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# Contextualizing urban road network hierarchy and its role for sustainable transport futures: A systematic literature review using bibliometric analysis and content analysis tools

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**Abstract** Urban road networks play a crucial role in transport and urban planning and have the potential to contribute to more sustainable futures if their hierarchy is properly understood. However, the concept of the urban road network hierarchy, which refers to street classification and prioritization, is not well defined within the domain of transport engineering management, leaving many questions unanswered. Is it simply a planning tool, or does it extend to defining the essence of cities? Is it a qualitative or quantitative concept? Does it emerge organically or require proactive planning? Given the lack of comprehensive answers to these questions, this research aims to provide a contextual understanding of the urban road network hierarchy through the lens of sustainable transport futures. To this purpose, we conducted a systematic literature review, which is an effective method for consolidating knowledge on a specific topic. A total of 42 articles were analyzed using both quantitative bibliometric analysis and qualitative content analysis. Our work demonstrates that the road network hierarchy consists of 16 sub-concepts. Four main research trends were identified and discussed: a) road morphology and structure, b) advanced algorithms for street classification, c) integrated street classification planning, and d) the social dimension of street classification. Recent literature indicates a shift toward alternative road network hierarchy approaches that prioritize sustainable mobility over car-centric models. In conclusion, our analysis reveals that the urban road network hierarchy is a

multifaceted yet under researched “vehicle for change,” which, if utilized effectively, offers opportunities to reimagine urban road environments.

**Keywords** road network hierarchy, street classification, sustainable mobility, systematic literature review, integrated planning

## 1 Introduction

Cities are places of diversity and complex interactions (Harvey, 2012) that if not planned and managed properly can become unsustainable (Gao et al., 2023; Tsagkis et al., 2023). While cities should provide a livable setting for people and goods, it is evident that urban ecosystems have historically been designed to prioritize vehicles over people (Lambrianidou et al., 2013). In this context, the structure and configuration of urban and transport networks play crucial roles in shaping mobility behavior. It is important to note that these networks are not homogeneous; rather, they exhibit hierarchical order (Lammer, Gehlsen, Helbing, 2006; Shang et al., 2020). According to Batty (2006), hierarchy is inherent in city systems, regardless of whether they are organic or ‘microwaved’. Hierarchy is a multidimensional concept that can be interpreted in four ways (Lane, 2006): a) *order hierarchy*, which depicts an “ordering induced by the values of a variable defined on some set of elements”; b) *inclusion hierarchy*, which refers to a recursive organization of entities; c) *control hierarchy*, which is related to (social) power such as an army or a political party; and d) *level hierarchy*, which describes “a particular kind of ontological organization, in which entities are posited to exist at different levels.”

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When looking into the transport dimension, it is worth emphasizing that the majority of roads within a network are considered trivial, whereas a minority are vital (Jiang, 2009). This distinction implies the existence of two types of hierarchy: order hierarchy and level hierarchy. Road network hierarchy refers to the classification of roads and streets into groups or classes based on specific characteristics such as form, use/function, relation, and designation (Marshall, 2005). This definition embodies order hierarchy and can also be interpreted as street network classification (Ribeiro, 2012). Similarly, Eppell, McClurg, Bunker (2001) described road hierarchy as a means of assigning each roadway a function to establish appropriate objectives and design criteria. Another definition, related to level hierarchy, suggests that road network hierarchy involves assigning a role or level to each road or street segment within the entire network (FHWA, 2013). These definitions collectively illustrate that road network hierarchy involves the process of ordering, classifying, and categorizing road networks.

The road network hierarchy can be either conventional (car-oriented) or alternative (multimodal and sustainable modes oriented). This difference leads to various road environments and urban landscapes (Marshall, 2005). The first classification plan was developed by Buchanan in the UK in 1963; he proposed two contrasting functions for the road network: movement/circulation and access (MoT, 1963). This approach resulted in three primary road categories: *arterials*, *collectors or distributors*, and *local roads*. Arterials emphasize car movement, while local roads prioritize property access (Levinson and Krizek, 2008). However, Buchanan's once progressive idea has become an outdated conventional approach, which has resulted in dysfunctional urban areas with significant societal and environmental issues (Marshall, 2004). Specifically, this car-oriented approach overlooks the social aspect of streets (McCann, 2013), creates barriers within the urban fabric, and leads to environmental degradation (Leurent and Windisch, 2011). In other words, it undermines the role of other modes of transport (Liu et al., 2017). Therefore, cities should adopt innovative, efficient, and inclusive strategies to enhance urban environmental conditions (Aletà et al., 2017; Tan et al., 2023). Establishing a culture of sustainable mobility in cities is a challenging task that requires a paradigm shift (Sdoukopoulos et al., 2019; Tzouras et al., 2023) built on an integrated and multimodal urban and transport planning approach (Bigotte et al., 2010; Melkonyan et al., 2020). New classification schemes should focus on promoting sustainable mobility, embracing multimodality, and reducing the dominance of cars (Stamatiadis et al., 2023; Tsigdinos et al., 2023). By prioritizing alternative modes of transport, these classification schemes seek to create new urban and road environments that are fair and accessible to all people (Marleau Donais et al., 2019).

Therefore, these schemes can be used in the future.

Revising the urban network hierarchy will shape the future of transport (Tsigdinos et al., 2022). New modes, technologies, and measures should be integrated into a single sustainable hierarchy/classification system. Failure to do so will pose significant challenges to urban environments, as each new and existing mode of transport will compete for dominance. On the other hand, sustainable and inclusive transport futures will prioritize the integration of all modes of transport, promote alternative modes, and encourage multimodality and coexistence. This approach has the potential to cultivate conditions for a truly viable transport future. Therefore, the direction of road hierarchy (conventional or alternative) and its role are crucial factors that determine the future of transport in urban areas.

Rethinking the current state of transport is a complex task, particularly when considering the hierarchy of urban road networks. This raises a number of pertinent questions: a) What exactly is the urban road network hierarchy? Is it purely a planning tool or does it include a broader concept? b) Is it qualitative or quantitative? c) Does it emerge naturally and as a dynamic process or is it solely the result of proactive planning? Additionally, in addition to understanding the nature of hierarchy itself, identifying prevailing trends and concepts that inform road network hierarchy schemes is also crucial. As these research questions have not yet been comprehensively and definitively answered, this study aims to explore the literature and provide a detailed interpretation of the nature of the urban road network hierarchy, thereby identifying challenges, opportunities, and perspectives that influence and are influenced by it.

Consequently, the objective of this study is to identify research papers published in Scopus-indexed scientific journals that address various aspects of street classification (such as methods, categorization definitions, and analysis). By doing so, we aim to provide clear and concise answers to the aforementioned questions. Our work adopts a systematic literature review (SLR) approach, which enables us to trace the evolution of scientific dialog on road network hierarchies over time. Furthermore, this process allows for a deeper examination of critical issues that shape the characteristics and properties of road hierarchy in urban environments. Through this systematic process, we not only draw valuable conclusions about current approaches and theoretical perspectives regarding hierarchies but also outline directions for future research—an essential endeavor for planning and delivering sustainable urban futures.

The remainder of the paper is structured as follows: the second section outlines the research methodology, detailing the fundamental steps undertaken to conduct the literature review; the third section presents the findings of the SLR process, including the results from the bibliometric analysis; the fourth section critically discusses the findings and presents policy recommendations and suggestions for

future research; and finally, the last section offers concluding remarks based on our research.

## 2 Research methodology

SLR, is a crucial technique in social science research. It involves systematically gathering and analyzing all available information on a specific topic or effect (Lavissière et al., 2020). The SLR serves as a method for identifying and critically evaluating relevant research (Kraus and Proff, 2021) as well as for collecting and analyzing data from that research (Liberati et al., 2009). Unlike traditional literature reviews, SLRs adhere to a set of principles to minimize potential biases in the sample of studies (Booth et al., 2016). This method is effective at synthesizing research findings and providing evidence at the meta-level (Snyder, 2019). Therefore, this approach is suitable for identifying key concepts related to the future of urban road network hierarchy. In this study, we utilize SLR to determine a solid theoretical foundation for the various concepts that may shape road hierarchy.

### 2.1 SLR process

In conducting the SLR process, this study adopts a three-step procedure, consistent with the approach used by Bask and Rajahonka (2017), Yigitcanlar et al. (2019), and Oliveira et al. (2017). The first step is the planning stage, which involves defining the objectives and review protocol for the systematic review and identifying the sources and procedures for literature searches. The second step refers to the conduction of the review process by applying the defined inclusion and exclusion criteria. Finally, the third step involves identifying concepts through a synthesis of the results in line with the established objectives.

#### 2.1.1 Keyword selection

First, a research plan was developed, outlining the research aim, questions, keywords, and a set of inclusion and exclusion criteria. The research aim was framed to identify concepts and approaches related to the hierarchy of urban road networks or street classification. Accordingly, a diverse set of keywords was compiled. These keywords were used to search for relevant articles in the titles and abstracts. The keywords used included “road classification” or “street classification,” “street functional classification,” “road network hierarchy,” “street hierarchy,” “street type,” “urban road classification” or “urban roadway classification,” “street reconfiguration,” “street functionality,” “street function,” “street planning,” “road categorization,” “road categories” or “street categories,” “street typology,” “strategic road network,” “complete

streets” or “road type.” All these keywords pertain to the process of classifying streets or roads.

The selection of keywords in a SLR process is of utmost importance. These keywords play a crucial role in determining the results of the method (Liao et al., 2017b). The relevance and specificity of the keywords to the subject under consideration are directly proportional to the efficiency of the process, enabling a thorough and meaningful analysis of the issue at hand, both in the present and in the future. It is evident that the list of keywords adopted in this research aims to provide a comprehensive background. In essence, these keywords comprehensively cover the topic of urban road network hierarchy, as documented in the literature. The selection process was straightforward and transparent; initially, a concise narrative review of papers related to road network hierarchy or similar terms was conducted, incorporating some trial keywords. This review process lasted for approximately one week, resulting in the identification of a wide range of relevant terms that formed the basis of the keywords employed in this study. Hence, these keywords are deemed appropriate because they reveal the emerging trends and sub-concepts related to the urban road network hierarchy. It is worth underlining that both “road” and “street” were included as keywords to capture a diverse range of scientific publications. In fact, within the literature, these terms are often used interchangeably and synonymously (Ershova and Smirnov, 2017). Additionally, these keywords are not accompanied by any other words, as the focus lies solely on classification and hierarchy rather than other specific characteristics or features.

#### 2.1.2 Defining inclusion and exclusion criteria

The inclusion criteria were determined to be academic journal articles (research articles or reviews) that were available online in full text and published in English and were relevant to the research objectives, specifically the urban road network hierarchy. These articles are considered useful contributions and provide versatility, diversity, and generalizability to our study. Additionally, only papers published after 2000 were selected, in alignment with other approaches of reviewing papers that use a specified date as a threshold for efficiency and timeliness (e.g., Tsigdinos et al., 2022). This decision allows us to capture the most recent trends and contextualize hierarchies through the lens of sustainable transport futures. Moreover, it ensures feasibility and facilitates a meaningful interpretation of the selected corpus. A preliminary examination revealed that more than 82% of the articles related to road hierarchy or classification were published after 2000, which is why the year was chosen. “Gray literature,” such as conference proceedings, books, and technical reports, was excluded from the corpus to ensure the high

quality of the studies analyzed (Lagorio et al., 2016). The search was conducted using the Scopus database.

In step 2, the search for relevant articles was carried out in April 2023, and the entire procedure lasted approximately one and a half months. The previously mentioned keywords were used in the search to identify articles that address concepts related to the transformation of the urban road of the future. Initially, the search returned a total of 2908 articles, including journal articles and (peer review) conference proceedings in all possible languages found in Scopus. After limiting the search to papers published between 2000 and 2022, the number of papers was reduced to 2392. Articles published in 2023 were not considered to ensure research consistency by only utilizing full years. Further narrowing the sample to include only journal articles (research articles or reviews) written in English resulted in a total of 1512 papers eligible for title and abstract screening.

