

Review

Assessing Trip-Generating Development Licensing from a Sustainable Urban Mobility Perspective: An Integrative Review with Evidence from Brazil

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Abstract

Licensing processes for trip-generating developments (TGDs), referred to in the Brazilian literature as *Polos Geradores de Viagens* (PGVs), remain predominantly guided by an operational logic centered on local roadway performance, despite progress in the literature on sustainable urban mobility. This article examines these regulatory frameworks from a sustainable urban mobility perspective through four analytical dimensions: licensing scope, metrics, urban context, and mitigation strategies. Based on an integrative review of scientific and technical–institutional sources, the results show that recent conceptual and normative advances have not translated into a substantive reorganization of regulatory practice. Level of service (LOS) continues to be the dominant reference, the built environment is incorporated only to a limited extent, and mitigation measures are still focused on expanding roadway capacity. The analysis of the regulatory frameworks of five Brazilian jurisdictions reinforces this diagnosis. The findings suggest that aligning TGD licensing with sustainable urban mobility principles requires coordinated changes across the four dimensions, moving beyond piecemeal adjustments and adopting an evaluative logic capable of supporting more accessible and sustainable urban environments.

Keywords: trip-generating developments; sustainable urban mobility; development licensing; transportation impact assessment; built environment



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1. Introduction

Trip-generating developments (TGDs), referred to in the Brazilian literature as *Polos Geradores de Viagens* (PGVs), are developments whose size, nature, and location produce distinct effects on travel patterns, road safety, and the environmental conditions of the surrounding urban area [1,2]. The PGV concept broadened the earlier notion of *Polos Geradores de Tráfego* (PGTs), centered on motorized traffic generation and roadway impacts [3], to encompass trips by all transport modes and a wider set of urban impacts [4,5]. Licensing is the instrument through which public authorities assess projected impacts, establish conditions for implementation, and define mitigation measures, and it has been progressively incorporated into urban regulatory frameworks across several countries [2,6]. However, the central aspects of this process, such as the criteria that determine which developments must be assessed, the metrics employed in the assessment, and the nature of

the required measures, vary across jurisdictions and have become the subject of increasing debate in the literature [7–9].

In this context, the assessment of TGD impacts requires the recognition that the externalities a development generates in regards to mobility do not arise solely from its size, typology, or operational pattern, but from the interaction between the development and the urban context in which it is embedded [10], shaped by land use and transport provision. From this interaction emerges accessibility, understood as the ease with which people reach opportunities from a given location [11,12]. In line with the sustainable mobility paradigm, this assessment should be guided by the promotion of accessibility; the reduction of automobile dependence; and the prioritization of strategies capable of mitigating social, environmental, and territorial impacts [13]. By recognizing accessibility as the integrated expression of the land use–transport relationship, the licensing of TGDs should not be limited to local roadway performance, but should also consider the development's effects on regional travel patterns, the conditions of the surrounding area, and the mitigation measures most compatible with sustainable urban mobility.

The planning of sustainable urban mobility involves concepts and methodologies that are relatively recent and still under consolidation [14]. In the field of TGD licensing and impact assessment, however, this conceptual evolution has not yet been fully translated into practice [9]. The literature indicates that these processes remain predominantly anchored in vehicle trip generation and operational metrics, with limited sensitivity to the urban context and incomplete incorporation of factors related to the built environment [15]. Within this framework, level of service (LOS) remains the dominant reference, despite criticism for prioritizing vehicular flow over systemic indicators such as vehicle kilometers traveled (VKT), which are more sensitive to the intensity of automobile use and its associated externalities [8,16,17].

The influence of built environment characteristics on travel patterns, widely documented in the literature, remains only partially incorporated into conventional assessment approaches, which tend to prioritize aggregate estimates of vehicular trips without adequately considering contextual factors [10,17]. In this context, required mitigation measures tend to remain centered on roadway capacity expansion, with limited consideration of travel demand management strategies [18]. Taken together, these gaps suggest that the conceptual evolution of sustainable urban mobility has not been matched, to the same extent, by licensing instruments, underscoring the need to understand the extent to which these processes approach or diverge from a sustainability-oriented approach [19].

This gap is particularly relevant in urban contexts marked by structural inequality, where the licensing of developments concerns not only the mitigation of negative impacts on the road system, but also the harnessing of positive externalities generated by developments, particularly in urban areas with deficits in accessibility to employment, commerce, and service opportunities [20]. The sustainable urban mobility perspective broadens the scope of licensing by articulating the economic, environmental, and social dimensions of urban development, a condition relevant for promoting fairer and more inclusive accessibility conditions in unequal contexts.

In light of this scenario, this article aims to analyze the conceptual and methodological evolution of TGD licensing from a sustainable urban mobility perspective. To this end, it systematizes the scientific literature and technical and institutional references according to four analytical dimensions: (1) licensing scope; (2) assessment metrics; (3) urban context and accessibility; and (4) mitigation strategies. The analysis is then discussed in light of the Brazilian context, based on the examination of licensing procedures in five jurisdictions, with a view to supporting the improvement of regulatory frameworks and assessment practices committed to sustainability.

Furthermore, the article articulates these dimensions within an integrated analytical framework, enabling examination not only of each dimension in isolation, but also of how they condition each other throughout the licensing process. This integrated reading constitutes the central contribution of the article: it explains why partial adjustments, such as replacing assessment metrics without revising licensing scope, contextual assessment, or orientation of requirements, tend to have limited transformative capacity. It also provides a diagnostic basis for identifying where regulatory practices diverge from the attributes expected of procedures aligned with sustainable urban mobility. The systematization of the scientific and institutional corpus and the diagnosis of the five Brazilian jurisdictions are complementary contributions derived from this integrated framework.

For this purpose, the study adopts an integrative review [21], drawing on two complementary sets of sources:

- Scientific output indexed in international databases;
- Technical and institutional documents, including manuals, regulatory frameworks, and legal provisions from the Brazilian, U.S., U.K. and European contexts.

The inclusion of these contexts is justified by the fact that the U.S. and European experiences express different traditions of urban and transport planning, with the former more closely associated with the operational assessment of development impacts and trip generation, and the latter more oriented toward strategic instruments of sustainable urban mobility. This contrast enriches the analysis of the Brazilian case, whose regulatory, institutional, and socio-spatial specificities are comparable to challenges faced by other developing countries.

The article is organized into four sections, in addition to this introduction. Section 2 describes the methodological procedures adopted in the integrative review. Section 3 presents the results, organized according to the four analytical dimensions. Section 4 discusses the findings. Section 5 presents the conclusions and implications for research and licensing practice.

2. Methodology

The study adopts an integrative review of the literature [21], an approach justified by the heterogeneous nature of the sources that inform the literature and practice of TGD licensing. A significant portion of the references that guide this practice are not published in scientific journals but in technical and regulatory documents, institutional guidelines, and legislation, and this plays a central role in defining the assessment criteria, analytical procedures, and mitigation measures. In this context, the scientific literature informs the conceptual and methodological debate, while technical and institutional references allow for the examination of how this debate is translated into practice through the criteria, metrics, and procedures adopted in licensing.

