Accessibility Analysis of Roads Network in Ma'an Governorate

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Abstract
This study aims at analyzing the level of accessibility of the roads network of different types in Ma'an governorate in the south of Jordan through a set of standards proposed by Shimbel in 1953. The study adopted the descriptive analytical approach in the analysis of geographical information and data related to road networks and urban communities. To achieve the objectives of the study, statistical methods were also used in measuring the accessibility to the road network through some methods such as Shimbel Index and the Associated Number and others using the matrix method. The study found that there are differences in the accessibility to the nodes located on the road network in Ma'an governorate. Ma'an node was the easiest to access because of its central location compared to the other nodes, while Al-Mudawwara, Ras Al-Naqab and Husseiniya nodes were the most difficult to access as a result of their marginal and extreme locations far from the other nodes.

1. Introduction

The change in the accessibility to the road network plays a positive role in economic and social development. The ability to transport goods and services is a crucial element for development. Accessibility also determines the spatial characteristic of a region in relation to other regions; thus, it contributes effectively to regional development (Al-Hussein, 2011). Moreover, accessibility is a key element in the geography of transport in particular and in geography in general. The relationship between transport and geography is strong, not only because it is related to the branch of economic geography, but also because transport affects other branches of geography such as geopolitics, urban geography and the geography of services (Thatcher, 1958).

Accessibility to nodes is an important indicator that helps to determine spatial relationships within any region, as it is essential in land use planning and transport decision-making. It is also an easy tool to guide planning and development decisions (Gregory et al., 2009). Accessibility has become a prerequisite for achieving integration of urban areas centers and the surrounding areas, as well as for organizing the spatial area of entire cities and urban centers (Li and Lu., 2005).The development of the transportation sector in Jordan is a key factor in the process of economic development. The establishment of road networks has helped to link areas to each other and thus facilitate getting around among them. It also helped in the creation of the so-called regional specialization in agriculture and in industry. Furthermore, the establishment of road networks led to the optimal utilization of human and natural resources such as phosphate, cement and other minerals in southern Jordan, which contributed to support the national economy and improve the standard of living of the inhabitants of those areas.

Ma'an governorate is the largest governorate in Jordan. It is characterized by the widespread urban communities and the long distances between those communities. As a result, in habitants face inter-governorate and intra-governorate accessibility problems. These problems include the long time of arrival and the high cost of transportation, as well as the numerous means of transport they use during their journey. Hence, an analysis of the accessibility of the road network in this governorate is required in order to identify the nodes or the central vertices that are easier to reach as well as those which are more difficult to reach. This study aims at achieving the following objectives:

1. Evaluating the actual accessibility between the nodes or vertices in Ma'an Governorate and classifying the urban communities according to the actual accessibility.
2. Identifying the nodes or vertices that have high accessibility, thus forming central vertices in Ma'an Governorate.
3. Identifying the nodes or vertices that have reduced accessibility, thus form in peripheral or marginal vertices in Ma'an Governorate.

4. Determining the status of the road network and its role in linking urban communities in Ma'an Governorate.

2.Previous Studies

Several studies have dealt with the issue of accessibility in various places. These studies have applied many statistical methods in this regard. These studies include the following:

1. Aldagheiri (2014) a study on the analysis of accessibility of the roads network in Al-Qassim region in Saudi Arabia by calculating the number of direct connections between urban centers and the number of nodes between each two major nodes. The study concluded that the road network in the region is capable of contributing to economic development and reducing distances between major urban centers.
2. Wazi (2012) a study on accessibility assessment in Sana'a city using isochron maps. The study relied on time to measure the accessibility between the city center and its outskirts in an attempt to identify the causes of low accessibility in the city and then develop a plan to address these causes.
3. Al-Dosari(2011) a study on the traffic jams and the accessibility to Kuwait City. The study relied on the equal-time lines on the axes of road network from the outskirts of the city towards its center. The study identified the most important connections that have accessibility problems and suggested solutions.
4. Ighraieb (2010) a study on assessing the accessibility to urban nodes on the road network and their degree of centrality in Hebron Governorate. The study adopted the method of matrices and their indicators in order to determine the centralization of the nodes. The study showed that Hebron was ranked first in accessibility according to the criteria used in the study.
5. Scheurer and Curtis (2007) on accessibility measures: overview and practical applications. The study discusses seven categories of accessibility measures: spatial separation model, contour measures, gravity measures, competition measures, time-space measures, utility measures, and network measures; as well as the rules that govern each of these categories.
6. Vandenbulcke et al. (2009) a study on accessibility analysis in Belgium for transport planning and land-use. The study addressed the definition of accessibility and its multiple measures by building a matrix of origin and destination based on the distance and time of the journey.
7. Ghallab (2014) a study on the geographical assessment of the spatial accessibility to health services in Kafr El Dawwar countryside in Egypt using the geographic information systems. The study concluded that some towns such as Zahra, King Osman and Abis Al-Mustagida are the easiest to reach the Central Hospital in Kafr El Dawwar while the two towns of the Tarh and Sidi Ghazi are the most difficult to reach.

3. Study Area

Ma'an Governorate is located in the southern region of Jordan, extending between longitudes 35°and38°E, and latitudes 29°12′ -31°12′N. The administrative boundary reaches north to the border of Amman Governorate. The eastern and southern borders of Ma'an are the border between the Hashemite Kingdom of Jordan And Saudi Arabia. The study area also has borders with Karak and Tafila governorates in the north and west and the governorate of Aqaba in the west, as shown in Figure 1. The study area is a link between the most important governorates of the Kingdom (Al-Fanatsah, 2015).

Ma'an Governorate is the largest in the Hashemite Kingdom of Jordan. It covers an area of 32832 km^2, which is 37% of the area of the Kingdom (Department of Statistics, 2015). Ma'an governorate is administratively divided into four districts, as shown in Figure 2, namely: Ma'an (Al-Qasaba) district, which includes about 34 urban communities; Petra district, 12 urban communities; Shobak district, 14 urban communities; and Al-Husseiniya district with three urban communities.According to the General Population and Housing Census, the population of Ma'an governorate reached about 148000 in 2015, with a population density of (4.5 per km^2) of the total population density of the Kingdom (57.4 per km^2).The governorate's population is divided over the four districts mentioned above as follows: Ma'an (Al-Qasaba) district (89.497), Petra district (20.380), Shobak district (19.820), and Al-Husseiniya district (17.810), (Department of Statistics, 2015).

