PLANNING TRANSIT-ORIENTED DEVELOPMENT (TOD): A SYSTEMATIC LITERATURE REVIEW OF MEASURING THE TRANSIT-ORIENTED DEVELOPMENT LEVELS

*SARA M. IBRAHIM[1,2], HANY M. AYAD[2] & DINA M. SAADALLAH[2]
[1]Department of Architectural Engineering, Delta University for Science and Technology, Egypt
[2]Department of Architectural Engineering, Alexandria University, Egypt

ABSTRACT

The recent decades have witnessed a growing trend towards transit-oriented development (TOD) to achieve sustainable development through maintaining the integration between land use and transport systems. It is believed that measuring the TOD level 'TOD-ness' is important for TOD planning. However, it has been found that the spatial studies and quantitative methods that comprehensively measure TOD-ness are still limited. Furthermore, some methods do not have standard frameworks, and they vary according to the research context and orientation. Accordingly, the major focus of this paper is related to the multi-criteria decision making (MCDM), quantitative measuring methods that prioritize potential areas for intervention. Based on a systematic review, this paper aims to evaluate the existing studies published between 2000 and 2020 in relation to TOD-ness measurement and its operationalization. This systematic review is an attempt to present the dominant methodologies used and analyse their pros and cons. Accordingly, the paper introduces a theoretical review of the TOD concept, its evolution and methods employed from the previous studies. Then, an analytical review is conducted for the eligible records, that are extracted from eight databases according to certain criteria. Finally, it is expected that the outcomes of the research will provide insight for further studies, in addition to presenting the best-adopted methods and assisting in developing MCDM models that measure TOD-ness quantitively.

Keywords: multi-criteria decision making (MCDM), TOD planning, TOD level, TOD measurement, transit-oriented development (TOD).

1 INTRODUCTION

Over the past few years, the population growth of cities has increased rapidly as a result of urbanization. The urbanization process impacts the spatial distribution of land use and the mobility demand created by the distribution of activities. Unfortunately, many urban areas across the world have become increasingly car-oriented, threatening the sustainability of the road structure as well as creating social, economic and environmental imbalances. Consequently, further road construction policies have failed to cope with the substantial increase in travel demands resulting from this rapid motorization, causing a transport vicious cycle. Meanwhile, transit-oriented development (TOD) has grown significantly, aiming to achieve sustainable development by maintaining the integration between land use and transport systems [1].

The concept of TOD has a variety of definitions, as given by many researchers, the researchers and stakeholders describe it differently in light of their different perspectives on the concept. Consequently, there is no general definition of TOD. Most commonly, TOD is

*ORCID: https://orcid.org/0000-0002-3715-7680

ISSN: 2058-8305 (paper format), ISSN: 2058-8313 (online), http://www.witpress.com/journals
DOI: 10.2495/TDI-V6-N4-378-398

considered a way to densify neighbourhoods, reduce congestion and increase accessibility and transportation options through land-use clustering and mixing. This could thus have a great impact on reducing the distance and time required for car trips; allowing a greater proportion of trips to be made via non-motorized transport; and reducing car ownership in some households. As a corollary, this reduces total transportation costs and helps to create a more liveable community [1], [2], [3].

The formulation of the TOD concept appeared in the USA during the late 1970s and early 1980s. However, it really gained prominence during the 1990s, through its strong association with the emerging planning movements in the USA at that time when Peter Calthorpe published 'The Next American Metropolis' in 1993. Therefore, studying TOD is crucial as it is considered as a specific component for smart growth, new urbanism sharing some common principles with the aforementioned movements.

More recently, a growing number of cities and regions have embraced the concept of tod, its planning policies and implementation at different scales for instance, Europe, in the Netherlands, Sweden and Austria. Asia, in Tokyo and Toyama in Japan. Australia, in Perth, in the USA such as California, Portland, the New Jersey transit village and many more. some cities have gained popularity through their tod qualities and successes, such as Curitiba (Brazil), Hong Kong (China), London (united kingdom) and Johannesburg (South Africa) [2]. In addition to that, the implementation of TOD varies, it can be utilized to develop around existing transit stations, or develop new transit stations [3]. Therefore, there is a crucial need to measure the outcomes of TODs, implementing more quantitative understanding of the existing situation when planning for TOD, and it is thus important to measure the overall TOD-ness (TOD level) of urban areas in order to carry out effective TOD planning [4].

It was found that the previous research concerned with TOD, are focused on two major orientations; first, the successful engagement of the private sectors in TOD implementation while the second, is the evaluation of TOD stations around transit corridors, such as bus rapid transit (BRT) or light rail transit (LRT). However, almost all of these studies have dealt with 'evaluating' completed TOD projects, with very little interest in 'measuring' TOD-ness. Further, most cases are mainly qualitative and with little quantitative analysis, simply discussing the success or failure of TOD plans at that location. Only limited research has been found that assesses TOD quantitively. In 2004, Schlossberg & Brown [5] carried out such study; assessing the TOD of 11 sites in Portland, Oregon using only the walkability indicator. This is considered to be an example of measuring TOD-ness quantitatively, utilizing ArcGIS as a spatial platform using one indicator. The literature shows that 'comprehensive' location-based TOD-ness measurements had not been attempted before that time. Over the past few years, some efforts have been made by researchers to fill this gap by proposing different spatial quantitative methods and models to measure TOD-ness comprehensively. Although the number of studies investigating this issue is growing, they are still limited and fragmented.

Accordingly, this research paper is an attempt to tackle this gap, as the spatial studies and quantitative methods that measure the TOD-ness of an area comprehensively are limited. Thus, the paper is an attempt to provide a useful synthesis of existing studies on TOD-ness measurement, through providing methodological and empirical systematic reviews. Moreover, it's major orientation relates to TOD-ness measuring methods that prioritize potential areas for intervention. The paper will focus on multi-criteria decision making (MCDM) methods and techniques that are employed for TOD-ness measurement in TOD planning, as a tool to support decision making process. Therefore, this paper seeks to examine the following research question:

Q: How did the studies measure levels of TOD quantitively using MCDM methods to prioritize the potential areas for an intervention?

As, MCDM process is one of the different methods that has proposed since the 1970s to select an optimal solution for a given situation from a set of alternatives and decision criteria [6], and has been used in many fields. In transportation planning, [7] was one of the first authors to propose an MCDM tool to be used for TOD planning purposes. This tool was aimed to 'assess the suitability of land use around proposed LRT stations of the Memphis metropolitan area' by applying the analytic hierarchic process (AHP) method in conjunction with geographic information systems (GIS). In 2005, Banai [8] added small improvements to convert it into a decision-support system through a 'land development concept plan'. Although the topic of measuring TOD employing MCDM methods has attracted considerable attention from researchers during the last decade, the number of studies is still limited, especially in developing countries.

2 METHODOLOGICAL FRAMEWORK

In this paper, a systematic review is adopted to synthesize the state of different research on measuring TOD-ness quantitatively and to build a strong theoretical basis. The systematic review is conducted using the selected studies from different electronic databases. Then, it provides literature analysis, which will be discussed with regard to the research gap. Finally, the paper presents the conclusion of this review by providing a summary of insightful findings, lessons drawn and directions for future research. This review follows the PRISMA method, as it is preferred in reporting items for systematic reviews and meta-analyses, which ensures a transparent, systematic review. In basic terms, the selection of publications follows the four stages of identification, screening, eligibility and inclusion.