### 2.1.3 Eye-balling

The selected papers were “eye-balled” through a rigorous title and abstract screening process to ensure the consistency and accuracy of the keywords used (Bhimani et al., 2019). The papers with relevant abstracts were included

in the next stage, resulting in a sample size of 147 articles. This task was challenging, so the preselected papers were divided into three groups (504 papers per group), and each author screened one group independently. This approach allowed for high flexibility and efficient handling of the preselection stage. The screening process took approximately three weeks. Notably, many of the initial articles included keywords related to road network hierarchy in a general or superficial manner rather than truly addressing the concept of hierarchy itself. This expedited the screening process. The full texts of the initially screened articles were then independently reviewed by all three authors based on the research aim. This led to a pool of 39 articles for which all three authors agreed were highly relevant. These articles were thoroughly read, categorized, and analyzed in terms of hierarchy and classification concepts. The literature selection procedure is presented through a PRISMA diagram (Fig. 1), which ensures transparent and comprehensive reporting of the SLR process (Liberati et al., 2009).

In step 3 (reporting and concept identification), the focus was on writing up and presenting the findings, specifically the critical concepts, approaches, and methods related to urban road network hierarchy. A synthesis

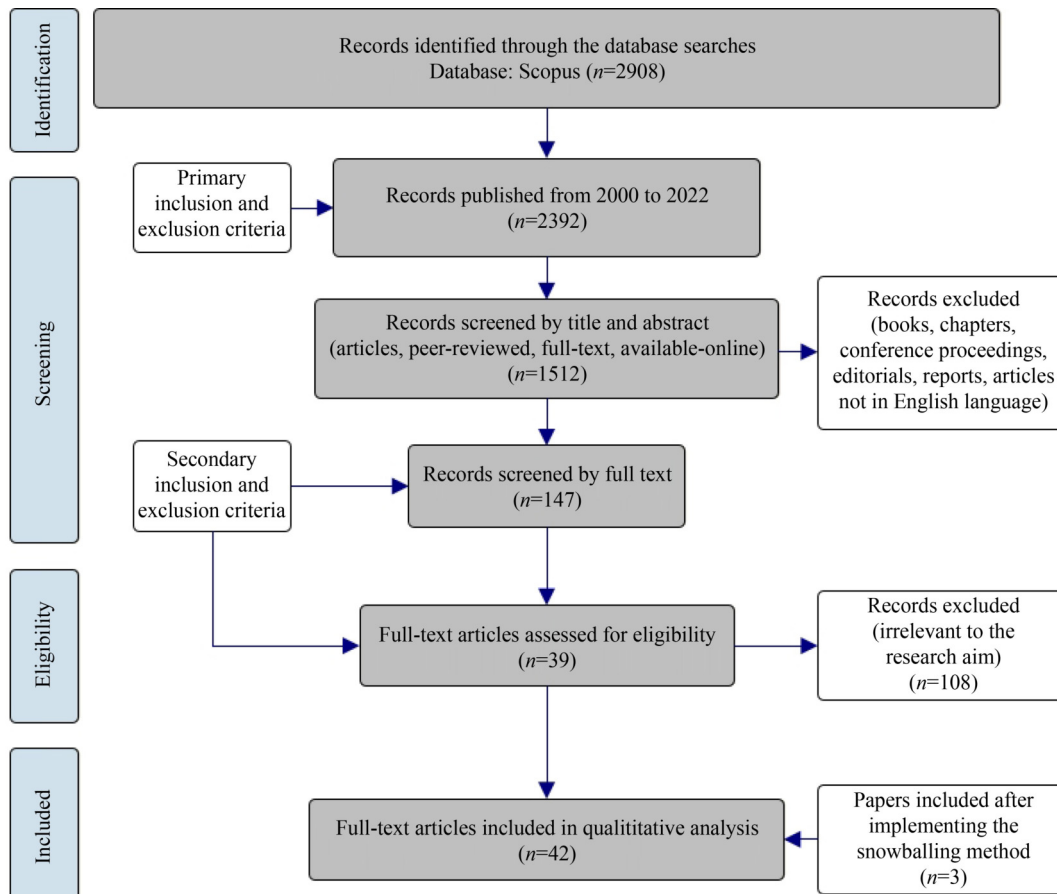


Fig. 1 PRISMA workflow and number of collected papers in each step.

process was conducted to highlight the fundamental elements and concepts associated with hierarchy. Additionally, relevant concepts were formulated by combining different elements found in the literature. It is worth underlining that other publications related to hierarchy and classification in urban areas were also utilized at this stage. As a result, the snowballing method, commonly used in scientific literature reviews (Lagorio et al., 2016; Lagorio et al., 2022; Tsigdinos et al., 2022), increased the number of reviewed references to 42 (an addition of 3 scientific articles).

### 3 Results

This section presents the research results, including descriptive and detailed bibliometric analyses. It provides an overview of the sample characteristics, identifies existing trends and their future potential, explores concepts related to hierarchy, and presents a citation network analysis to illuminate the interactions between the current literature components.

#### 3.1 Bibliometric analysis: Describing the corpus

First, when it comes to contextualizing and understanding the research agenda on a specific topic, it is essential to observe the development of the corpus of literature over the years. A bibliometric analysis allows us to unravel the evolutionary nuances of a particular field and shed light on emerging areas within that field (Donthu et al., 2021). Therefore, a time series illustrating the number of publications related to road network hierarchy per year was created (Fig. 2).

Figure 2 clearly demonstrates that the evolution of the relevant literature is not stable. Over the past two decades, there have been several fluctuations. Local peaks and

troughs can be observed, as evident from the irregular shape of the line in the corresponding diagram. Notably, the highest number of publications occurred in 2022, 2021, and 2019, with five relevant articles published each year. This was followed by 2014 and 2008, in which four publications were published each year. In the remaining years, the number of relevant articles ranged from one to two, with a few cases where three articles were published per year, acting as minor “outbreaks.”

Recently, there has been a steady increase in the relevant literature, indicating a dynamic trend toward future research. However, this trend is relatively new, as, prior to 2020, the corpus of literature experienced significant outbreaks, with a substantial number of articles published every five or six years. The cumulative diagram in Fig. 2 portrays the cumulative dynamics of the literature evolution. As depicted in this figure, the literature evolution can be divided into two discrete stages. The first stage extended until 2008, during which the corpus had only one relevant paper, indicating limited scientific debate on the realization of road network hierarchy in urban areas. However, 2008 marked a turning point, after which the relevant literature expanded significantly, a trend that persists until the present. In the second stage, notable changes in the slope can be observed at four specific moments: 2011, 2014, and 2018. Regarding the publications on road network hierarchy, it is important to note that the sample includes a variety of scientific journals from different fields. Specifically, there are 32 journals representing 9 general fields and 18 specific fields. This diverse range of journals reflects the multidimensional nature of the road network hierarchy and its interdisciplinary nature. The literature covers various aspects, such as social, economic, and technological factors, going beyond the traditional perspectives of urban planning and transport. These journals, along with their fields and the number of relevant papers they contain, are presented in Table 1.

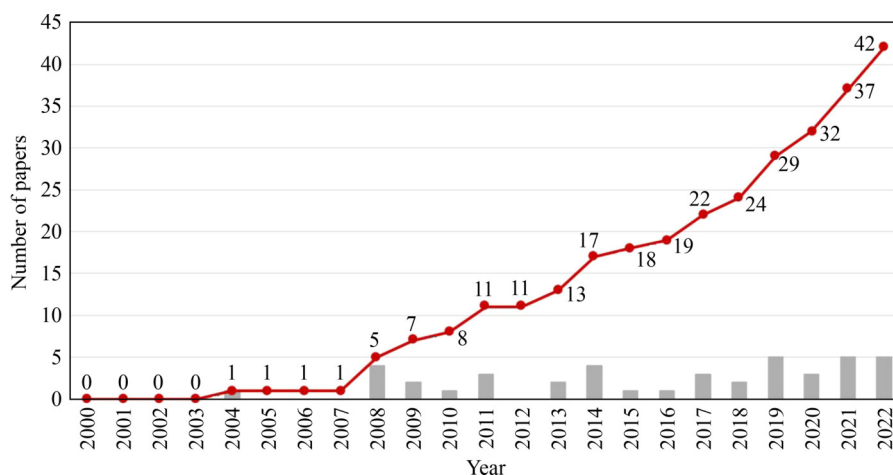


Fig. 2 Literature evolution during the period from 2000 to 2022 (plus cumulative outline).

**Table 1** Scientific journals and respective fields

id	Name	General field	Specific field	Papers numbers
1	Accident Analysis and Prevention	Medicine	Public health	2
2	Acta Polytechnica Hungarica	Engineering	General engineering	1
3	Baltic Journal of Road and Bridge Engineering	Engineering	Building and construction	1
4	Case Studies on Transport Policy	Social Sciences	Urban studies	2
5	Cognitive Research: Principles and Implications	Psychology	Experimental and cognitive psychology	1
6	Environment and Planning B: Planning and Design	Engineering	Architecture	1
7	EPJ Data Science	Mathematics	Computational mathematics	1
8	European Journal of Geography	Social Sciences	Geography, planning and development	1
9	European Transport- <i>Trasporti Europei</i>	Engineering	Automotive engineering	1
10	Geocarto International	Social Sciences	Geography, planning and development	1
11	IATSS Research	Social Sciences	Urban studies	3
12	Infrastructures	Earth and Planetary Sciences	Geotechnical engineering and engineering geology	1
13	International Journal of Engineering and Advanced Technology	Engineering	General engineering	1
14	International Journal of Geographical Information Science	Social Sciences	Geography, planning and development	1
15	International Journal of Sustainable Transportation	Social Sciences	Geography, planning and development	2
16	ISPRS International Journal of Geo-Information	Social Sciences	Geography, planning and development	1
17	Journal of Transport Geography	Social Sciences	Geography, planning and development	1
18	Journal of Urban Planning and Development	Social Sciences	Urban studies	1
19	Pattern Recognition	Computer Science	Software	1
20	Pollack Periodica	Engineering	Civil and structural engineering	1
21	Progress in Planning	Social Sciences	Geography, planning and development	1
22	Road and Transport Research	Engineering	Mechanical engineering	1
23	Safety science	Social Sciences	Safety research	1
24	Science of the Total Environment	Environmental Science	Environmental engineering	1
25	Scientific Reports	Multidisciplinary	Multidisciplinary	1
26	Sustainability	Social Sciences	Geography, planning and development	2
27	Town Planning Review	Social Sciences	Urban studies	1
28	Transport	Social Sciences	Automotive engineering	1
29	Transport Reviews	Engineering	Transport	1
30	Transportation Research Record	Engineering	Mechanical engineering	4
31	Urban Design International	Social Sciences	Urban studies	2
32	WIT Transactions on Ecology and the Environment	Environmental Science	General environmental science	1

It is worth noting the representation of different fields in the discussions around the urban road network hierarchy. Each journal is affiliated with a general field and a more specific field, determined through Scopus rankings. According to [Table 1](#), the most prevalent general fields are Social Sciences, with 15 papers (46.49%), and Engineering, with nine papers (28.13%). Another field with notable impact is Other Environmental Science, which had two papers (6.25%). Moving on to the prevailing specific fields, geography, planning and development ranks first with eight papers (25.00%), followed by urban studies with five papers (15.63%). Automotive engineering, general engineering, and mechanical engineering are

tied in third place with two papers each (6.25%). The combination of prevailing fields and the overall variety of fields illustrates the interdisciplinary nature of the urban road network hierarchy. Therefore, policy recommendations should adopt integrated approaches rather than conventional, monothematic ones.