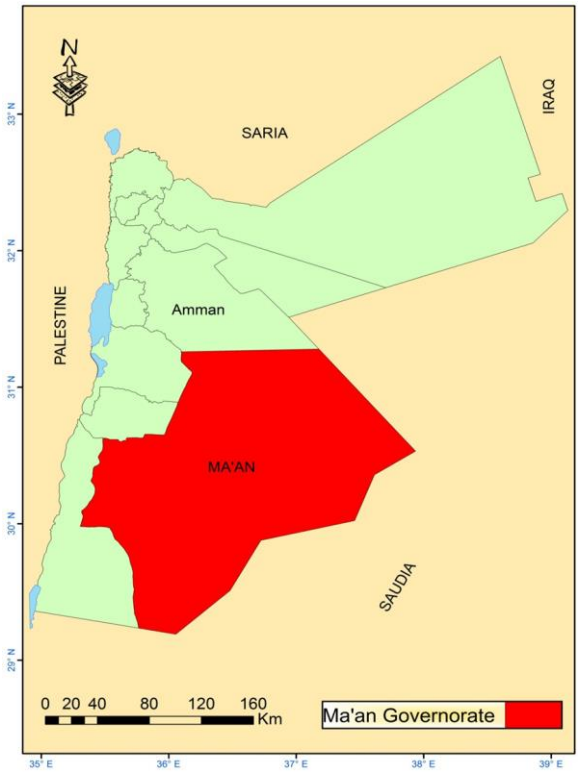

Figure 1: Study area

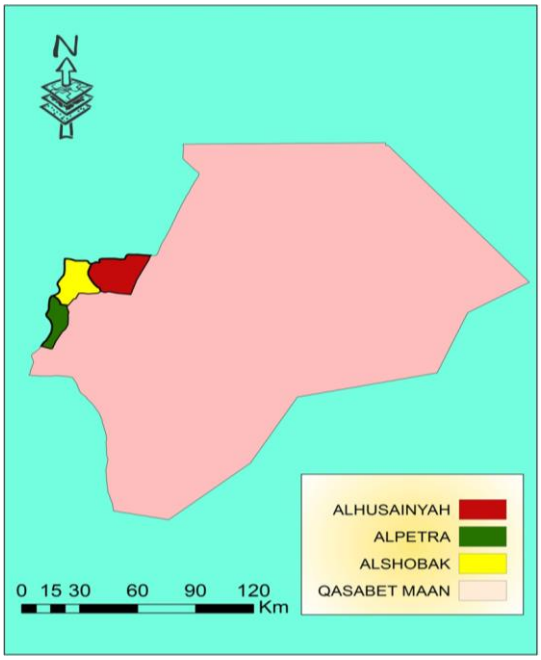

Figure 2:Districts of Ma'angovernorate

4.1 The Descriptive Analytical Approach

The study adopted the descriptive analytical approach. The locations of urban communities were examined in terms of their distribution and expansion in Ma'an governorate. Geographical information and data related to road network and urban communities were analyzed. Some methods were used to achieve the objectives of the study, including utilizing statistical methods in measuring the accessibility of the road network through using*Shimbel Index* and the *Associated Number* as well as using the matrix method. Furthermore, geographic information system (GIS), especially the *ArcGis 10.2* software was used to create the topological map of the road network which converts the complex road network to a simple abstract network that consists of lines and points, neglecting the direction and the real distance of the roads and traffic density on them.

4.2 Measuring Accessibility

There are multiple classifications and measurement methods for accessibility. For example, the classification of Handy and Niemeier in 2007 which classified accessibility into three categories, namely the Isochrone scale, an interaction-based scale, and a utility-based scale. Another classification suggested four basic accessibility criteria: an infrastructure-based scale, an activity-based scale, a passenger-based scale, and a utility-based scale (Gregory et al., 2009).

The classification on which the study was based is the one proposed by Shimbel (Rodrigue, 2020), based on the construction of a matrix to measure accessibility and communication between the nodes of the network (Abu Radhi, 1989). Accessibility is relative, depending on a number of geographic factors that distinguish nodes and the connections that link them to each other. Thus, preparing an Accessibility Matrix is one of the best quantitative methods to measure the relative importance of the nodes on transportation routes (Al-Zouka, 2005). The matrix is an appropriate means of storing data and showing the distances in the transport network. It is a table placed on the axes of the nodes or studied vertices to clarify the relations between them. The size of this relationship varies according to the various variables used in measuring accessibility such as the number of connections ending at each node and the distance between the nodes (Abdo, 2007). The value of zero is given for direct connection that does not need to be changed, while values are increased by the increase in the number of connections between the nodes or vertices in the network; and decreases when the connection between one node and the other is easy (Abu Assi, 2011).

4. Results and Discussion

Accessibility reflects the ease of movement within the region or territory. This ease reflects the comprehensiveness of the road network and its

ability to connect areas to each other. The more roads (direct connections) between nodes or vertices, the easier the transition from one node to another. Thus, accessibility to these nodes is increased (Muhammad, 2003). The accessibility indicator is one of the most important quantitative indicators used to measure the ease of access to any node or station in the network. The node on the road network is described as accessible or inaccessible. An accessible node is a node that is located near other nodes on the network and can be accessed with as few roads as possible (Al-Khashman, 2013).

