Science mapping of transit oriented development (TOD), typology and travel demand research

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Abstract. Transit Oriented Development is a concept that is used as a tool to plan a compact area. Despite the growing interest in TOD research, there has yet to be a comprehensive review of the knowledge structure, research hotspots, and emerging trends regarding TOD research. This study tries to fill this gap based on data from Scopus, which is visualized with VosViewer, which will get trends and hotspots in TOD. The main objective of this study is to synthesize a collection of literature on TOD, typology, and travel demand, examine publication trends and topic patterns around TOD and travel demand, and visualize the interrelationships between authors, topics, sources, and geography. The results showed a significant increase in TOD research publication, with most articles published in the United States and China. The most productive authors are Cervero, Ewing, and Bertolini. Four hotspots of the frontier are determined by analysing the keywords of development-oriented model, typology, travel demand, and travel behaviour.

1 Introduction

Population growth and urbanization give rise to various urban problems, such as congestion and suburban sprawl [1-2]. Transit Oriented Development is a concept that is used as a tool to plan a compact area [3]. Transit Oriented Development is used as a city planning tool [4] with high density, spatial patterns, road network patterns, mass public transport frequencies and their services [5]. The multiple TOD planning strategy is a planning concept that is parallel to the transportation network so that it becomes a solution to regional problems stemming and vehicles [6-7]. The settlement is carried out by clustering urban development around the transit area, planning mixed areas, and being pedestrian-friendly [5].

The main objective of the TOD strategy is integration between land use and transportation systems [7]. Integration, specifically urban development and transportation system services, can mutually maximize economic goals, reduce the use of private vehicles, and benefit mass public transportation [8-11]. Integration can create a healthy environment by reducing emissions [12], sustainability of social life to increase interaction between communities [13].

The TOD concept is defined as creating a mixed-use area that can be reached in 10 minutes on foot in a transit transportation system. [14]. TOD topics are widely discussed in various parts of the world, with results published in various journals, conferences, and books to consolidate various special topics and theme relations related to TOD [15-17].

Topics were related to TOD, such as the concept of TOD, TOD effects, and TOD planning. Specifically, topics regarding typology and travel patterns in the TOD area in developing countries such as Indonesia have yet to be widely carried out. These studies use traditional approaches and methods that emphasize the development of TOD venation. This method makes it difficult to know the development and progress of TOD research. So it is essential to do a systematic article review and according to a synthetic approach [18]. Reviewing all research fields qualitatively by reading each document and extracting patterns is difficult, so a quantitative approach is needed to review the article in a bibliometric way [17].

Recently, bibliometric analysis for measuring specific research topics is becoming more common [19]. The traditional literature review method, when compared to the bibliometric analysis method, is more effective in identifying the spatiotemporal distribution, structure of research, and growth of the literature [20]. Bibliometric analysis using VosViewer software provides a visual bibliometric analysis tool that can help describe research topics and research trends.

In 1993 Peter Calthrope discovered the first concept of TOD; until 2022, many studies have been carried out, but the topic of TOD travel demand and travel behaviour trends has yet to be carried out the analysis. This study tries to fill this gap based on data from Scopus, which is visualized with VosViewer, which will get trends and...
hotspots in TOD. The main objective of this study is to synthesize a body of literature on TOD and travel demand, examine publication trends and topic patterns around TOD and travel demand and visualize the interrelationships between authors, topics, sources, and geography.

2 Methodology

The bibliometric analysis uses bibliometric research to map knowledge in a particular research field derived from citations, indexation, and keywords. It is evolving and useful for continuously visualizing and generating big data [21], so that it can be used to classify and map scientific fields, especially the topics of TOD, travel demand and travel behaviour in this paper.

This study compiles published studies on TOD topics related to travel demand and travel behaviour from 1993 to 2022 using Google Schola and Scopus. The science mapping methodology in this study uses the VosViewer program.

2.1 Data sources

Scientific publication for bibliometric analysis using data extracted from Scopus database. As a trusted database commonly used in selected research publications worldwide, it contains handy information for bibliometric analysis. This paper uses the CSI and RIS data formats to ensure high data quality. Topic search Transit Oriented Development. The publication language was set to English; only the article document type was set while excluding book reviews, reviews, and books. The search was conducted on January 2023, and 1,101 documents were initially obtained with the subject area of engineering and social science.

2.2 Analysis methods

Bibliometric analysis is a method for measuring scientific products quantitatively [22]. Compared to the old method, the advantages of bibliometric analysis are the results of multidimensional analysis, objective, quantitative descriptions, and the evolution of this research topic [19]. There are various software as tools for conducting bibliometric analysis, such as SciMAT [20], BibExel, VosViewer and CiteSpace.

There are four stages of discussion in the bibliometric analysis in this paper. The first is the trend of TOD research publications presented through bibliometric analysis. The second is an analysis of the network of contributing countries. The third analyses the authors who contributed a lot. The last is identifying and analysing keywords that are often used and discussed in the research.