2.1 Search strategy

The systematic search was conducted between since December 2018 and December 2020 and yielded more than 2,535 records. The different electronic databases were screened to continue the literature search. They sometimes use 'Boolean operators' – simple words such as AND, OR and NOT – to combine and/or exclude specific terms for a quick search. Initially, an explorative keyword search was employed to determine appropriate search terms for the study. The search used different combinations of the generic terms 'transit-oriented development' and 'TOD measurement'. Additionally, the search strategy did not restrict the search to the transportation planning domain but also considered related fields such as urban planning and geo-information science. The combination of search terms listed in (Table 1) was used (with some syntactic variants) and applied to the title, abstract, keywords and full text of the databases mentioned previously.

Based on the most frequent terms used to describe TOD-ness measurement, found in several studies, the researchers constructed some search strings – for example (Web of science):

TS (Topic) = ('transit-oriented development' OR 'TOD') AND TS= ('TOD-ness' OR 'TOD level' OR 'TOD Evaluation' OR 'TOD Measurement' OR 'Measuring TOD' OR 'MCDM' OR 'TOD planning' OR 'Potential locations for TOD' OR 'Planning Support System' OR 'Spatial Decision Support System' OR 'Spatial Models' OR 'Smart Growth').

2.2 Literature identification

Initially, the scholarly databases were searched to determine which ones provided relevant results, through an extensive search of international journals, articles, reports and other

Table 1: [Keywords used in guiding the systematic review and the literature search. *(Source: Authors.)*].

	Keyword list	
Generic	Transit-Oriented Development (TOD) – TOD measurement	
Specific	TOD Measurement	MCDM methods
	Measuring TOD	Potential locations for TOD
	TOD Evaluation	Planning Support System (PSS)
	TOD Planning	Spatial Decision Support System (SDSS)
	TOD-ness	Spatial Models
	TOD level	Smart Growth

scientific web resources. In addition, a sample from grey literature resources was also included in the search, such as theses, dissertations and conference proceedings. The literature search was conducted across eight electronic scholarly databases: (1) Google Scholar, (2) ProQuest, (3) Science Direct, (4) Scopus, (5) EBSCOHost, (6) Springer, (7) SAGE and (8) Web of Science. In cases where publications appeared relevant but were not accessible, the researchers attempted to gain access via scientific communities (e.g. Egyptian Knowledge Bank (EKB), ResearchGate or Academia). After the initial database searches, preliminary criteria were established to narrow down the results, focusing on studies that were: (1) written in English and (2) published between 2000 and 2020.
This time-frame was chosen to limit the search based on the literature review conducted by [9]. Malczewski's review [9] revealed that the publishing of MCDM spatial methods such as SMCA-related (spatial multi-criteria analysis) articles has increased exponentially post-1995, with modest developments between 1990 and 1995. Finally, after narrowing down the results, the next inclusion/exclusion criteria were implemented, and the search was further refined.

2.3 Selection of eligible literature: Inclusion/exclusion criteria

In the first stage, the authors eliminated irrelevant papers through an initial screen. The foci of the eliminated papers were on TOD node typologies, TOD node models, TOD street design, TOD road network analysis, TOD real-estate prices, residential location, residential self-selection, or other irrelevant fields. Moreover, papers focusing on travel behaviour and/or environmental outcomes related to travel were also eliminated because they did not meet the scope of the current paper. During the second stage, titles and abstracts were screened to determine which ones are accepted for full paper screening. This was accomplished through selecting eligible literature resources based on a predefined criterion. The papers therefore had to meet the following inclusion criteria to be considered relevant for the research approach:

1. Papers must have a TOD measurement (quantitative) focus. Additionally, they must include planning aspects in line with TOD features and principles.
2. Papers must contain applied research that includes indicators or criteria identification.
3. Papers must have used an MCDM method or analytical technique (paper scope).

After removing the duplicated records, all titles and abstracts were screened based on the inclusion/exclusion criteria in order to select the relevant studies. Finally, 25 potentially

relevant papers that matched the search criteria were identified for further analysis. Following each step in the previously mentioned databases, the final search results were exported into Mendeley.

3 SEARCH RESULTS AND SELECTION PROCEDURE

The four-level structure of the literature search and selection process is illustrated in PRISMA flow diagram (see Fig. 1). During the screening process of the full texts, 195 records were excluded due to the following reasons:

1. They evaluated suburban neighbourhoods or focused on measuring one indicator only which did not fall within the scope of the research.
2. They were less focused on TOD measurement or discussed several topics at once.
3. They contained a theoretical basis for measuring TOD-ness or TOD evaluation but did not carry out a case study implementation.
4. Although some studies aimed to bring out optimal TOD locations using one of the MCDM methods, they used it to classify the transit node typology needed for the areas under study.
5. They met the selection criteria, but they focused on a TOD behavioural study.
6. Although the American study by [10] was found to evaluate the potential locations for TOD, but it had a slightly different focus. It focused on developing an index model to identify the areas where changes in the TOD-related variables were consistent with a positive or negative relation to the surrounding urban environment.

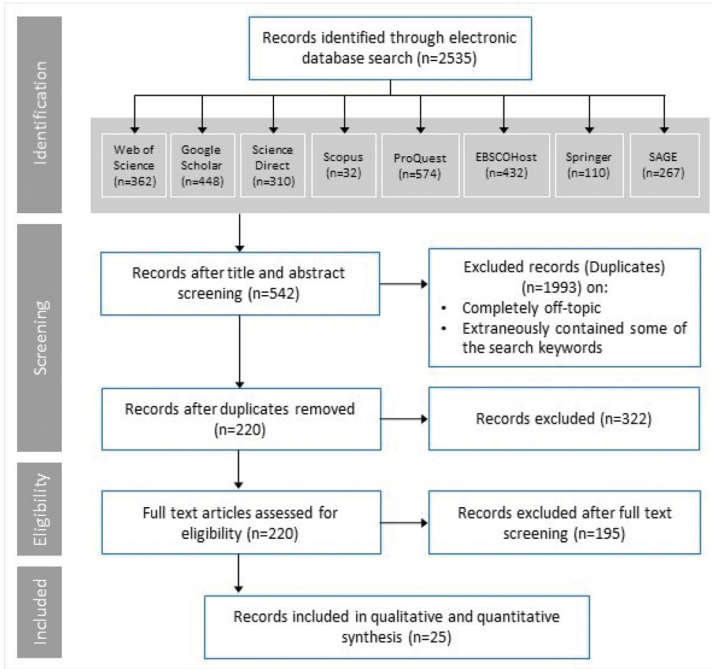

Figure 1: [The PRISMA flow diagram for the literature search. (*Source: Authors.*)]. The PRISMA diagram adopted from www.prisma-statement.org.

7. The review study by [11] was found to discuss only the necessary criteria and indicators that should be included in any study to establish an accurate TOD index which is used to measure TOD-ness. However, it did not discuss the methodology of measuring of TOD-ness via TOD index.

After the full-text screening, a total of 25 eligible records were included for data extraction and analysis and the review results are presented below through a narrative synthesis approach.