The four analytical dimensions were defined at the intersection between the operational structure of TGD licensing and the principles of sustainable urban mobility [13]. From an operational standpoint, TGD licensing involves four recurrent analytical decisions: defining which developments are subject to assessment, establishing how their impacts are measured, considering the urban context in which those impacts occur, and determining which measures are required as conditions for approval, as reflected in Brazilian and international impact assessment guidance [2,3]. This correspondence with the operational structure of the licensing procedure, rather than a thematic selection, explains why these four dimensions, instead of alternative categories, were adopted. The first dimension (D1) concerns the licensing scope, that is, the criteria by which developments are defined, classified, and subjected to impact study requirements. The second (D2) addresses the metrics employed to measure a development's impacts on the mobility system. The third

(D3) examines the influence of the urban context and accessibility as conditioning factors of these impacts. The fourth (D4) analyzes the nature and orientation of mitigation strategies, distinguishing between responses centered on roadway capacity and approaches oriented toward travel demand management and sustainable mobility. From a normative standpoint, these same stages correspond to the main points of tension, as documented in the literature, between the conventional approach, centered on roadway performance and traffic accommodation, and the sustainable mobility perspective, i.e., the criteria for framing and screening developments [22], the shift from level of service toward VKT-oriented metrics [16], the incorporation of the interaction between development and the built environment [10], and the reorientation of mitigation measures from capacity expansion toward travel demand management [7]. The dimensions, therefore, do not constitute isolated themes but rather interdependent components of the licensing process, analyzed in an integrated manner.

Issues such as distributive equity, social participation, and governance were not treated as recurrent operational stages of the licensing procedure, but as attributes that cut across the entire process, bearing on the scope of assessment; the choice of metrics; the interpretation of the urban context; the definition of mitigation measures, and the monitoring of their implementation; for this reason, they are addressed as cross-cutting elements in the discussion. Implementation monitoring, in turn, is examined within the mitigation strategies dimension (Section 3.4).

Taken together, these dimensions provide a framework to contrast the trends identified in the scientific literature with the prescriptions contained in technical and institutional documents, examining both the advances and the persistent gaps in the evolution of licensing. The dimensions, their respective analytical foci, and the guiding questions of the review are presented in Table 1.

Table 1. Analytical dimensions and guiding questions of the review.

Dimension	Guiding Questions
Licensing scope	How are TGDs defined for licensing purposes? What criteria guide their classification? What thresholds trigger impact study requirements?
Assessment metrics	What metrics are used to assess impacts? Do they remain centered on operational traffic performance, or do they incorporate objectives associated with sustainable urban mobility?
Urban context and accessibility	To what extent are built environment attributes (such as density, land use diversity, urban design, and transport provision) considered as factors that shape TGD impacts? How is accessibility, understood as the integration between transport and land use, incorporated into the assessment?
Mitigation strategies	What mitigation strategies are required or recommended? Are they predominantly oriented toward expanding roadway capacity or promoting sustainable urban mobility?

The guiding questions presented in Table 1 provide a framework for reviewing, extracting data from, and comparing the selected sources, facilitating the identification of convergences, discrepancies, and gaps between the scientific literature and the technical and

institutional documents regarding the main components of TGD licensing. The following subsections describe the search and selection strategies for scientific sources (Section 2.1), the identification of technical and institutional documents (Section 2.2), and the analytical procedures applied to the full corpus (Section 2.3).

2.1. Review of the Scientific Literature

The scientific literature was identified through searches in the Web of Science and Scopus databases, selected for their international coverage, standardized metadata, and frequent use in literature reviews on transport [23]. To capture the conceptual evolution of the field and approaches aligned with sustainable mobility, no starting date restriction was applied to the search. Search queries were structured around a core theme of TGD licensing and impact assessment, combined with specific terms corresponding to the four analytical dimensions of the review. This strategy aimed to retrieve studies directly related to the focus of the review, while excluding articles that, although linked to urban mobility, did not focus on development licensing or impact assessment. Table 2 presents the search strings and parameters used. The screening process, including identification, duplicate removal, eligibility assessment, and inclusion, is summarized in Figure 1.

Table 2. Search strategy for scientific literature.

Criterion	Description
Databases	Web of Science, Scopus
Base search string	("trip generation *" OR "traffic impact stud *" OR "traffic impact analysis" OR "transportation impact stud *" OR "transportation impact analysis" OR "trip-generating development *")
Dimension 1: TGD licensing scope	Base string AND ("development review" OR "development approval" OR "review process" OR "impact assessment" OR "land use regulation" OR "zoning")
Dimension 2: Assessment metrics	Base string AND ("level of service" OR LOS OR "vehicle kilometers traveled" OR VKT OR "vehicle miles traveled" OR VMT OR "multimodal level of service" OR MMLOS OR "mode share" OR sustainability)
Dimension 3: Urban context	Base string AND ("built environment" OR "transit accessibility" OR "destination accessibility" OR "distance to transit" OR density OR "land use mix" OR "mixed use" OR walkability OR pedestrian OR "transit-oriented development" OR TOD)
Dimension 4: Mitigation strategies	Base string AND (mitigat * OR "travel demand management" OR TDM OR "trip reduction" OR "trip cap" OR "parking management" OR "mobility management" OR "sustainable transport *" OR "sustainable mobility")
Search fields	Title, abstract, and keywords
Period	No starting date restriction; searches conducted up to March 2026
Document types	Peer-reviewed journal articles
Analysis tool	VOSviewer version 1.6.20

* Truncation wildcard used to retrieve terms with different endings.

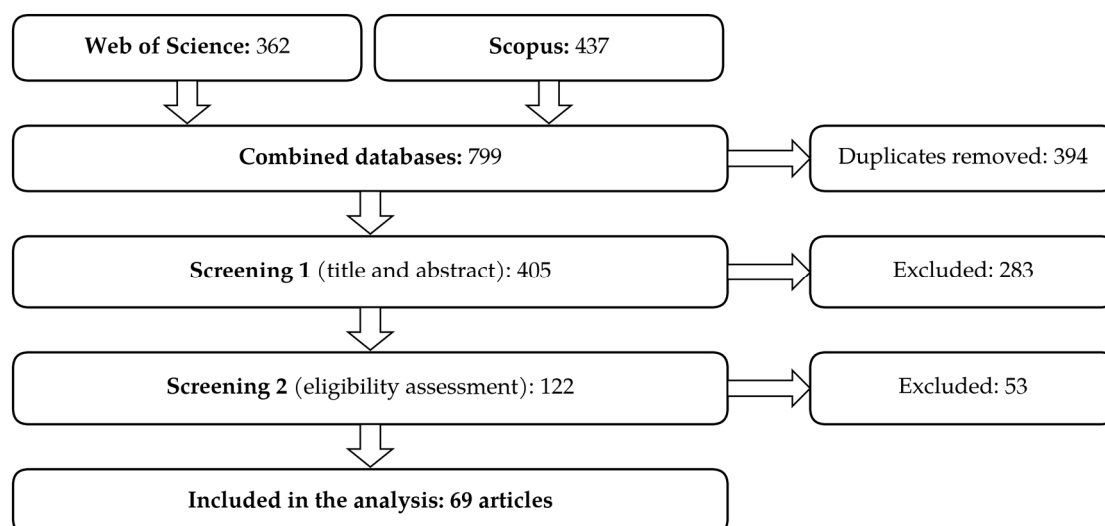


Figure 1. Flow diagram of the article selection and screening process. Source: adapted from PRISMA recommendations.

Figure 1 summarizes the article selection process. Searches in the Web of Science and Scopus databases yielded 799 records. After removing 394 duplicates, 405 articles were subjected to title and abstract screening (Screening 1), resulting in the exclusion of 283 articles that did not address development impact assessment. The remaining 122 articles underwent an eligibility assessment (Screening 2) to verify the relevance and distinct contribution of each study to at least one analytical dimension. At this stage, 53 articles were excluded for three predominant reasons: typology-specific trip-rate calibration without methodological contribution beyond local rate adjustments; redundancy with more comprehensive studies already included in the corpus; and lack of direct connection to TGD licensing or impact assessment. The final corpus comprised 69 articles included in the analysis.

