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THE ROLE OF GEOGRAPHIC INFORMATION SYSTEMS IN EQUITABLE URBAN AND REGIONAL PLANNING: A NARRATIVE REVIEW

Samuel Nukporfe *

Northeastern University Boston, MA.
* Corresponding Author

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ABSTRACT

Geographic Information Systems (GIS) are increasingly a key element in planning for land use, infrastructure, and environmental protection in cities and regions across the United States. They have provided planners with the tools to visualize and analyze spatial data with greater precision than was possible a generation ago. GIS has, however, not necessarily led to more just outcomes; while GIS can identify spatial inequities, it can also subscribe to them without a conscious effort to consider data selection, community voice and who wins. This narrative review collates research that investigates GIS in equitable urban and regional planning in the United States, with a focus on four domains: methodological framework for urban and regional GIS analysis, environmental justice and cumulative impacts mapping, participatory and community engaged GIS, and application of GIS in transportation and green space equity. GIS provides its greatest equity benefits when it is used with intentional methodology and community-based indicator choice, and when it is scored in a transparent fashion to aggregate impacts. Without these choices, GIS-based techniques run the risk of replicating the gaps in transit service, green space, and environmental quality that they were intended to accurately identify. As a path for further study and practice, a conceptual matrix linking data selection, participatory action, and analytical results with equitable outcomes is proposed.

Keywords: Geographic Information Systems, Urban Planning, Regional Planning, Spatial Equity, Environmental Justice.

1 INTRODUCTION

Geographic Information Systems (GIS) allow planners to place environmental, demographic, infrastructure and land-use data on a common spatial reference system to help them make decisions using maps as their analytical tool and tables of data (Gorjian, 2025; Malaker & Meng, 2024). With the increasing number of systematic reviews on the use of GIS for urban analysis in the past few years, the state of application fields of GIS in quantifying and visualizing intra-urban inequality has been mapped (Gorjian, 2025), which includes accessibility, green space, health-related disparity, socioeconomic status, and open space provision. This is reflected in parallel reviews of transportation planning, which also show an increasing trend in equity-focused GIS applications, stakeholder participation, and, more recently, the use of artificial intelligence in spatial analysis applications (Zaroujtaghi et al., 2025; Liu et l., 2026).

This technical capability comes at a time when U.S. cities are still struggling with the ongoing challenge from spatial inequities in environmental exposure, transportation and mobility access, and distribution of green space, which

increasingly are diagnosed and, in theory, mitigated through GIS (Besse & Rojas-Rueda, 2025; Aman & Smith-Colin, 2020). The use of GIS based environmental justice tools has gained a pivotal role in pinpointing disproportionate exposure to pollution and hazard effects among communities (Rigolon, 2024; Min et al., 2019). Similarly, GIS-based accessibility analysis is now a routine practice for determining transit and green space gaps that focus in historically underserved neighborhoods, both through supply-demand gap modelling and dynamic measures of accessibility that reflect potential users instead of only actual users and through geospatial assessment of green space quality and distribution in individual cities (Aman & Smith-Colin, 2020; Robbennolt & Witmer, 2023; LaReaux & Watkins, 2025). Despite this growing toolkit, there is a consistent disconnect between GIS technical capabilities and equitable outcomes in practice. While methodological reviews of GIS-based urban analysis have reported the increasing number of accessibility metrics and disparity measures, they have shown that the research has been focused on specific contexts in industrialized societies and that accessibility often has been quantified using simplified distance-based measures that can be misleading when it comes to actual barriers to access (Gorjian, 2025; Malaker & Meng, 2024). Thematic reviews of transportation also draw comparable conclusions but from a different perspective. They review progress toward equity and involvement of stakeholders in GIS-transportation research, and found relatively little influenced by the general literature and work done on urban disparity. (Hoover et al, 2023; Zaroujtaghi et al., 2025). Environmental justice mapping research shows that a mapping tool's design, what indicators are included, how to measure cumulative impact, and whether the community is involved in designing the tool greatly influence whether disparities are discovered or hidden (Sun et al., 2026; LaReaux & Watkins, 2025). Although participatory GIS is not widely used in formal planning, there are some advantages to be had by integrating community engagement with spatial techniques, such as creating more locally valid and actionable results than mapping by experts alone (Sadler et al., 2019). In the meantime, studies on green infrastructure planning demonstrate that, even when cities have tools to analyze equity through GIS, the capacity to do this does not necessarily equate to a distribution of benefits (Hoover et al., 2023; Robbennolt & Witmer, 2023). Also, research on individual city plans indicates that the city-specific assessments of greenness and the advocacy organizations that seek to fill the gap do not demonstrate this equitable benefit distribution (Rigolon et al., 2024; LaReaux & Watkins, 2025). Despite these strands being largely disconnected, planners have no single sense of what makes a technically capable GIS application an equitable one, nor a rationale for selecting from divergent designs of tools and modes of engagement.