4 DESCRIPTIVE ANALYSIS OF LITERATURE RESULTS

The discussion of results was analysed according to the following: the origin of the studies, frequently analysed case studies and the transport modes included in the studies, the time of publication, the methods employed, the buffer size of the area of analysis and the main aims of the research.

The first observation was that the number of studies on TOD-ness evaluation or measurement has grown over the last decade, which has contributed to a better understanding of TOD indicators and criteria. However, no systematic reviews were found in the review results discussing this point. Moreover, the literature is dominated by studies from Northern Europe and South Asia, particularly the Netherlands (NL) and Indonesia.

As shown in (Table 2 and Fig. 2), it was found that 18 out of 25 selected studies were conducted in Northern Europe and South Asian countries, while four studies took place in Southern Europe and Western Asia, two studies were conducted in North America, particularly in the USA, and only one study in East Africa, particularly in Addis Ababa.

The second observation was that Arnhem-Nijmegen (SAN) was the most frequently analysed metropolitan area (n = eight, 32%) followed by Jakarta Metropolitan Region (JMR) (n = four, 16%). Most studies focused on more than three modes (11 studies), whereas fewer analysed only a single mode (nine studies) or two modes (two studies). Train stations were the most frequent focus of the studies (n = seven, 28%) and were included in multi-mode studies. Additionally, BRTs were included in eight studies (including one in which it was the exclusive focus), LRTs in ten studies (exclusively in two), MRTs in 11 studies (exclusively in two), rail-based stations in 20 studies (exclusively in three) and public transit stations in 21 studies (exclusively in five).

Another point observed was that a significant increase in the number of studies focusing on measuring TOD-ness had not been identified until very recently, after the TOD index appearance in 2007. One study was found in the years 2010, 2013, 2019 and 2020; two in 2012; four in 2014; three in 2015; and five and seven were published in 2017 and 2018, respectively. Concerning the publication year, although the review time-frame was from 2000 to 2020, some studies included earlier influential studies. These earlier studies were descriptive qualitative studies that discussed the indicators used to measure or evaluate TOD-ness.

Concerning the MCDM methods employed, the reviewed literature demonstrated a variety of methods being used, divided between analytical methods and simulation-based methods. A cumulative number of ten analytical techniques was obtained by grouping them into three main categories (suitability analysis, hierarchal decision process and statistical analysis). Among the most reliable methods, suitability analysis techniques (n = 19, 76%) were most common, especially multi-criteria decision-analysis (MCA) techniques, followed by spatial statistical analysis (n = 11, 44%) and then the hierarchal decision process (n = five, 20%). Much more common were those studies that used combined methods, which accounted for 52% (n = 13) of the total studies. Among the least reliable methods, the multivariate

Table 2: [Results of literature analysis sorted by year of publication ascendingly. *(Source: Authors.)*].

Reference	Case study	Type
[6]	Ahmedabad, India	Thesis
[12]	Gaza city, Palestine	Thesis
[13]	--	Book Chapter
[14]	SAN – NL	Thesis
[15]	SAN – NL	Thesis
[16]	Azambuja, Portugal	Research paper
[17]	SAN – NL	Conference paper
[18]	SAN – NL	Research paper
[19]	SAN – NL	Conference paper
[20]	SAN – NL	Dissertation
[21]	SAN – NL	Research paper
[22]	Rangsit Campus, Thailand	Research paper
[23]	Denver, Colorado, USA	Research paper
[24]	JMR, Indonesia	Research paper
[25]	SAN – NL	Research paper
[26]	Tehran, Iran	Research paper
[3]	Tehran, Iran	Research paper
[27]	JMR, Indonesia	Conference paper
[28]	Faridabad city, India	Research paper
[29]	JMR, Indonesia	Research paper
[30]	JMR, Indonesia	Conference paper
[1]	New Jersey, USA	Thesis
[31]	Depok City, Indonesia	Conference paper
[32]	Palembang city, Indonesia	Conference paper
[33]	Addis Ababa, Ethiopia	Research paper

regression method (n = one, 4%) was used in only one study by [16]. Moreover, the models were classified into four main categories (GIS-based, agent-based, AHP-based and statistical-based models).

The dominant models used were GIS-based models, which accounted for 92% (n = 23) of the total studies. Only the study by [23] used an AHP-based model without employing GIS, while the study by [3] was the only one that used an agent-based model, thus belonging to the category of simulation-based methods.

According to the studies that defined a specific radius for the area of analysis, the buffer size ranged from 300 to 1,200 m. Most of the researchers acknowledged that a 500 m boundary is a suitable distance for TOD development. However, the 'pedestrian catchment area' of built environment indicators found in ten studies (40%) measured the area within 800

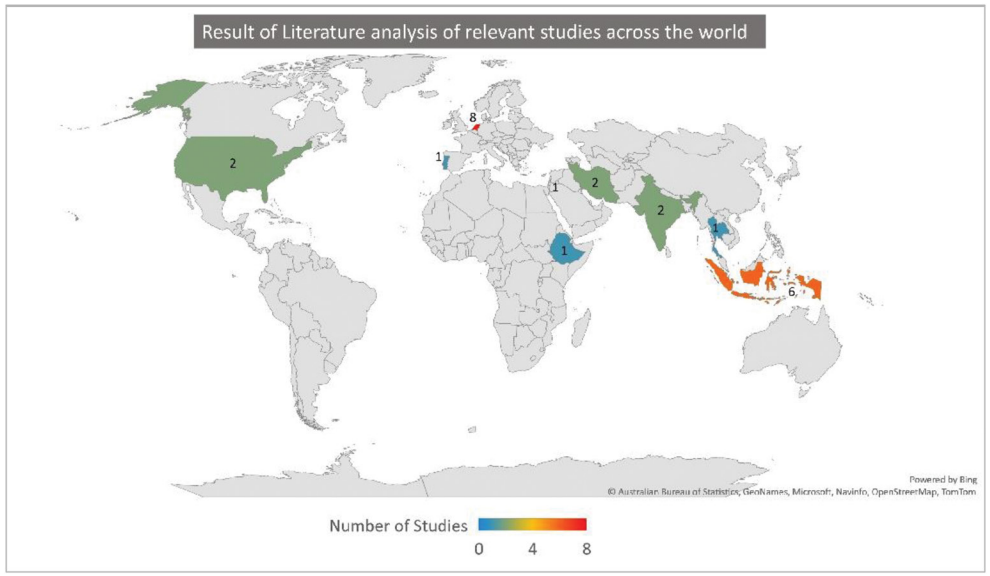

Figure 2: [The map depicts the results of literature analysis of relevant studies. (*Source: Authors.*)].

m around the stations, while seven studies (28%) measured within an area of 300 m and three studies (12%) within 500 m. The remaining four studies measured the area around the neighbourhoods or the stations within 400, 700 and 1,200 m each depending on the transport mode, corresponding station services and the context of the region. The reason for this disparity was highlighted by [15], who stated that a walkable boundary is not standard in all regions. For example, [34] defined a comfortable walking distance as a ten-minute walk within 609.6 m from the station in the context of American cities, while in the past 1,000 m (1 km) has been used as a comfortable walking distance for Australian urban settings. In conclusion, it is recommended for the study of TOD in different cities that the definition of an adequate distance for walking is based on the city context.