2.2. Technical and Institutional Review

Unlike the scientific literature, many of the references that guide TGD licensing practice are formalized in technical manuals, regulatory frameworks, and legal provisions. These documents define classification criteria, study requirements, assessment metrics, and mitigation guidelines, directly shaping how licensing is conducted in each regulatory context. The review covered four institutional contexts, selected because they represent distinct trajectories in the structuring of TGD licensing and different stages in the incorporation of sustainable mobility principles.

In Brazil, the review considered federal frameworks that establish general guidelines for trip-generating developments, notably the DENATRAN guidelines [3] and the National Urban Mobility Policy [24]. Although TGD licensing in Brazil falls under municipal jurisdiction, local regulations are examined in Section 4, where the review findings are contrasted with the licensing frameworks of five Brazilian jurisdictions.

The United States context was included because of its historical influence on the methodological foundations of TGD impact assessment and recent changes in licensing metrics and objectives. California’s regulatory framework, represented by the Governor’s Office of Planning and Research technical guidance [22], was considered an emblematic case of replacing level of service with VKT as the reference metric in environmental review under the California Environmental Quality Act (CEQA). National reference manuals were also examined, including the Trip Generation Manual [25] and its earlier editions, and the Multimodal Transportation Impact Analysis for Site Development [2]. Additionally, the

review included Florida's Multimodal Transportation Site Impact Handbook [26], which formalizes the transition toward multimodal site-impact assessment.

The United Kingdom was included, given the integration of transport impact studies into the land-use planning system, guided by national principles on accessibility, sustainable development, and development impacts [6], with operational guidance on travel plans and transport assessments [27]. European Union documents were considered because they establish strategic guidelines for sustainable urban mobility planning, particularly through Sustainable Urban Mobility Plans (SUMP) [28,29], reinforced by Regulation (EU) 2024/1679 [30], which mandates the adoption of SUMP by the 431 urban nodes of the Trans-European Transport Network (TEN-T) by 2027. These references operate primarily at the strategic mobility planning level, while individual development licensing remains regulated at the national or local level. Their inclusion provides a counterpoint to the U.S. tradition, reflecting a planning approach more closely associated with land use–transport integration, compact urban development, and sustainable mobility.

Taken together, these contexts were selected because each expresses a distinct regulatory tradition against which the four analytical dimensions can be examined: the operational, trip-based tradition of the United States; the discretionary and planning-integrated tradition of the United Kingdom; the strategic and supranational guidance developed within the European Union; and the Brazilian tradition, which combines a federal normative framework with municipal implementation. The selection does not exhaust the range of relevant international experiences, a restriction acknowledged in the limitations section. Rather, it prioritizes the institutional contexts most frequently referenced in the reviewed literature and those that offer direct counterpoints to the Brazilian case, which constitutes the applied focus of the article. This comparative basis also structures the transition to the Brazilian municipal analysis: the international contexts define a spectrum of regulatory responses within each dimension, against which the Brazilian frameworks are subsequently positioned.

Technical and institutional documents of this nature are not uniformly indexed in bibliographic databases and are often dispersed across official institutional portals. Their identification, therefore, followed a purposive selection strategy, which is appropriate in integrative reviews dealing with heterogeneous sources [21]. The documents were selected from the official websites of the relevant authorities in each jurisdiction and from institutional references recurrently cited in the literature on TGD licensing and transport impact assessment. The selection followed two criteria: institutional authority, considering official publications from government agencies, regulatory bodies, or recognized technical organizations; and direct relevance to TGD licensing or transport impact assessment, prioritizing materials that prescribe procedures, metrics, classification criteria, or mitigation guidelines, or that establish the sustainable mobility frameworks within which such procedures operate. Table 3 presents the documents analyzed, organized by institutional context and institutional function.

The documents listed in Table 3 do not share the same legal nature, nor do they perform the same function within their respective regulatory systems. They were therefore classified according to their institutional function into three groups: binding legal instruments, official guidelines, and technical reference manuals. Although the ITE manuals do not constitute legally binding instruments, they were included because they operate as a widely used technical reference for trip generation estimation and development impact assessment [31]. This heterogeneity reflects the hybrid character of the regulatory field of TGD licensing, in which legal norms, governmental guidance, and technical references jointly shape assessment practice. In light of these differences, each document was interpreted according to its institutional function, and comparisons across contexts were

conducted at the level of the analytical dimensions, avoiding direct comparisons between documents of a different nature.

Table 3. Technical and institutional documents selected for analysis.

Country/Region	Document	Year	Institutional Function
Brazil	DENATRAN—Procedures for the treatment of TGDs [3]	2001	Official guideline
	Federal Law No. 12,587/2012—National Urban Mobility Policy [24]	2012	Binding legal instrument
United States	OPR—Technical Advisory on Evaluating Transportation Impacts in CEQA [22]	2018	Official guideline
	ITE—Trip Generation Manual (11th ed.; 12th ed.) [25,32]	2021; 2025	Technical reference manual
	ITE—Multimodal Transportation Impact Analysis for Site Development (MTIASD) [2]	2023	Technical reference manual
	FDOT—Multimodal Transportation Site Impact Handbook [26]	2024	Official guideline
United Kingdom	GOV.UK—Travel Plans, Transport Assessments and Statements (NPPG) [27]	2014	Official guideline
	NPPF—National Planning Policy Framework (revised 2024) [6]	2024	Official guideline
European Union	European Commission—Urban Mobility Package [28]	2013	Official guideline
	Rupprecht Consult—SUMP Guidelines (2nd ed.) [29]	2019	Official guideline
	Regulation (EU) 2024/1679 [30]	2024	Binding legal instrument

2.3. Data Analysis and Coding Procedures

The material gathered in the previous stages was analyzed according to the four dimensions defined in Table 1, which served as the primary coding categories. The guiding questions for each dimension directed the systematic extraction of data on criteria, metrics, procedures, and guidelines, enabling the identification of convergences, discrepancies, and gaps across the analyzed sources.

Coding was conducted using a structured extraction guide based on the guiding questions presented in Table 1. The sources were read in full and classified by one of the authors according to the four analytical dimensions. Given the interdependence among these dimensions, multiple coding was allowed, enabling a single source to contribute to more than one analytical category. The classification and extracted syntheses were critically reviewed by the second author, and any interpretive divergences were resolved through discussion until consensus was reached, in line with the need for systematization and transparency in the analytical stage of integrative reviews [21].

The findings within each dimension were evaluated against the sustainable urban mobility principles proposed by Banister [13]: (i) shifting the focus from vehicular traffic to activity accessibility; (ii) treating travel as a derived demand subject to management rather than mere accommodation; (iii) recognizing the systemic impacts of land-use and transport decisions; and (iv) prioritizing strategies that reduce automobile dependence. These principles guided the identification of gaps between the current state of the practice and the regulatory attributes required to support this sustainable paradigm.

Within each dimension, the analysis proceeded by contrasting the two sets of sources. First, the provisions within regulatory frameworks and institutional guidelines were identified to establish the current or formally recommended practices in each jurisdiction. Next,

the scientific literature was examined to identify critiques, expansions, or proposed alternatives to these institutional frameworks. This comparative procedure enabled a clear distinction between what institutional references mandate and what academic research identifies as limitations or necessary advancements.

