Measurement of physical environment characteristics for supporting transit-oriented development areas for the Kufa city -Iraq

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Abstract

Planning for transit-oriented development TOD around existing stations or transportation nodes contributes to the development and improvement of the region in economic, environmental, and social terms. Therefore, this article seeks to identify the characteristics of the areas that encourage the establishment of a successful TOD project, and it was concluded that there are four basic characteristics in achieving, these are: adequate density, diversity in land use, mobility and accessibility, high economic development, good urban design, which in turn are divided into many measurable indicators, to provide a way to measure the potential TOD in these nodes, as the current transit-oriented development conditions will be assessed, and identifying the characteristics that need improvement, this matter will contribute to drawing up policies, plans, programs and financial interventions most effective in planning a successful and effective TOD that serves the city and contributes to its development.

Three nodes have been selected in the Kufa city -Iraq, which are: Mosque of Kufa node, University of Kufa node, and Cultural Palace node. It was found, through its study and analysis, that the Mosque of Kufa node contained the largest number of characteristics and indicators supporting the establishment of the TOD project.

Keywords: Transit-oriented development (TOD) , GIS, spatial analysis, characteristics (Cha.), indicators (Ind.), and standard (Sta.).

1. Introduction:

Transit-oriented development researchers provide a variety of definitions of this concept and use a variety of related concepts as well, including: "transit villages" and "transit-friendly design". Architect and planner Peter Calthorpe defined it as a mixed-use community located at an average distance of 2,000 feet on foot from a transit station and a prime commercial district. TOD combines residential, retail, public and office use and open spaces in a walkable environment, making it good and convenient for residents and employees to travel by transit, bike, foot, or car. Thus the basic principle of TOD is to provide a multi-use development close to transit and serve it well[1]. TOD works to develop cities for the better, by contributing land uses to reducing congestion and pollution, as well as supporting the economy of urban agglomerations by creating new job and housing opportunities that can be accessed through public transport, while providing multiple options from other modes of transport, reducing the need for using a private car, and achieving integration between transportation and land use, this is what helps

cities to become attractive places for work and housing[2]. TOD is defined as a relatively high-intensity urban development with a healthy mix of land use and an urban environment that is walkable, cycling or using public transportation instead of their cars, so the concept of TOD is an approach to sustainable development that relies on integration between land use and transportation[3].

Planning of TOD should not only be limited to establishing TOD, but also traffic must be brought to those sites that already possess the physical characteristics of a typical TOD, but do not have the transitory connection at that location, this indicates to follow a two-sided planning approach that ensures that the necessary planning interventions are made either to make urban development more transit-oriented or to transfer transit to places where the project is directed, i.e. the presence of appropriate density and other characteristics that encourage the establishment of TOD [4].

The research seeks to know and clarify the characteristics that encourage TOD in the Kufa city as a case study to contribute to the development of this city, and to be a guide in developing other Iraqi cities that have the same characteristics. By using the advantage of the environment of geographical information systems (GIS) that provide a good environment for decision-makers to get the best decisions in development issue[5].

2. Theory and formula

It has been proven that the presence of a number of environmental factors and physical design features greatly affect TOD's ability to increase passenger rates, the interest in the physical characteristics of the transit station and TOD has emerged as an integrated approach to transportation and land use planning, and the assessment of the current TOD condition and understanding of the heterogeneity of the

environment has also been emphasized before implementation becomes necessary to enhance the success of TOD nodes and stations[6].

Three main categories have been identified as important for planning TOD projects at the station level: the densities required to maintain transportation investments, mixed-use, and general environmental quality, especially in the issue of pedestrian access. An element of supporting material planning for TOD projects[7]. Other trends also emerged indicating the importance of distance to the station, and ease of access to the intended destination (land uses) in determining sites for development directed by transportation[6], also application management has been introduced that includes display and cost of parking as a sixth dimension and demographics as a seventh dimension[8].

The high urban density of residential and commercial real estate is an important and necessary issue for the success of TOD due to the efficient use of land close to the transit nodes, and it is also necessary to ensure that residents can walk or ride bicycles to reach the nearest public transport station[9, 10]. Density can be measured through many secondary indicators, namely population density and commercial density[6]. The high economic development in the area surrounding the transportation leads to a high potential for TOD[2], as economic development is related to employment levels and the intensity of commercial establishments[3], This results in an increase in the number of trips that people take at different times.