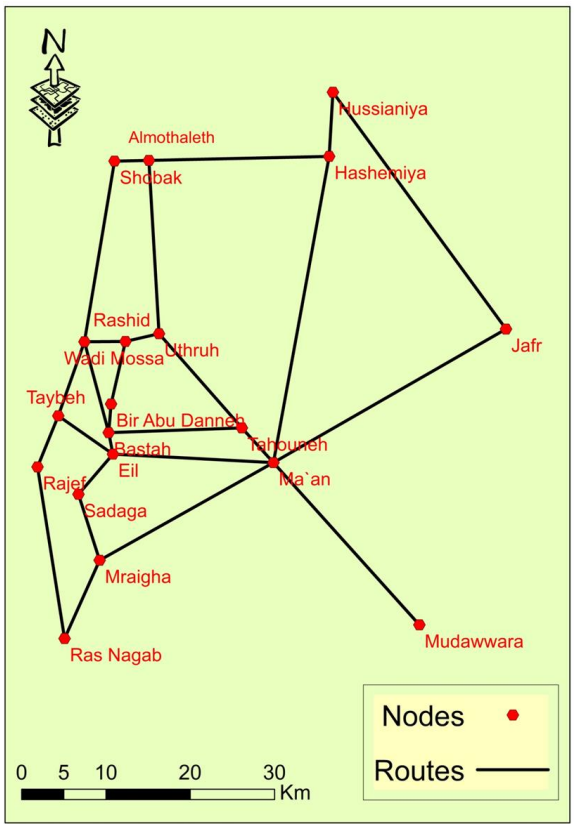

Figure 3:Topological Map of Ma'angovernorate

Determining the accessibility to the nodes or vertices located on the road network is beneficial for regional and urban planning processes. It guides decision-makers in selecting the optimal location for government services and facilities such as hospitals, universities, schools, civil defense centers, etc. These facilities are usually located in the most central urban centers for ease of access from all parts of the region or city in the shortest and least number of routes, thus reducing the distance and thereby reducing journey time and cost (Al-Khashman., 2013).It is so easy to identify nodes or central and remote vertices if the road network is simple; but when the road network is complex and contains a large number of roads and nodes, as in the case of Ma'an governorate, it is difficult to identify easily accessible nodes and inaccessible nodes. In that case we turn to other methods to measure accessibility (Muhammad, 2003).

Any road network has to be simplified and converted to a topological map prior to being studied and analyzed (Abu Hajjaj, 1989). Therefore, the road network in Ma'an governorate has been converted into a topological form using the ArcGIS 10.1 program. Due to the large number of populated areas in the governorate; the study was limited to the selection of the largest and most important populated places, which included 19 communities to cover the study area as shown in Figure 3. The road network in Figure 3 consists of nodes (peripheral populated areas), vertices (central populated areas), and edges (the roads that link nodes and vertices together).

4.1 Accessibility According to the Number of Connections between the Nodes (Shimbel Index)

To calculate accessibility according to the number of connections between nodes, we determine the number of connections in the matrix. Then, the nodes are arranged according to accessibility on the basis that the node that is connected to the rest of the other nodes through the least number of connections is the most accessible; while the node that is connected to the rest of the other nodes through the largest number of connections is the least accessible as shown in (Table 1). By applying this variable on the road network in the study area as shown in (Figure 4) we find the following:

1. There isn't any node or vertex in the road network that connects directly to all other nodes or vertices.
2. Ma'an node is ranked first in terms of accessibility with the lowest number of connections (35); thus, it is a central node. Eil node came second with (39) connections, then came Al-Tahounah node in third place with (40) connections.
3. Some of the other nodes came in the same rank: two nodes came in the fourth place with (42)connections, two nodes came in the fifth place with (43) connections, two nodes came in ninth place with (50) connections, two in the tenth place with (52) connections, and two in the thirteenth place with (56) connections.
4. Al-Husseiniya node came in the last place with the highest number of connections (58). This is due to the fact that it occupies a peripheral and marginal position in the

network and is isolated from the rest of the nodes in the far north of the governorate.

5. The distribution of some of the network nodes that are close to each other reveals the longitudinal extension of the road axes in Ma'an Governorate from north to south.