3. Results

The final review corpus comprises 69 peer-reviewed articles and 12 technical and institutional documents. The selected works span the period from 1986 to 2025, with a growing concentration over the last two decades, indicating the recent intensification of the debate regarding development impact assessment. Among the journals with the highest concentration of publications, the *Transportation Research Record* and the *ITE Journal* are the most represented (14 articles each), followed by the *Journal of the American Planning Association* and the *Journal of Transport and Land Use* (four articles each). Studies addressing the U.S. context predominate, followed by contributions from China, Brazil, the United Kingdom, and Australia. The U.S. predominance reflects the suburban, automobile-dependent urban development model that historically shaped methodological benchmarks such as the ITE trip generation rates.

Figure 2 presents a keyword co-occurrence map with a temporal overlay, generated from the corpus of scientific articles. The centrality of terms such as trip generation and land use indicates that the relationship between these two variables remains central to the structuring of the field. Terms such as traffic management, travel demand, TIA, ITE, and level of service are associated with relatively older publications and reflect the conventional approach to assessment. By contrast, terms such as VMT, multi-modal, housing, and sustainability appear in more recent publications, suggesting the growing integration of systemic indicators and urban context attributes into the field. The position of accessibility and built environment in intermediate areas of the map is consistent with their bridging role between different assessment approaches. Building on this general overview, the results of the review are presented in the following subsections, organized according to the four analytical dimensions defined in Table 1. A comparative synthesis of these findings, covering prevailing practices, identified trends, and persistent gaps in each dimension, is presented at the end of the section in Table 4.

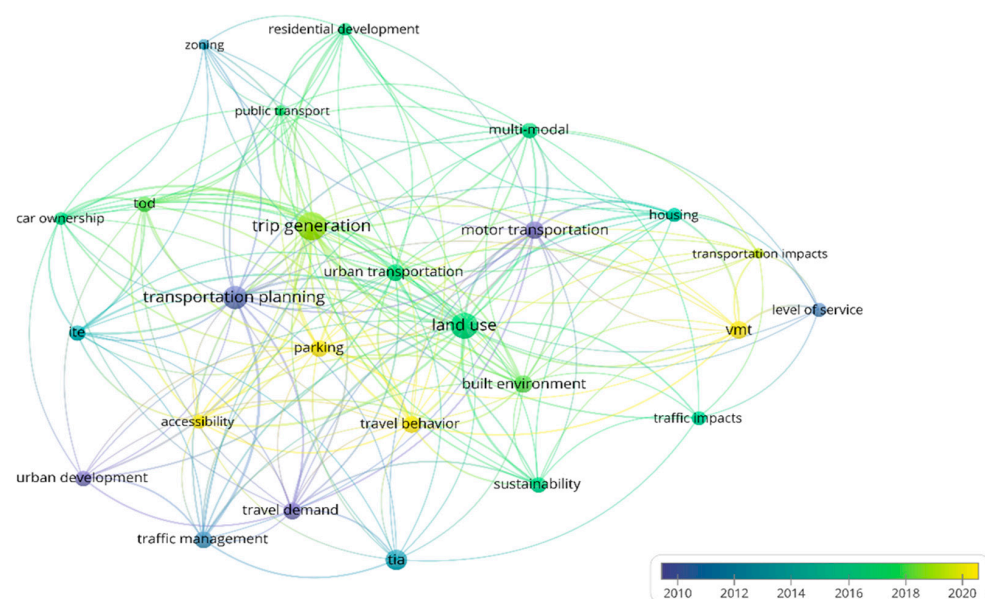


Figure 2. Keyword co-occurrence map of the review's scientific corpus, with temporal overlay generated using VOSviewer.

3.1. Licensing Scope (D1)

The scope of TGD licensing involves the criteria by which developments are defined, classified, and subjected to impact assessment requirements. The review shows that the conceptual framing of these developments has evolved from formulations centered on motorized traffic, such as the traffic-generating development (PGT) concept of DENATRAN [3] and the U.S. tradition of linking land uses to vehicular trip generation rates [25], toward more comprehensive formulations that incorporate impacts on different modes, on the built environment, and on quality of life. In Brazil, this shift is expressed in the transition from PGT to the broader PGV concept [4]; internationally, it is reflected in the multimodal reframing of assessment guidance [2,15,32].

This conceptual evolution, however, has translated unevenly across jurisdictions. In the United States, California's Senate Bill 743 established a regulatory regime that adopts vehicle miles traveled (VMT) as the core metric for environmental review under CEQA. VMT, the U.S. equivalent of the internationally used vehicle kilometers traveled (VKT), is evaluated using screening criteria that are sensitive to the urban context and proximity to public transit [22,33]. In the United Kingdom, the requirement for assessment derives from the local authority's judgment regarding the nature, scale, and location of the project, without fixed national numerical thresholds [6]. The European Union sets strategic guidelines and frameworks for urban mobility, among which Sustainable Urban Mobility Plans (SUMP) stand out [29,30], while their implementation and adaptation remain under the responsibility of Member States and competent authorities in each national and local context. In Brazil, fixed criteria based on built-up area, parking spaces, and occupancy capacity predominate, in continuity with the federal guidelines of DENATRAN [3], with limited sensitivity to the urban context of implementation. This heterogeneity across jurisdictions reflects different degrees of translation of the conceptual evolution into operational parameters: while California has partially reorganized the regulatory basis of licensing, Brazil and many U.S. jurisdictions retain structures based on size-based classifications and fixed thresholds.

Regarding assessment scope, a progressive shift is observed away from an approach restricted to the roadway performance of the immediate surroundings toward multimodal assessments with an expanded area of influence, as documented in technical guidelines such as ITE [2,32] and FDOT [26]. Most jurisdictions, however, continue to operate with restricted scopes, and screening criteria sensitive to the urban context remain the exception [15].

In summary, the D1 findings indicate that, although technical and regulatory references signal a progressive expansion of the licensing scope, with advances in specific jurisdictions such as California and in strategic initiatives within the European context, the reviewed literature documents the persistence of definitions centered on motorized traffic, size-based classifications, and fixed thresholds as the prevailing pattern [15,33].

3.2. Assessment Metrics (D2)

The assessment of TGD impacts has historically centered on vehicular level of service (LOS), as formalized by the Highway Capacity Manual [34] and combined with vehicular trip generation estimates [3,25]. More recent literature, however, has advocated for vehicle kilometers traveled (VKT) as a primary metric, accompanied by complementary multimodal indicators [7,16,17]. This paradigm shift remains restricted to a handful of jurisdictions. For instance, in evaluating the implementation of California's Senate Bill 743, Barbour et al. [18] demonstrated that the operational coexistence of both paradigms, rather than a complete transition, is the rule rather than the exception.

The second aspect examined is the extent to which these metrics capture broader externalities. Metrics restricted to vehicular flow only partially reflect a development's

impacts, with limited connection to emissions, energy consumption, and traffic safety outcomes [16,35]. By shifting the focus from localized congestion to the overall intensity of motorized travel, systemic metrics enable impact assessments to incorporate externalities that were neglected under the previous paradigm. Even so, LaJeunesse et al. [9] demonstrate that, even in jurisdictions with regulatory advances, the incorporation of these externalities into operational procedures remains limited, particularly with respect to road safety, which is systematically subordinated to vehicular flow.

