Research Progress Knowledge Mapping on Transit Oriented Development (TOD) Typology

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ABSTRACT

This paper presents a global research on the different aspects of Transit Oriented Development (TOD) typology, conducted from 2007 to 2024. The knowledge mapping and research theoretical framework were derived from procuring datasets, obtained from the Web of Science (WoS) and Scopus databases, with a total of 112 articles on TOD Typology having been selected. Bibliometrix (Biblioshiny) programming utilizing R Studio was employed to process and analyze the datasets, enabling open-source visualization. Criteria, such as the most prominent authors, most cited publications, and most productive nations were visualized in the findings. A significant rise in publications related to TOD typology research was observed, with China and the USA being the most significant contributors. The most productive and most cited researchers along with the most prolific Universities in TOD typology were identified. The most relevant journal source with the largest number of publications was also identified, while the most popular keywords utilized were "Typology", "Land Use", and "Transit Oriented Development".

Keywords-transit oriented development typology; bibliometric analysis; knowledge mapping; network visualization

I. INTRODUCTION

Transit Oriented Development (TOD) conceptualization was initiated in the late 1980's as the focus towards neighborhood planning grew, generating the need for faster access to services and housing. Mixed-use development was the triggering factor in TOD typology concept enactment, which includes various development patterns around the transit nodes [1]. Depending upon numerous kinds of needs and typologies, the transit station node varies in functionality, size, type, form, use, character, and can be part of the Bus Rapid Transit (BRT), rail transport, metro system, etc. [2]. TOD is a planning method that aims to create compact, walkable, mixed-use communities, centered around high-quality public transportation services. By integrating land use and transportation planning, TOD can deliver multiple benefits, including reduced congestion, increased transit ridership, improved air quality, and more livable communities [3-5]. TOD can take different forms depending on the specific context and can be implemented using a variety of transportation modes, including rail, bus, ferries, and bike-sharing. Corridor-level Transit-Oriented Development (C-TOD) is a planning approach that seeks to optimize access and amenities for people within transit travel-sheds. A travel-shed is the area that can be reached within a typical daily travel budget of 60-90 minutes via public transit [6]. C-TOD expands on the traditional TOD approach, which has focused on pedestrian travel-sheds within reach of transit nodes, to include areas along the transit corridors [6, 7].

TOD typology provides insightfulness regarding density, scale, land use patterns, functions, proximity, connectivity, and sustainability aligned with the required standards. It ensures emphasizing on mixed-use development, transit environments, and pedestrian friendly designs. Certain common TOD typology types are the urban core TOD, utilized in very high density city centers, or Central Business Districts (CBDs), urban neighborhood TOD, where medium to high density is noted with local amenities, suburban TOD in which the density is low to medium and parking and riding services are provided, neighborhood TOD, which is of a primarily residential nature with low to medium density, employment TOD, encountered in work centers, and Corridor TOD, which is mostly linear in nature [6-8, 12]

Despite the potential benefits of TOD and its typologies, its implementation can be challenging due to various barriers, including financial, legal, and socio-cultural factors, mainly detected in the developing nations. Addressing these barriers will require collaboration among planners, developers, policymakers, and communities to create TOD projects that are financially viable, legally feasible, and socially equitable.

Successful outcomes cannot be ensured just by implementing a TOD alone. Density and transport are not the only factors affected by successful TOD typology implementation. The latter includes the accessibility of a wide variety of choices in housing, recruitment, and other services, as well as the upgradation of place-making and social cohesion [14]. Research has found that the application of sustainable and equitable transit-oriented development is quite stimulating practically because of its intricate associations and the supportive bordering and design policies required [5].

The key research questions raised in the current paper concern identifying research progress in the TOD typology field, finding the most prominent authors, top cited articles, countries and organizations where related research is pursued, and the collaboration networks among researchers. The bibliometric analysis, which deploys quantitative methods to analyze patterns in the literature, addresses this challenge by providing a systematic way to identify TOD typology trends in research.