The main aims of the reviewed studies were grouped by the authors of this paper into eight different aims: (1) develop a TOD score for the study area, (2) measure the degree of TOD-ness of an area, (3) find station best allocation based on model/scenarios, (4) develop a framework to measure TOD-ness, (5) develop a GIS-based model to measure TOD-ness, (6) evaluate how the transit nodes function as TODs, (7) analyse the most feasible location for TOD planning or (8) develop DSS model used for choosing TOD site. Developing a TOD score, developing a GIS-based model for the study area and measuring the degree of TOD-ness of an area were the most extensively studied aims in the scientific work on this topic.

5 CONTENT ANALYSIS AND DISCUSSION

In this section, the discussion of the reviewed articles is grouped into seven topics: (1) the limited number of studies, (2) the indicators included in the studies, (3) the focus, TOD indices and scale of the studies, (4) the framework of analysis, (5) the methodological strengths and weaknesses of the studies, (6) stakeholder involvement and (7) study relevance for real-world practices.

5.1 The limited number of studies

It is quite surprising to find only two American studies in the review results, considering that TOD has received considerable attention in the USA and many American cities have undertaken TOD projects over the last decades. The notable thing about the literature review containing many USA studies that focused on the evaluation of existing TOD projects and discussed 'success/failure' factors at that location or the success of the project. In addition, only one study was found in African cities. Possible limitations to explain this are that selection bias might have occurred due to the exclusion of non-English records, some research papers were closed-access.

5.2 The indicators included in the studies

According to Calthorpe [34], TOD planning principles support the perspective of the 'physical-based TOD view', especially the walkable environment. Similarly, Cervero & Kockelman [35] focused on built environment principles and shed light on the '3Ds' (density, diversity and design), which are recognized as essential anchors in TOD planning. Dittmar & Ohland [36] also stressed the physical TOD aspects, while Ewing & Cervero [37] added 'two more Ds' as criteria of the built environment (destination accessibility and distance to transit), thus expanding it to the 5Ds. However, some researchers believe that it is not sufficient to analyse only physical TOD dimensions, despite their necessity. Hence, other researchers have tackled TOD from the perspective of the 'performance-based TOD view' and have moved beyond those variables to include others. For instance, Belzer & Autler [38] defined TOD from this perspective and Ewing & Cervero [39] added two more 'Ds', with demand management (including parking supply and cost) as the 'sixth D' and demographics as the 'seventh D'.

However, others have jettisoned the alliterative use of the letter D and employed their own formulations as shown in Fig. 3. Later, Evans et al. [40]'s report, identified the ten most frequently defined 'quantifiable' indicators to measure the existing TOD via an 'index'. Such an index allowed measuring all the indicators of TOD areas to identify which areas needed greater TOD-ness or better transit connectivity. As reported in a review study by Patel & Shah

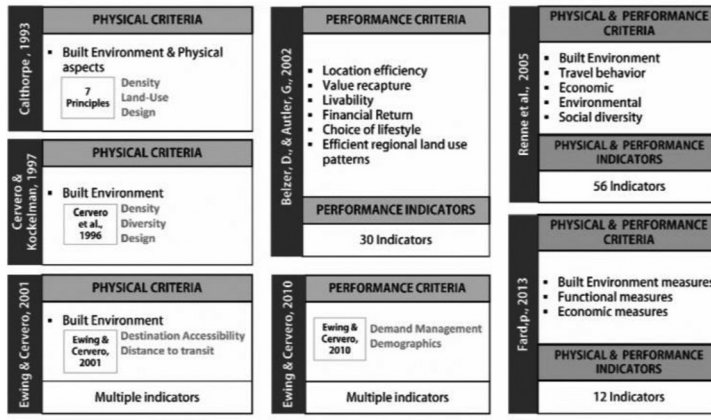

Figure 3: [Synthesizing the researchers' perspectives on TODs, their criteria and indicators. (*Source: Authors.*)].

[11], the necessary criteria to be included in any study in order to establish an accurate TOD index are: (1) density, (2) diversity, (3) walkable and cycle-able distance and 4) economic development. Regarding the indicators used in the studies, the number varied from four (in two studies) to 22 indicators (in one study). Furthermore, just over half of the studies (n = 22, 88%) used more than four indicators. The most frequently analysed indicators were density, diversity and design (n = 23, 92%).

Table 3 shows that five studies focused on physical TOD indicators only, while the majority of studies (n = 17, 68%) used physical and performance indicators. The literature acknowledged that since researchers' aims in regard to TOD vary, the indicators also differ. Further, the more the indicators included in any study, the more precise the results that the researchers will obtain. Several researchers, such as [3] tried to put this into practice by considering more comprehensive indicators in their study. They used public transit infrastructure indicators (i.e. route performance and service performance) and TOD-level indicators (i.e. density, diversity, design and economic development), which were evaluated at the neighbourhood scale. From the review, it was found that researchers such as [14], [15], [6], [18] excluded some indicators in their studies due to different limitations, including data availability (i.e. the meta-data for the dataset), time and energy resources.

For these reasons, some studies, such as that by [14], had to adjust some indicators, thus they became less precise. Further, the authors of six studies modelled the link between land use and transport by using Cervero's 1997 '3Ds' indicators. However, while these indicators can explain the relationship between land use and transport, they might not be comprehensive and efficient enough for the TOD-ness measurement of an area. As emphasized by many researchers, studies must include the '3Ds' and economic development indicators when measuring TOD-ness comprehensively. Further to this, some indicators change over time, such as accessibility, passenger load, etc., because these services differ across the duration of a day. Hence, it is highly recommended that a time-based dimension should be considered within TOD planning.

5.3 The focus, TOD indices and scale of the studies

It should be noted that TOD typically encompasses different types of development, as it sometimes refers to a development around new transit stations and sometimes refers to station re-development. The different foci of the studies revealed from the literature analysis are shown in Table 3. Some studies focused on a single TOD approach (n = 21, 84%) while others utilized both TOD approaches (n = two, 8%). From the review, it was noticed that Approach 1 (see Table 3) was the most adopted (n = 13, 52%) in the selected studies.

Many researchers, such as Singh, Fard, et al. [18], suggested that TOD planning for a region should address two approaches:

1. Approach 1: To identify the areas that surround high-quality transit but where TOD levels are low, and the transit orientation of these places needs improvement. Its objective: Plan for higher TOD levels in different areas where transit connectivity is available, but TOD levels are low.
2. Approach 2: To identify the areas that are characterized by urban development with high transit orientation but poor or absent access to high-quality transit. Its objective: Plan for transit connectivity at those locations or areas where high levels of TOD exist but transit connection is absent or poor.

Table 3: [Comparative analysis matrix between different studies on measuring TOD-ness. Note: 'n.a.' not applicable. *(Source: Authors.)*].

