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Measuring the accessibility of road networks: Diwaniya/Iraq as case study

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Networks,
Road,
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A B S T R A C T

Road networks, as one of the oldest infrastructures of transport in the world and it is play a main role in modernization, sustainable development, and human daily activities in both ancient and modern times. One of the most important problems in road network is how to evaluate the accessibility.To overcome this problemand measure the accessibility for each node in network must be extracted from the T-matrix, after indicated the class of it (spinal, grid or delta), and the degree of conductivity. In this research take the network ofDiwaniya city / Iraq as a case study;it was found the network of study area classified as grid type and great complexity,withwell connectivity between nodes. The node has more accessibility in the study area is (V82), the node has less accessibility is (V6), and can reach from any node to other in the network of study area at sixteen steps or less.

Introduction

The integrated development of any region depends fundamentally on the accessibility in general and the transport infrastructure in particular, (A. Ribeiro& J. Silva, 2011). Road networks, as one of the oldest infrastructures of transport in the world, it is play a key role in the urban spatial structure. One of the most important problems in road network is how to evaluate the accessibility (H. Weiping& W. Chi).Beside to the accessibility, the connectivity is important network Analysis techniques. Therefore, in this research attempts to find the accessibility and connectivity of road networks in Diwaniyacity.The accessibility of study area is determined by the T-matrix.The connectivity extracted from indices (Alpha, Beta and Gamma) depending on the degree of completeness link between street (linkages) and vertices (nodes).

Study area

The present study is restricted toDiwaniya city is considered the center of Qadisiyah province, Located in the central region of Iraq (the Middle Furat region) at 180 km south of Baghdad, Its absolute location at 32°00'N latitude and 45°00'E longitude, its area equal to fifty-two square kilometers,Diwaniya River divides Its into two parts (the big and the small side). The city is well connected by road with the major cities of IraqBabylon, Najaf, Wasit, Muthanna and Dhi- Qar.As shown in Figure (1)

Network analysis

Road networks, as one of the oldest infrastructures of transport in the world, occupy a significant locality in modernization, sustainable development, and human daily activities in both ancient and modern times. The road network of a high quality increases a nation's economic output by reducing journey times and costs, making a region more attractive economically, (M. Rogers, 2003).

The connection and arrangement of a road network is usually abstracted in network analysis as a directed planar graph G {v,e}, where v is a collection of nodes (vertices) connected by directional links (edges).

A two-way road consists of two adjacent and opposite one-directional links.(F. Xie& D. Levinson, 2007).

Many techniques have been done in the transportation network and for characterizing different ways are there (D. Levinson, 2012). Following are the most important Network Analysis Techniques.

1. Connectivity
2. Circuitry
3. Accessibility

Connectivity

The most fundamental properties of a Transportation network are measured by the Alpha Index, Beta Index and Gamma Index. For extraction of connectivity index it requires a road network (linkages), vertices (nodes). These indices can be useful for change detection system in network structure and also for traffic analysis.

An Alpha Index for connectivity is a ratio of circuits to the number of maximum possible circuits in the network. It gives possible values from 0.0 to 1.0, higher the value of index, higher the degree of connectivity within the network.

$\alpha = (e - v + 1) / (2v - 5)$ -------- (1)

Where, e = No. of edges (Line)
v = No .of Vertex (Node)

The Beta Index Measures the connectivity relating the no. of edges to the no. of nodes. It is more useful for simple network where no circuits are involved.Its value ranges from 0.0 to 1.0 and greater, where network are well connected. (A. D. Nagne, 2013), (A. D. Nagne& others, 2013).

$\beta = e / v$ ----------- (2)

Where, e = No. of edges (Line)
v = No .of Vertex (Node)

The Gamma Index is a Ratio of actual no. of edges to the Maximum possible no. of edges in the network.

$\gamma = e / (3(v - 2))$ ----------- (3)

Where, e = No. of edges (Line)
v = No .of Vertex (Node)

It's a useful ratio to evaluating the relative connectivity of an entire network values ranges from 0.36 to 1.0. Can use the gamma index to categorize those networks that fall between minimal and maximal connection. A classification used by engineers consists of three basic network configurations: spinal, grid and delta. (E. J. Taafe& others, 1996), (A. D. Nagne& others, 2013)

Spinal =$1/3 \leq \gamma \geq 1/2$
Grid = $1/2 \leq \gamma \geq 2/3$
Delta =$2/3 \leq \gamma \geq 1$

Accessibility

There are many definitions of accessibility in the literature; however, a general definition is that accessibility is the ease (or difficulty) that opportunities (e.g., employment) or services can be reached from a location. Accessibility captures the effort required to overcome the spatial separation of two locations, and usually reflects the utility (e.g., travelling from home to a job) associated with travelling between these locations (A. C. Ford & others, 2015).