Diversity in land-uses is essential for effective utilization of transit in post-peak hours, and many literatures indicates that the above-mentioned density is the most beneficial to the success of TOD when it results in a mix of residential, commercial and office uses, as

most successful TOD projects are characterized by diversity In the uses of the land, which results in trips throughout the day and throughout the week[11], as the merging of services such as stores, health care, and schools encourage more domestic travel, evidence has shown that residents residing in various TOD regions in the United States of America have been making a large number of short trips, and this leads to a multiplicity of sustainable transportation options [9].

TOD projects depend on the good urban design due to its role in coordinating transportation types, mixing land uses and creating attractive public spaces [12], urban design also plays an important role in TOD as it creates easy-to-use environments to encourage pedestrian and bicycle users, provide public spaces and green spaces, as people come together and enjoy their neighborhood, as well as provide ideal parking spaces for cars and bicycles [6].

Many sources indicate the need for high-frequency and high-quality transport services to make public transport a good and attractive alternative to use instead of private cars [9].

Thus, we can conclude that there are a set of main characteristics that must be distinguished by the areas in which successful TOD projects can be established, and these characteristics, in turn, are divided into a set of measurable sub-indicators, which are as follows:

a- Density: as its presence contributes to supporting the establishment of a successful TOD project, and it can be measured through several secondary indicators, which are population density, commercial density, and business intensity as follows:

- Population density, which represents the number of inhabitants per unit area, as the percentage of the population within each service area, is measured with a radius of 800 meters, and it can be measured by adopting the formula: $PD = NP / A$….(1), and it is the standard of 120-200 people per hectare[13].

- Employment intensity can be measured by adopting 100 jobs per hectare.

- The density of intersections per hectare, the preferred boundaries are within 1.6 intersection/ha.

b-Land uses diversity: Diversity in land uses is an important measure to encourage TOD. Diversity requires a balanced mix of different land uses and is measured using the Simpsons Index [14]. It is calculated by the equation:

$$D_i = 1 - \sum(n/N)^2 ……(2)$$

In which n represents the area of each selected land use type (residential, commercial, and civic, for example) in hectares within the node. N represents the total area of the node, D_i is the resulting diversity index and is expressed as a value ranging from 0-1, where values closer to 0 mean less diversity and values closer to 1 mean greater diversity. Land allocated to public streets is typically excluded[15].

c-Movement and accessibility: It refers to the possibility of reaching places on short trips, as trips can be made outside working hours on foot if the residential land uses are sufficiently mixed with other types of land uses. It is measured through several secondary indicators:

-The effectiveness of the pedestrian and bicycle movement, it can be measured based on α index, its value ranges between (0-1), where the high value indicates greater effectiveness of the movement of the tire and bicycles[16].

$$α = (e - ν + 1)/(2ν-5) ...……(3)$$

Where (e) represents the number of segments (linkages) and the number of nodes (ν) in the street network respectively, and the α index value ranges between (0-1) and the higher value represents a high degree of

connectivity for the walking and riding network degrees, which means that a person can reach several places by different paths[17]

-The degree of network connectivity: as the network with good connectivity enables people to move safely and effectively, and gives a variety of options, allowing the choice of the appropriate road and means of transportation for the person, and it also reduces the time of travel, especially the response time to emergency services [18], network connectivity is defined as the extent to which streets are connected to each other with a numerical density of intersections, a large number of short links, and a small number of cul-de-sacs[19]

The average block length equation can be relied on to calculate this indicator according to the following equation:

ABL = Sum linkage length per unit of area / # nodes per unit of the area……(4)

-Frequency of transport service: The establishment of a TOD project is affected by the scale of the frequency of the transport service, as the frequency of the public transport means is calculated based on the number of transport means operating per hour at each station.

d-Urban design: It affects the quality of the city and can provide a wonderful design for the supposed TOD areas, it can be measured through many secondary indicators as follows:

-The existence of green spaces: The sources indicate the existence of several types of standards and methods of measurement to estimate the area required for the green area[20], and one of the most popular of these criteria is to determine a percentage of the total area of the urban area, and this percentage is usually determined at 10% of the total area[21].

-Car parking: There must be parking lots and the effective use of these spaces, as effective use is more than 90%.

-Existence of bicycle parking: The existence of spaces designated for parking bicycles and the effective use of more than 90%.