Criteria & indicators				Focus of study			TOD index			Scale of analysis						Framework of analysis				
Study	Physical	Performance	Physical & Performance	Approach 1	Approach 2	Both approaches	TOD index score	Actual TOD index	Potential TOD index	TOD station / site	TOD station area	TOD neighbourhood	TOD corridor	TOD city region	TOD regional	Developed SMCA-based framework	Adopted Singh et al., [13] framework	Developed a framework based on Singh et al., [13]	Developed a new TOD (PSS)-based frameworks
[6]	●			●			●				●		●			●			
[12]	●			●			n.a.	n.a.	n.a.			●		●					●
[14]	●				●				●					●	●		●		
[15]			●	●				●			●						●		
[16]			●	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.				●						
[17]			●		●				●					●	●		●		
[18]			●		●				●					●	●		●		
[19]			●			●		●	●		●			●	●			●	
[20]			●			●		●	●		●			●	●			●	●
[21]			●	●					●					●	●		●		
[22]			●	●			●			●									●
[23]			●	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.		●			●					●
[24]			●	●				●			●		●			●			
[25]			●	●				●			●			●				●	

Table 3: *(Continued)*

Criteria & indicators				Focus of study			TOD index			Scale of analysis						Framework of analysis			
Study	Physical	Performance	Physical & Performance	Approach 1	Approach 2	Both approaches	TOD index score	Actual TOD index	Potential TOD index	TOD station / site	TOD station area	TOD neighbourhood	TOD corridor	TOD city region	TOD regional	Developed SMCA-based framework	Adopted Singh et al., [13] framework	Developed a framework based on Singh et al., [13]	Developed a new TOD (PSS)-based frameworks
[26]			●		●		●					●							●
[3]			●	●			●					●							●
[27]	●			●			●				●		●			●			
[28]	●			●				●			●		●					●	
[29]			●		●				●					●	●	●			●
[30]			●		●		●		●					●	●	●			●
[1]	●				●		●							●	●	●			
[31]			●	●				●			●					●			
[32]			●	●			●				●					●			
[33]	●			●			●				●		●					●	
Total	7	0	17	13	7	2	9	7	7	1	13	3	6	12	9	9	5	5	8

Concerning TOD indices, Singh, He, et al., [17] claimed that the indicators proposed by [38] have not yet been used comprehensively. They also argued that a single TOD index is not sufficient, since the two approaches differ in terms of area, scale and measuring indicators. Hence, they proposed two TOD indices for each of the previously mentioned approaches, referred to as an 'actual TOD index' and a 'potential TOD index'.

1. Actual TOD index: An index must measure TOD levels within walking distance of each transit node. It should also measure the characteristics not just of urban development's surrounding the node but also of transit services in that area (eight criteria and 25 indicators).
2. Potential TOD index: An index must be able to measure urban development characteristics in all areas of the region. It cannot measure transit characteristics as it is found that those areas where transit connectivity is absent and is desired (four criteria and 11 indicators).

Noticeably, the approaches adopted by researchers are reflected in the scale of the studies in the review results. The station area and city scale were the most frequently analysed scales (n = 12, 48%), followed by the urban-regional scale (n = seven, 29.16%), then the transit corridor scale (along MRTs, BRTs and LRTs) (n = six, 24%) and lastly the neighbourhood-scale (n = three, 12%). From the review, it was recognized that TOD is a multi-scale concept that uses several scales. Many researchers have argued about this since Calthorpe [34] defined TOD as a conducive development that surrounds transit stops/stations and considered station level as the most critical scale of TOD planning. Some of the researchers adopted the local scale (i.e. station area and its neighbourhood level), believing that this scale is critical for developing transit-oriented activities as well as understanding the community. Nevertheless, others argued that the TOD should be applied to a region or a city, rather than around transit nodes. In their opinion, this scale helps to achieve a more efficient and comprehensive result for TOD planning and to ensure coordination between other existing regional plans.

It can be concluded that the two approaches towards measuring TOD-ness are essential to ensure the comprehensive elaboration of the studied area. However, research that used the two approaches for the same area was rare in the literature reviewed. Only three studies were found to be complementary to each other: [18], [20] and [21]. Working on both approaches for the same study areas is recommended as it can help to understand TOD-ness at a regional level and to establish significant strategies and scenarios that stand on the assessed indicators. This can also help the stakeholders and decision-makers to move towards a greater TOD-ness or better transit connectivity when choosing a TOD site for development.

5.4 The framework of analysis

To answer the question asked in the introduction of this paper, the review revealed the tools and methodological frameworks employed, but some caveats exist. The authors of 23 articles used computerized simulation tools and models that used spatial analysis to measure the degree of TOD-ness of an area. The authors of 24 articles employed different models in case studies to qualitatively measure the TOD-ness of an area, and one study developed a conceptual model only. As mentioned before, suitability analysis techniques (n =19, 76%) are the most reliable methods. Additionally, the majority of the reviewed studies did use a TOD index score to measure the TOD-ness of an area but with different methodological frameworks. To calculate the TOD index, it was found that many researchers employed an

SMCA analysis method. In general, MCA has been acknowledged as an effective method that aggregates multiple indicators into a single composite index. Moreover, 'GIS-based MCA' or 'SMCA' has been employed when dealing with spatial indicators. Singh et al. [13] took the TOD index to fruition within a proposed SMCA-methodological framework that calculated multiple 'spatial criteria' and combined them into this index. They described this framework as an extension of the work of [40].

Likewise, a number of studies (n = nine, 36%) developed the SMCA-based framework, while some researchers (n = five, 20%) operationalized the same framework as Singh et al. [13], which employed a GIS-based spatial model as an analytical measurement tool to measure the existing TOD-ness of an area. Moreover, four studies (20%) developed a framework based on that of Singh et al. [13] and eight studies (32%) developed a new TOD PSS-based framework (see Table 3). Additionally, [28] adopted Singh [19] framework while Semeraro c adopted that of Singh, Fard, et al. [18] and Sulistyaningrum & Sumabrata [31] adopted that of Singh et al., [25] . Moreover, the data obtained in the study by Fajri & Sumabrata [32] was analysed using Sulistyaningrum & Sumabrata [31] TOD measurement method and the TOD evaluation method by Galelo, et al. [16].

5.4.1 Interpretation of studies' results

It was found that visual analysis and statistical analysis were employed by researchers in TOD studies to aid in recommending alternative TOD locations for development or building. The methods found in the reviewed literature using visual analysis were spatial analytical and spatial statistical, which can facilitate in interpreting spatial indices. Many researchers admitted that the potential TOD index could only be used to make a comparison between locations in order to identify the potentially more transit-oriented location, but that the index may not clarify the magnitude of the differences. Moreover, Fard [14] added that computing the maps of SMCA analysis (i.e. in the form of either a suitability map or a TOD index map) provides us with different values without indicating the required actions in practice.

Likewise, almost all of the reviewed studies (96%) employed the spatial analysis using a GIS platform except Strong [23]'s study, which used statistical analysis. Seven studies (28%) employed spatial statistical analysis and six studies (24%) employed both spatial analysis and statistical tests. Almost all the studies that employed spatial statistical analysis studied the statistics of spatial association through 'spatial clustering' using global or local cluster statistics methods.

Arguably, the review revealed that the findings of the previous studies could not be compared in order to identify their degree of success in the future due to the diversity of the methods employed. Hence, without comparison or validation scores, it is difficult to know which method would produce the best results. The literature provided a few studies (n = 11, 44%) that suggested which policies were needed for improvements or suggested detailed TOD site decisions based on the results as in [33]. However, some researchers claimed that planners would still need more information on land use plans, planning policies or political motivations in order to make physical plans when the need arises. Finally, the review also revealed that the PSS-based framework in many studies could not predict or simulate how the increase in densities, jobs or economic development could affect the number of transit ridership.