II. METHODOLOGY

Bibliometric analysis is a calculable method to assess bibliographical facts, which could be decoded into two major types: performance analysis and scientific mapping (network analysis) [16]. Performance analysis involves measuring the productivity and influence of a bibliographic unit, such as a publication, author, or journal, using metrics, such as citation counts and average citation rate. Citation-based metrics are often considered to be a more accurate reflection of a unit's impact than document counts, as they reflect the degree to which other researchers have cited and built upon that work [16, 17]. Network analysis is a technique for investigating bibliographic information by inspecting the institutional relationships between its constituent parts. In the context of bibliometric analysis, nodes can represent various entities, such as publications, authors, journals, keywords, or organizations. The links or connections between these nodes can be created in different ways, involving co-authorship links (when two authors collaborate on a publication), citation links (when one publication cites another), co-citation links (when two publications are cited together in a third publication), bibliographic coupling links (when two publications cite the same reference), or co-occurrence links (when two publications share the same keyword or topic). Network analysis can be employed to identify clusters of related publications, influential authors or organizations, and other patterns or trends in the bibliographic data.

A. Data Sources

Relevant scientific publications were gathered from WoS and Scopus, both of which are widely recognized databases with necessary and reliable information for bibliometric analysis. The search was conducted using "Transit Oriented Development" or "TOD" as keywords, and the language was restricted to English. All article categories were kept selected and the chosen datasets for the provided keywords addressed only engineering, transportation, urban development, human geography, and decision sciences. The searching criteria along with the utilized Boolean operators are provided below:

1) WoS Search

TS=("transit oriented" AND "development " AND "typology") OR TS=("TOD" AND "typology")

2) Scopus Search

(TITLE-ABS-KEY("transit oriented" AND "development" AND "typology") OR TITLE-ABS-KEY("TOD" AND "typology")) AND PUBYEAR > 2003 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"re"))

The search was performed on 17th December, 2024, having resulted in an initial set of 87 documents from WOS and 66 from Scopus.

B. Data Merging and Processing

The two datasets obtained from WoS and Scopus were combined using the R (Version 4.4.2+) program, which removed duplicate documents and built the datasets, after titles and abstracts were manually reviewed. Irrelevant and duplicate documents were eliminated to ensure that the selected literature was typical and relevant. Finally, a total of 112 articles were chosen between 2007 and 2024, and were retained as the primary data for analysis. Bar and line graphs were deployed in Excel. Furthermore, maps of geographical and citation source networks were created, utilizing Bibliometrix (Biblioshiny), a science mapping workflow package of the R programming language, which helped analyze the quantitative data of the above publications and perform network visualization. The statistic summary of the studied published documents is provided in Table I.

TABLE I. STATISTIC SUMMARY OF PUBLISHED DOCUMENTS

Key Information	Results
Timespan	2007:2024
Sources (Journals, Books, etc)	59
Documents	112
Annual Growth Rate %	20.85
Document Average Age	3.02
Average citations per document	21.26
Keywords Plus (ID)	326
Keywords (Authors)	396
Authors	324
Authors of single-authored docs	10
Single-authored documents	10
Co-authors per document	3.4
International co-authorships %	14.29
Article	108
Article Early Access	1
Review	3
Others	0

Source: WoS and Scopus, 2024

III. RESULTS

The research studies on TOD typology have been rising over time, having reached a peak in 2024. This indicates a growing interest in the topic and highlights the need for continued research on this field. However, during 2007-2015 there was hardly any increase in TOD typology scientific

research. Publications and the interest of scholars and researchers grew after 2017 onwards, almost having doubled from 8 publications per year in 2018-2019 to 16 in 2023. The desire for legislative changes and the global implementation of TOD projects may have been the cause of this trend. However, it would be interesting to know about the upcoming research outputs for 2025, further stressing the importance of this study area. The publication trends are illustrated in Figure 1.