3 Results and discussion

3.1 Publication trend

As shown in Fig. 1 shows, the number of periodic annual publications related to TOD research shows a clear upward trend; with the beginning of 1994, there were only 2 papers rising to 150 papers in 2022.

Developments during the first 11 years from 1994 to 2004 at most 10 articles were published on the TOD topic. Only 2.6% of the total number of publications during the year was produced during this period. In that span of years, the TOD concept phase was generally accepted and laid the theoretical basis for further research [23-24]. Density, Diversity, and Design the 3Ds identified by Cervero and Landis 1997 which became the characteristics of TOD planning in that period [25].

Developments from 2006 to 2022 The number of publications is increasing yearly, showing an increase of 77.4% of the total. At that time, the concept of TOD matured. The characteristic dimensions developed from 3Ds to 5Ds, namely destination accessibility and distance to transit [16]. TOD research develops with case studies of cities in the world. In 2014 Ogра and Ndebele offered the TOD planning dimension to 6Ds, which contains Demand Management [26].

![Fig. 1. Distribution of article publications 1994-2022.](image-url)
3.2 Influence countries

For two decades starting in 2013 there was a surge in publications. The surge occurred mainly in the United States, where the concept of the TOD theory was first fully applied. Since then, studies on TOD have developed in more and more countries, as shown in Fig. 2. Based on the search results, the United States and China clearly lead as the countries with the most research articles on TOD, followed by Australia, Canada, Hong Kong, the Netherlands and South Korea. All these countries are developed countries. The United State and China are the main TOD research centres in these two countries, and they have strong academic research networks with other countries described in Fig. 3.

European countries have recently adopted TOD as an approach to urban planning, such as in Netherlands, England, and Sweden. Cities in Asia Pacific have also adopted a TOD strategy in recent decades of developing mass transit corridors in metropolises and megacities. The TOD concept was first introduced to China's urban system after 2000 and became popular in 2010. [22]

Fig. 2. Network visualization influence country.

Fig. 3. Country rank based on number of papers.
3.3 Influence author

Fig. 4 tells the author who published his writing with the main topic TOD. Authors included in the criteria are authors who have published more than five articles. Author R Ewing with 19 articles in the first place, then there are L. Bertolini with 15 articles, Cervero with 14, and Kamruzzaman and Liu Y with 12. These authors are the most active and write extensively related to TOD research. The first researcher in the field of TOD was Dr. Robert Cervero published his first paper in 1996.

Fig. 4. Network visualization of the author.

Suburbanization and transit oriented development in China papers [27] It is the most cited paper, with 247 citations. Table 1 describes the ten documents most cited by other researchers.

Table 1. Ten most cited papers in the TOD research.

<table>
<thead>
<tr>
<th>Documents</th>
<th>Publication Year</th>
<th>Country</th>
<th>Total Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suburbanization and transit oriented development in China</td>
<td>2008</td>
<td>United States</td>
<td>386</td>
</tr>
<tr>
<td>Transit oriented development in high density: identifying its association with transit ridership in Seoul, Korea</td>
<td>2011</td>
<td>South Korea</td>
<td>255</td>
</tr>
<tr>
<td>Build environment as determinant of walking behaviour nonwork pedestrian travel in Portland, Oregon</td>
<td>2001</td>
<td>United States</td>
<td>140</td>
</tr>
<tr>
<td>The impact of transit-oriented development on housing prices in Sand Diego, CA</td>
<td>2011</td>
<td>United States</td>
<td>137</td>
</tr>
<tr>
<td>Transit oriented development’s ridership bonus: product of self-selection and public policies</td>
<td>2007</td>
<td>United States</td>
<td>133</td>
</tr>
<tr>
<td>Rail based transit oriented development lessons from New York and Hongkong</td>
<td>2010</td>
<td>Hong Kong</td>
<td>119</td>
</tr>
<tr>
<td>Transit’s value added effects: light and commuter rail services and commercial land values</td>
<td>2022</td>
<td>United States</td>
<td>108</td>
</tr>
<tr>
<td>Hedonic price effect of pedestrian – and transit-oriented development</td>
<td>2011</td>
<td>United States</td>
<td>105</td>
</tr>
<tr>
<td>Comparing transit-oriented development sites by walkability indicators</td>
<td>2004</td>
<td>United States</td>
<td>102</td>
</tr>
<tr>
<td>Advance transit oriented development typology: case study in Brisbane Australia</td>
<td>2014</td>
<td>Australia</td>
<td>97</td>
</tr>
</tbody>
</table>

Table 1 (continued). Ten most cited papers in the TOD research.
3.4 TOD keyword trend

This section presents findings on keywords that appear more than five times in a publication. Keywords can be used as a method to identify the topic of research. This analysis helps identify the most popular keywords (themes) used in TOD topic publications. The term TOD and its synonyms (e.g., transit-oriented development) were excluded from this analysis.

A total of 3819 keywords used in 1101 research results were analysed and visualized in a network that is interrelated in the keywords (Fig. 2). The network reflects the structure of knowledge and displays the relationships between keywords. Co-occurrence analysis was carried out using 10 research results as a minimum threshold. These keywords must be used in at least 10 research results. The results are visualized in Fig. 2.