Sensitivity to the urban context constitutes the third aspect. Spatially uniform parameters, applied regardless of a development's location, persist as the prevailing pattern, despite consolidated evidence that density, land-use diversity, and transport provision influence the generation of motorized trips to the TGD [36–38]. The influence of development location is recognized in the literature but is rarely translated into operational parameters within regulatory procedures [15,39]. In a related line of critique, the basis for trip estimation has been questioned: standardized rates are widely adopted, without local calibration or multimodal baselines [39–41]. This limitation may compromise impact studies, whose calibration with local data remains restricted to isolated applications, without adoption as a regulatory requirement. The 12th edition of the Trip Generation Manual [32] shows a trend toward addressing these critiques, with an expanded empirical base, the incorporation of multimodal data, and filters by geographic context, although its effects on regulatory practice remain a subject for future research.

In summary, the findings for this dimension indicate that the metrics employed in TGD licensing reflect distinct evaluative foci: while an operational logic centered on local roadway performance persists, systemic approaches are emerging, with VKT occupying a relevant role. However, VKT remains insufficient when used in isolation. As a vehicle-based metric, it does not directly capture accessibility, the quality of multimodal options, or the distribution of impacts across social groups. Consequently, it is consistently framed as the core of a broader set of indicators rather than as a single substitute for LOS [16]. The literature documents that the transition between these approaches remains restricted to a few jurisdictions [18,33], with operational coexistence between them. The gap in relation to the principles of sustainable urban mobility lies in the maintenance of metrics that only partially capture the systemic externalities of developments and that operate with limited sensitivity to the urban context.

3.3. Urban Context and Accessibility (D3)

The third dimension examines the extent to which built environment characteristics are incorporated as parameters in TGD impact assessment processes. In this dimension, accessibility is used in its locational sense (an attribute of the development's location), while its distributive sense is addressed as a cross-cutting issue in the discussion. The review identified consistent evidence that density, land-use diversity, and accessibility to public transit and active modes influence motorized trip generation [10], but this evidence remains only partially translated into operational parameters within regulatory procedures [15,39].

Density and land-use diversity constitute the first set of variables whose incorporation remains limited. Walters and Ewing [42] and Ewing et al. [43] document the association between increased density and reduced motorized trips, evidence confirmed on a broader scale by Tian et al. [44], who show, based on multi-regional data, that the influence of the built environment varies according to context, reinforcing the inadequacy of uniform parameters. With respect to land-use diversity, Millard-Ball and Siegman [45], Walters et al. [46], and De Gruyter et al. [47] show that mixed-use developments reduce the generation of external trips through internal trip capture, an effect systematically underestimated by the conventional method. In Brazil, Grieco et al. [48] identified the influence of the built

environment on modal choice in Niterói, while Gonçalves and Portugal [19] observed that impact studies in Rio de Janeiro do not systematically consider these variables.

Accessibility to public transit, when considered in evaluation procedures, tends to be reduced to physical distance to transit, without consideration of service quality or network connectivity [49,50]. Geurs and Van Wee [12], however, distinguish accessibility as an attribute of the surroundings from accessibility as an integrating concept between land use and the transport system, a distinction taken up by recent works that show the role of systemic accessibility in explaining trip generation in mixed-use developments [17]. This perspective is particularly relevant for developments located in high-capacity corridors, such as transit-oriented developments (TODs), in which integration with the network constitutes a central element of the project itself. Walkability, cycling infrastructure, and urban design follow an analogous pattern: adjustment methods for mixed-use developments, incorporating internal capture of non-motorized trips, have already been developed [51,52], and technical references have begun to incorporate these factors among the criteria for multimodal impact analysis [2,32,53].

In summary, the robust scientific evidence on the conditioning role of the built environment in trip generation contrasts with its limited translation into operational parameters for impact assessment, as documented in the references and practices examined. In light of the principles of sustainable urban mobility, this means that licensing operates as if location were neutral, disregarding precisely the attributes of the surroundings that most influence travel behavior.

3.4. Mitigation Strategies (D4)

The fourth dimension examines the nature of the measures required as conditions for development approval, distinguishing between responses centered on roadway capacity expansion and approaches oriented toward travel demand management (TDM). The review indicates that, in line with the predominance of LOS as the assessment metric (D2), the mitigation measures required in regulatory procedures remain concentrated on physical interventions aimed at preserving roadway capacity, such as road widening, turning lanes, signal retiming, and expanding parking supply [7,9,35]. In Brazil, Gonçalves and Portugal [19] confirm this pattern by documenting that the mitigation measures required in Rio de Janeiro remain predominantly oriented toward roadway interventions in the immediate surroundings, with low incorporation of TDM strategies.

In the academic literature, alternatives to this model have been documented internationally, anchored in TDM and multimodal analytical frameworks that incorporate active modes, integration with public transit systems, and calibration to the urban context. The differentiation of measures by context, however, remains limited: generic measures, with low sensitivity to location and to the profile of the development, predominate over tailored approaches, despite the availability of references that guide such calibration [26,54].

The quantitative estimation of the expected effect of measures constitutes the third aspect. Since the work of Ferguson [55] was published, parameters and methods to estimate reductions in motorized trips from TDM strategies and parking provision have been discussed in the literature. Concrete applications confirm the potential of such measures: Jennings, Jr. [56] documented reductions of 40% to 50% relative to ITE rates in the Arlington, Virginia (U.S.) program, integrated with development approvals along high-capacity transit corridors, and Ewing et al. [50], in studies of transit-oriented developments (TODs) in the United States, reinforced the possibility of quantifying the effect of measures associated with parking and multimodal provision. Despite this, the quantitative demonstration of the expected effect is rarely required as a condition for approval in the regulatory procedures examined.

The implementation and monitoring of measures constitute the least developed aspect. De Gruyter et al. [47] and Currans et al. [57] document the localized adoption of monitoring mechanisms in some jurisdictions, but the specific literature on post-implementation monitoring remains scarce. Hosseinzade et al. [33], in analyzing California's transition to VMT, observe that even in jurisdictions with more recent regulations, the monitoring structure is fragmented and not generalized, compromising the effective verification of the results of the required measures.

In summary, the gap in relation to the principles of sustainable urban mobility lies in the persistence of mitigation measures oriented by the logic of roadway capacity, even in contexts where alternative metrics have been partially adopted. When the assessment remains centered on roadway performance (D2) and has limited sensitivity to the urban context (D3), the resulting measures tend to be generic, disproportionate, and oriented toward the expansion of roadway supply, to the detriment of responses based on TDM, multimodal integration, and sensitivity to the urban context.

3.5. Synthesis of Results

Taken together, the findings show that the incorporation of sustainable urban mobility principles into TGD licensing frameworks remains partial and uneven. The specific characteristics of the Brazilian context are further examined in Section 4.2. Table 4 synthesizes prevailing practices, emerging trends identified in the literature, and persistent gaps across the four analytical dimensions.

Table 4. Synthesis of TGD licensing dimensions from a sustainable mobility perspective.

Analytical Aspect	Prevailing Practice	Emerging Trend	Persistent Gaps	Key Sources
D1—Licensing scope				
TGD definition	Focus on motorized traffic	Multimodal and externalities integration	Conceptual evolution from PGT to TGD not yet translated into operational criteria	[2,3,15]
Classification	Land-use and size-based	Location, accessibility, and multimodal provision	Land-use and size-based classification predominates	[6,25]
Assessment thresholds	Fixed thresholds (built-up area, peak-hour trips)	Context-sensitive screening (VKT, transit, mixed-use)	Context-sensitive thresholds limited to few jurisdictions	[3,22,33]
Assessment scope	Localized roadway performance	Multimodal scope and expanded area of influence	Expansion limited to intersections and immediate access points in most jurisdictions	[26,28,29]
D2—Assessment metrics				
Core decision metric	Predominance of LOS, centered on vehicular delay and V/C ratio	Adoption of VKT with complementary multimodal indicators	Transition from LOS to VKT restricted to few jurisdictions	[7,16,18]
Capture of externalities	Restricted to vehicular flow indicators, with limited capture of systemic externalities	Systemic metrics linked to emissions, energy, and safety outcomes	Systemic externalities, particularly road safety, remain only partially captured	[9,16,35]

Table 4. Cont.