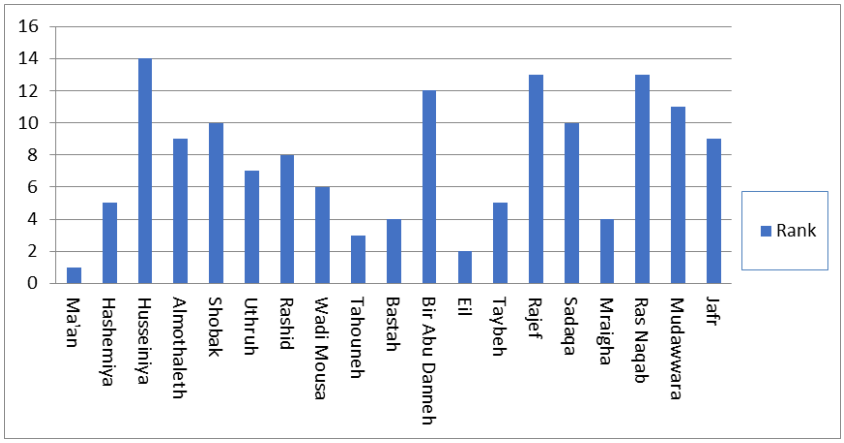

Figure 4: Nodes ranks according (*Shimbel Index*)

Table 1: Accessibility Matrix according to the number of connections between nodes (*Shimbel Index*)

Nodes	Ma'an	Hasheniya	Husseiniya	Almothaleth	Shobak	Uthruh	Rashid	WadiMousa	Tahouneh	Bastah	Bir Abu Danneh	Eil	Taybeh	Rajef	Sadaqa	Mraigha	RasNaqab	Mudawwara	Jafr
Ma'an	-	1	2	2	3	2	3	3	1	2	3	1	2	3	2	1	2	1	1
Hashemiya	1	-	1	1	2	2	3	3	2	3	4	2	3	4	3	2	3	2	2
Husseiniya	2	1	-	2	3	3	4	4	3	4	5	3	4	5	4	3	4	3	1
Almothaleth	2	1	2	-	1	1	2	2	2	3	3	4	3	4	5	4	5	3	3
Shobak	3	2	3	1	-	2	2	1	3	2	3	3	2	3	4	5	4	5	4
Uthruh	2	2	3	1	2	-	1	2	1	2	2	3	3	4	4	3	4	3	3
Rashid	3	3	4	2	2	1	-	1	2	2	1	3	2	3	4	4	4	4	4
WadiMousa	3	3	4	2	1	2	1	-	2	1	2	2	1	2	3	4	3	4	4
Tahouneh	1	2	3	2	3	1	2	2	-	1	2	2	3	4	3	2	3	2	2
Bastah	2	3	4	3	2	2	2	1	1	-	1	1	2	3	2	3	4	3	3
Bir Abu Danneh	3	4	5	3	3	2	1	2	2	1	-	2	3	4	3	4	5	4	4
Eil	1	2	3	4	3	3	3	2	2	1	2	-	1	2	1	2	3	2	2
Taybeh	2	3	4	3	2	3	2	1	3	2	3	1	-	1	2	3	2	3	3
Rajef	3	4	5	4	3	4	3	2	4	3	4	2	1	-	3	2	1	4	4
Sadaqa	2	3	4	5	4	4	4	3	3	2	3	1	2	3	-	1	2	3	3
Mraigha	1	2	3	4	5	3	4	4	2	3	4	2	3	2	1	-	1	2	2
RasNaqab	2	3	4	5	4	4	4	3	3	4	5	3	2	1	2	1	-	3	3
Mudawwara	1	2	3	3	5	3	4	4	2	3	4	2	3	4	3	2	3	-	2
Jafr	1	2	1	3	4	3	4	4	2	3	4	2	3	4	3	2	3	2	-
Total	**35**	**43**	**58**	**50**	**52**	**45**	**49**	**44**	**40**	**42**	**55**	**39**	**43**	**56**	**52**	**2**	**56**	**54**	**50**
Rank	**1**	**5**	**14**	**9**	**10**	**7**	**8**	**6**	**3**	**4**	**12**	**2**	**5**	**13**	**10**	**4**	**13**	**11**	**9**