3.   Experimental setup:

Kufa is an Iraqi city and a district center that is administratively affiliated to the province of Najaf in the central Euphrates region , south of the capital, Baghdad, about 156 km away from it and 10 km northeast of Najaf with global coordinates of 44˚ 23' 55" latitude and 32˚ 02' 11" longitude. It is witnessing a continuous development and increasing population [22]. Three nodes were selected in Kufa city to test the presence of indicators that encourage the establishment of TOD, namely: Mosque of Kufa(A), University of Kufa(B), and Cultural Palace(C). It was chosen because it covers about 70% of the area of Kufa city. The previously mentioned indicators have been calculated as follows:

1-**Calculation of indicators of density**: Three indicators were adopted: the population density index, the business and employment intensity index, and the intersections density index, and the results appeared as in the table 1.

The population density was high in the Mosque of Kufa node, and very few in the University of Kufa node, the standard adopted in them was not achieved, but it was achieved in the Cultural Palace node as it reached 127 p/h, as shown in Figure (1).
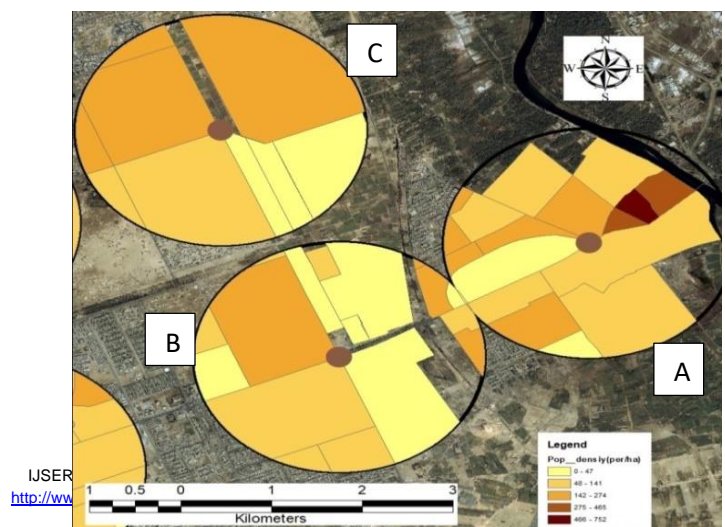

Figure 1 population density in study area.

Table 1 Calculation of indicators of density

characteristics	indicators	standard	A	B	C
Density	Population density	120-200 per / hectare	239	80	127
	Employment intensity	100 jobs per hectare	150	110	36
	Intersections density	1.6 intersection/h	0.94	1	1.85

The results showed that employment intensity was high in the Mosque of Kufa node, and the University of Kufa node, and it was very low in the Cultural Palace node, as shown in Figure (2). As for the intersections density, it was below the standard in the Mosque of Kufa node and the University of Kufa node, and it was close to the standard in the Cultural Palace node, as shown in Figure (3).
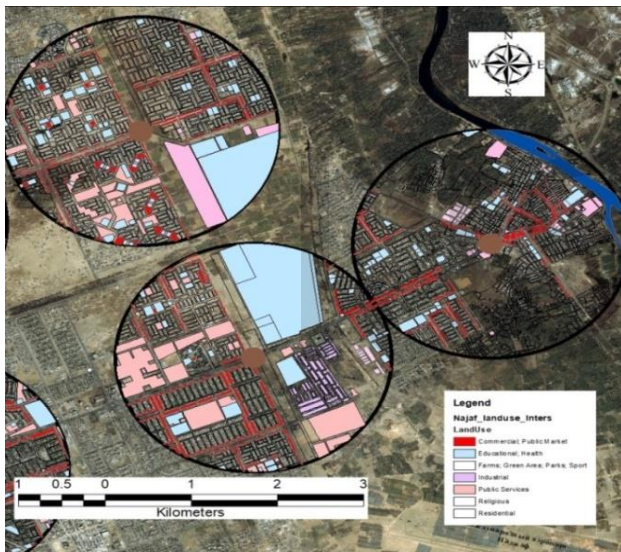
2-**Calculation of land use diversity**: To calculate the diversity indicators, the Simpson index was used for the selected nodes, and based on which the results of the selected nodes appeared in table 2.

From table 2 it shows that the value of the Simpson index was medium at the Mosque of Kufa node and the Cultural Palace node, it good at the University of Kufa node, as shown in Figure 4 .

Table (2) Calculation of land use diversity.