Analytical Aspect	Prevailing Practice	Emerging Trend	Persistent Gaps	Key Sources
Sensitivity to urban context	Spatially uniform parameters, applied regardless of location	Differentiation of parameters by density, land-use diversity, and transit provision	Locational differentiation acknowledged in the literature but rarely operationalized	[1,37,38]
Validity of trip generation rates	Widespread use of standardized rates without local calibration	Local data calibration and alternative multimodal baselines	Calibration restricted to isolated studies, without adoption as a regulatory requirement	[39–41]
D3—Urban context and accessibility				
Surrounding density	Not considered as adjustment parameters in impact assessment	Evidence of reduced motorized trips in denser contexts	Rarely used as an operational parameter in licensing	[42–44,48]
Land-use diversity	Not considered as an adjustment parameter in assessment	Robust evidence of reduced motorized trips in mixed-use contexts	Rarely used as an operational parameter in licensing	[45–47]
Accessibility to public transit	Reduced to physical distance to transit, when considered	Effect documented in different contexts; isolated use as a screening criterion	Application as an assessment criterion restricted to specific jurisdictions	[44,49,50]
Walkability, cycling infrastructure, and urban design	Absent from conventional impact studies	Internal trip capture methods for mixed-use developments	Methodological advances largely confined to academic debate	[2,51,52]
D4—Mitigation strategies				
Prevailing orientation	Focused on roadway capacity expansion (widening, turn lanes, signal retiming)	TDM, TOD, and multimodal impact analysis	TDM and TOD adoption remains restricted, despite documented effectiveness	[7,19,35,50]
Differentiation of measures by context	Generic measures, with low sensitivity to location and development profile	Measures calibrated to urban context and local sustainable mobility potential	Disconnection between required measures and surrounding characteristics	[26,54,58]
Quantitative estimation of expected effects	Measures required without quantitative estimation of expected effect	Estimates of motorized trip reductions from TDM, parking management, and TOD applications	Quantitative demonstration rarely required as a condition for approval	[50,55,56]
Implementation and monitoring	Absence of monitoring mechanisms in most procedures	Isolated adoption of monitoring mechanisms in some jurisdictions	Fragmented and inconsistent implementation	[47,57]

Figure 3 distills this synthesis, contrasting prevailing practices and emerging trends in each dimension and highlighting the interdependencies through which changes in one dimension condition the others.

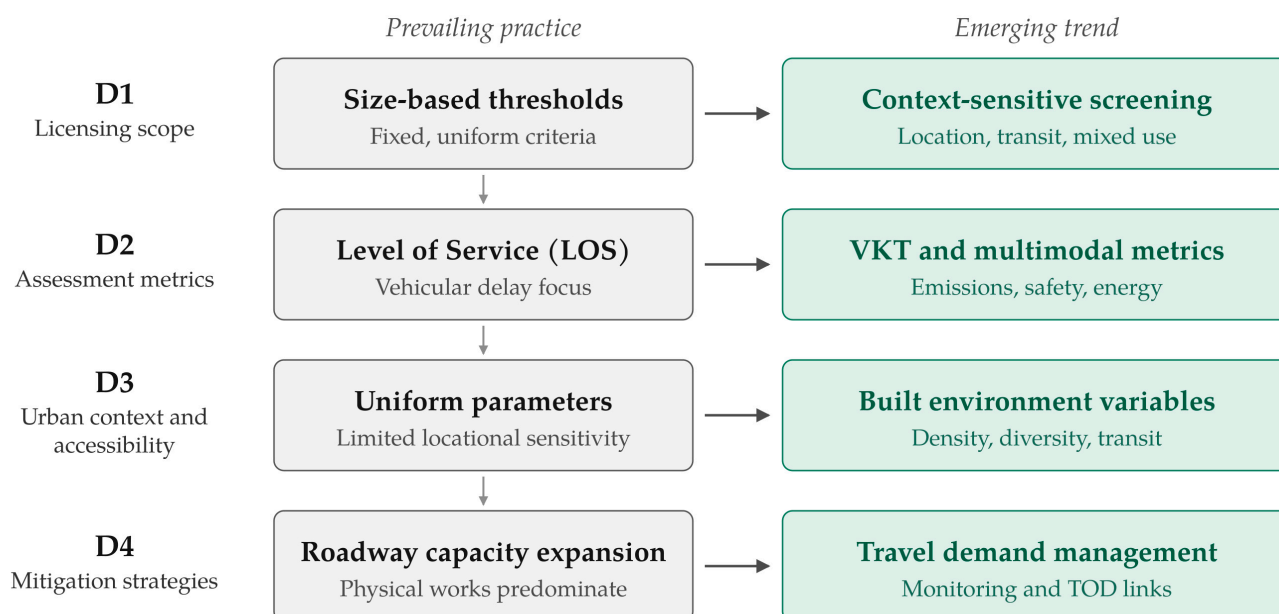


Figure 3. Synthesis of prevailing practices, emerging trends, and interdependencies across the four analytical dimensions of TGD licensing. Source: elaborated by the authors.

4. Discussion

4.1. Analysis of Results

The integrated reading of the four dimensions suggests that the incorporation of sustainable urban mobility into TGD licensing has occurred in a partial and uneven manner. The results indicate the coexistence of more recent references that expand the scope of assessment, incorporate systemic metrics, and value the urban context, on the one hand, and regulatory practices still based on local roadway performance, on the other. This pattern recurs across the four analyzed dimensions and helps to explain why important conceptual changes have had limited translation into current licensing procedures.

The results suggest that this pattern is not explained solely by regulatory lag, but by the way scope, metrics, urban context, and mitigation strategies are articulated within licensing processes. When impact is defined primarily in terms of local roadway performance (D1), the most compatible metric tends to be LOS (D2); when this metric predominates, the urban context tends to occupy a secondary position (D3), and, in this arrangement, mitigation is more readily oriented toward the restoration of roadway capacity than toward demand management (D4). This sequence, synthesized in Figure 3, suggests that partial changes, when not accompanied by adjustments in the other dimensions, tend to have limited transformative capacity.

In this respect, the California experience is illustrative, although not representative, of U.S. practice in general: as indicated in Section 3.1, most U.S. jurisdictions retain size-based classifications and fixed thresholds. The adoption of VMT as the reference metric in environmental review represents a relevant change, but it remains circumscribed to specific segments of the decision-making process and coexists with LOS in other stages of development approval [18,33]. The comparison across the regulatory traditions examined further indicates that each model faces limits of its own: the California approach depends on local technical capacity to estimate and mitigate VMT; the British discretionary model offers greater sensitivity to context, without ensuring consistency across decisions; and the European SUMP guidelines operate mainly at the strategic planning level, without directly regulating the licensing of individual developments. These differences suggest that the incorporation of sustainable mobility into licensing does not follow a single trajectory: each

tradition resolves part of the problem while reproducing, through distinct mechanisms, the centrality of roadway performance.