4.2 Accessibility According to the Associated Number

The associated number indicates the highest number in the cells of the column or row connected to the vertex or node in the accessibility matrix. To calculate accessibility according to the value of the number associated to the nodes, we determine the highest value connected to each vertex in the matrix. Then, the nodes are arranged on the basis that the node which is connected to the other nodes with the lowest number associated to the nodes is the most accessible to the rest of the nodes of the network, while the node that is connected to the rest of the nodes with the largest number associated to the nodes is the least accessible (Table 2). When applying this variable to the road network in the study area, as shown in (Figure 5), we find the following:

1. There is no significant difference between the nodes or vertices of the study area in accessibility according to the Associated Number, as the values of the associated number ranged between 3-5 connections.
2. Ma'an node was ranked first in terms of accessibility according to the associated number and thus represents a central node. It had the lowest value of the number associated to it at 3 connections, which indicates that it has a central location.
3. Many nodes in the study area had the same rank of accessibility. Nine nodes had the second rank and other nine had the third rank in accessibility.
4. It was found that Husseiniya node or vertex came in last place in accessibility. This corresponds to the result of the analysis of accessibility according to the number of connections between the nodes.
5. Most of the nodes that were inaccessible according to the number of connections between the nodes were ranked last in accessibility according to the Associated Number, such RasNaqab, Rajef, Abu Danneh, Mudawwara, Shobak and others.

Table 2: Accessibility Matrix according to the number of connections between nodes (*Associated Number*)

Nodes	Ma'an	Hasheniya	Husseiniya	Almothaleth	Shobak	Uthruh	Rashid	WadiMousa	Tahouneh	Bastah	Bir Abu Danneh	Eil	Taybeh	Rajef	Sadaqa	Mraigha	RasNaqab	Mudawwara	Jafr
Ma'an	-	1	2	2	3	2	3	3	1	2	3	1	2	3	2	1	2	1	1
Hashemiya	1	-	1	1	2	2	3	3	2	3	4	2	3	4	3	2	3	2	2
Husseiniya	2	1	-	2	3	3	4	4	3	4	5	3	4	5	4	3	4	3	1
Almothaleth	2	1	2	-	1	1	2	2	2	3	3	4	3	4	5	4	5	3	3
Shobak	3	2	3	1	-	2	2	1	3	2	3	3	2	3	4	5	4	5	4
Uthruh	2	2	3	1	2	-	1	2	1	2	2	3	3	4	4	3	4	3	3
Rashid	3	3	4	2	2	1	-	1	2	2	1	3	2	3	4	4	4	4	4
WadiMousa	3	3	4	2	1	2	1	-	2	1	2	2	1	2	3	4	3	4	4
Tahouneh	1	2	3	2	3	1	2	2	-	1	2	2	3	4	3	2	3	2	2
Bastah	2	3	4	3	2	2	2	1	1	-	1	1	2	3	2	3	4	3	3
Bir Abu Danneh	3	4	5	3	3	2	1	2	2	1	-	2	3	4	3	4	5	4	4
Eil	1	2	3	4	3	3	3	2	2	1	2	-	1	2	1	2	3	2	2
Taybeh	2	3	4	3	2	3	2	1	3	2	3	1	-	1	2	3	2	3	3
Rajef	3	4	5	4	3	4	3	2	4	3	4	2	1	-	3	2	1	4	4
Sadaqa	2	3	4	5	4	4	4	3	3	2	3	1	2	3	-	1	2	3	3
Mraigha	1	2	3	4	5	3	4	4	2	3	4	2	3	2	1	-	1	2	2
RasNaqab	2	3	4	5	4	4	4	3	3	4	5	3	2	1	2	1	-	3	3
Mudawwara	1	2	3	3	5	3	4	4	2	3	4	2	3	4	3	2	3	-	2
Jafr	1	2	1	3	4	3	4	4	2	3	4	2	3	4	3	2	3	2	-
Associated Number	**3**	**4**	**5**	**5**	**5**	**4**	**4**	**4**	**4**	**4**	**5**	**4**	**4**	**5**	**5**	**5**	**5**	**5**	**4**
Rank	**1**	**2**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**3**	**2**	**2**	**3**	**3**	**3**	**3**	**3**	**2**