This review fills this gap by summarizing the literature in four thematic areas of urban analysis using GIS, environmental injustice and cumulative impacts mapping, participatory and community engaged GIS, and GIS in transportation and green space equity. It unfolds by describing the approach to the search, presenting the thematic synthesis, suggesting a linkage of the domains to equitable outcomes, and reflecting on the implications of the evidence for research and practice.

2 METHODS

The literature reviewed in this paper was done using peer-reviewed papers that were found through Google Scholar, ScienceDirect, PubMed and arXiv and were limited to papers published between 2019 and 2025, to provide the very latest in methodological and applied evidence on the use of GIS to inform equitable planning. In an iterative process, across the four thematic domains of the review, a series of searches was done using GIS, urban planning, regional planning, spatial equity, environmental justice mapping, cumulative impact assessment, participatory GIS, transit accessibility, and green infrastructure equity, as keywords.

Sources were considered if they had been published since 2019, if they covered planning functions other than GIS that could be linked to the issue of spatial equity, if there were methods that were applicable to the U.S. planning context, and if there were methods discussing spatial equity related planning functions (environmental burden, access to transit, green space distribution) or equity outcomes. Sources not mentioning GIS as a planning or equity component were not included, nor were sources published prior to 2019, as well as those sources that discussed equity in a context outside the U.S. The retained sources were sorted by the primary contribution and subsequently grouped together in the next sections.

3 DATA SYNTHESIS

The reviewed literature is grouped into four areas that collectively outline the influence of GIS on equity outcomes in the planning process in the United States: methodological foundations, environmental justice and cumulative impact mapping, participatory and community engaged GIS, and applications in transportation and green space equity. This structure is a manifestation of a trend in the recent literature, moving from GIS as a general analytical technology to the identification of disparities, to who is the actor in this identification, to actual domains where the actors' decisions give rise to tangible distributive effects. The sources were identified as the primary contributor and combined to create the conceptual framework in Section 3.2.

3.1 Theme 1: Methodological Foundations of GIS-Based Urban Analysis

Recent systematic reviews have shown that GIS-based urban inequality studies have developed into a specific methodological domain with identifiable thematic groups and common methodological shortcomings. Based on an analysis of peer-reviewed studies applying GIS in the field of intra-urban disparities, Gorjian (2025) identifies five main domains of study: accessibility, green space, health disparities, socioeconomic status, and open space provision; and concludes that current research focuses primarily on industrialized settings like the United States, compared to which rapidly urbanizing regions are comparatively under-researched. This is not just about representativeness, as the analytical techniques detailed in the review are developed from well-resourced and data-rich U.S. metropolitan contexts, fine-grained parcel data, high-resolution imagery, integrated municipal datasets, which are not necessarily at the disposal of jurisdictions with less dense or standardized spatial data; thus, the methodological maturity evident in the review is unevenly distributed across the very geographies of GIS. The review also points to a longstanding methodological risk: numerous accessibility analyses use the simplified Euclidean distance measure, which can overlook some of the actual obstacles that can hinder access to a resource, especially for applications focused on equitable access, because a measure that underestimates barriers to access for transit-dependent or mobility-constrained populations can also conceal the true disparities that a tool is intended to highlight. Socioeconomic status was also identified as often being used as a background control variable instead of a primary lens of analysis, thereby understating the amount of influence socioeconomic variables have on the spatial pattern of accessibility, green space, or health disparity outcomes (Hoover et al., 2023).