Turning to the scientific journals themselves, “Transportation Research Record,” a renowned journal in the field of Engineering, has the most relevant publications, with four papers. “IATSS Research,” representing the field of urban studies, follows with three publications. “Accident Analysis and Prevention,” “Sustainability,” “International Journal of Sustainable Transportation,”

“Case Studies on Transport Policy,” and “Urban Design International” also make significant contributions, each with two publications. “Accident Analysis and Prevention” belongs to the field of medicine, while the others fall under the social sciences.

### 3.2 Content analysis

At this point, a content analysis of the findings deriving from the SLR process follows.

#### 3.2.1 Development of the SLR overview table

The approach of SLR, particularly meta-synthesis (De Gruyter et al., 2019), proves exceptionally beneficial. It utilizes a systematically structured methodology for the collection and analysis of relevant data. Moreover, this technique probes more profoundly into the core of each paper, emphasizing essential concepts and viewpoints. To facilitate this analysis and provide a comprehensive overview, an overview table (Table A1) has been created (Appendix A). This table includes detailed information about the articles in the sample, as well as future directions and insights into the urban road network hierarchy.

Table A1 serves as the main tool for analyzing and distilling meaningful knowledge from the articles. It consists of 13 columns, each displaying different information and features. The first column lists the authors of the articles, while the second column notes the publication dates. The third column highlights the key topic represented by each article, focusing on the constituent concepts of the urban road network hierarchy. Notably, only one topic is included for consistency reasons.

The fourth column presents the objective of each work, aiming to identify the role of the urban road network hierarchy within the context of the entire article. The subsequent two columns address the research methods used. The fifth column indicates the general research method employed (quantitative, qualitative, mixed), while the sixth column specifies the certain type of method utilized (methodological, case study, analysis, etc.). Each paper was assigned to a single category that was deemed most appropriate for that particular study, ensuring clarity and coherence.

The seventh column illustrates the spatial level at which each research work is focused (national, urban, route, etc.), and the eighth column specifies the exact study area, whether real or hypothetical. The ninth column provides a summary of the main findings of each article, while the tenth column presents any proposed methods for classifying the urban road network, if applicable. The eleventh column outlines the approach taken by each study in defining the urban road network hierarchy. This approach can be either conventional or alternative

(multimodal), connecting each paper to the theory of urban road network hierarchy and the prevailing social and political goals.

The twelfth column indicates whether the proposed or existing road hierarchy system considers the urban dimension when formulating road categories. This finding highlights the potential connections between transport and the urban domain. Finally, the thirteenth column focuses on the future, highlighting the contribution of each study to the formulation of a new urban road network hierarchy system. The values in this column range from 1 to 5, where 1 represents a very low contribution and 5 represents a very high contribution. For the sake of clarity and readability, Table A1 is presented separately in the Appendix of this paper (Appendix A).

#### 3.2.2 Descriptive analysis and general comments on the SLR table

Upon careful examination of Table A1 and subsequent descriptive statistical analysis, several noteworthy findings emerge. The majority of articles in the sample (59.52%) adopt an alternative approach to the urban road network hierarchy, indicating a discernible shift toward sustainability- and multimodality-centric perspectives within the literature. When it comes to the contribution of the sample to a new future hierarchy and the spatial level, Fig. 3 is rather interesting.

Specifically, Fig. 3(a) reveals that half of the papers exhibit a high or even very high level of contribution. These two categories are followed by papers characterized by a medium level of contribution (40.48%), while only 9.52% of the examined studies have a low or very low level of contribution. This finding signifies that current research related to road network hierarchy not only embraces an alternative rationale but also formulates effective strategies for future transport scenarios. As mentioned, another intriguing feature is the spatial level addressed by the papers included in the sample. As shown in Fig. 3(b), more than half of the papers pertain to the urban or municipal spatial level, while a notable percentage (21.43%) focus on hierarchy strategies for specific routes. This indicates that the urban road network hierarchy is not confined to urban or metropolitan policy schemes on a macroscale; rather, it can be implemented on a microscale. Thus, this tool functions as a multilevel strategy in urban areas.

Figure 4 depicts the number of road/street categories suggested in the papers included in the sample. The number of road/street categories is particularly crucial, as an effective hierarchy system requires a proper balance (Kosztolányi-Iván et al., 2019). Specifically, when a system has numerous categories (more than 10), achieving readability can be challenging. Conversely, a small number of categories (less than 5) fail to involve all

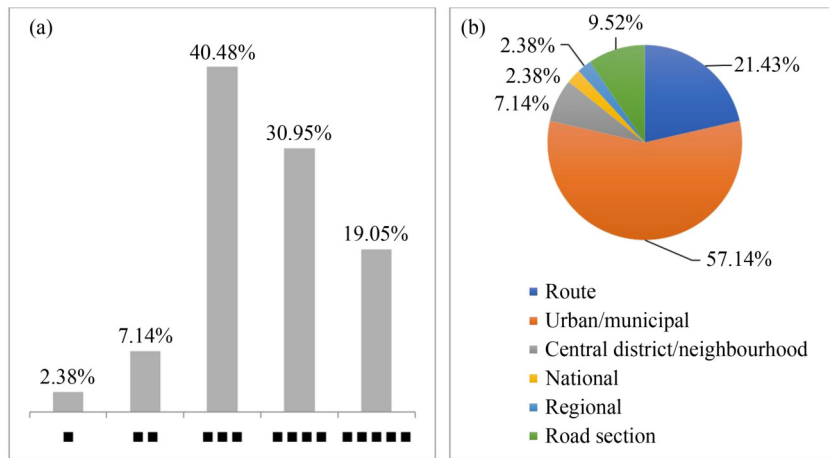


Fig. 3 (a) Contribution to an alternative hierarchy and (b) Spatial level scheme.

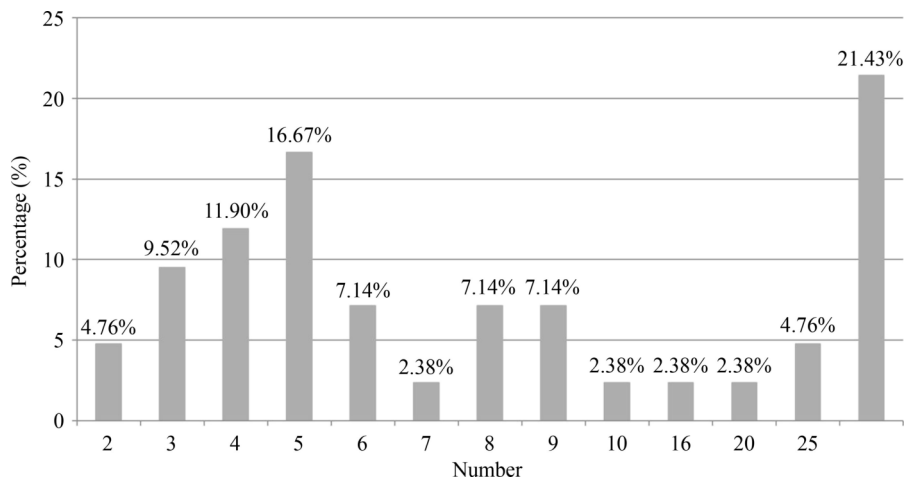


Fig. 4 Number of road/street categories.

potential aspects and priorities, thereby neglecting the various modes encountered in urban road environments. In general, a small number of categories corresponds to conventional approaches, while a large number aligns with alternative approaches.

A considerable percentage of the related studies (21.43%) do not propose a specific hierarchy method but instead they extensively examine existing hierarchy methods. These papers do not provide any relevant information about the number of street categories and are represented as “no data” in the diagram. The remaining articles displayed a range of 2 to 25 hierarchy categories. Notably, papers in five categories had the highest percentage (16.67%), followed by those in four categories (11.90%). This indicates that the current literature primarily employs urban road network systems with a small number of categories, suggesting a potential need for future alternative approaches with more concise hierarchy schemes. When looking into the “optimal” number of categories, i.e., above four and less than 11, it is evident that 42.86% of all the papers fall within this

range (including those that do not propose a new hierarchy system). This signifies that a substantial proportion adopts “the right mix”, but there should be a greater focus on formulating alternative and innovative schemes with an appropriate number of categories.

What is more, the descriptive analysis of the SLR table identifies both general and specific research methods utilized. It is important to note that out of the 34 papers, only nine (21.43%) exclusively adopted qualitative research methods, while the rest were almost equally divided between those that utilized quantitative methods (43%) and those that employed mixed methods (quantitative and qualitative) (36%). This indicates a distinct trend in the literature to prefer quantitative tools and procedures.

Figure 5 provides further insight into the actual types of methods used, such as methodological, modeling, and review methods, which also shed light on how the urban road network hierarchy is analyzed, determined, and evaluated.

The figure (Fig. 5) clearly demonstrates that more than

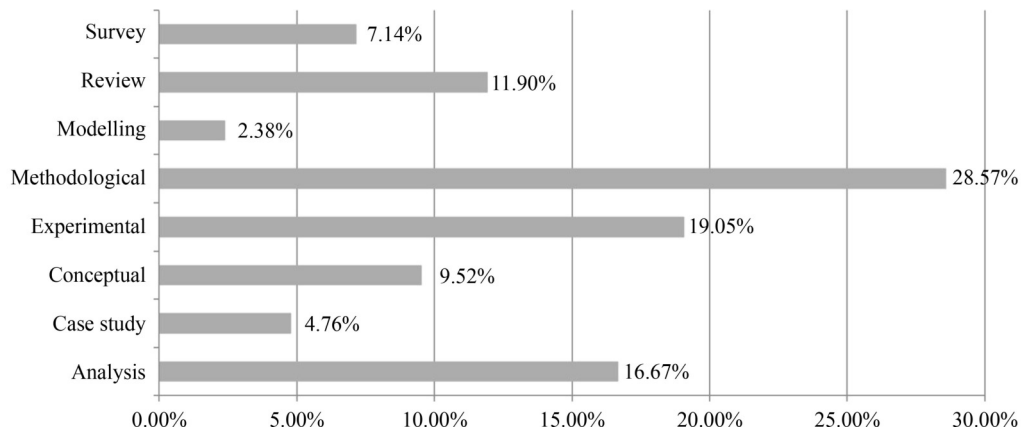


Fig. 5 Type of research papers.

a quarter of the sample is methodological in nature, followed by papers undertaking “experimental applications” with significant percentages (e.g., analyzing changes in road hierarchy). Similarly, articles incorporating analysis techniques (primarily with geographical criteria) to examine the current situation and propose future recommendations constitute a large portion of the literature. Therefore, papers related to urban road networks mainly fall into the categories of methodological, analytical, and experimental research, with fewer being conceptual, review-based, or case study-based.

### 3.2.3 Interpreting the SLR table: Trends and insights

The SLR table (Table A1) has contributed significantly to identifying current trends and providing valuable insights for future transport scenarios. One observed trend is the utilization of road hierarchies to recognize the morphology of urban road networks and highlight major road segments (Jiang, 2009; Huang et al., 2016; Han et al., 2020). Similarly, Paraskevopoulos et al. (2022) employed space syntax analysis to classify the road network in the Athens Metropolitan Area. Other similar research trends or ideas are reflected in the articles of Iván (2014) and Kosztolányi-Iván et al. (2019) who placed special emphasis on user participation, to determine which and how many road network categories a hierarchy system should have. Also, Chan and Cooper (2019) investigated whether hierarchy can be used as a tool for predicting traffic flows.

Another research direction focuses on utilizing advanced algorithms, particularly machine learning techniques, for the automatic classification of urban road networks. Noori et al. (2020), Bosurgi et al. (2019), D’Andrea et al. (2014), and Gülgen (2014) demonstrated methodological approaches for determining the geographical hierarchy of road networks. Gharaee et al. (2021) introduced a novel learning-based approach, adopting graph convolutional neural networks, to classify

the road network in urban areas. Tsigdinos et al. (2021a) used network analysis algorithms to introduce autonomous vehicles into a street classification system. However, it is important to note that these studies primarily follow a conventional, car-oriented approach, which raises questions about their applicability within a sustainability-oriented framework in the future.