Cha.	Ind.	Sta.	A	B	C
Land uses diversity	Number of uses and their areas	0-1	0.65	0.8	0.62

Figure (2) employment intensity in study area
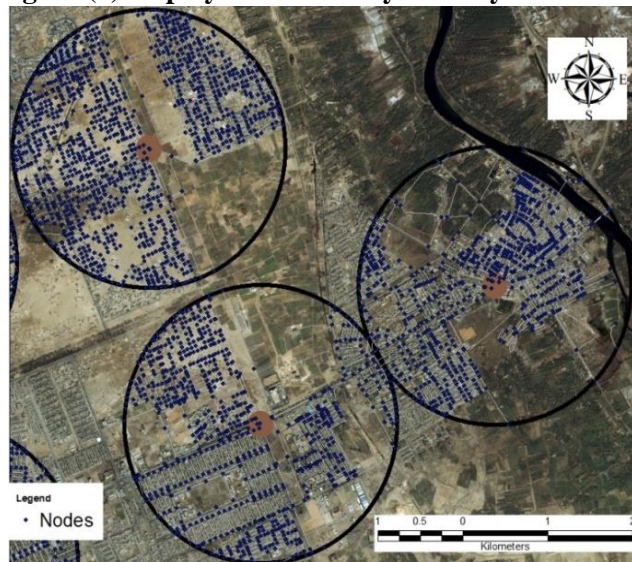
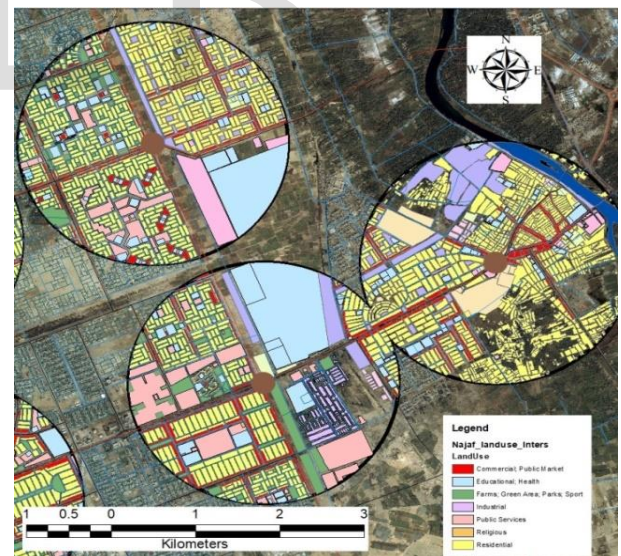**Figure (3) intersections density in study area**

Figure 4 land use diversity in study

3-Calculation of accessibility indicators: Alpha index, block length index, and transmission frequency index were used, and the results are as shown in table 3.

The results show that the Alpha index was higher in the Mosque of Kufa node than the other two nodes, as shown in Figure (5).

The results also showed that the block length index was consistent with the standard in the Mosque of Kufa node and Cultural Palace node, but it was higher than the standard specified in the University of Kufa node, due to the presence of long blocks for industrial land use, as shown in Figure 6.
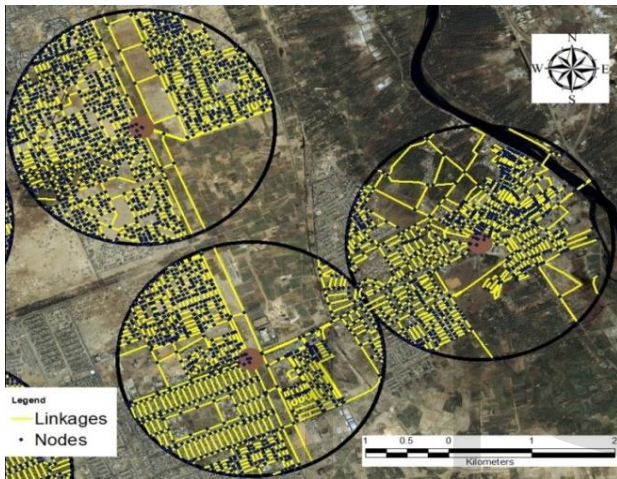