In a supporting systematic review of urban disparity analytics, Malaker & Meng (2024) report a similar expansion of the field in terms of techniques, including the addition of longitudinal analysis and composite inequality indices, but also a lack of integration and disciplinary diversity. While they used to analyze disparity by comparing maps from a single snapshot, they now consider mapping through time to determine whether a particular intervention, transit line, rezoning decision and green infrastructure investment among others, actually reduces or increases disparity over time, which is important because cross-sectional maps alone do not tell whether it is a one-time or long-term improvement. This fragmentation is also reflected in the transportation-specific literature examined by the reviews by Zaroujtaghi et al., (2025) and Malaker & Meng (2024), which found a clear shift over the last 21 years (2004–2024) toward the themes of equity, stakeholder engagement and AI in transportation planning, while noting that these thematic advancements have progressed largely outside of the larger framework of urban disparities examined by the reviews by Zaroujtaghi et al., (2025) and Malaker & Meng (2024). They demand more integration of non-traditional data sources, such as social media and remote sensing, and interdisciplinary collaboration between urban planners, public health and data analytics, since this separation itself hinders the production of GIS-based analysis that planners can act on with confidence. Another consequence of this fragmentation is that results of one application domain (for instance; health-related disparity metrics) do not often inform methodological decisions in another (for instance; modelling transit accessibility), even though the underlying spatial reasoning (what can be reached by whom at what time or distance within a cost), is similar across them (Min et al., 2019). These methodological reviews taken together give reason to believe that the technical complexity of analyzing an urban area using GIS has now surpassed the standardization and validation of how this analysis is conducted, and that this in itself is highly significant for equity related applications of urban analysis, as outlined in the themes that follow, where a methodological decision made without cross-domain awareness can silently reproduce a bias, such as the use of simplified distance metrics or background-variable treatment of socioeconomic status, that another field of study has already resolved.

3.2 Theme 2: Environmental Justice and Cumulative Impact Mapping

Environmental justice mapping tools, which bring together environmental, socioeconomic, health and demographic information to help define communities that are disproportionately exposed to pollution and other hazards, have exploded in the past few years both nationally and at the state level (Gorjian, 2025). In their recent review of 25 such tools in the United States, Besse & Rojas-Rueda (2025) identifies significant differences in geographic resolution, frequency of updates, breadth of indicators, and meaningful gaps in representation of U.S. territories and the absence of communicable disease or climate-related indicators. This variation is not just theoretical: a tool, which is built at the census-tract level, can fail to capture the block-by-block variation in an exposure situation, and a tool that is updated every several years can fall behind the curve of a rapidly changing exposure situation, like a new industrial permit or an unexpected increase in extreme heat days, in a way that could compromise its usefulness in informing a real-time policy decision. Studies propose cumulative impact assessments should be more consistently incorporated into tools, as the mix and weighting of hazard and vulnerability indicators will either bring them to the surface or obscure them from view to the impact of most vulnerable communities (Robbennolt & Witmer, 2023; Zaroujtaghi et al., 2025). The review also notes that the lack of a common indicator framework for tools created by agencies makes it difficult to compare disparities across state lines, and makes it difficult for a community on one side of a state line to be identified by a tool on the other when the underlying hazard (such as a shared watershed or airshed) does not respect the line.

Assurance and methodological parameters are combined in state-level tools. In order to facilitate comparisons of environmental health disparities at the census tract level across the state, Min et al., (2019) describe the development

of the Washington Environmental Health Disparities Map, which integrates nineteen environmental and population indicators into a cumulative impact ranking created through an open community–academic–government collaboration. Of particular interest is the development of the tool itself, which did not start with a set of indicators already available in the existing national tools, but in which the development team consulted community members together with academic and government partners to identify which of the nineteen indicators was most important and how they should be ranked in relation to each other; this took a lot longer than selecting an off-the-shelf list of indicators but is essential for rankings to be accepted by the communities affected as accurate (Robbennolt & Witmer, 2023; Liu et al., 2026). Studies emphasize that many of the current mapping tools have not explicitly included community voice and lived experience in their development, a gap their community-driven framework was created to fill, and which sets a truly equity-oriented cumulative impact tool apart from one that is just comprehensive in terms of its data inputs (Sadler et al., 2019; Besse & Rojas-Rueda, 2025). The technical-comprehensiveness versus community-grounded-validity distinction can be found throughout the environmental justice mapping literature, and foreshadows the participative GIS theme that is detailed in the next section, as the Washington tool is essentially a combination of the cumulative impact methodology of Theme 2 and the participative design principle of Theme 3 (Min et al., 2019; Besse & Rojas-Rueda, 2025).