Moving on to different research directions that emphasize the social dimension and multimodality of streets and roads, it is important to highlight several articles that aim to redefine the hierarchy of urban road networks through the promotion and adoption of “complete streets” policies.

In particular, Gregg and Hess (2019) conducted a comprehensive literature review on the design issues of complete streets, while Elias (2011) gathered and categorized the appropriate criteria for designing such streets. Additionally, Kingsbury et al. (2011), Hui et al. (2018), and Kumar et al. (2019) developed innovative tools to assess the quality of these schemes and related infrastructure. Consistent with this, Dehghanmongabadi and Hoskara (2022) created a holistic method outlining the main steps for planning an efficient complete street, considering both the built environment and the social context.

Delbosc et al. (2018) contributed to the scientific debate by comparing complete streets (predominantly favored in the USA) with the corresponding policy scheme in Australia (smart roads). Their conclusion highlighted the benefits of a combined rationale as a means of introducing a new and alternative road hierarchy approach. Similarly, Curtis and Tiwari (2008) and Tsigdinos et al. (2021b) highlighted the value of multimodal corridors and their positive impact on the urban road environment. They proposed cohesive strategies for redesigning urban arterial roads. Furthermore, Mirzahosseini et al. (2022) made a significant contribution by outlining a cohesive method to prioritize arterial roads for transformation into multimodal corridors. Another take from Sheikh-Mohammad-Zadeh et al. (2022) formulated

an assessment process based on transit, access, and place, which could serve as the basis for a new classification system.

Other works of significant interest and contribution to the formulation of a new urban road network hierarchy are those of Stamatiadis et al. (2017), Tsigdinos and Vlastos (2021), and Tsigdinos et al. (2020). These works established a coherent methodological framework for redefining the hierarchy of the urban network at the metropolitan and citywide levels utilizing the two-dimensional classification approach initially proposed by Jones et al. (2008) and Jones and Boujenko (2009) through the concept of Link and Place. This concept, which is steadily gaining popularity, combines the urban planning and transport dimensions, taking into account the multimodality of urban streets and the variety of activities that occur within them. A similar rationale was adopted by Oguchi (2008), who proposed a two-dimensional matrix for formulating road hierarchies at the national level in Japan. Additionally, an interesting study incorporating this bidimensional classification was conducted by Su et al. (2022), who proposed an activity-based street reconfiguration scheme, thereby expanding the scope of traffic-related road hierarchies.

Finally, several works embrace the social dimension of streets, effectively linking the concept of hierarchy with similar concepts and serving as a catalyst for future studies that move beyond conventional practices. For instance, Charlton et al. (2010), Walker et al. (2013), Charlton and Starkey (2017), and Theeuwes (2021) examine the connection between the urban road network hierarchy and road safety, while Carmona (2015) and Sauter and Huettenmoser (2008) explore hierarchy in relation to land use/activity and social relations. These perspectives demonstrate that the urban road network hierarchy is not merely a process of categorizing streets but rather a broader framework that influences other aspects of urban street environments and social nexus.

### 3.2.4 Identifying the fundamental components and their evolution

In addition to descriptive statistics and significant trends or insights, the SLR table facilitated the identification of the fundamental components of the urban road network hierarchy. These components are sub-concepts that are closely intertwined with the main concept of hierarchy. This type of analysis is also evident in relevant literature review papers (e.g., Lagorio et al., 2016) and serves as a valuable tool for gaining a deeper understanding of the main concept, i.e., the urban road network hierarchy.

These components essentially represent the main focus of each article included in Table A1. They were determined through the careful interpretation of the papers in the

SLR sample. This process distinguished 16 relevant constituent concepts that span a broad spectrum of the urban and transport domains. These concepts were thoughtfully selected to ensure coherence and comprehension, aiming to capture the general content. All these components are presented in Fig. 6 and are organized according to specific time periods. These periods were established based on the number of components and the year they were first introduced, resulting in a clear depiction of their evolution over time. Notably, the evolution of these components serves as a meaningful indicator for contextualizing the urban road network hierarchy and the underlying process. In Fig. 6, the components introduced for the first time are depicted in gray, while those that reappear are shown in light purple.

During the 2000–2010 period, seven new components emerged (found in eight articles). The concept of Link and Place, which pioneered two-dimensional classification, is featured in two publications. Therefore, alternative (more sustainable) approaches to hierarchy have been part of the literature since then.

During 2011–2015, ten new scientific articles introduced eight novel concepts, with road safety being the only concept adopted from previous research. In contrast, previously prevalent concepts such as network analysis, street reconfiguration, and multimodality disappeared. This shift exemplifies the dynamic and diverse nature of the urban road network hierarchy, where concepts evolve and others wane. Notably, ‘complete streets’ and ‘pattern recognition’ emerged as dominant concepts during this period, reflecting interdisciplinary influences from urban mobility and computer science (image processing), respectively.

In the subsequent period, 2016–2022, the field stabilized, with 23 new publications. Of the eight concepts discussed, only two—trial classification and spatial analysis—are new. The remaining concepts re-emerge from earlier periods. The dominant themes included network analysis, street reconfiguration, and complete streets, followed by multimodality and pattern recognition. This finding indicates a balance of qualitative and quantitative research orientation in the literature.

These three stages involve shifting dominant concepts, likely influenced by advancements in technology, computational methods, urban planning, transport priorities, and community awareness. For example, pattern recognition is technology-driven, whereas complete streets stem from human-centric priorities. Understanding these evolving concepts is not a mere identification task; it requires additional analytical tools. Table 2 elucidates the relationships between various concepts and the methods employed in their study.

Table 2 enhances our understanding of the methods utilized in each fundamental concept. Generally, the range of methods is evident, as almost every concept, that

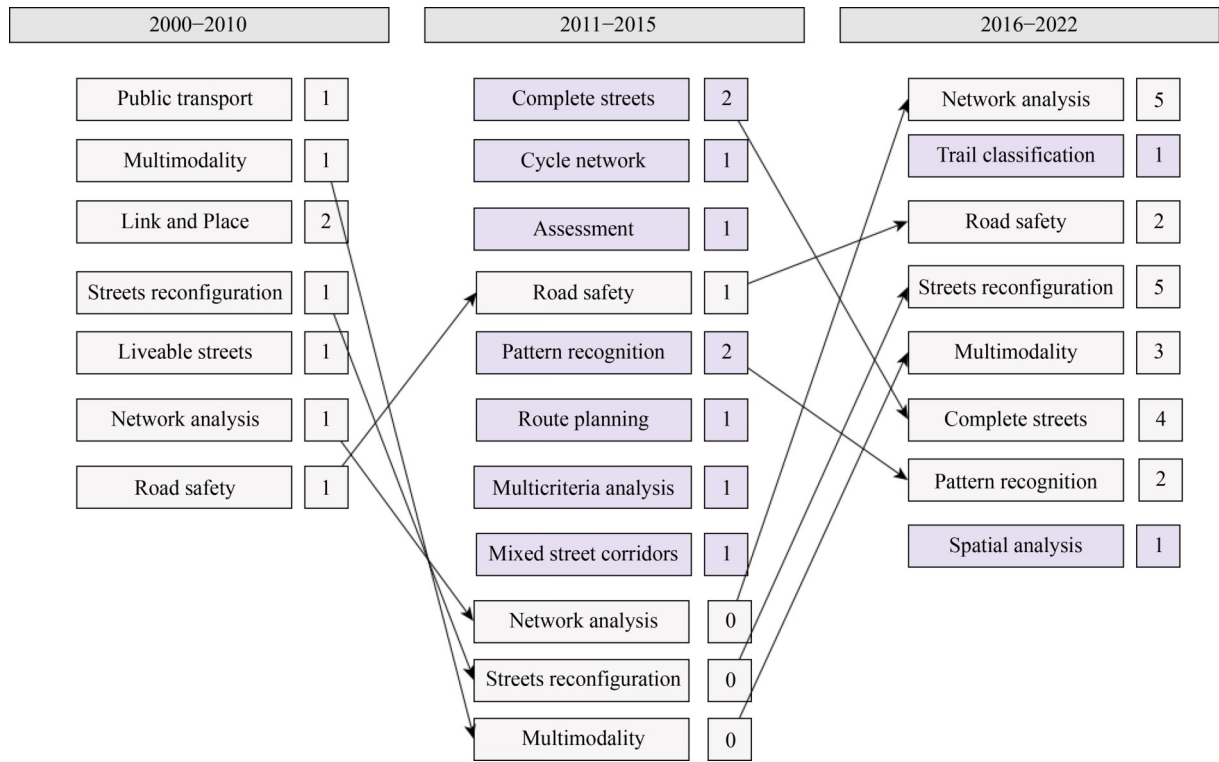


Fig. 6 Fundamental components of hierarchy and their evolution.

Table 2 Concepts and methods

Concept/Method	Analysis	Case study	Conceptual	Experimental	Methodological	Modeling	Review	Survey	Total sum
Assessment	1		1						2
Complete streets				1	1		3	1	6
Cycle network					1				1
Link and place			2						2
Livable streets								1	1
Mixed street corridors								1	1
Multicriteria analysis					1				1
Multimodality		2			1		1		4
Network analysis	5				1				6
Pattern recognition	1			2	1				4
Public transport					1				1
Route planning				1					1
Spatial analysis						1			1
Streets reconfiguration			1	1	4				6
Traffic safety				3			1		4
Trail classification					1				1
<b>Total sum</b>	<b>7</b>	<b>2</b>	<b>4</b>	<b>8</b>	<b>12</b>	<b>1</b>	<b>5</b>	<b>3</b>	<b>42</b>

is represented by multiple papers, has been examined using different approaches. When examining the prevailing concepts closely, the following points should be highlighted: On the one hand, it appears that certain concepts are investigated primarily using specific types

of methods. For example, “complete streets” are predominantly discussed in review papers, “network analysis” is frequently found in analysis papers, “street reconfiguration” is principally encountered in methodological articles, and “traffic safety” is found in studies carrying out

experiments. On the other hand, concepts such as “multi-modality” and “pattern recognition” are found in a variety of paper types, indicating greater diversity.

In summary, the evolution of these components highlights two key aspects: a) the “diverse” nature of the hierarchy and b) the continuous enrichment and expansion of the literature with new constituent concepts that enhance coherence while redefining the concept of hierarchy itself over time. Furthermore, certain concepts are closely associated with specific methods, while others are amenable to various tools and techniques.

### 3.2.5 Citation network analysis

Citation network analysis is an integral part of SLR and has the ability to shed light on the interactions among scientific articles through an extensive network of citations (Lagorio et al., 2016; Aria and Cuccurullo, 2017). In this study, citation network analysis was employed to visualize the connections among the literature related to urban road hierarchy. Only the papers included in the sample were considered, in line with Lagorio et al. (2016) and Gustafsson et al. (2014), to ensure feasibility and facilitate interpretation. This tool helps identify influential articles and those that lack research interaction. It is based on graph theory, widely utilized in network analysis (Rodrigue, 2020), and proves particularly valuable for recognizing interdependencies and relationships. Specifically, articles are represented as nodes, and citations are represented as edges, forming networks with specific topological properties (McLaren and Bruner, 2022). This study adheres to the convention where each arrow points from the citing document to the cited document, representing the “cite” relationship.

According to Fig. 7, our citation network consists of three main entities, indicating that the literature on urban

network hierarchy is influenced by various factors. First, there are several articles that have no contact or relationship with the rest of the relevant literature; these articles form 11 sub-networks consisting of only one node (blue color in Fig. 7). Notably, these 11 articles, the majority of which were published after 2010, appear to be isolated without any interaction with the main body of literature.