This network analysis involves spatial, social and economic aspects with detail data, and involves a large amount of computation. Accessibility analysis is the collection, processing, and analysis of spatial and non-spatial data, (A. D. Nagne,2013).

The accessibility matrix

Representation of network as a matrix permits us five important aspects of network analysis that are not effectively treated by full network measures:

1. Placement: consideration should be given not just to the total number of linkage but also to where they are located within a given network.
2. Direct and in direct linkages: should both consider.
3. Attenuation: the differences between direct and in direct linkages should be treated.
4. Redundancy: corrections should be made for meaningless round trips.
5. Unequal linkages: in some cases, linkages should be assigned different weight instead of assuming that all are equi-valued. (E. J. Taafe& others, 1996).

The total accessibility (T-matrix)

Matrix tells us more than the indices (Alpha, Beta and Gamma), it does take into account the placement of linkage in the network. The total accessibility matrix produces from sum of multiplication series matrices that do show the number indirect connections or paths between individual nodes, this multiplication lasts until to have nonzero values in all cells or the two most remote nodes are linked to each other,(E. J. Taafe& others, 1996).

$T = \Sigma C^1 + C^2 + C^3 + \ldots.. + C^n$----------- (3)
$C^2 = C^1 * C^1$, $C^3 = C^1 * C^2$, ……, $C^n = C^1 * C^{n-1}$

Where, T = Total accessibility matrix
C^1 = accessibility matrix power 1,
C^2 = accessibility matrix power 2,....,C^n = accessibility matrix power n.

Material and Data

The data was extracted from the colorsatellite image which has a resolution of 0.6 m (cell size = (*X distance:* 0.600000, *Y distance:* 0.600000) m), three raster band. Geographic Coordinate System of these images isGCS_WGS_1984_UTM_Zone_38N and Projection is Transverse Mercator.

Methodology

Foranalysis the road network of the study area and evaluate theAccessibility and connectivity have been followed Methodologyas shown in Figure (3).

Digitizing process was conducted for roads and intersections of the city by used two types of features(Arc GIS 9.3,Arc Map, Arc Info), first feature is a point and the second is a line, where the points represent all the essential intersections (nodes) in the city and the line features represent the roads (linkages) connected between them.

Using the Microsoft Excel program conducted calculations of the network analysis for conductivity index and creation of successive matrices to junctions theintersections of network until reaching the total accessibility matrix (T- matrix).

Discussion

To find out the accessibility and connectivity of road networks in the study area, create a map contains no. of nodes = 136 and no. of linkages = 217. The nodes numbered from 0 to 135 (the two remote nodes in the network) and thelinkagesjunction between them numbered from 1 to 217, as shown in fig (4).

Connectivity of Road Networks in Study Area

The degree of connectivity is explainedfrom Alpha, BetaandGamma Index by using equation 1, 2 and 3, above as in the table (1).These indices is determined by relations between number of edges and number of nodes in network.

The connectivity of the network of the study area is well (the beta index values are more than 1) and has great complexity.

The networkof the study area classified as grid because the value of the gamma index is located between 1/2 and 2/3 and the Alpha index indicate the existence ofcircuits in the network.

Accessibility of Road Networks in Study Area

Accessibility is another important characteristic of transportation network. To evaluate the accessibility of individual nodes most look carefully at the internal structure of the network, and to do this,making a matrix each linkage is represented by cell contains a value equal to one,orit is contains a value equal to zero in a cell that no linkage between that particular origin node, *i*and destination node, *j*.The accessibility matrix of the network for the study area consists of 18496 cells, as shown in figure 5.

Figure5 shows the sample of accessibility matrix consists of 136 rows and 136 columns, for the study area.

The first measure of accessibility for each node comes from sums of rows for that vector,which represents the total of other nodes in the network that are connected to*i* by direct or one step connections.