3.3 Theme 3: Participatory and Community-Engaged GIS

Another strand of literature reflects a concern with "who decides what" GIS tools measure, as it asserts that the design process of these tools is a contested process and that the role of community in the design of these tools is a crucial factor in equitable planning outcomes, rather than an add-on (Hoover et al., 2023; Sun et al., 2026). Sadler et al., (2019) present an in-depth case study of the application of this principle in Flint, Michigan, where community and academic partners collaborated to identify and calculate the values of the variables from each of the six categories (amenities, environment, green space, housing, infrastructure, and social issues) and to determine how to weight these variables using a structured multiple-criteria decision-making process called the analytic hierarchy process. The approach used was to have community and academic specialists independently assign a relative importance to each variable category, and then mathematically combine the experts' opinions into consistent weights, a methodology specifically selected to ensure that disagreement among the experts is surfaced and resolved in a systematic way, rather than informally in favor of the voice with the most institutional authority in the room (Sadler et al., 2019). The resulting index showed significant differences in how healthy neighborhoods were throughout Flint, and the authors' major innovation is methodological: They asked community partners instead of experts to select and weigh the input variables, resulting in an index that reflects community priorities rather than outside assumptions about what makes a neighborhood healthy (Sadler et al., 2019). The process was an analytic hierarchy exercise that involved residents, however, and generally took a long time, whereas a purely expert-driven index would not have taken that long; however, the authors argue that this is a worthwhile tradeoff because by involving residents in the process, it adds legitimacy and local accuracy to the resulting map, and because allocation of the additional time in the project timeline is directly relevant to planning agencies, as it is what distinguishes true co-design from a token consultation exercise that is crammed into the back end of a project timeline.

This case also points to a more general theme in participatory GIS literature: the process of participatory GIS, even when carried out in a technically sound manner, can end up being a tool for imposing the analyst's priorities on the community that is being analyzed, priorities that may not correspond to the community's lived priorities. Factors that lead to an informal reputation of a specific corner or inconsistent lighting that no typical data set would record, or a history of a specific incident can influence a resident's felt sense of an unsafe or unhealthy block and could be designed into a jointly developed indicator framework to approximate. Where community members themselves are engaged in the process of variable selection, as in the Flint healthfulness index, an extra layer of validity is added to the spatial products, one that cannot be attributed solely to technical approaches. The same contradiction between technically sound and community-validated GIS output that characterized the most effective environmental justice tools from Theme 2 also reappears in the transportation and green space applications discussed below, where the same question – whose definition of need or benefit is built into the model – determines whether a technically elegant accessibility or suitability analysis translates into a plan the affected community recognizes as just.