The second entity consists of six articles, forming a small path with six nodes and five edges (green color in Fig. 7). At this point, we utilize the connectivity index  $\gamma$ , defined as follows (Rodrigue, 2020):

$$\gamma = \frac{e}{3(v-2)}, \quad (1)$$

where  $e$  are the edges of the graph and  $v$  are the vertices of the graph.

The  $\gamma$  index of this small path, which equals 0.42, shows that the graph is not particularly connected. Consequently, as evidenced by its linear shape, the articles do not interact with each other, except for two of them (Charlton et al., 2010; Charlton and Starkey, 2017), which have node degrees of 3 and 2, respectively. These nodes are more connected, reflecting the prominence of these two projects in the entire sub-network. Additionally, it should be noted that this path is not connected to the main network and functions as a separate entity. This sub-network first appeared in 2010, and the articles belonging to this cluster primarily address road safety and pattern recognition issues.

Finally, the main body of literature establishes a large sub-network of articles and citations characterized by a complex shape (red color in Fig. 7). This sub-network clearly demonstrated the interactions among most of the articles included in the sample. It consists of 25 nodes and 42 edges. The connectivity index  $\gamma$ , which is 0.61, indicates that the current sub-network is moderately connected. This implies that some of the articles (nodes)

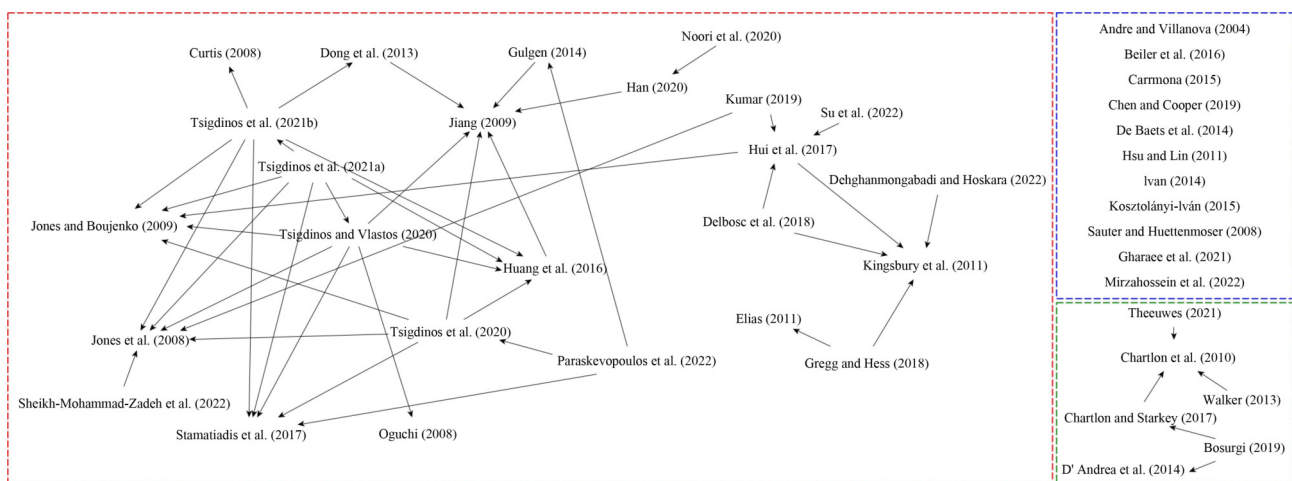


Fig. 7 Citation network.

consider previous ones, and in general, the influence of older research works on newer ones can be considered relatively significant. The articles included in this sub-network cover a wide range of topics related to urban road network hierarchy, such as geography and development, urban studies, transport, computer science, and environmental sciences. These conditions highlight once again that hierarchy is not an isolated issue but resides within a wider scientific debate. Moreover, the interaction of these different types of articles and topics cultivates a comprehensive context for understanding the urban road network hierarchy.

In accordance with Fig. 8, which was generated using yEd software, known for its network management capabilities, the most influential articles based on their citation count within the corpus are as follows:

First, the studies conducted by Jiang (2009) and Jones et al. (2008) are notable, with a node degree of 6. These works have evidently influenced all the connected articles, demonstrating their critical value to the entire literature. These papers can be regarded as the principal pioneers of the relevant literature. Next, the research of Jones and Boujenko (2009) and Stamatiadis et al. (2017) followed with a node degree of 5. Finally, notable studies that have influenced the literature corpus include Huang et al. (2016), Kingsbury et al. (2011), and Charlton et al. (2010).

To summarize, the articles highlighted by the SLR process appear to represent the most crucial research on the urban road network hierarchy in the literature corpus. This process not only illustrates the evolution of the literature but also demonstrates the profound and continuous interactions among its constituent parts, i.e., the articles. Furthermore, the citation network analysis clearly revealed which articles play a vital role in shaping the complex landscape of the literature corpus.

## 4 Discussion

### 4.1 Main findings and research issues

In a rapidly evolving research landscape in the field of urban and regional design (Cao and Zhang, 2022), our research dealt with a fundamental notion of both urban and transport planning: the urban road network hierarchy. This work is one of the few to date that scrutinized the complex process of classifying streets and roads from multiple perspectives. The primary objective was to contextualize the notion of hierarchy and determine its properties. By employing a SLR process, this research sheds light on existing trends and the evolution of relevant literature over time. This study provided a comprehensive overview of the selected sample, including its composition, characteristics, and development of the related literature. The use of this review method in previous urban and transport studies (e.g., Scheepers et al., 2014; Wang et al., 2022; McKane and Hess, 2023; Papaix et al., 2023) further enhances the value of our study.

Our analysis revealed a significant increase in the number of articles published primarily after 2010, with peak values occurring in 2019, 2021, and 2022. The journals included in our sample represent diverse scientific fields, reflecting the multidimensional nature of the urban road network hierarchy. However, it is noteworthy that the fields of geography and urban studies, followed by engineering, are the most prominent. Despite this spatial-centric focus, road hierarchy remains an interdisciplinary topic requiring integrated approaches for analysis and transformation toward sustainability. Pumain (2006) and Corominas-Murtra et al. (2013) also discussed the inherent nature of hierarchy in depth. In addition to general descriptive bibliometric analysis, our study developed an overview table using the SLR methodology to provide

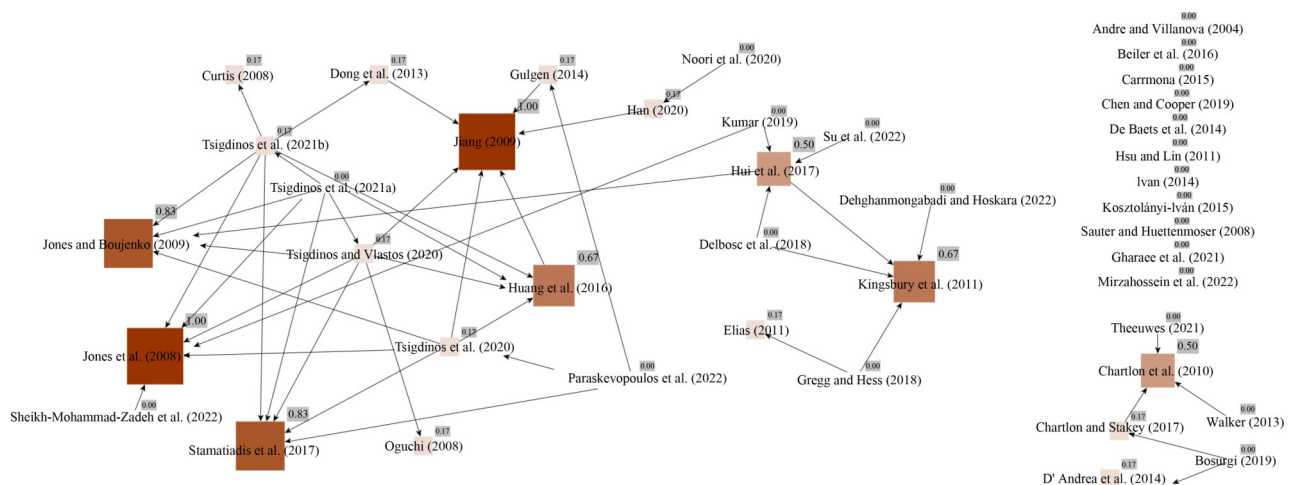


Fig. 8 Most influential articles.

detailed information on the included articles and offer significant insights into the urban road network hierarchy (similar tables can be found in [Butler et al., 2021](#)). This table consisted of 13 columns, including information such as the objectives, methodology, proposed hierarchy systems, and key findings of each article. Through this comprehensive overview, readers can gain a clear understanding of the characteristics of the literature in this field. Furthermore, this table helps identify emerging trends and dynamics toward future transport scenarios.

The descriptive statistical analysis of the table features provides valuable insights. First, it was demonstrated that the majority of articles focus on the urban and municipal spatial level, while others address specific routes. This indicates that the urban road network hierarchy is not limited by macroscopic and strategic analysis but can also be implemented at the microscale, thereby serving as a multilevel strategy in urban areas. This finding is in line with that of [Okraszewska et al. \(2018\)](#), who emphasized the significance of a multiscale transport system planning framework.

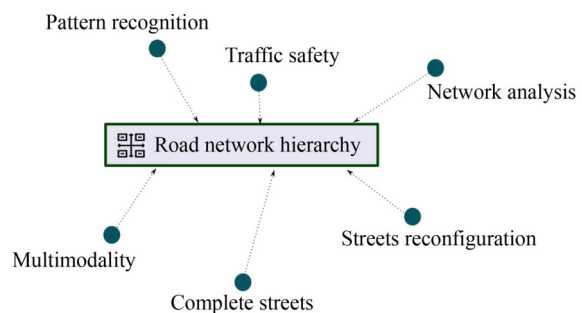
When it comes to the methods employed, most articles utilize mixed and quantitative methods (e.g., [Hsu and Lin, 2011](#); [Dong et al., 2013](#); [De Baets et al., 2014](#)), indicating a clear preference for spatial analysis or geoinformatics either alone or coupled with organizational procedures to determine road hierarchy schemes. The use of mixed procedures represents a recent trend in hierarchy analysis, combining the development of new categories with the determination of their geographic attributes (also see [Rychlewski, 2016](#)). With regard to the approaches utilized (conventional or alternative), it is encouraging to observe that the alternative approach has a notable influence on the majority of published works, emphasizing sustainable modes of transport and multimodality. This shift aligns with the narratives surrounding sustainable mobility ([Holden et al., 2020](#)) and aims to promote a new ethos of mobility.

In addition to the adopted approach, it is important to highlight the proposed hierarchy systems. Categories with 4 or 5 levels are the most prevalent, while approximately 40% of the papers fall within the optimal range of 5 to 10 categories. This indicates that the current literature tends to employ urban road network systems with a limited number of categories, presenting a somewhat mixed message for the future-advocating for an alternative approach but with more concise hierarchy schemes. Furthermore, 55% of the papers considered the urban planning dimension, creating a conducive environment for the promotion of sustainable mobility schemes. Existing literature on transport planning embraces integrated approaches ([Miller, 2018](#); [Capasso Da Silva et al., 2020](#)), aligning with the current research trend of adopting cohesive strategies that include both urban and transport dimensions ([Sarri et al., 2023](#)). Finally, most papers make

a substantial or even highly significant contribution to the establishment of a new hierarchy. This demonstrates that current research on road network hierarchies not only adopts an alternative rationale but also strives for coherent strategies in future transport scenarios.