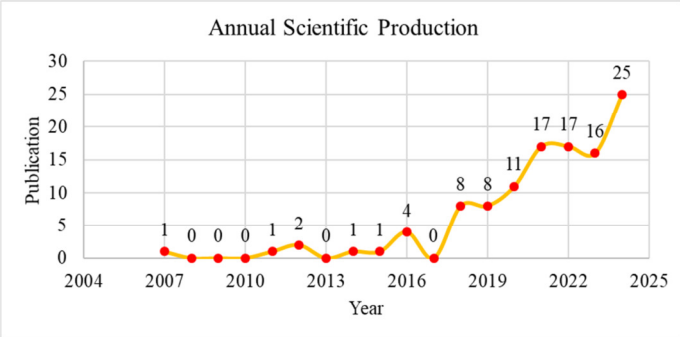

Fig. 1. Publication Trends in WoS and Scopus.

A. *Productivity in Transit Oriented Development Typology Research*

There are 112 study results in the selected TOD literature, and 324 authors are linked to them through authorship or co-authorship while only a few of them have authored more than one paper.

1) *Authors*

The 5 most productive authors in the TOD typology field, with more than 3 research outputs each, are: Tao Wu, Linna Gao, Shiliang Su, Long Chen, and Mingjing Li. Table II lists the 15 most prominent authors contributing in TOD research.

TABLE II. TOP 15 AUTHORS IN TOD TYPOLOGY RESEARCH (DOCUMENTS ≥ 1)

	Authors	Articles	Fractionalized articles
1	T. Wu	5	1.5
2	L. Gao	4	0.9
3	S. Su	4	0.8
4	L. Chen	3	0.5
5	M. Li	3	1.1
6	Y. Liu	3	0.6
7	D. Vale	3	1.7
8	H. Zhang	3	0.4
9	M. Zhang	3	1.0
10	J. Zhou	3	0.9
11	Y. Zhou	3	0.8
12	B. Appleyard	2	1.3
13	L. Bertolini	2	0.6
14	Y. Bian	2	0.5
15	Z. Chen	2	0.3

2) *Citations*

The ranking of papers based on global citations in TOD typology research reveals the significant contributions and influence of these studies in the field, as displayed in Table III. The paper with the highest citation number (263) globally is [8], where the key achievements in TOD investigation, such as reducing car dependency and investigating the role of mobility, are highlighted and examined and the challenges in finances and governance are further showcased. This paper's widespread recognition demonstrates its importance in shaping TOD research. The high citation counts of the papers listed in Table III reflect the enduring impact and relevance of TOD research on urban planning, transportation systems, and sustainable development practices worldwide.

TABLE III. TOP 10 GLOBALLY CITED PAPERS AND THEIR AUTHORS (CITATIONS ≥ 70)

Rank	Paper	Total citations	Total citations/ year
1	[8] 2020	263	52.6
2	[19] 2014	200	18.2
3	[3] 2015	183	18.3
4	[20] 2016	159	17. 7
5	[21] 2016	115	12.8
6	[22] 2021	106	26.5
7	[23] 2019	95	15.8
8	[24] 2018	88	12.6
9	[25] 2021	75	18.7
10	[26] 2016	71	7.9