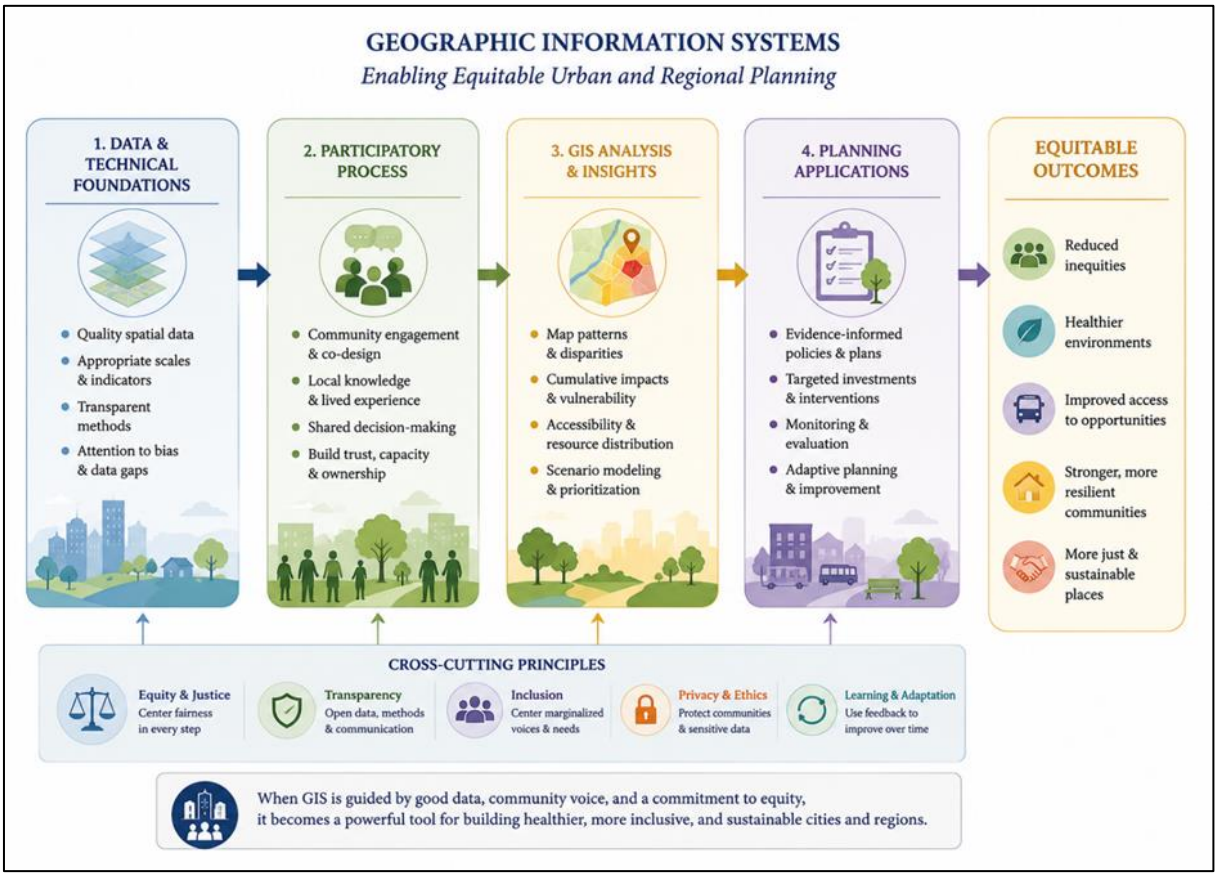
3.4 Theme 4: GIS Applications in Transportation and Green Space Equity

GIS-based equity analysis has been translated into practice in two of the most tangible areas: transportation and access to green space. Inspired by the idea of a transit desert, Aman & Smith-Colin, (2020) create a GIS-based equity analysis of public transit accessibility that measures the inequity in public transit supply and the demand of transit-dependent populations, finding that inequity disproportionately affects neighborhoods with greater percentages of low-income residents as well as minorities. Robbennolt & Witmer, (2023) take this work on a methodological step further by using a GIS-based dynamic accessibility approach to measure accessibility to transit in Champaign-Urbana, Illinois, using potential riders instead of current riders, thus revealing that traditional ridership-based measures of accessibility systematically understate the service gap in communities that are not served by transit just because they are not served

by transit. This result has direct implications for how transit agencies measure accessibility to transit, as well as their own measures of transit equity, beyond relying on ridership data collected from the population using the service.

Equity for green space has also been taken up separately. In their analysis of 122 official green infrastructure plans from 20 cities in the United States, Adu et al., (2025) report that although the overwhelming majority of plans list the benefits of green infrastructure for reducing flooding, heat and other hazards, less than 10% of plans address the underlying causes of inequitable distribution and vulnerability, and even fewer explicitly examine issues of gentrification and displacement. While many plans refer to "equity", fewer plans explicitly define the concept, and even fewer explicitly define justice, and the authors conclude that, despite the frequent use of GIS in site selection and suitability analysis, formal green infrastructure planning in U.S. cities does not often lead to equitable outcomes (Hoover et al, 2023; Gorjian, 2025). At the city level, applying geospatial analysis to the problem of green space equity in Detroit, Michigan, LaReaux & Watkins, (2025) further confirm this, revealing that the amount of green space, while important, does not necessarily reflect meaningful inequities in quality, quantity, or type of green space, and by itself, it is a poor indicator of the value that a specific patch of green space provides to its surrounding community. Rigolon et al., (2024) examining a national initiative to support green space equity advocacy, conclude that the most successful NGOs in terms of moving the needle on municipal investment; use evidence from GIS and continued policy engagement with a variety of stakeholders such as politicians and youth organizers, showing that such technical mapping efforts are not enough to improve planning outcomes without a broader organizing push to drive action on the maps produced. Another methodological review of GIS-based approaches to assessing urban green infrastructure reveals that whilst the data and analytical approaches used to evaluate green infrastructure have progressed significantly, the relationship between such analysis and the development of equitable implementation guidance is still in its infancy and a large gap exists between what can be identified through GIS analysis and what is actually implemented in planning practice (Hoover et al., 2023; Wu et al., 2025). Taken with Theme 2 and Theme 3 this pattern demonstrates a common thread throughout the review: the technical capacity of GIS to identify inequity has advanced faster than the planning processes, community engagement structures, and organized political commitments needed to act on what it reveals.