5.5 The methodological strengths and weaknesses of the studies

After investigation, many researchers admitted that the methodological framework of Singh et al. [13] has obvious points of strength because:

1. It can quantitatively measure the TOD-ness of an area via the TOD index.
2. It is transparent and back-traceable.
3. It is simple, which makes it repeatable and easily applied in other countries as well.
4. The results can provide an input for an SDSS environment and can then be assessed by stakeholders in order to propose planning interventions in those areas.

Correspondingly, Singh, He, et al., [17] developed the framework and tool that had been proposed previously in the work by Singh et al. [13]. This development has strengths as follows: The researchers proposed two separate indices – an 'actual' and a 'potential' TOD index – where they differ in scale and indicators. They used spatial statistical analysis, which leads to higher accuracy in results. Moreover, the study is considered one of only a few studies across the entire study area that measured TOD-ness via a TOD index. In general, many researchers emphasized the advantages of measuring TOD-ness via a TOD index, as it can help in: assessing the existing TOD characteristics, maintaining effective TOD planning or evaluating TOD projects, justifying poor TOD performance such that proposed policies, programs or interventions can be created to improve TOD conditions and identifying whether an area is moving towards or away from performance threshold values.

Another argument was made by Lukman [15], who criticized Fard [14]'s study for applying the potential TOD index to the whole areas regardless of whether the areas had transit access or not. Therefore, the consideration of some transit system elements was missed in this study. However, [3,26] argued that Singh, He, et al., [17]'s study has some weak points: Ignoring accessibility or street connectivity, which are considered as efficient indicators in developing a TOD index. The indicators were computed in a 'raster format', which is considered inappropriate because data collection is usually represented in a 'vector format' in urban planning. Finally, they did not propose any scenarios for improving the TOD-ness of areas in the region, especially public transit service areas that had the potential for development.

Despite these weak points, Singh et al., [25]'s study employed the same methodology but discussed the first approach throughout an entire urban area. Finally, Motieyan & Mesgari [26] developed a four-stage methodology to calculate a TOD index score using an AHP analytical method. According to the results of the assessment, they described their method as robust and efficient for sustainable urban planning. stating that using this analytical method had many advantages for their modelling approach because: It produces the TOD index from the stakeholders' point of view. By calculating the indicators' weights using pairwise comparisons, it provides robust results where the inconsistency is computed. Additionally, by modelling uncertainties in stakeholders' views (sensitivity analysis), it gives more precise results.

Finally, the spatial data of the majority of studies used vector representation in GIS. Many researchers confirmed that the vector format has many advantages in producing reliable results, regarding either attributes or the spatial dimension. For instance, [26]'s study computed the indicators in the vector format at a neighbourhood scale, which they justified with the following reasons: Some errors may potentially result if data is converted into other levels because the majority of datasets are compiled at the neighbourhood level. The raster cell square area contains different urban environment areas with different characteristics, so using the vector format at a neighbourhood level is more efficient than the raster format. Density, diversity and land use mixedness indicators are usually employed at the neighbourhood level, thus utilizing them on other levels is inefficient.

5.6 Stakeholder involvement

It has been acknowledged that achieving efficient TOD requires cooperation between planners, policymakers, private investors, administrators, etc. Also, it is believed that stakeholder participation is a way to encourage the bottom-up approach in the planning process. Similarly, the researchers believed in the role of stakeholders' involvement in TOD planning studies. From the review, many researchers considered SMCA as the preferred analytical method for prioritizing potential locations for intervention, due to stakeholder participation twice during the process: first, their major role in assigning the weights to each indicator before calculating the TOD index, and second, when discussing the TOD indices. Further to this, the other advantage of SMCA or multi-criteria methods is that stakeholder bias can be eliminated after performing a sensitivity analysis to test the small change in the weights of the TOD scores.

From the review, a drawback was noticed regarding the weighting of the criteria that were determined through interviews or surveys. For instance, the ranks in the study by Shastry [6] were determined by a group of six people through interviews, which is a very small dataset. Moreover, not all of the interviewees were from the city of Ahmadabad and they were not representative of the entire list of stakeholders. Taki & Maatouk [29]-[30] overcame this drawback and obtained their AHP data (the primary data) from interviews and questionnaires answered by 12 experts in various scientific fields to obtain the weight value of each indicator. In Lukman's study [15], the weights were derived from a previously held stakeholder workshop by Singh [41], who worked on the same topic as Lukman's research. The weights were only derived from government representatives at the municipality level. In the study by Galelo et al. [16], the weights were derived from a national survey in the USA that used the opinions of 30 professionals, while in the study by Singh, He, et al., [17], a workshop was held with the municipal heads of all 20 municipalities, where they were asked to rank the indicators in order of their importance in the realization of TOD.

5.7 Study relevance to real-world practices

At a broader level, this review helps in identifying where the relevant research exists to help academics to be consistent with past and recent progress, as well as the considerations needed for future research. Moreover, the authors believe that exploring this kind of study can also help decision-makers to identify priorities and provide computerized models to be assembled and used. The review revealed that the direct impact and relevance of the studies are mostly on urban planning, TOD planning and decision-making processes. As mentioned before, only 11 studies had a direct impact on the policy-making process as well as TOD planning. The researchers admitted that measuring TOD-ness would help decision-makers to determine which areas had more potential for development. In addition, the results of the studies can provide an input for an SDSS environment (e.g. GIS) and can then be assessed by stakeholders again to propose planning interventions in those areas. Consequently, the selection of proper measurement frameworks needs more consideration, because without measuring the TOD-ness outcomes correctly, investment strategy mistakes will occur repetitively.

In some cases, such as that of Shastry [6], the secondary data (i.e. the number of jobs) has decimal values, which indicate that the data has been calculated using a mathematical operation and not been collected onsite. Hence, the authors believe that more empirical research on measuring TOD-ness is needed using real-world data, derived from interviews with stakeholders, reports, surveys and other sources, in greater detail. Although the PSS-based

frameworks used by the reviewed studies are valuable in choosing potential TOD sites for development, they have not determined what is needed from the market demand perspective. Therefore, the use of more market studies should be another important topic that deserves further exploration by both academics and practitioners. Some researchers recommended that the results of 'spatial clustering' hotspots analysis could be further followed up with a detailed technical feasibility analysis or a financial/economic feasibility analysis.

6 CONCLUSION

Arguably, TOD has become the catchphrase of the planning world over three decades. It is widely recognized as one of the most comprehensive sustainable planning approaches. Moreover, it is believed that TOD has many aims that eventually achieve smart growth principles for enhancing local communities. It also attempts to orient land use and development towards the transport system. In line with this, this paper conducted a systematic literature review on the state of research on TOD-ness measurement and its operationalization. The systematic review method gathers search results from different resources and allows the effective analysis of relevant research studies. In the end, the paper has focused on some important considerations after reviewing 25 relevant studies published between 2000 and 2020. It should be noted that the total number of 25 eligible studies found for a systematic review is a rather small proportion.