3) *Sources*

The top ten relevant journals to TOD typology is presented in Table IV. At the forefront is the Journal of Transport Geography with 19 prominent articles, encompassing a wide range of transportation and station node TOD typology topics, making it highly influential. The Sustainability Journal with 8 articles follows, focusing on the sustainability aspects of transportation and their relevance to TOD typology. Additionally, the IOP Conference Series: Earth and Environmental Science, despite being primarily a conference proceedings publication, has contributed significantly with 57 articles, highlighting the interdisciplinary nature of TOD typology research. Other prominent journals are Transportation Research Part D: Transport and Environment, entailing 5 articles concentrating on environmental concerns. Cities, Journal of Transport and Land Use, and Land Use Policy include 4 articles, each addressing land use and urban policy. Other contributions came from Frontiers in Environmental Science, Land, and Sustainable Cities and Society, providing 3 articles, respectively, which exhibited interdisciplinary approaches to TOD typology. Similarly, Transportation Research Part A: Policy and Practice, offers insights for the policy framework. These rankings demonstrate the aforementioned journals' significance in shaping the discourse on TOD typology, covering diverse aspects, such as planning, land use, education, governance, finance, environment, and research. Researchers and practitioners seeking up-to-date knowledge on TOD typology can, thus, benefit from exploring these reputable journals/sources.

4) *Organizations*

The top ten organizations in TOD research and their corresponding number of publications are portrayed in Table V. Wuhan University, China secures the first position with 9 publications, highlighting its contribution to TOD typology studies.

TABLE IV. TOP RELEVANT SOURCES/JOURNALS (DOCUMENTS ≥ 3)

Rank	Sources	Articles
1	Journal of Transport Geography	19
2	Sustainability	8
3	Transportation Research Part D-Transport and Environment	5
4	Cities	4
5	Journal Of Transport and Land Use	4
6	Land Use Policy	4
7	Frontiers In Environmental Science	3
8	Land	3
9	Sustainable Cities and Society	3
10	Transportation Research Part A-Policy and Practice	3

TABLE V. TOP ORGANIZATIONS AND NUMBER OF PUBLICATIONS ACROSS DIFFERENT PERIODS (DOCUMENTS ≥ 5).

Rank	Affiliation	Articles
1	Wuhan University	9
2	Tongji University	8
3	Wuhan University Science and Technology	8
4	San Diego State University	7
5	Seoul National University	6
6	University of Hong Kong	6
7	University of Toronto	6
8	Chongqing University	5
9	City University Hong Kong	5
10	Keio University	5

5) Country

The top ten countries in terms of scientific publications and citations on TOD typology are shown in Table VI.

TABLE VI. TOP COUNTRIES WITH HIGHEST CITATION AND CITATION FREQUENCY AND AVERAGE

Rank	Country scientific productions	Articles	Citations	Average article citations
1	China	129	655	17.2
2	USA	37	232	17.8
3	Australia	21	278	46.3
4	Canada	21	143	17.9
5	Japan	13	16	4
6	South Korea	12	21	5.2
7	UK	11	90	18
8	Portugal	10	534	133.5
9	Belgium	8	38	19
10	Netherlands	7	159	159

The People's Republic of China leads the list with 129 publications, with a citation frequency of 655, demonstrating its dominant and apex position in TOD typology research while the USA ranks second with 37 publications and 232 citations, indicating its significant contributions to the field. The results in Table VI highlight the commitment of these countries to advance knowledge and understanding about TOD typology by various means and research methodologies through their substantial scientific publication outputs.

6) Keywords

The most frequently used keywords in the research are showcased in Table VII. These most frequently used words emphasize important themes and concepts in TOD typology research. Figure 2 depicts the word cloud per frequency.

TABLE VII. MOST FREQUENTLY OCCURING KEYWORDS IN TOD RELATED PAPERS

Rank	Words	Frequency	%
1	Typology	52	10.0
2	Land-Use	43	8.3
3	Transit-Oriented Development	33	6.4
4	Transport	28	5.4
5	Accessibility	27	5.2
6	Travel	27	5.2
7	Integration	26	5.0
8	TOD	23	4.4
9	Node-Place Model	20	3.9
10	Station Areas	17	3.3