3.5 Conceptual Framework



Source: Author's construct, 2026.

Figure 1: Geographic Information Systems: Enabling Equitable Urban and Regional Planning

The four thematic domains synthesized in this review converge on a single underlying pathway: GIS advances equitable planning only when sound data and technical foundations are paired with genuine participatory process, and only when

the resulting analysis is actually carried through into planning applications rather than left as a diagnostic exercise. The evidence base of this review was used to create a conceptual framework that captured this pathway. This framework organized the contribution of GIS into five sequential stages: data and technical foundations, participatory process, GIS analysis and insights, planning applications, and equitable outcomes. These stages are connected by a set of cross-cutting principles that must hold true at each stage for the pathway to work as intended. Figure is displayed in the framework.

As shown in Figure 1, the pathway starts with data and technical pathways, but quality of the spatial data is essential, as is appropriate scales and indicators, transparent pathways, and explicit consideration of bias and any gaps in data; poor or incomplete inputs at this stage, will impact all subsequent steps. This foundation is linked to a participatory process where community participation, co-design, community knowledge and shared decision-making shape the meaning of the indicators and priorities embedded in the data, not just assumptions made from the outside. When these two steps are integrated, GIS analysis and insight actually matter; it can be used to map patterns and disparities, to gauge cumulative impacts and vulnerability, to model accessibility and resource distribution, and to run scenarios to prioritize action. These insights are translated into planning applications, evidence informed policies, targeted investments, continuous monitoring, and adaptive planning, that translate a diagnosis into an application of intervention. This journey ends in a more equitable world with less inequity, healthier environments, better access to opportunities, more resilient communities, and more just and sustainable places. Underlying all five stages are the cross-cutting principles of equity and justice, transparency, inclusion, privacy and ethics, and learning and adaptation, which are not a separate stage in the pathway but are the conditions that need to be met for the pathway to hold together, otherwise, a technically competent dataset that does not follow the principles of privacy, or a participatory process that does not put the voice of marginalised groups at the heart of the process, breaks the chain. When combined, the framework explicitly illustrates that GIS can be a powerful instrument for creating healthier, more inclusive and sustainable cities and regions only if applied to good data, community voice, and a consistent and sustained focus on equity throughout the entire process rather than just one step.

4 CONCLUSION

This narrative review aimed to pull together the latest evidence from four seemingly interrelated domains: methodological foundations of GIS-based urban analysis, environmental justice and cumulative impact mapping, participatory and community-engaged GIS, and GIS applications in transportation and green space equity, in order to conclude that GIS's role in equitable planning in the United States is not merely a function of its technical sophistication, but of its deliberate design and application choices. The evidence is strong: technically comprehensive tools, but that lack these commitments risk reinforcing the inequities they were designed to identify; tools created with the help of community-determined indicators and accessibility measures that take into account potential as well as actual users often yield more equitable results. However, as the evidence cited here also demonstrates, the design process is not enough to gain equity, it is only when this effective design stage is translated into policy, investment, and adaptive monitoring that several of the studies reviewed saw even technically robust tools stalling. As GIS continues to move beyond the traditional boundaries of planning practice, the evidence amassed here indicates that the value of GIS may be determined more by how planners engage with community-led data and indicator design, and how planners then address the follow-through needed to enact what the data suggests than by how they continue to make GIS technically better.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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