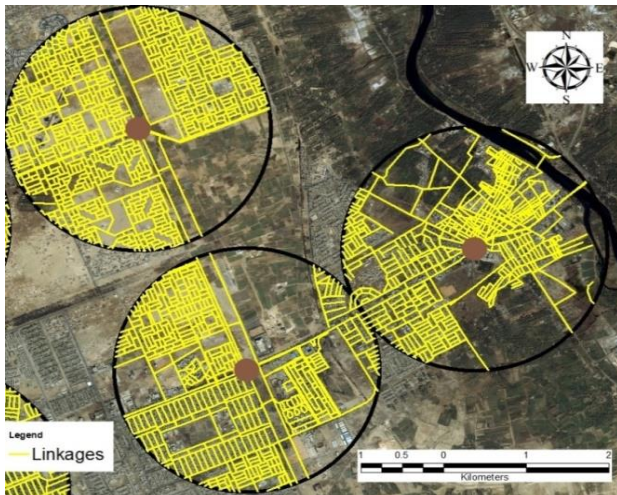**Figure 5 Alpha index in study area.**

Figure 6 Block length index in study area.

It was also evident through the field survey that the transport service frequency indicator was very high in Mosque of Kufa node and University of Kufa node, as it was at the rate of one public transport bus every five minutes,

which means there are 12 public transport buses per hour, this is a good and high rate, either in the Cultural Palace node where there is no public transport but rather relied on private transportation only.

Table 3 Calculation of accessibility indicators.

Cha.	Ind.	Sta.	A	B	C
Acc.	Alpha index	0-1	0.23	0.12	0.13
	block length index	150 M	129	184	91
	transmission frequency index	6Cars/ hour	12	12	0

4-**Calculation of urban design indicators**: We have been relying in this aspect on three indicators: the presence of green spaces, the existence of car parks, and the existence of bicycle parking, and it was found through the field survey that the last two indicators were not present in the study area, as there are no planned stops, but rather areas that are not Official and unplanned spread in separate locations, as for the presence of green spaces, the three nodes have achieved good proportions, as shown in the table (4) and Figure 7.

Table 4 presence of green spaces

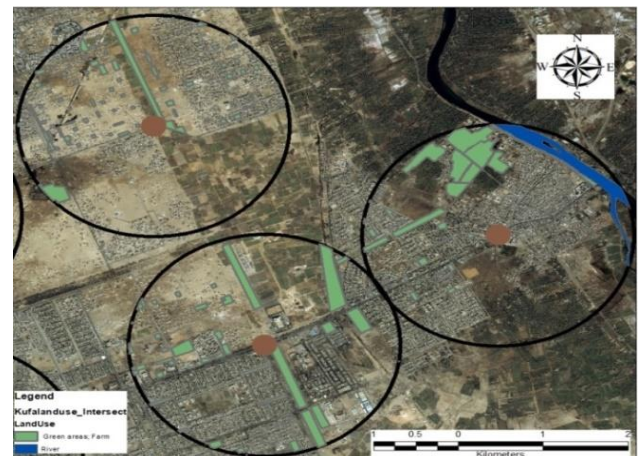| Nodes	percentage of green spaces
A	0.22
B	0.12
C	0.10

Figure 7 presences of green spaces in study

4. Result discussions

By reviewing the reality of the study area, it was found that the Mosque of Kufa node contains the largest number of characteristics and indicators that support and encourage the establishment of the TOD project, as it contains a high population density of about 239p/h, and a high business density about 150j/h, with a medium percentage of land use diversity, as well as the height of the alpha index and the block length index as well as the frequency of transport service, with a high percentage of green spaces. As for the University of Kufa node, despite its low population density, it is characterized by a high business intensity due to the presence of the buildings of the University of Kufa and the industrial district as well as many commercial jobs and this makes it an attractive area for trips, as it is characterized by a good percentage of diversity in land uses, and good frequency in transfer service, and good rate of green spaces. As for the Cultural Palace node, although its population density is within the limits of the standard, it is very poor in business intensity and this is what makes it an unattractive area for trips, as it contains a medium percentage of diversity in land uses, and a good block length rate, but it lacks the frequency in the transportation service as it depends on private transportation, with a percentage of green spaces less than other nodes.

Conclusion:

This article explains how the current features around the nodes can be used to support and encourage the establishment of TOD projects, this is what makes it easier for planners to work with regard to proposals and policies for development, financing, and investment, which also contributes to achieving the greatest benefit from the TOD projects that will be completed, as the nodes and the surrounding areas are more vibrant and effective than before. The current conditions have been assessed, and the characteristics that need improvement have been identified. This matter will contribute to drawing up policies and plans, programs, and financial interventions that are most effective in planning a successful and effective TOD that serves the city and contributes to its development.

Acknowledgements

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