The first matrix (direct linkage) showed many of the nodes have the same accessibility, the table (2) explain the some nods that have the same value of accessibility

The most remote nodes (V0 & V135) in the network are linked to each other at amatrix power eight; can reach from V0 to V135 by eight steps.But thematrixpower eight has zero values in some cells (there is cells don't connected together yet).

Thematrix power Sixteenhave nonzero values in all cells,can reach from V0 to any nodes in the network of study area at sixteen steps or less, the decision now must be stop powering the connection matrix, and add these matrices (from first matrix tomatrix power sixteen) to produce a useful single matrix (totalaccessibility matrix (T-matrix)).

After remove meaningless (redundancies) round trips from the row sums of T-matrix by eliminate the main diagonal cells (t_{ii}), the node has more accessibility in the network for area of study is (V82), Whichshows clearly its location on the network in Figure (6), all nods arranged descending from the moreaccessibility (V82) to less accessibility (V6), in table (3).

Conclusion

Accessibility is important characteristic of transportation network.The measure of accessibility for each node in the network must be extracted from the T- matrix,after indicated the class of it (spinal, grid or delta), and the degree of conductivity, the multiplication of accessibility matrices lasts until to the matrix with power (n) have nonzero values in all cells, andcannot sustainment linking themost remote nodes in the network.

The node has more accessibility in the network of the study area is (V82), and the node has less accessibility is (V6).

In the network of the study area,multiplication process of matrices stopped at matrix powersixteen, can reach from any node toother in the network of study area at sixteen steps or less.

Thenetwork of study area classified as grid type and it's have greater complexity.

The indices(Alpha, BetaandGamma) denote that the connectivity between nodes in the networks for area of study it's havingwell connected to each other.

Table.1 the degree of conductivity to the study area

No. vertices	No. Actual edges	No. minimum edges	No. maximum edges	α index	β index	Y index
136	217	135	402	0.307116105	1.595588235	0.539800995

Table.2 some of nodes have the same value in the direct connections accessibility matrix

All nodes have accessibility value = 4									
V1	V8	V12	V16	V20	V24	V28	V32	V33	V35
V40	V44	V47	V48	V49	V50	V52	V53	V54	V55
V56	V57	V61	V64	V65	V66	V68	V69	V71	V72
V73	V76	V81	V83	V84	V88	V90	V91	V92	V93
V96	V97	V98	V100	V101	V102	V103	V104	V106	V111
V112	V122	V124	V125	V126	V127	V130			

Table.3 all nodes arranged descending from the more to less accessibility

no.	Nodes	no.	Nodes	no.	Nodes	no.	Nodes
1	V82	35	V85	69	V7	103	V59
2	V71	36	V63	70	V28	104	V21
3	V72	37	V86	71	V125	105	V42
4	V83	38	V16	72	V120	106	V9
5	V54	39	V97	73	V78	107	V123
6	V55	40	V64	74	V58	108	V36
7	V88	41	V76	75	V17	109	V131
8	V53	42	V98	76	V29	110	V2
9	V84	43	V110	77	V126	111	V119
10	V90	44	V65	78	V31	112	V95
11	V48	45	V74	79	V79	113	V128
12	V101	46	V57	80	V94	114	V22
13	V49	47	V112	81	V62	115	V23
14	V47	48	V75	82	V20	116	V10
15	V73	49	V99	83	V8	117	V133
16	V102	50	V106	84	V35	118	V25
17	V91	51	V93	85	V34	119	V11
18	V89	52	V33	86	V121	120	V135
19	V69	53	V41	87	V27	121	V117
20	V52	54	V104	88	V105	122	V12
21	V70	55	V60	89	V122	123	V3
22	V81	56	V61	90	V129	124	V0
23	V100	57	V96	91	V114	125	V13
24	V87	58	V124	92	V19	126	V37
25	V56	59	V32	93	V130	127	V118
26	V111	60	V66	94	V80	128	V26
27	V44	61	V108	95	V1	129	V43
28	V92	62	V113	96	V18	130	V14
29	V50	63	V67	97	V127	131	V5
30	V46	64	V39	98	V116	132	V132
31	V40	65	V109	99	V115	133	V4
32	V103	66	V51	100	V134	134	V38
33	V68	67	V107	101	V24	135	V15
34	V45	68	V77	102	V30	136	V6