The review also suggests that institutional capacity strongly influences the possibility of adopting alternative approaches. Combs et al. [15], in a survey of 63 U.S. jurisdictions, identified that the most substantive changes are concentrated in contexts with greater urban density, higher pressure for the approval of new developments, and better technical conditions for implementation. In contexts with limited data availability, lower technical support, and less flexible regulatory frameworks, the incorporation of new metrics, of urban context as an assessment parameter, and of demand management strategies tends to occur in a more limited manner.

The review identified two topics that remain underdeveloped in the specific literature on TGD licensing. The first is the limited incorporation of distributive equity criteria, that is, the determination of who bears the externalities of developments and who benefits from mitigation measures, with attention to groups such as low-income communities, pedestrians, public transit users, and peripheral neighborhoods, a dimension particularly sensitive in contexts of urban inequality such as those found in Brazilian cities [20]. The second is the limited attention given to mechanisms of social participation in the procedures analyzed. These absences are not confined to a specific dimension but cut across the four analytical dimensions, gaining particular relevance in contexts marked by structural inequality where, as outlined in the Introduction, licensing could operate not only as an instrument for controlling negative externalities, but also as a mechanism for inducing positive impacts by expanding access to opportunities in underserved areas. None of the frameworks analyzed, however, incorporates criteria of this nature. These themes, although developed in adjacent literatures of urban planning and mobility equity studies, remain underdeveloped in the specific field of TGD licensing, constituting a relevant future research agenda for the alignment between licensing and the principles of sustainable urban mobility.

Building on Table 4, the following section analyzes licensing procedures in Brazilian jurisdictions, observing how scope, metrics, urban context, and mitigation are articulated in local regulatory frameworks.

4.2. TGD Licensing in Brazil: Evidence from Five Jurisdictions

In Brazil, TGD licensing is primarily a municipal responsibility, resulting in heterogeneous procedures across jurisdictions. Several contextual specificities shape the incorporation of sustainable urban mobility principles into TGD licensing, including structural urban inequality, uneven provision of transport infrastructure, and unequal access to opportunities across central and peripheral areas. In addition, limited availability of reliable data on travel patterns and the built environment restricts the local calibration of trip estimates and the monitoring of mitigation effects. Against this backdrop, it is relevant to examine the extent to which municipal regulatory frameworks incorporate sustainable urban mobility principles.

The TGD licensing frameworks of five Brazilian jurisdictions were analyzed: São Paulo, Rio de Janeiro, Belo Horizonte, Curitiba, and the Federal District. Two criteria guided the selection: the existence of specific or related legislation on TGDs and the diversity of institutional arrangements among the cases. This diversity refers to variation in the instruments mobilized, the agencies responsible for assessment, the criteria used to classify developments as TGDs, the type of impact study required, and the degree of integration between urban licensing and mobility impact assessment. In economic terms, the five jurisdictions rank among the largest municipal economies in Brazil [59], reinforcing their relevance as contexts of intense development pressure and travel generation.

The selected jurisdictions are also among the most consolidated cases in Brazil, as they have specific regulatory frameworks and documented licensing procedures; therefore, they are treated as reference cases rather than as a representative sample of Brazilian municipalities. This condition qualifies the scope of the findings while reinforcing the diagnosis: if even these institutionally more developed jurisdictions remain largely anchored in roadway performance, municipalities with lower technical capacity may face even greater obstacles to incorporating sustainable mobility principles into licensing guidelines. Among the five jurisdictions, Rio de Janeiro receives more detailed attention because it combines the most recently updated regulatory framework in the set [60] with licensing practice documented in the literature [19], providing the richest documentary basis for analysis. Each case was examined in light of the four analytical dimensions used in the review, allowing local regulatory frameworks to be compared with the trends identified in the international literature. Table 5 synthesizes the regulatory aspects addressed by the Brazilian legislation across the four dimensions.

Table 5. TGD licensing procedures in Brazilian jurisdictions ¹ across the analytical dimensions.

Aspect	São Paulo	Rio de Janeiro	Belo Horizonte	Curitiba	Federal District
D1—Licensing scope					
Terminology	Traffic-generating development	Trip-generating development (TGD)	Impact-generating development	Development	Trip-generating development (TGD)
Classification criteria	Parking thresholds; built-up area by land use	Built-up area, trip generation, land use, area of influence, and impact intensity (P0/P1/P2)	Built-up area (>6000 m ² non-residential) or residential units (>150)	Size and zoning (small <400 m ² ; large >2000 m ²)	Parking spaces (200–400) or built-up area (3750–25,000 m ²)
Assessment instrument	Development guidelines certificate	Roadway impact analysis report	Impact-Based Licensing	Neighborhood Impact Study	Neighborhood Impact Study + Urban Mobility Contribution
D2—Assessment metrics					
Analytical focus	Trip generation, roadway capacity, LOS	Trip generation, road impacts, pedestrian safety, LOS	Urban, environmental, and traffic impacts	Neighborhood quality of life; traffic generation	Access points, parking, boarding/alighting
Sustainability metric	Not defined	Partial	Partial	Partial	Not defined
D3—Urban context and accessibility					
Locational sensitivity	Partial: differentiated thresholds for special traffic areas	Roadway hierarchy, accessibility, public transit, and areas of influence	Not explicit in the legislation	Present: size thresholds vary by zoning and transport corridors	Not explicit; legislation does not link assessment to surrounding context

Table 5. *Cont.*

Aspect	São Paulo	Rio de Janeiro	Belo Horizonte	Curitiba	Federal District
D4—Mitigation strategies					
Orientation of measures	Roadway works in the surrounding area: retiming, signage, CCTV	Roadway interventions and improvements at development access points	Environmental compensation: tree planting, water reuse, public spaces, parking	Environmental compensation: area restoration, maintenance of public spaces	Urban furniture, pedestrian and cycling infrastructure
Maximum cost	Not specified	0.35% to 1.5% (+required measures)	Up to 0.5%	Not specified	0.5% to 1.5%
Responsibility	Developer	Developer	Developer	Developer	Developer
TDM/TOD measures	Not explicitly required	Not explicitly required	Not explicitly required	Not explicitly required	Not explicitly required

¹ Compiled from local legislation: São Paulo (Law 15,150/2010) [61]; Rio de Janeiro (Complementary Law 111/2011 [62], Ordinance 005/CET-RIO/2024 [60]); Belo Horizonte (Laws 9959/2010 [63] and 11,181/2019 [64]); Curitiba (Law 15,511/2019 [65]); Federal District (Law 5632/2016 [66]).

Table 5 synthesizes the TGD licensing procedures of five Brazilian jurisdictions examined in light of the four analytical dimensions. Despite formal differences in terminology, ranging from traffic-generating development and trip-generating development to impact-generating development and generic development, as well as the heterogeneity of the instruments mobilized (development guidelines certificate, roadway impact analysis report, impact-based licensing, neighborhood impact study, and analysis by mobility agencies), the procedures converge in a common evaluative logic with low adherence to the principles of sustainable urban mobility.

In terms of licensing scope (D1), the classification of developments remains centered on physical and functional attributes, such as built-up area, number of parking spaces, land-use typology, size, and occupancy intensity across all five jurisdictions. Even in cases where differentiation by zoning (Curitiba) or by special traffic areas (São Paulo) is observed, the structuring criterion remains the potential for trip generation, without systematic incorporation of parameters associated with sustainable mobility.