Furthermore, the meta-synthesis process revealed four main research trends pertaining to the hierarchy of urban road networks within the sample. The first trend focuses on analyzing the morphology and structure of urban road networks, while the second trend aims to develop techniques for automatically determining the hierarchy of road networks. In contrast, the third and fourth trends underline the social dimension of streets, proposing multidimensional hierarchy systems that include urban planning and transport aspects. Despite their differences, these trends should be seen as complementary rather than conflicting, as both spatial and social perspectives are essential in understanding road networks. Integrated approaches, such as those discussed in [Melkonyan et al. \(2020\)](#), advocate for a holistic view of urban and transport systems, utilizing both analytical tools and organizational strategies. Moreover, given the uncertainty of the future, it is crucial to adopt inclusive and multidimensional approaches rather than narrow approaches to envision and shape desirable future scenarios ([Lyons and Davidson, 2016](#); [Vallet et al., 2020](#)). As a result, these four emerging trends can be consolidated into two overarching categories, namely, analysis and planning, which can serve as driving forces for future transport street classification planning schemes.

Shifting focus to the contextualization process, this study distinguished the components closely associated with the hierarchy of urban road networks, specifically the concepts that are most relevant in this regard. The SLR summary table indicates a total of 16 concepts that are interconnected with various aspects of urban environments. As depicted in [Fig. 9](#), the prevailing concepts cover a wide range of dimensions, including “complete streets,” “network analysis,” and “street reconfiguration,” all of which are closely linked to hierarchy. Additionally, there are concepts that may not initially appear to be highly relevant; however, they significantly impact the



**Fig. 9** Prevailing concepts relevant to hierarchy.

road hierarchy within a city (e.g., pattern recognition). The analysis of these components reveals two key insights: the diverse nature of hierarchy and the continuous emergence of new constituent concepts within the literature. The evolution of these concepts can be attributed to advances in technology, improvements in computational methods, shifts in urban planning and transport priorities, and increased community awareness.

Another important aspect to consider is the analysis of the citation network. This process identified three main entities or subnetworks:

a) Independent studies that do not cite each other or the rest of the sample.

b) A small path consisting of a limited number of papers that are connected to each other but not to the rest of the literature.

c) The main body of the published corpus, which is a dynamically connected entity (with an adequate value of index  $\gamma$ ) that demonstrates the interaction between the papers in the sample.

In particular, the third sub-network constitutes the driving force behind new publications covering a wide spectrum of topics related to urban road network hierarchy, such as geography, urban studies, engineering, transport, computer science, and environmental sciences. The analysis of the citation network provides insights into the evolution of the literature and reveals the continuous interactions between the articles. Furthermore, we explored which articles had the most influence on the development of the literature corpus.

When it comes to the research questions, the SLR and supplementary methods such as citation network analysis have provided insights for each research question. Specifically, in response to the question about the nature of hierarchy (question a), the study has demonstrated that hierarchy is a concept that enables a comprehensive understanding of urban space and is an essential tool for future cities. It plays a central role in spatial planning, including both urban and transport dimensions. This study highlights the critical role of hierarchy, which should be further enhanced in the future.

Concerning whether hierarchy is mostly qualitative or quantitative (question b), it has been shown that hierarchy is not solely one of these options but rather a dynamic combination that involves both qualitative and quantitative approaches.

With the regards to the question of whether hierarchy emerges or is solely a matter of planning (question c), the findings indicate that hierarchy sometimes emerges from the topological properties of space. However, it has been proven to be the result of both planning and auto-formulation.

In general, the urban road network hierarchy should be deemed as a constitutional element of all (strategic) urban and transport planning schemes, regardless of spatial

scale. Other planning and design activities should be guided and controlled to ensure a cohesive and coordinated transformation of the urban environment. Within this framework, a new definition considering multimodality and sustainability is articulated. Specifically, “road network hierarchy is the process of categorizing roads based on at least two features, (e.g., urban activity and transport significance) with the aim to prioritize the movement of sustainable modes through the lens of an integrated and multimodal analysis and planning perspective.” Hence, this new definition embraces an alternative approach that now serves as the cornerstone of an integrated planning process. It places importance on sustainable modes of transport, such as active modes and collective transport, while also considering multimodality or coexistence by proposing concepts such as complete streets, shared spaces and other similar ones. The proposed definition aims to facilitate sustainable and viable transport futures, where the road network hierarchy plays a crucial role in overseeing both urban and transport planning procedures and could function as a mechanism for coordinating different transport modes in accordance with the principles of sustainability.

Specifically, the uncertainty and complexity of transport futures have been widely recognized (Vallet et al., 2020). With the emergence of new modes, technologies, and measures, it is crucial to avoid dealing with these modes in isolation to prevent chaos and inequities in future cities, particularly in the domain of transport. Consequently, road network hierarchy should be prioritized and it should prevail as a centerpiece of future planning rationales. A planning rationale that incorporates both urban and transport planning will organize and categorize all these new modes and measures under a common “umbrella.” This approach ensures sustainable transport futures where technological advancements, people, and the environment can coexist harmoniously, operating and living in a coordinated way. The role of hierarchy, in this case, becomes that of a “binder” for cities, fostering cooperation and coordination. Thus, the emphasis should be on adopting integrated approaches to avoid conflict and the creation of dysfunctional and dystopian futures caused by antagonistic new modes. Consequently, the interpretation of roads as corridors of movement and stay expanding beyond the ground floor (air, sea, underground) and as an extent the concept of road network hierarchy as the general way of classifying every transport network in urban areas are actions directly linked to sustainable transport futures. Interestingly, sustainable transport futures may view a sustainably oriented hierarchy as a prerequisite. In this context, hierarchy aspires to inaugurate a planning rationale through understanding strategic perspectives and providing guidance to lower spatial levels. It functions as a means to radically rethink urban environments while also serving as a tool for reimagining

and shaping urban futures toward sustainability. This article serves as a facilitator for this shift from conventional rationales to alternative and sustainable ones.

#### 4.2 Contribution

This paper sheds light on the significance of integrated transport and urban planning by examining and breaking down one of its fundamental planning tools, namely, the urban road network hierarchy. This is one of the first studies to comprehensively explore the road network hierarchy from a broad perspective using a systematic and holistic approach. More specifically, the SLR process revealed established or emerging concepts (e.g., multimodality, link and place, network analysis) and research trends (e.g., focus on the social dimension of streets), thus enriching the literature. Furthermore, this study introduces a new definition for road network hierarchy, establishing a direct connection to sustainable transport futures.

In this context, the research presented herein has the potential to significantly contribute to the scientific discourse surrounding the redefinition of hierarchy in urban planning. Specifically, it offers insights into the integration of multimodality and sustainability, which can serve as a catalyst for the development of a new mobility culture that prioritizes people over cars. In essence, by comprehending road hierarchy as a comprehensive planning tool and a facilitator of alternative modes of transport, it is anticipated that a paradigm shift toward coexistence and inclusivity can be achieved (Holden et al., 2020). Moreover, the findings of this study have implications for policy-making and practical implementation, as they can guide consultants, policymakers, and planners seeking to adopt integrated planning approaches and effectively utilize the concept of the urban road network hierarchy. It is worth noting that the road network hierarchy plays a fundamental role in establishing effective urban transport management strategies, guiding the implementation of sustainable policies and interventions such as travel demand management and promoting active modes of transport (Ling et al., 2021).

Hence, policymakers and administrators stand to benefit on two fronts. First, a revised road network hierarchy was established that gives precedence to sustainable modes of transport through spatial configuration (e.g., the designation of ring roads for motorized vehicles and radial arterial roads for public transport and active modes), as well as the creation of new categories specifically designed to accommodate these modes (e.g., the inclusion of active mode boulevards or strategic public transport corridors). Second, policy measures, interventions, and maintenance activities that adhere to the established hierarchy should be implemented. For example, active transport boulevards should be equipped with dedicated cycling infrastructure

and sidewalks with a minimum width of 2.1 m.

#### 4.3 Limitations and future research

Understanding and contextualizing the hierarchy of urban road networks is a complex issue that cannot be fully explored by a single study. Continuous effort in undertaking further research initiatives is essential to enrich the literature and influence the planning practices of local and international communities. In this framework, the SLR process documented the components of the urban road network hierarchy and their evolution over time. However, it did not proceed to analyze the relationship between these factors in detail, as such an objective would require different explanatory tools. To this end, future research might examine how these constituent elements interact with each other through structural analysis or participatory multicriteria techniques. Conducting in-depth interviews with various experts, such as policy makers, stakeholders, consultants, politicians, and associations, would be beneficial in this context. Additionally, while the SLR process aimed to encapsulate the most relevant articles; therefore, the number of the final pool may have appeared small. However, in the context of a broader work addressing urban road network hierarchy (including also gray literature), more papers could be useful. What is more, this research concentrated on the forms of urban road network hierarchy, rather than the definitions within each scientific paper. Hence, new papers could shed light on the content of urban road hierarchy, thus articulating new definitions and interpretations.

Regarding further research options, it is recommended that new efforts could concentrate on developing an analytical policy framework related to different road hierarchy schemes. This framework is crucial for facilitating the implementation of road hierarchy principles in real-life scenarios, effectively bridging the gap between theory and practice. The development of this analytical framework could result from a comprehensive qualitative approach that incorporates both systematic reviews and interviews.

Apart from studying hierarchy itself, this study highlights the importance of examining the impacts of hierarchy on accessibility and equity. For instance, Liao and van Wee (2017) demonstrated how different transport hierarchy options, such as car-oriented or public transport-oriented systems, can affect the robustness of the transport network through accessibility measures. Another related study conducted by Liao et al. (2017a) showed how various transport scenarios, each with different hierarchy priorities, can influence accessibility and travel patterns. In this context further research could be carried out, considering the appropriate social and demographic indicators to detect how new road hierarchy systems influence the opportunities of people to move and interact in urban

areas. Evaluating hierarchies using multiple indicators is crucial for future research. Notably, one potential area of investigation is how road network hierarchy can contribute to ensuring the resilience of transport systems, as highlighted by similar research conducted by Ma et al. (2023) on urban road network configuration and resilience. Furthermore, future research uptakes should explore the relationship between road management and hierarchy in more depth, especially with regard to safety issues (e.g., Liu et al., 2023) and traffic management (e.g., Sirmatel and Yildirimoglu, 2023).

Finally, beyond urban road network hierarchy related to the “ground floor,” future research works can also focus on the organization of other transport modes, such as air, sea, and public transport, particularly metro or rail systems operating underground. This idea emerged during the preparation of this paper and presents an exciting challenge for further research. Ultimately, hierarchy and classification are fundamental concepts in all transport systems, whether rural or urban. Tellingly, further research is necessary to advance our understanding of road network hierarchies. Exploring new research questions and topics will contribute to the scientific literature on this subject and inform daily practice, promoting accessibility, energy efficiency, and overall sustainable cities.

## 5 Conclusions

This paper covered a critical topic that underpins sustainable city planning—the urban road network hierarchy. The key insight is that this hierarchy goes beyond being just a tool for transport planning and should be considered a way to rethink the urban environment. It is argued that hierarchy is a fundamental concept that can shape an integrated urban and transport planning framework for the future. It may function as the cornerstone of new spatial planning schemes with the aim to coordinate the complex nature of the urban domain. Due to its multiple dimensions, the examination of hierarchy requires both qualitative and quantitative methods. Various research trends have emerged, offering different possibilities and opportunities for further studies.

Moreover, when planning hierarchy systems, it is

important for policy makers, planners, and consultants involved in the process to exercise caution, as hierarchy can impact every aspect of the realities of urban areas and transport in cities. This research provides planners and stakeholders with valuable knowledge that can assist in redefining the road network hierarchy in their respective areas of responsibility, particularly in terms of facilitating sustainable modes of transport. For instance, new categories could be formulated to prioritize active modes, or advanced geospatial tools could be developed to configure the new strategic road network.