The circle sizes in Fig. 4 represent the number of keywords in the 1101 documents. The bigger the circle, the more keywords appear in the TOD literature. Keywords are represented in red, green, blue, yellow, and purple.

The most significant red colour represents the design TOD relationship with 19 related keyword items. The green colour depicts TOD goals and priority policies, with a total of 16 items that appear. The blue colour describes TOD planning with 15 related keywords appearing. The yellow and purple colours explain the analytical methods that are often used in research related to TOD that appear 11 and 10 keywords.

The results of the keyword overlay in Fig. 5 represent the average keywords that appear in publications each year. Fig. 3 shows the year of publication with keywords that frequently appear from 2012 to 2018. The yellow color on the overlay of Fig. 3 shows relatively new keywords such as transportation development and transportation system. Visualization of keyword overlay results Fig. 4 is used to represent the dynamics of keywords that appear temporally and serves to identify keywords associated with a higher average number of citations (Fig. 6).

The most cited publications focus on travel behaviour with an average of 27 citations, followed by transportation development with 19 citations, and transportation planning with 17 citations. Studies focusing on railway transport and travel demand receive a modest citation rate of 16. Both themes were relatively new in 2017. Four hotspots of the frontier are determined by analyzing the keywords of, namely development-oriented model, typology, travel demand, and travel behaviour.
Fig. 6. Overlay visualization of keyword co-occurrence average publication per year.

Fig. 7. Overlay visualization of keyword co-occurrence average citation per year.
3.5 Popular TOD and Travel Demand Keyword Trends

Keyword searches can help identify popular topics in the research period being conducted. Regarding publication trends, TOD topic development is divided into three phases: the embryonic phase, the heyday, and the new era. [30]. The development of research since 2003, which analyses the effects of TOD on behavior and travel patterns, has been carried out in many developed cities. Then in 2018, there was research that evaluated the integration of land use and transportation on a local scale so that TOD could be implemented at various levels, namely city, region, and station [31]. Furthermore, several studies have used the approach that ridership reflects people using the transit and this can be used as an indicator for evaluating TOD [32].

Based on Fig. 3, the popular keywords that started in 2017 are railway transport, travel demand, travel pattern, and typology used as an approach to development studies in developed countries such as the United States, Australia, and China. This research can be used for the formation of supporting characteristics of TOD and improvement of TOD following population growth [33]. Research patterns that identify environmental characteristics and land use influence people to travel [34]. Then typology aims to categorize TOD based on the number of stations and properties in the surrounding area [35].

Research by discussing the formation of TOD typology based on travel demand, travel behaviour and performance of railway services has not been widely carried out, especially in developing countries based on keywords that often appear.

4 Conclusion

TOD is a structuring concept that has been considered one of the successful planning methods for sustainable cities and transportation as shown in Fig. 4. The results of the science mapping obtained 1,101 documents related to TOD.

The results of the performance of research entities regarding TOD consisting of authors, publications, sources, and countries show that two components for measuring performance, namely productivity and influence, are essential points in grouping them.

The results of mapping the most influential researchers with many of their writing articles that are widely cited and research with many TOD topics are Robert Cervero, Robert Ewing, Md Kamruzzaman, Luca Bertolini, Jhon Renne, and Carey Curtis. Countries that produce the most research that can be called the most influential are the United States and China. Other influential developed countries, namely Australia, the Netherlands, Britain, Japan, Canada and South Korea, are consistent with Western hegemony in the transportation sector [36].

TOD research topics develop in nine specific areas. Four themes were identified through the co-occurrence analysis, namely:

a) TOD design and outcomes,
b) Broader TOD policy priorities and objectives,
c) TOD planning,
d) Method of analysis in TOD research.

The analysis resulted in five thematic TOD research structures: TOD contextual effects, TOD design and outcomes of travel behaviour, accessibility and TOD typology, and economic and social impacts of TOD. The findings of the analysis show that the focus of the investigation is in a dynamic process with TOD design and results being one of the newest focuses [17].

The output of research on TOD topics that are commonly used, such as land use does not always attract many citations; on the other hand, research that focuses on average TOD results is widely cited, such as accessibility and travel behaviour. Accessibility refers to a person's ability to reach their goals easily [37-38]. On travel behaviour, measurements are carried out using many methods. In the TOD literature, travel behavior is mainly measured by mode selection behaviour. Other outcomes such as active transport, affordability, and equivalence are not used frequently, which indicates this research is limited [18]. New topics related to TOD are railway transport, planning, and travel behaviour related to demand.

The studies in this paper offer the development of holistic research topics related to TOD to ensure sustainability and TOD planning systems according to the characteristics of cities and countries. The results obtained are expected to increase knowledge and future researchers can identify and address gaps in the research field, which require further research to complete the current research literature. Nevertheless, this study has several weaknesses. All the publications were only derived from Scopus, and only publications written in English were considered. This may lead to the mission of several valuable publications and affect the research results.

References