within 15 minutes of an essential service on an average day but experience substantial variability. For time-sensitive trips such as childcare pickup, medical appointments, or shift work, the 90th-percentile travel time may be more relevant than the mean. A proximity model that ignores reliability can overstate practical accessibility.

4. Smart-City Technologies and the Opportunity for Dynamic Measurement

Recent scholarship increasingly connects the 15-minute city with digital transformation. Nica et al. (2026), in a bibliometric study of the 15-minute city and smart-city technologies, identify growing attention to digital twins, advanced communications, and data-driven urban mobility. Roscia et al. (2025) argue that smart and sustainable technologies can support accessibility, mobility, and well-being within proximity-based planning. The question is how to translate that technological potential into a defensible planning metric.

Digital twins are particularly relevant because they can integrate static spatial layers with changing system states. A city-scale accessibility model could update transit headways, elevator availability, bicycle-share supply, road closures, air-quality conditions, or extreme-weather exposure. The objective would not be to create a perfect real-time replica of urban life. It would be to identify when and where nominal proximity fails.

Smart-city data can also improve evaluation after interventions. If a city adds a school street, bus-priority treatment, cycle connection, or new community facility, planners can compare changes in accessibility not only spatially but temporally. This creates a stronger connection between smart-city sensing and planning accountability.

5. The Dynamic 15-Minute Accessibility Model

This article proposes three nested concepts. Potential accessibility describes what the built environment and service geography make possible under assumed conditions. Realized accessibility describes what residents can reach under observed conditions at a particular time. Reliable accessibility describes what residents can expect to reach consistently despite normal variation.

A Dynamic Accessibility Index (DAI) can be structured around six components. Destination availability measures whether an essential service exists and is open. Network travel time measures time through the actual walking, cycling, or transit network. Service reliability captures variability in transit or other mobility supply. Temporal availability captures changing schedules of both destinations and transport. Universal accessibility accounts for barriers such as missing curb ramps, elevator outages, steep grades, or other conditions affecting travelers with disabilities. Data confidence reports the quality and recency of the underlying information.

The index should not collapse all dimensions into an opaque score unless weights are transparent and justified. A dashboard approach may be preferable, allowing planners to see whether an accessibility deficit results from missing destinations, weak mobility connections, limited operating hours, poor reliability, or physical barriers. The diagnostic value is more important than producing a city ranking.

6. Paris as a Policy Anchor

Paris is closely associated with the contemporary 15-minute-city agenda and provides a useful policy anchor for dynamic accessibility. The city's proximity strategy has emphasized local services, walking, cycling, school streets, public-space reallocation, and mixed urban functions. At the same time, Paris possesses the dense transport and digital-data environment necessary for more temporally detailed accessibility analysis.

A static analysis might show that a resident can reach groceries, schools, parks, and transit within 15 minutes. A dynamic analysis would ask whether the same bundle remains accessible at 7 a.m., midday, evening, and Sunday; whether transit disruptions alter the result; whether bicycle availability changes access; and whether the result differs for a slower walker or a person requiring step-free transit. The result is not one 15-minute map but a family of accessibility surfaces.

This approach could also clarify the relationship between proximity and metropolitan mobility. The 15-minute city should not imply that all urban life must remain local. Residents need access to specialized employment, universities, hospitals, cultural institutions, and social networks across the metropolitan region. Dynamic neighborhood accessibility should therefore complement, not replace, high-quality regional transit.

7. Equity and the Risk of a Technocratic 15-Minute City

A smart version of the 15-minute city could reproduce the weaknesses of smart-city planning if it privileges data availability over social need. Neighborhoods with better sensors, richer POI databases, and higher digital participation may appear more legible to planners than informal or underserved areas. Data confidence should therefore be reported explicitly rather than allowing missing data to masquerade as poor performance or, worse, invisibility.

Equity analysis should disaggregate accessibility by population group and traveler capability. A 15-minute threshold based on an able-bodied adult's walking speed can overstate access for older adults, children, or people with mobility impairments. Similarly, real-time digital information is less useful to residents who lack reliable connectivity or cannot use app-based services. Smart-city technology should help expose these differences rather than define a technologically idealized traveler.

Abbiasov et al. (2024) also demonstrate that stronger local living can have complex social consequences, including relationships with experienced segregation. Proximity planning must therefore avoid turning neighborhoods into self-contained social territories. The goal is to increase choice and reduce forced long-distance travel, not to restrict metropolitan interaction.

8. Implementation Pathway for Planning Agencies

A practical implementation pathway can begin with a static baseline using open street networks, verified destination datasets, and multimodal travel-time analysis. The second stage adds temporal service information, including opening hours and scheduled transit. The third stage adds reliability and observed operations using real-time or historical feeds. The fourth stage incorporates universal-accessibility and environmental layers. Only after these foundations are stable should a city consider a full digital-twin environment.

Cities should publish assumptions, data sources, update frequencies, and known gaps. Sensitivity testing is essential because threshold-based accessibility can change materially with walking speed, POI definitions, and network assumptions. The recent GIS literature provides increasingly robust methods for measuring and visualizing proximity and public-transport supply (Vale et al., 2026). Dynamic analysis should build on that methodological transparency rather than replace it with proprietary black-box analytics.

Planning applications include neighborhood plan evaluation, school and clinic siting, transit-service planning, pedestrian capital programs, resilience planning, and equity screening. Dynamic accessibility can also support scenario testing. Planners could estimate how a bus-frequency increase, new crossing, protected bicycle link, extended library hours, or elevator repair changes the number of residents with reliable access to essential functions.

9. Discussion

The concept of Dynamic 15-Minute Accessibility reframes the relationship between smart cities and proximity planning. Technology is not the objective. Its value lies in revealing conditions that static planning misses. A sensor-rich city that does not improve everyday access is not necessarily more successful than a lower-tech city with well-distributed services and reliable mobility.

The approach also restores time to chrono-urbanism in an operational sense. Time is not only a travel threshold; it is a property of service schedules, reliability, daily rhythms, and changing network conditions. This distinction is particularly important for workers with nonstandard schedules, caregivers, older adults, and people whose travel choices are constrained.

Further empirical research should test the DAI across contrasting urban contexts and evaluate which dynamic variables materially change planning decisions. Comparative work could examine dense European cities, rapidly urbanizing Indian cities, and lower-density North American metropolitan areas. Such research would help determine where real-time complexity adds genuine planning value and where simpler accessibility measures remain sufficient.

10. Conclusion

The 15-minute city has helped re-center urban planning on proximity and everyday accessibility. Its next methodological challenge is to move beyond static representations without losing conceptual clarity. Smart-city data provide an opportunity to measure when proximity works, when it fails, for whom it fails, and why.

Dynamic 15-Minute Accessibility distinguishes potential, realized, and reliable access and evaluates destination availability, travel time, reliability, temporal availability, universal accessibility, and data confidence. This framework positions digital technology as a diagnostic instrument for human-centered planning. The smart 15-minute city should therefore not be defined by the quantity of sensors or sophistication of its digital twin, but by its capacity to make essential urban opportunities reliably accessible across people, places, and times.

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