The main tool for contextualizing the notion of urban road network hierarchy was our SLR. By building an organized framework of collection, categorization and analysis of relevant papers, we explored in depth and underlined critical issues such as the components and evolution of the existing body of literature. Overall, four main research trends were identified: a) road morphology and structure, b) advanced algorithms for street classification, c) integrated street classification planning, and d) the social dimension of street classification.

This paper contributes to the current state of the art by highlighting the interdisciplinary nature of road hierarchy, emphasizing that it is more than just a planning tool. It offers insights into how the transport network functions and its impact on other dimensions, such as safety, sustainability, and multimodality. In addition to its theoretical value, this study intends to influence the planning process itself by underscoring new attributes of hierarchy that may have gone unnoticed. Future studies or projects can benefit greatly from this scene-setting work, ultimately leading to the creation of just and sustainable cities.

**Competing Interests** The authors declare that they have no competing interests.

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## Appendix A

Table A1 Summary of SLR results

Author(s)	Year	Key topic	Objective	Research method	Type	Spatial level	Study area	Findings	Hierarchy categories	Approach	Urban dimension	Contribution
André and Villanova	2004	Public transport	Preliminary recognition of the routes' pattern of a bus network	Quantitative	Methodological	Urban	Paris, France	Successful recognition of 5 main categories of bus routes. Category 4 dominates	Category 1: High density areas and primary road networks Category 2: Isolated housing Category 3: Concentrated mixed housing and isolated housing Category 4: Main road network Category 5: Concentrated group housing (town center)	Alternative	√	
Oswald Beiler, McGoff, McLaughlin, .	2017	Trail classification	Thorough analysis of collector paths to identify accessibility and connectivity of the road network for non-motorized vehicles	Mixed	Methodological	Route	Buffalo Valley Rail Trail, Union County, Pennsylvania	This method applied results in reconfiguration proposals related to the infrastructure, safety and compatibility of the bicycle movement	A new street hierarchy is not proposed	Alternative	√	
Bosurgi et al.	2019	Pattern recognition	Automatic classification of the road network using pattern recognition techniques	Quantitative	Methodological	Route	Provincial road Messina-Trapani, Italy	Each segment of the examined road network is classified in a specific category	Class A: National road Class B: Regional road Class C: Provincial road Class F: Municipal road	Conventional	×	
Carmona	2015	Mixed street corridors	Thorough exploration of the issue of mixed traffic corridors using central London's arterials as an example	Mixed	Survey	Urban	London, UK	Mixed arterial roads, which accommodate multi-modal traffic (with segregated or shared infrastructure), are a particularly complex issue for cities. Moreover, they constitute noteworthy urban spaces presenting both metropolitan and local significance, while at the same time they have a vacant perspective of strategic development	A new street hierarchy is not proposed	Alternative	√	

(Continued)

Author(s)	Year	Key topic	Objective	Research method	Type	Spatial level	Study area	Findings	Hierarchy categories	Approach	Urban dimension	Contribution
Chartlon and Starkey	2017	Road safety	Better and more accurate understanding of how drivers perceive, describe and classify the roads they use	Quantitative	Experiment	Road section	32 road sections in New Zealand	It is demonstrated that the classification of the road network and the accompanying speed limits are not fully understood by the drivers. Additionally, possible changes in the hierarchy of the road network are often not made understandable to users resulting in ambiguous safety conditions	1: National Strategic network 2: Regional Strategic network 3: Arterial 4: Primary collector 5: Secondary collector 6: Access road	Conventional	×	
Chartlon et al.	2010	Road safety	Description of a project which aimed to establish a self-explanatory road (SER) design scheme on existing roads within an urban area	Quantitative	Experiment	Route	8 roads in Auckland, New Zealand	The project was found successful as road safety levels have improved both in real and perceived dimensions	1: Local road 2: Collector road 3: (Regional) Arterial	Conventional	×	
Chan and Cooper	2019	Spatial analysis	Examining the capability of identifying and predicting traffic flow through the concept of road network hierarchy	Quantitative	Model development	Urban	Cardiff, UK	It is demonstrated that hierarchy could be used as a proxy for predicting the level of traffic flow, thus reducing the complexity of prediction model and the need for obtaining detailed data as well	Category 7: Motorways Category 6: Non-residential Dual Carriageways Category 5: Residential Dual Carriageways Category 4: Primary Roads Category 3: Secondary Roads Category 2: Tertiary/Roads Category 1: Local Roads Category 0: Traffic-free Paths	Conventional	×	

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Author(s)	Year	Key topic	Objective	Research method	Type	Spatial level	Study area	Findings	Hierarchy categories	Approach	Urban dimension	Contribution
Curtis and Tiwari	2008	Multimodality	Development of a coherent management tool to support the transformation of urban arterials into activity corridors or multimodal corridors	Mixed	Case study	Urban	Perth, Australia	The transformation of existing arterials into multimodal corridors is a rather difficult process that must be addressed at both local and supra-local level	Bidimensional hierarchy for multimodal corridors 1) Transport Dimension a) High Speeds vs Low Speeds b) High Traffic Volumes vs Low Traffic Volumes c) Controlled Access vs Open Access 2) Activity/Built form Dimension a) High Intensity Activity vs Low Intensity b) Human Scale vs Vehicular Scale c) Sensitive to Through Traffic vs Not sensitive to Through Traffic	Alternative	√	
D'Andrea et al.	2014	Pattern recognition	Development of a method for formulating an “objective” functional classification of the road network	Quantitative	analysis	Route	Provincial road Messina-Trapani, Italy	Each segment of the examined road network is classified in a specific category	1) Class A 2) Class B 3) Class C 4) Class F 5) Rest	Conventional	×	
De Baets et al.	2014	Route planning	Examining whether the main road routes suggested by the navigation programs differ from the socially desirable routes suggested by the Flanders road network hierarchy plan	Quantitative	Experiment	Regional	Flanders, Belgium	It is found that the navigation programs usually choose roads of a lower category with a high urban value, creating safety issues. Instead, the proposed classification scheme protects vulnerable areas while attempting to optimize the time and the attractiveness of the routes	1) Main road 2) Primary road I 3) Primary road II 4) Secondary road I 5) Secondary road II 6) Secondary road III 7) Local road I 8) Local road II 9) Local road III	Conventional	×	

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Author(s)	Year	Key topic	Objective	Research method	Type	Spatial level	Study area	Findings	Hierarchy categories	Approach	Urban dimension	Contribution
Dehghanmoghaddi and Hoskara	2022	Complete streets	Creation of an integrated framework for planning successful toward promoting sustainable mobility	Qualitative	Review	Urban	30 cases (24 cities, 3 states and 4 counties) in USA	The proposed framework outlines the main steps and variables that must be considered in planning process for creating successful complete streets within different communities. Notably, this method included built-environment and social-context variables. Moreover, street classification plays an important role.	A new street hierarchy is not proposed	Alternative	√	
Delbosch et al.	2018	Multimodality	Comparative analysis of Complete Streets and SmartRoads systems with emphasis on latter and its implementation in the state of Victoria, Australia	Qualitative	Review	Urban	Melbourne, Australia	These two planning schemes, despite having several common characteristics, they present notable differences. A transfer of knowledge between them in the future could yield even stronger benefits for the city	Multimodal corridors 1) Preferred traffic route 2) Traffic route 3) Tram Priority Route 4) Bus Priority Route 5) Bicycle Priority Route 6) Pedestrian Priority Area 7) Local Primary Access Route 8) Local Secondary Access Route 9) Other Local Road	Alternative	√	
Dong et al.	2013	Assessment	Development of a quantitative evaluation method for urban road networks	Quantitative	Analysis	Urban	Beijing, China	The multiple data used, provided efficiency to the method. Hence, critical issues in terms of mobility, accessibility, and the accommodation of through flows were identified	1) Primary arterial 2) Secondary arterial 3) Collector road 4) Local road	Conventional	×	

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Author(s)	Year	Key topic	Objective	Research method	Type	Spatial level	Study area	Findings	Hierarchy categories	Approach	Urban dimension	Contribution
Elias	2011	Complete streets	Exploration of the appropriate criteria for the design of a complete street via examining different street cross-sections	Mixed	Experiment	Road section	Hypothetical roads	It is demonstrated that through the proper planning and road space re-allocation, a complete street can improve the service level of both cycling and walking, while reducing the dominance of motorized vehicles	<ol style="list-style-type: none"> <li>1) Main arterial</li> <li>1a) Auto-oriented</li> <li>1b) Complete Street</li> <li>2) Minor Arterial</li> <li>2a) Auto-oriented</li> <li>2b) Complete Street</li> <li>3) Main Collector Road</li> <li>3a) Auto-oriented</li> <li>3b) Complete Street</li> <li>4) Minor Collector Road</li> <li>4a) Auto-oriented</li> <li>4b) Complete Street</li> </ol>	Alternative	×	
Gharraee et al.	2021	Network analysis	Utilization of a novel learning-based approach to graph representations of road networks incorporating state-of-the-art graph convolutional neural networks (Graph Attention Isomorphism Network, GAIN)	Quantitative	Analysis	Urban	17 cities in Sweden	The results demonstrate that show that GAIN outperforms state-of-the-art methods on the road type classification problem. However, it still needs some improvements to be ready for practical applications	<ol style="list-style-type: none"> <li>1: Strategic</li> <li>2: Tertiary road</li> <li>3: Local Road</li> <li>4: Residential Road</li> <li>5: Living-street</li> </ol>	Conventional	×	
Gregg and Hess	2019	Complete streets	Systematic analysis of the content of complete streets policies and how they influence strategic planning and road space allocation priorities	Qualitative	Review	Municipal	Municipalities in USA with different size	It is observed that most complete streets policies at the municipal level do not support the redistribution of available road space. Instead, they are in favor of an equal distribution of road space without considering the actual needs of the various road users	A new street hierarchy is not proposed	Alternative	√	

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Author(s)	Year	Key topic	Objective	Research method	Type	Spatial level	Study area	Findings	Hierarchy categories	Approach	Urban dimension	Contribution
Gülgen	2014	Multicriteria analysis	Formulation of a complex framework for defining road hierarchy	Quantitative	Methodological	Neighborhood	Istanbul, Turkey	The classification of a road with respect to the entire road network is more important than its individual characteristics	1) Major roads 2) Local roads	Alternative	×	
Han et al.	2020	Network analysis	Development of a method for employing road network classification based on topological properties	Quantitative	Analysis	Neighborhood	15 cities worldwide	Successful network morphology recognition	A new street hierarchy is not proposed	Alternative	×	
Hsu and Lin	2011	Cycle network	Measurement of the suitability of the road network and its classification system to facilitate bicycle movement	Quantitative	Methodological	Urban	Taipei, Taiwan	Central areas show higher values, while in a general framework, low values prevail. These results could be utilized as a background for changing the street classification	1) Level A (Very high level of suitability) 2) Level B (High level of suitability) 3) Level C (Medium to high level of suitability) 4) Level D (Low to medium level of suitability) 5) Level E (Low level of suitability) 6) Level F (Very low level of suitability)	Alternative	×	
Huang et al.	2016	Network analysis	Investigating road network hierarchy conditions in an urban area	Quantitative	Analysis	Urban	Wuhan, China	20% of the streets in the city, serve 98% of the traffic and strikingly 1% of the major streets over 60%	1) High significance (Major) roads 2) Medium significance roads 3) Low significance roads	Conventional	×	
Hui et al.	2018	Complete streets	Development of a methodological framework for the evaluation of complete streets	Qualitative	Review	Urban	-	It is found that the criteria for the evaluation of a complete street should be divided into the following categories: mobility/transport, environment and urban planning.	A new street hierarchy is not proposed	Alternative	√	
Iván	2014	Pattern recognition	Exploration of how many and which categories of roads are distinguished by the users of the road network	Mixed	Experiment	Road sections	Road sections in Hungary	New classification system was formulated and compared with existing classification frameworks. Users distinguish 4-5 categories	1) Speed above 90km/h 2) 90km/h 3) 50km/h 4) Speed below 50km/h	Conventional	√	