This extensive review revealed some well-known facts about the TOD concept. First, the available literature on TOD is very vast and covers many aspects of the concept. Thus, the attempts to evaluate TODs have also been conducted differently by researchers and urban planners worldwide, as they perceive the concept differently. It is also very clear that TOD planning implementation is a multi-scale endeavour. At the same time, the review revealed that there is insufficient work in the literature that measures TOD-ness in certain areas quantitatively. Although the literature is rich with station-area studies attempting to measure levels of TOD, they did not quantify them until 2007. Furthermore, the review revealed that more published articles on this topic have been observed since 2010. With respect to the methods employed, combined methods using a suitability analysis SMCA and spatial statistical analysis techniques dominated the TOD measurement studies. At the same time, the authors of a few articles employed agent-based, AHP-based and statistical-based models in their work. In accordance with content analysis, the reviewed studies were classified according to seven topics.

In general, the review confirmed some results in the existing literature. For instance, many researchers have encouraged the development of a TOD index that can quantify TOD-ness to measure TOD comprehensively. This helps to identify what is lacking in the existing situation and what developmental interventions need to be carried out based on the location potentials. Moreover, review found that the literature is rich with studies that used a mix of 'spatial' and 'non-spatial indicators' to calculate such an index that is both measurable and quantifiable at the same time. Most commonly, the researchers excluded some indicators in their studies due to different limitations, including data availability or time constraints. However, some studies emphasized that certain indicators should be included to maintain effective TOD planning (e.g. the 3Ds and economic development). In addition, a temporal dimension should also be considered because some indicators differ across the duration of a day, such as accessibility, passenger load, etc. The review also revealed that these types of studies can have a valuable impact on real-world practices such as urban planning, TOD planning and decision-making processes. The results of the TOD scores can provide identification for decision-makers in order to focus their efforts on these locations.

To sum up, the review provided the following considerations needed for further research: First, this review has a 'methodological focus' and, to the best of the authors' knowledge, this is one of few attempts at a systematic review on this topic. Therefore, the authors believe that an additional review with an empirical focus is needed. If the same literature is used, the authors recommend a new angle to be investigated, resulting in different conclusions. Second, although there is a large amount of TOD research focusing on how users living in or moving to a TOD change their travel behaviour, this review did not consider travel behaviour and/or environmental outcomes related to travel. However, travel behaviour and mode shift should potentially be measured along with the TOD-ness measurement at some point, in order to strengthen the argument behind this paper.

Third, working on two approaches to measuring TOD-ness for the same study area is recommended, as it can help to understand the level of TOD at a regional level and to establish significant scenarios that stand on the assessed indicators. The researchers also suggest using the results of the studies on which to base the policies needed for improvements or a detailed TOD site decision in order to help policymakers to identify the priorities. Fourth, it is also recommended that studies that capture built environment indicators should define the adequate walking distance based on their local context. Moreover, the consideration of more stakeholder involvement as well as government policies would certainly have a major impact on the criteria weighting that may affect the value of each indicator. Therefore, the involvement of the local communities, the private sector and the public sector is considered an essential element to maintain a successful TOD.

Fifth, for further implementation of the methods, this review focuses on the methods and models used in Fard & Lukman studies [14,15], which measure the actual or potential implementation of the TOD concept in an area. It also suggests using combined methods to ensure a methodologically balanced approach. In addition, it is important to assess the model used in order to examine its efficiency by comparing and validating the resulting TOD scores. Further to this, future research should enlarge the TOD-ness measurement scope. For instance, people living in proximity to transit stations are affected by government policies and the demography of the area. Hence, there is a need for more agent-based models to consider other characteristics of the area. Further research should also include additional interviews to provide a vision of what the community wants, and whether they support or are against the proposed development. Finally, there is a need to conduct more studies that employ big and open data (BOD)-derived variables in the future, which allow planners to revalidate existing TOD planning principles, refine TOD analytics of measuring TOD-ness and evaluate different TOD plans and adapt them to local contexts.

REFERENCES

[1] Semeraro L., *Approaches to Transit-Oriented Development (TOD): How existing infrastructure can lend itself to implementation of Transit Oriented Development Techniques*. Graduate School of Architecture Planning and Preservation,Columbia University: New York, 2018. https://doi.org/https://doi.org/https://doi.org/10.7916/D8281R2S.

[2] World Bank., Volume 3 Benchmarking Transit-Oriented Development- Integrated Transport and Land Use Planning Strategy Dar es Salaam Bus Rapid Transit (BRT) Phase 1 Corridor 2015:128.

[3] Motieyan, H., Mesgari, S.M., An Agent-Based Modeling approach for sustainable urban planning from land use and public transit perspectives. *Cities*, **81**, 91–100, 2018. https://doi.org/https://doi.org/10.1016/j.cities.2018.03.018.

[4] TRB., Transit-Oriented Development and Joint Development in the United States: A Literature Review - Research Results Digest. 2002.
[5] Schlossberg, M., Brown, N., Comparing Transit-Oriented Development (TOD) Sites by Walkability Indicators. *Transportation Research Record: Journal of the Transportation Research Board*, 34–42, 2004. https://doi.org/https://doi.org/10.3141/1887-05.
[6] Shastry, S., Spatial assessment of Transit Oriented-Development (TOD) in Ahmedabad, India. Faculty of Engineering Technology, Civil Engineering and management, University of Twente, Netherlands, 2010.
[7] Banai, R., Transit-Oriented Development Suitability Analysis by the Analytic Hierarchy Process and a Geographic Information System: A Prototype Procedure. *Journal of Public Transportation*, **2**, 43–65, 1998. https://doi.org/10.5038/2375-0901.2.1.3.
[8] Banai, R., Land Resource Sustainability for Urban Development: Spatial Decision Support System Prototype. *Environmental Management*, **36**, 282–96, 2005. https://doi.org/10.1007/s00267-004-1047-0.
[9] Malczewski, J., GIS-based Multi-Criteria Decision Analysis: A survey of the literature. *International Journal of Geographical Information Science*, **20**, 703–26, 2006. https://doi.org/10.1080/13658810600661508.
[10] Coolbaugh, D., Evaluating the Potential Locations for Transit-Oriented Development (TOD): A Case Study of Mecklenburg County, NC. The University of North Carolina at Greensboro, 2016.
[11] Patel, I.M., Shah, J., A Review study on Transit-Oriented Development (TOD) Index by using different Criteria. *Global Research and Development Journal for Engineering (JRD) Journals- Emerging Research and Innovations in Civil Engineering (ERICE - 2019)*, **029**,137–40, 2019.
[12] Maher, S.A., Abu Rass, A., Building a Sustainable and Smart Urban Development Model based on Transit-Oriented Development (TOD) Gaza City (Implementation Area). The Islamic University, Faculty of Engineering, Gaza, 2012.
[13] Singh, Y, Zuidgeest, M.H.P., Flacke, J., van Maarseveen MFAM., A design framework for measuring transit oriented development. *WIT Transactions on the Built Environment*, **128**, 719–30, 2012. https://doi.org/10.2495/UT120611.
[14] Fard, P., Measuring Transit Oriented Development (TOD): Implementing a GIS-based analytical tool for measuring existing (TOD) levels. University of Twente, University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), Netherlands, 2013.
[15] Lukman, A., Development and Implementation of a Transit-Oriented Development (TOD) index around the current transit nodes. University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), Netherlands, 2014.
[16] Galelo, A., Ribeiro, A., Martinez, L.M., Measuring and Evaluating the Impacts of (TOD) Measures – Searching for Evidence of TOD Characteristics in Azambuja Train Line. *Procedia - Social and Behavioral Sciences*, **111**, 899–908, 2014. https://doi.org/https://doi.org/10.1016/j.sbspro.2014.01.124.
[17] Singh, Y.J., He, P., Flacke, J., Maarseveen, M v., Measuring Transit-Oriented Development (TOD) over a Region using an Index. 12th Annual Transport Practitioners Meeting, London, UK, 2014.
[18] Singh, Y.J., Fard, P., Zuidgeest, M., Brussel, M., Maarseveen, M v., Measuring Transit-Oriented Development (TOD): A spatial multi criteria assessment approach for the City Region Arnhem and Nijmegen. *Journal of Transport Geography*, **35**, 130–43, 2014. https://doi.org/10.1016/j.jtrangeo.2014.01.014.