Figure.1 shows the residential neighborhoods of Diwaniya city

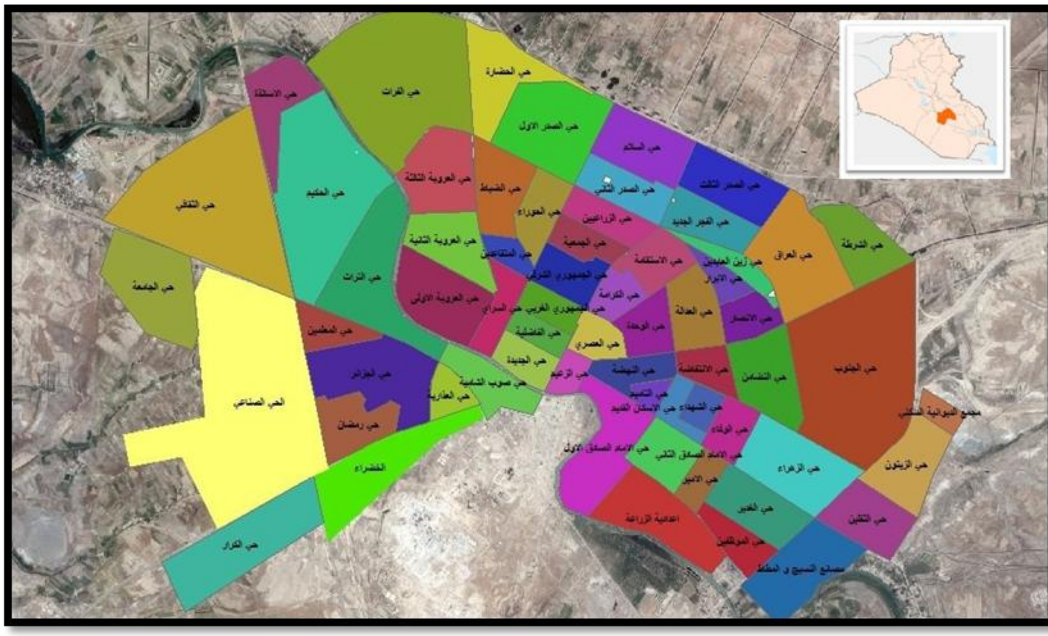


Figure.2 shows the satellite image of study area

Figure.3 shows the Methodology of Road Network Analysis

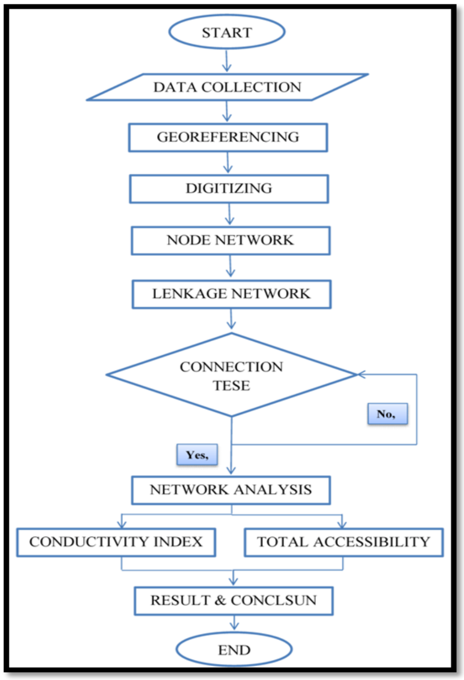
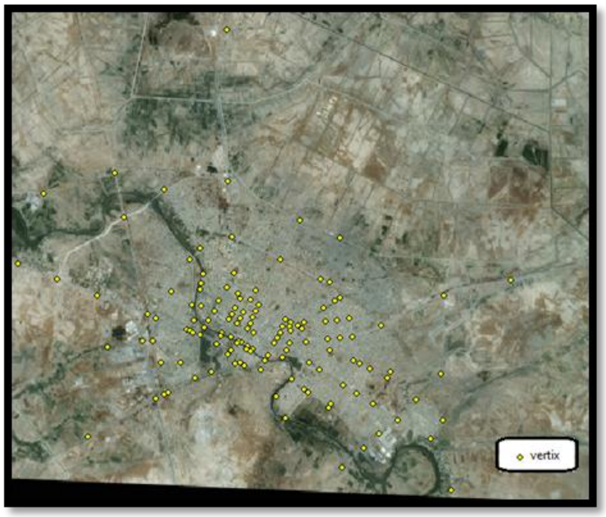
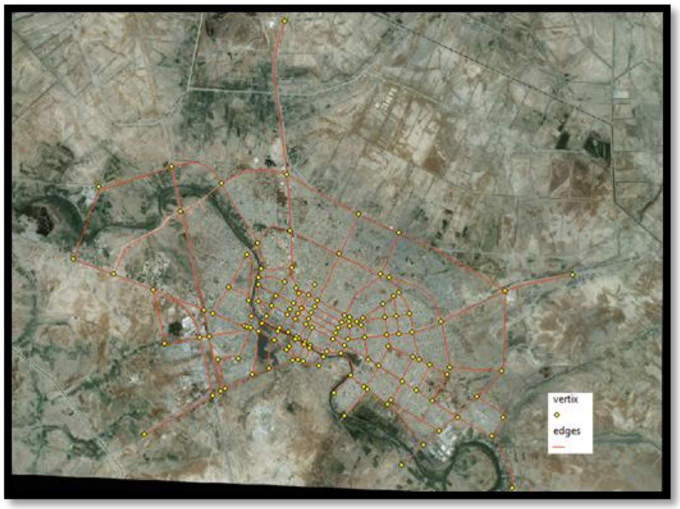