Regarding assessment metrics (D2), the focus predominantly rests on trip generation, roadway capacity, safety, access conditions, and parking provision. Rio de Janeiro, Belo Horizonte, and Curitiba show partial consideration of sustainability-oriented metrics, with different emphases: Rio de Janeiro pays attention to pedestrian safety and flow, Belo Horizonte references environmental repercussions, and Curitiba addresses neighborhood quality of life. In none of these cases, however, do these elements reconfigure the central axis of the assessment, nor were operational metrics such as VKT, modal share, multimodal accessibility, or motorized trip reduction targets identified as formal decision parameters.

With respect to urban context and accessibility (D3), an asymmetry is observed among the jurisdictions. São Paulo, Rio de Janeiro, and Curitiba incorporate, to varying degrees, variables of the surrounding environment (special traffic areas, roadway hierarchy, distance to public transit, areas of influence, and links to zoning). Belo Horizonte and the Federal District do not explicitly establish a clear association between the assessment of the development and the characteristics of its surroundings. Even in the cases most sensitive to context, the classification of impact remains predominantly qualitative, without quantitative criteria that systematically translate the principles of sustainable urban mobility.

As for mitigation strategies (D4), São Paulo and Rio de Janeiro maintain a predominance of physical works and interventions, with Rio also admitting monetary contributions to the Sustainable Urban Mobility Fund (FMUS); Belo Horizonte and Curitiba direct part of the compensations toward environmental and urban measures; and the Federal District provides less-specific TGD-related mitigation requirements, while measures under the neighborhood impact study include pedestrian and cycling infrastructure. In none of the jurisdictions, however, were travel demand management measures identified, nor was there explicit orientation toward transit-oriented development (TOD) approaches as structured elements of mitigation, reproducing the gap documented in D4 of the international review.

In summary, the findings suggest that TGD licensing in Brazil remains anchored in an approach centered on roadway performance, in line with the pattern identified in the international review and still distant from the trends of context-sensitive assessment and sustainability-oriented mitigation.

The persistence of this logic does not stem solely from regulatory lag but also from institutional factors that the analysis of the frameworks helps to identify. The first is the methodological legacy of the DENATRAN manual [3], whose traffic engineering matrix continues to structure local classifications and requirements more than two decades after its publication, as evidenced by the continuity of size and parking criteria in Table 5. The second is municipal autonomy in urban policy, which Federal Law No. 12,587/2012 [24] presupposes but does not support with coordination instruments, resulting in heterogeneous procedures without common sustainability metrics. The third is the administrative separation between traffic agencies, responsible for impact analysis, and territorial planning bodies, responsible for urban licensing, which restricts the integrated reading of land use and mobility advocated in the literature. The last is the limited capacity for post-approval monitoring: expressed in the widespread absence of follow-up requirements in Table 5, it prevents the effects of mitigation measures from feeding back into the process, a difficulty also documented in the use of impact studies in Rio de Janeiro [19].

5. Conclusions and Future Remarks

Using an integrative review, this article examined the extent to which licensing processes for TGDs incorporate principles of sustainable urban mobility. The analysis, organized along four dimensions, revealed a persistent gap between the conceptual advances documented in the literature and their implementation in regulatory practice. The central contribution of the study lies in this integrated reading: by articulating the four dimensions within a single analytical framework, it reveals not only the isolated gaps within each dimension, but also how these dimensions mutually condition one another throughout the licensing process. This helps explain why partial changes, when not accompanied by adjustments in the other dimensions, tend to have limited transformative capacity.

Across the four dimensions, the findings reveal a coherent pattern: restricted licensing scope, metrics centered on local roadway performance, a secondary role for the urban context, and road-based mitigation (Sections 3.1–3.5; Table 4). The analysis of licensing procedures across five Brazilian jurisdictions reinforced this diagnosis within a developing-country context. Despite the heterogeneity of the instruments mobilized, the procedures converge in a common evaluative logic with low adherence to the principles of sustainable urban mobility. This pattern is compounded by specificities of the Brazilian context, namely structural urban inequality, uneven provision of transport infrastructure, and the limited availability of reliable data, which amplify the identified gaps and render the alignment between licensing and sustainable mobility particularly challenging.

The review further reveals that aspects related to the distributive equity of impacts and to social participation in licensing procedures remain underdeveloped in the specific

literature on TGD licensing. These absences cut across the four analyzed dimensions and acquire particular relevance in contexts of structural inequality, where licensing could operate not only as an instrument for impact control, but also as a mechanism for promoting fairer and more inclusive mobility conditions.

The results point to directions for improvement, organized by dimension. In D1, classification criteria should be revised to incorporate variables of the built environment, accessibility, and the effective area of influence. In D2, the progressive adoption of VKT is recommended, integrated with multimodal indicators, systemic externalities, and road safety. In D3, built environment attributes should be translated into operational evaluation parameters. In D4, mitigation measures should be reoriented to account for the urban context, with strengthened strategies focused on travel demand management and TOD approaches. In the Brazilian case, these improvements further call for the updating of federal frameworks and better integration of urban, environmental, and traffic-related licensing instruments.

The framework also has direct applications for stakeholders involved in TGD licensing. Municipal governments and licensing agencies can use the four dimensions and the guiding questions in Table 1 as a structured reference to review their regulatory frameworks, identify requirements still anchored in roadway performance, and prioritize revisions. Practitioners and consultants can apply the same structure to broaden the scope of impact studies beyond vehicular analysis, incorporating urban context variables and demand management measures from the outset. For researchers, the framework offers a common basis for comparative analyses across jurisdictions and for developing future diagnostic protocols.

The study has some limitations. First, it relied primarily on works indexed in the Web of Science and Scopus databases, complemented by selected technical and institutional references. Although this strategy provides rigor and traceability, it may have excluded relevant materials published in non-indexed journals, academic books, and reports from local traffic agencies. In addition, the analysis of the Brazilian jurisdictions is restricted to the content of regulatory and institutional frameworks; it does not capture implementation practice or the effects of the mitigation measures adopted, whose systematic assessment constitutes an agenda for future research. Available evidence on licensing practice, although limited, is consistent with this regulatory diagnosis, particularly in the case of Rio de Janeiro [19]. Finally, the institutional documents examined are restricted to Brazil, the United States, the United Kingdom, and the European Union. As a result, the conclusions should be understood primarily as referring to the regulatory designs analyzed here, and caution is required when extending them to other contexts, particularly to other Global South countries with distinct legal traditions, planning cultures, and institutional capacities.

The literature gaps identified in this article point to the need for licensing processes that incorporate criteria sensitive to urban context, development location, and accessibility conditions, while integrating the economic, environmental, and social dimensions of sustainability. Future research could build on these findings by developing diagnostic protocols to assess how different regulatory arrangements incorporate these principles into licensing practice. This agenda is particularly relevant in developing countries, where structural urban inequalities, uneven transport infrastructure provision, and data limitations may amplify the distributive effects of licensing processes. In such contexts, licensing may also exhibit transformative potential by supporting the strategic location of developments that can expand access to employment, services, and urban opportunities in underserved areas.

This potential must nonetheless be read at the appropriate institutional scale. Development licensing is only one component of a wider urban and transport governance system. It operates at the scale of individual developments and cannot substitute for metropolitan planning, land-use and housing policy, or sustained investment in public transit and

active-mode infrastructure, whose combined action the sustainable mobility paradigm presupposes [13]. Its contribution, therefore, depends on coordination with these broader instruments. Licensing should be understood as a strategic point of articulation between land use and mobility at the development scale, complementing rather than replacing structural planning and investment decisions.

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