During the initial stage of TOD typology knowledge and research works, David S. Vale (2015-2018) with an h-index of 3 and 303 citations elaborated the Node-Place Model, integrating the accessibility by pedestrians and local scale assessments, having influenced subsequent typology research. Shiliang Su (2019-2022) with an h-index of 4 and a total of 241 citations made efficient efforts towards finding out the metro ridership and vibrancy through various modeling approaches. Tao Wu and Linna Gao (2022-2024) have an h index of 2 and 1, with 14 and 9 citations, respectively. The former have recently introduced methods for emphasizing comparative regional frameworks, such as the butterfly model, having integrated spatial vitality metrics. Mengyuan Zhang and Hui Zhang (2021-2024) have further developed the TOD typology by having incorporated equity performance and big data utilization into station typology. Overall, these findings provide insights into the authors' publication productivity and their distribution over time, as evidenced in Figure 2.

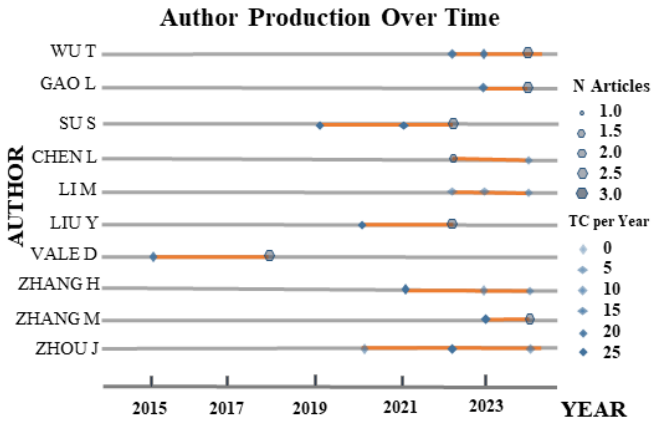

Fig. 2. Top authors' production over time.

B. Visualizing Research Linkages

Several software applications that enable bibliometric analysis are Bibliometrix [27], SciMAT [28], BibExcel [29], VOSviewer [30], and CiteSpace [31]. The Bibliometrix (Biblioshiny) tool with RStudio was deployed for both

conventional and bibliometric visualization of data in this investigation. The performance analysis results are presented utilizing conventional tools, such as tables and charts. Bibliometric networks are represented employing two kinds of graph-based visualization techniques: network visualization and overlay visualization.

1) Mapping Transit Oriented Development Study Trends using Keyword Co-Occurrences

This section presents the findings of the keyword co-occurrence analysis, a technique frequently employed to identify research themes in the literature [32]. The keyword co-occurrence analysis enabled identifying the TOD typology literature's most frequently used keywords (themes). From the 112 research outputs, a total of 326 keywords, including author and index keywords, were extracted, and visualized as a keyword co-occurrence network. The size of the circles in Figure 3 indicates the occurrence frequency of each of the keywords utilized in TOD typology literature, with deeper links suggesting a higher frequency. The distance between two keywords in a network reflects their relative importance and subject similarity. Four distinct colors for the clusters (green, purple, red, and blue) are used to color-code the keywords. Cluster 1 (green): to be considered a niche theme, representing typology, land use, and TOD. Cluster 2 (red): urban design, which is an emerging theme, showcasing the urban design role of sustainability, planning, etc. Cluster 3 (purple): related concepts of housing market, affordable housing, and performance. Cluster 4 (blue): urban planning and transportation development and visualisation highlight the importance of mapping and optimizing the topics related to transit and mobility strategies. There were also small clusters identified based on topics, such as area, ridership, and travel behavior.

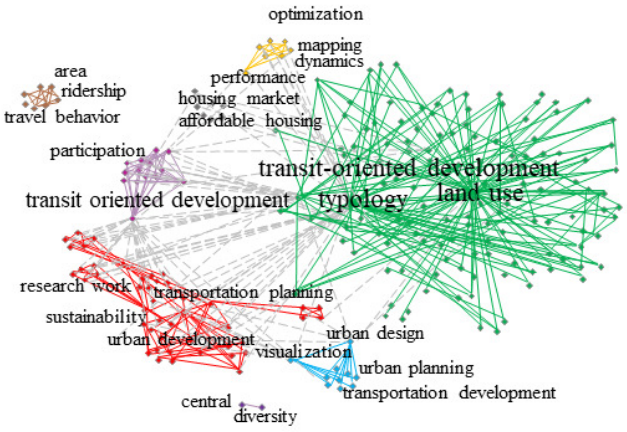

Fig. 3. Keyword co-occurences.