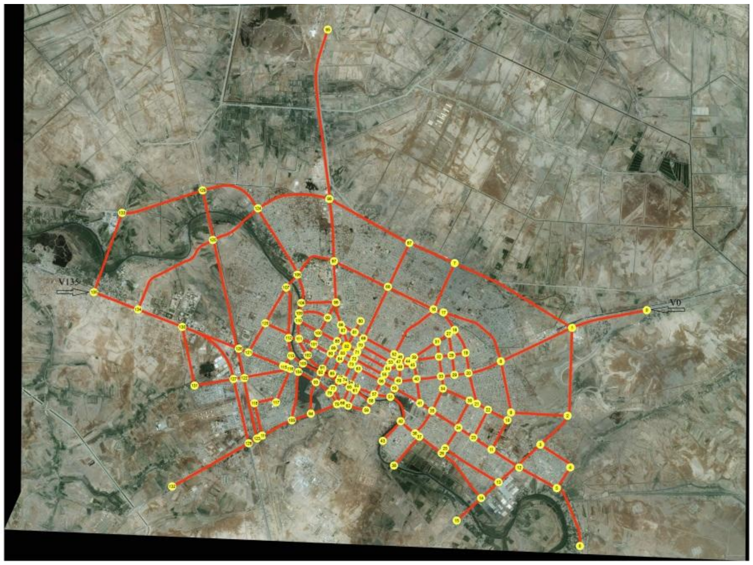
Figure4 (a) shows the nodes onsatellite image of study area, (b)shows the linkageon satellite image of study area, (c)shows the nodesand linkageof study area as a map with the most remote nodes V0 & V135



(a)



(b)



(c)

Figure.5 shows the sample of accessibility matrix consists of 136 rows and 136 columns, for the study area

	V0	V1	V2	V3	V4	V5	V6	v7	v8	....	V133	V134	V135
V0	0	1	0	0	0	0	0	0	0	----------------	0	0	0
V1	1	0	1	0	0	0	0	1	1	----------------	0	0	0
V2	0	1	0	1	0	0	0	0	0	----------------	0	0	0
V3	0	0	1	0	1	0	0	0	0	----------------	0	0	0
V4	0	0	0	1	0	1	0	0	0	----------------	0	0	0
V5	0	0	0	0	1	0	1	0	0	----------------	0	0	0
V6	0	0	0	0	0	1	0	0	0	----------------	0	0	0
V7	0	1	0	0	0	0	0	0	0	----------------	0	0	0
V8	0	1	0	0	0	0	0	0	0	----------------	0	0	0
:	:	:	:	:	:	:	:	:	:	: :	:	:	:
:	:	:	:	:	:	:	:	:	:	: :	:	:	:
:	:	:	:	:	:	:	:	:	:	: :	:	:	:
V133	0	0	0	0	0	0	0	0	0	----------------	0	0	1
V134	0	0	0	0	0	0	0	0	0	----------------	0	0	1
V135	0	0	0	0	0	0	0	0	0	----------------	1	1	0

Figure.6 shows the more accessibility node (V82) in the network of the study area

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