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Author(s)	Year	Key topic	Objective	Research method	Type	Spatial level	Study area	Findings	Hierarchy categories	Approach	Urban dimension	Contribution
Jiang	2009	Network analysis	Formulation of a generalized model for identifying the major roads in an urban road network	Quantitative	Analysis	Urban	Gavle, Sweden	It is found that about 20% of the roads account for 80% of the traffic flow and 1% of these major roads account for more than 20% of the entire traffic flow	1) Major roads 2) Local roads	Conventional	×	
Jones and Boujenko	2009	Link and place	Development and implementation of a new approach to urban street planning that considers the functions of link and place, including indicators for transport performance, economy and environment	Mixed	Conceptual	Urban	London, West Midlands, UK	The Link and Place classification system can play a critical role toward the improvement of urban road environments. It also forms a common framework for an interdisciplinary way of managing street space	Link and Place 1) Link function a) National Significance b) City Significance c) District Significance d) Neighborhood Significance e) Local Significance 2) Place function a) National Significance b) City Significance c) District Significance d) Neighborhood Significance e) Local Significance	Alternative	√	
Jones et al.	2008	Link and place	Introduction and presentation of the concept of Link and Place. Particularly, this research work highlights the variety of activities and users encountered in urban street space with the aim to create a hierarchy system adapted to humans and not to vehicles	Mixed	Conceptual	Urban	Bloxwich, Birmingham, UK	The conventional hierarchy cannot take into account the multimodality of the urban street. The Link and Place classification system can play a critical role toward the improvement of urban road environments. It also forms a common framework for an interdisciplinary way of managing street space. The public and stakeholders gladly supported the Link and Place approach	Link and Place 1) Link function a) National Significance b) City Significance c) District Significance d) Neighborhood Significance e) Local Significance 2) Place function a) National Significance b) City Significance c) District Significance d) Neighborhood Significance e) Local Significance	Alternative	√	

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Author(s)	Year	Key topic	Objective	Research method	Type	Spatial level	Study area	Findings	Hierarchy categories	Approach	Urban dimension	Contribution
Kingsbury et al.	2011	Complete streets	Formulation of an innovative way to assess the “completeness” of complete streets given the spatial context and public opinion	Mixed	Survey	Route	67 routes in Moscow, Idaho, USA	Several road segments resulted in a better “picture” than expected (the areas around the center), while also the contribution of volunteer citizens contributed significantly to the proposed methodological framework	Bidimensional hierarchy 1) Link function a) A b) B c) C d) D 2) Community significance a) I b) II c) III d) IV	Alternative	√	
Kosztolányi-Iván et al.	2019	Pattern recognition	Examination of how many road categories, users can distinguish	Mixed	Experiment	Road section	Road sections in Hungary	Up to 7 clusters are recognized. From 7 classes and above, users cannot perceive the differences in the network. Therefore, 5-6 categories are recommended	1) Freeways 2) Primary rural roads 3) Roads without physical separation with 4 lanes 4) Roads without physical separation with 2 lanes 5) Simple rural roads 6) Transition zones 7) Roads inside built-up areas	Conventional	√	
Kumar et al.	2019	Complete streets	Development of a quantitative and qualitative evaluation framework related to the transformation of conventional to complete streets	Mixed	Methodological	Route	67 routes in Gurgaon, India	The state of “completion” of a road segment depends on the urban character of the road, the quality of service for the various users, the streetscape elements of the road space and the elements related to the facilitation of pedestrian movement The method utilizes a thorough literature review, AHP and spatial analysis. Potentials for making complete streets and multimodal corridors are also presented. The results show that five high priority streets were identified to be considered as a solution.	1) A (High quality complete street) 2) B (Good quality complete street) 3) C (Moderate quality complete street) 4) D (Low quality complete street) 5) E (Very low quality complete street)	Alternative	√	
Mirzahosseini et al.	2022	Multimodality	Delineation of a comprehensive method for redesigning main road network in an urban area	Mixed	Methodological	Urban	Qazvin, Iran	A new street hierarchy is not proposed		Alternative	×	

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Author(s)	Year	Key topic	Objective	Research method	Type	Spatial level	Study area	Findings	Hierarchy categories	Approach	Urban dimension	Contribution
Noori et al.	2020	Network analysis	Investigation of developing a combinatorial method for street classification	Quantitative	Methodological	Urban	Tehran, Iran	The method fits better in grid networks compared to those with more irregular network structure	1) Major arterial 2) Secondary arterial 3) Collector road 4) Local road	Conventional	×	
Oguchi	2008	Streets reconfiguration	Development of an exploratory road network classification method	Mixed	Methodological	National	Japan	Planning process was destined for controlling demand and not to be controlled by demand. Existing conditions related to hierarchy were significantly improved	Bidimensional matrix 1st dimension: Urban identity 2nd dimension: Traffic 1) Urban expressway 2) Urban highway 3) Local Highway 4) Primary Avenue 5) Local Distributor 6) Access Road 7) Mall 8) Community	Alternative	√	
Paraskevopoulos, Tsigidmos, Pigaki	2022	Network analysis	Development of a reproducible methodology for identifying active and network centralities via using land-use patterns and space syntax	Quantitative	Analysis	Metropolitan	Athens, Greece	Network centralities identified 3 road types in a metropolitan scale. This new classification is roughly similar with the planned one. This classification method could influence real life practice	1: Metropolitan road 2: Citywide road 3: Local road	Conventional	×	
Sauter and Huettenmoser	2008	Livable streets	Investigating the impact of street design and hierarchy as well as traffic flow on social relations in urban neighborhoods	Mixed	Survey	Route	5 routes in Basel, Switzerland	The results show that urban neighborhoods are still places of interaction and communication, despite the prevailing individualization. Specifically, road categories such as traffic calming streets and shared space allow the interaction between citizens even more comfortably, shaping “areas of socialization,” beyond traffic conduits	A new street hierarchy is not proposed	Alternative	√	

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Author(s)	Year	Key topic	Objective	Research method	Type	Spatial level	Study area	Findings	Hierarchy categories	Approach	Urban dimension	Contribution
Sheikh-Mohammad-Zadeh et al.	2022	Assessment	Formulation of a holistic framework to evaluate streets based on their actual use by all users	Qualitative	Conceptual	Urban	-	The developed framework builds on street use evaluation in terms of 3 discrete functions: a) transit, b) access and c) place. This approach underlines the multifunctional nature of streets and could be a basis for new classification systems	A new street hierarchy is not proposed	Alternative	√	
Stamatiadis et al.	2017	Streets reconfiguration	Development of a functional classification framework that aims to achieve optimal geometric design solutions, while taking into account the context, user needs and road function	Mixed	Conceptual	Central district	Kentucky, USA	A decision support tool is developed. The proposed hierarchy provides space to all users, while at the same time it perceives urban street space as an integrated entity. Microscale design directions are also presented	<p>Bi-dimensional matrix</p> <p>1) Roadway (Traffic)</p> <p>a) Primary arterial</p> <p>b) Minor arterial</p> <p>c) Collector</p> <p>d) Local</p> <p>2) Context (Regional-Urban)</p> <p>a) Rural</p> <p>b) Rural Town</p> <p>c) Suburban</p> <p>d) Urban</p> <p>e) Urban core</p>	Alternative	√	
Su et al.	2022	Streets reconfiguration	Introduction of an activity-based street classification framework to categorize street segments based on their temporal activity patterns	Quantitative	Experimental	Urban	Boston, USA	This work demonstrates that a street classification framework based on temporal street activity patterns has the potential to identify street categories adequately and understand their profile. This means that the proposed classification can offer useful implications for state-of-the-art urban management and planning.	<p>Bi-dimensional hierarchy</p> <p>1: Activity dimension</p> <p>a) Hybrid</p> <p>b) Leisure</p> <p>c) Work</p> <p>2: Intensity dimension</p> <p>a) Calm</p> <p>b) Moderate</p> <p>c) Vibrant</p> <p>3: Category no 10: Subdued</p>	Alternative	√	

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Author(s)	Year	Key topic	Objective	Research method	Type	Spatial level	Study area	Findings	Hierarchy categories	Approach	Urban dimension	Contribution
Theeuwes	2021	Traffic safety	Detailed outline of the Self-explaining Roads (SER) concept and its effect on human behavior	Qualitative	Review	Route	-	The SER concept influences human behavior significantly and therefore road network hierarchy systems should take this into consideration. Roads should be a) recognizable, b) distinguishable and c) interpretable	1: Flow (Through) road 2: Distributor 3: Access road	Conventional	×	
Tsigdinos and Vlastos	2021	Streets reconfiguration	Exploration of possible ways to redefine the strategic road network of a metropolitan area by giving emphasis to sustainable modes	Mixed	Methodological	Urban	Athens, Greece	The following improvements are estimated: Readability of the strategic network Better road safety Promotion of multimodality Unification of urban fabric and protection of central areas	1) Regional significance with priority to automobile 2) Metropolitan significance with priority to automobile 3) Metropolitan significance with priority to public transport 4) Metropolitan significance with priority to active modes 5) Citywide significance with priority to public transport 6) Citywide significance with priority to active modes	Alternative	√	
Tsigdinos et al.	2021a	Streets reconfiguration	Integration of Autonomous Buses in the street functional classification system via creating a new street type devoted to pedestrians, cyclists, ABs and micromobility modes	Quantitative	Methodological	Municipal	Kallithea, Athens	Simple and cohesive method promoting sustainable mobility, while considering Abs. A path for urban environments of co-existence. It is estimated that the implementation of this new street type will bring about efficiency and better accessibility of the public transport system	1: Motorway 2: Primary arterial 3: Secondary arterial 4: Tertiary road 5: Autonomous Bus Route	Conventional	√	
Tsigdinos et al.	2021b	Multimodality	Formulation of a method for redefining urban arterials in multimodal corridors	Mixed	Case study	Urban	Athens, Greece	A decision support tool is developed. Implementation can promote sustainable mobility, integrate the urban fabric, improve accessibility and equity level	1) (Metropolitan) Arterial with mixed priority conditions 2) (Metropolitan) Arterial with sustainable modes priority conditions 3) (Citywide) Boulevard with mixed priority conditions 4) (Citywide) Boulevard with sustainable modes priority conditions	Alternative	√	

(Continued)

Author(s)	Year	Key topic	Objective	Research method	Type	Spatial level	Study area	Findings	Hierarchy categories	Approach	Urban dimension	Contribution
Tsigdinos et al.	2020	Streets reconfiguration	Development of a methodological framework for the reorganization of the hierarchy of the main road network in a metropolitan city	Mixed	Methodological	Urban	Thessaloniki, Greece	A decision support tool is developed. Implementation can promote sustainable mobility, protect neighborhoods and focal centers, improve accessibility and equity level. Also, a balance between radial arterials and ring roads is proposed.	1) Primary (Strategic) with priority to automobiles 2) Primary (Strategic) with mixed priority (both automobiles and public transport) 3) Primary (Strategic) with priority to sustainable modes 4) Secondary (Intermunicipal) with priority to automobiles 5) Secondary (Intermunicipal) with mixed priority (both automobiles and public transport) 6) Secondary (Intermunicipal) with priority to sustainable modes	Alternative	√	
Walker et al.	2013	Road safety	Integration of theories on situational awareness into the concept of self-explanatory pathways	Quantitative	Experiment	Route	West London, Surrey and Berkshire, UK	The results suggest the systemic nature of the interaction within the scheme driver-vehicle-road and also indicate that situational awareness depends on the road category. Highways prove to be the most compatible with the concept of self-explanatory roads, while as the categories go down the hierarchical scale, the ambiguity in their understanding increases.	1: Motorway 2: A/B roads (major roads) 3: Urban roads 4: Rural roads 5: Residential roads	Conventional	×	

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