2) Author Collaboration

In [33], the bibliographic coupling concept was defined, which suggests that scientific papers are related when they share one or more references, as can be seen in Figure 4. Cluster 1 focuses on TOD typology and sustainability principles, promoting equitable access and multimodal transport opportunities. The internal structure of cluster 1 is robust. Z. Shen and L. Chen are equally significant. Within their author collaboration, J. Zhou and Y. Lai, are well linked and have a high closeness centrality [34-36]. Cluster 2 concentrates on TOD typologies, deploying urban design and visualization techniques, while also focusing on land use patterns, and layouts, facilitating accessibility optimization. J. Zhou and Y. Lai take the lead with a high proximity centrality and strong connections within their group, [37, 38]. Cluster 3 focuses on accessibility and TOD typology. It integrates design, efficiency in travel, and development in diverse community, considering inclusiveness an important principle. Z. Chen, T. Wu, and L. Gao are the prominent influences [12, 39, 40]. Cluster 4 emphasizes on the evaluation and impact assessment of TOD typologies. It includes metrics to determine success values, such as land value increase, transit ridership increase, and environmental benefits. There is no connection between the smaller, more isolated author pairings in Clusters 5–10. The network as a whole lacks inter-cluster coordination, with many groups functioning independently [25, 35, 41-43]. There were certain niche aspects related to the TOD typology ones, the key focus of which was on the technology of transit systems, regional studies, socio economic impacts, and diverse urban setting [44, 45].

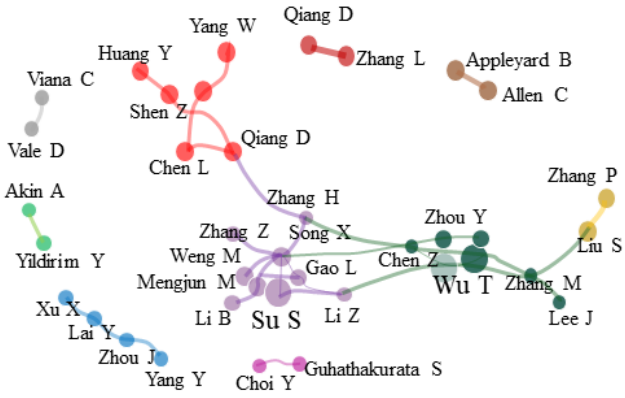

Fig. 4. Author collaboration analysis.

IV. DISCUSSION AND CONCLUSIONS

This paper examines the evolution of Transit Oriented Development (TOD) typology, considering its shortcomings and strengths, while identifying future research needs. The volume of international research and publications on TOD typology is on the rise. This indicates that the demand for and discourse surrounding the latter are equivalently increasing. The present study deploys bibliometric analysis to discern trends in TOD typology and establish research goals for future investigations, as well as a global TOD implementation. Comparing TOD typology using bibliometric analysis necessitates a quantitative examination of TOD literature, which reveals study patterns, key topics, and TOD typologies investigated by scholars. A comparative bibliometric study of TOD typology will explain its past research history, demonstrate how TOD typologies are applied in various urban areas, and how they relate to sustainability, equality, and mobility. This paper provides insights towards a more

integrated approach in the fields of transportation, planning and geographical studies, aiming to link TOD typology with other fields and aspects, such as sustainable practices, climate-resilient urban planning, station area planning, real estate, and land management, related to the former.

The main limitation of this study is that the information and data used in the current paper for bibliometric analysis are dynamic and constantly changing.

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