[19] Singh, Y.J., Lukman, A., Pengwei, H., Flacke, J., Zuidgeest, M., Maarseveen van M., Planning for Transit Oriented Development (TOD) using a TOD index. 94th Annual Meeting of the Transportation Research Board at Washington, USA 2015;1st Editio:17.

[20] Singh, Y.J., Measuring Transit-Oriented Development (TOD) AT Regional and Local scales – A Planning Support Tool. University of Twente, University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), Netherlands, 2015. https://doi.org/https://doi.org/10.3990/1.9789036539982.

[21] Singh, Y., He, P., Flacke, J., Maarseveen van, M., Measuring (TOD) over a region using GIS based Multiple-Criteria Assessment Tools. *SPA Journal of School of Planning and Architecture*, **19**, 1–22, 2015.

[22] Srivanit, M., Selanon, P., GIS-based Land Suitability Analysis to Support Transit-Oriented Development (TOD) Master Plan: A Case Study of the Campus Station of Thammasat University and Its Surrounding Communities. *International Journal of Building, Urban, Interior and Landscape Technology (BUILT)*, **9**, 49–60, 2017.

[23] Strong, K., Ozbek, M., Sharma, A., Akalp, D., Decision Support Framework for Transit-Oriented Development (TOD) Projects. *Transportation Research Record: Journal of the Transportation Research Board*, **2671**, 51–8, 2017. https://doi.org/10.3141/2671-06.

[24] Taki, H., Maatouk, M.M., Qurnfulah, E.M., Re-Assessing (TOD) index in Jakarta Metropolitan Region (JMR). *Journal of Applied Geospatial Information*, **1**, 26–35, 2017. https://doi.org/10.30871/jagi.v1i01.346.

[25] Singh, Y.J., Lukman, A., Flacke, J., Zuidgeest, M., Maarseveen, M v., Measuring (TOD) around Transit Nodes - Towards (TOD) policy. *Transport Policy*, **56**, 96–111, 2017. https://doi.org/10.1016/j.tranpol.2017.03.013.

[26] Motieyan, H., Mesgari, M.S., Towards sustainable urban planning through Transit-Oriented Development (A case study: Tehran). *ISPRS International Journal of Geo-Information*, **6**, 1–16, 2017. https://doi.org/10.3390/ijgi6120402.

[27] Budiati, W., Grigolon, A., Brussel, M., Rachmat, S., Determining the potential for Transit-Oriented Development along the MRT Jakarta corridor. *The 4th PlanoCosmo International Conference, IOP Conf. Series: Earth and Environmental Science (158) 012020*, p. 1–15, 2018. https://doi.org/10.1088/1755-1315/158/1/012020.

[28] Pal, S., Measuring Transit-Oriented Development (TOD) of Existing Urban Areas around Metro Stations in Faridabad City. *International Journal of Built Environment and Sustainability*, **5**, 115–26, 2018. https://doi.org/10.11113/ijbes.v5.n1.251.

[29] Taki, H.M., Maatouk, M.M., Spatial Statistical Analysis for Potential Transit-Oriented Development (TOD) in Jakarta Metropolitan Region. *Journal of Geoscience, Engineering, Environment, and Technology*, **3**, 47–56, 2018. https://doi.org/10.24273/jgeet.2018.3.01.1091.

[30] Taki HM, Maatouk MM. Spatial planning for potential green (TOD) using suitability Analysis at the Metropolitan Region scale. *IOP Conference Series: Earth and Environmental Science*, IOP publishing. vol. 160, 2018. https://doi.org/10.1088/1755-1315/160/1/012020.

[31] Sulistyaningrum, S., Sumabrata, J., Transit-Oriented Development (TOD) index at the current Transit nodes in Depok City, Indonesia. *IOP Conference Series: Earth and Environmental Science*, IOP publishing. vol. 126, p. 1–11, 2018. https://doi.org/10.1088/1755-1315/126/1/012217.

[32] Fajri, F.M., Sumabrata, J., Analysis of Transit-Oriented Development (TOD) Potential on Light Rail Transit Palembang, Simpang Polda Station Area. *MATEC Web of Conferences*, 259, 05003, 2019. https://doi.org/10.1051/matecconf/201925905003.

[33] Teklemariam, E.A., Shen, Z., Determining transit nodes for potential transit-oriented development: Along the LRT corridor in Addis Ababa, Ethiopia. *Frontiers of Architectural Research*, 2020. https://doi.org/10.1016/j.foar.2020.03.005.

[34] Calthorpe, P., *The Next American Metropolis: Ecology, Community, and the American Dream.*, Canada: Princeton Architectural Press, p. 1–73, 1993.

[35] Cervero, R., Kockelman, K., Travel Demand and the 3Ds: Density, Diversity, and Design. *Transportation Research Part D: Transport and Environment*, **2**,199–219, 1997. https://doi.org/http://dx.doi.org/10.1016/S1361-9209(97)00009-6.

[36] Dittmar, H., Ohland, G., The New Transit Town: Best Practices In Transit-Oriented Development. Bibliovault OAI Repository, the University of Chicago Press 2004.

[37] Ewing, R., Cervero, R., Travel and the Built Environment: A Synthesis. Transportation Research Record. *Journal of the Transportation Research Board*, vol. 1780, p. 87–114, 2001. https://doi.org/10.3141/1780-10.

[38] Belzer, D., Autler, G., Transit-Oriented Development (TOD): Moving From Rhetoric to reality. The Brookings Institution Center on Urban and Metropolitan Policy and The Great American Station Foundation 1–46, 2002.

[39] Ewing, R., Cervero, R., Travel and the Built Environment. *Journal of the American Planning Association*, **76**, 265–94, 2010. https://doi.org/10.1080/01944361003766766.

[40] Evans, J.E., Pratt, R.H., Stryker, A., Kuzmyak, J.R., Transit Oriented Development (TCRP Report 95) Traveler Response to Transportation System Changes Handbook, Transport Research Board of the National Academies. WASHINGTON, D.C. 2007. https://doi.org/10.17226/14077.

[41] Singh, Y.J., Identification of Indicators to measure Transit-Oriented Development (TOD). University of Twente, University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), Netherlands. (Unpublished Ph.D. Research), 2013.