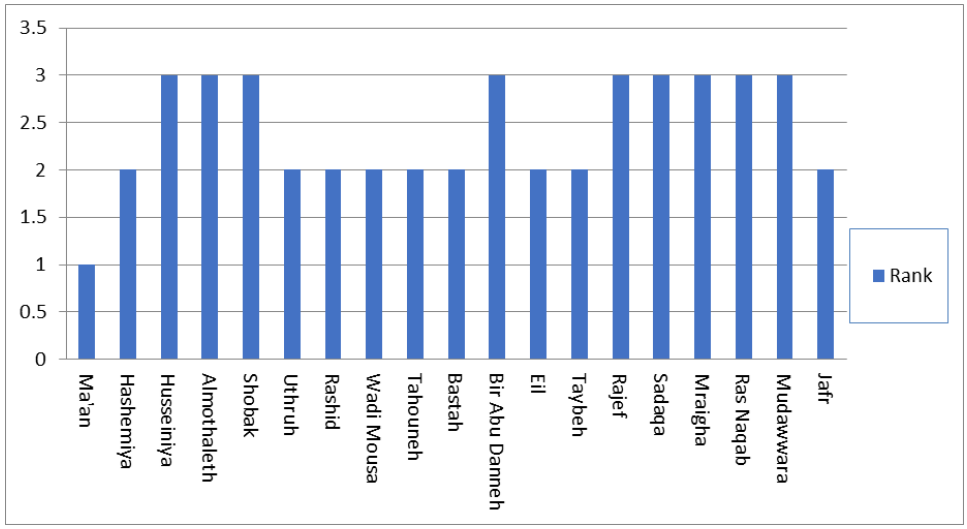

Figure 5: Nodes Ranks according to the Associated Number

Table 3: Accessibility Matrix according to the length of connections between the nodes/km

Nodes	Ma'an	Hashemiya	Husseiniya	Almothaleth	Shobak	Uthruh	Rashid	WadiMousa	Tahouneh	Bastah	Bir Abu Danneh	Eil	Taybeh	Rajef	Sadaqa	Mraigha	RasNaqab	Mudawwara	Jafr
Ma'an	-	39	47	63	67	23	33	36	4	23	27	21	30	40	34	26	41	125	66
Hashemiya	39	-	8	29	33	65	72	75	43	62	36	60	69	79	81	65	80	164	60
Husseiniya	47	8	-	37	41	73	80	83	51	70	44	68	77	87	89	73	88	172	54
Almothaleth	63	29	37	-	4	36	46	39	55	53	49	56	49	59	64	89	104	188	87
Shobak	67	33	41	4	-	38	50	35	59	57	53	60	45	55	68	93	108	192	91
Uthruh	23	65	73	36	38	-	10	13	19	17	13	20	33	43	28	46	61	148	91
Rashid	33	72	80	46	50	10	-	13	29	7	3	10	23	33	18	36	51	158	99
WadiMousa	36	75	83	39	35	13	13	-	32	15	11	18	10	20	26	41	51	161	102
Tahouneh	4	43	51	55	59	19	29	32	-	19	23	22	31	41	30	34	59	129	95
Bastah	23	62	70	53	57	17	7	15	19	-	4	3	12	22	11	25	48	148	89
Bir Abu Danneh	27	36	44	49	53	13	3	11	23	4	-	7	16	26	15	29	44	152	93
Eil	21	60	68	56	60	20	10	18	22	3	7	-	9	19	8	22	37	146	87
Taybeh	30	69	77	49	45	33	23	10	31	12	16	9	-	10	18	31	41	155	96
Rajef	40	79	87	59	55	43	33	20	41	22	26	19	10	-	13	27	31	165	106
Sadaqa	34	81	89	64	68	28	18	26	30	11	15	8	18	13	-	14	29	159	100
Mraigha	26	65	73	89	93	46	36	41	34	25	29	22	31	27	14	-	15	151	92
RasNaqab	41	80	88	104	108	61	51	51	59	48	44	37	41	31	29	15	-	166	107
Mudawwara	125	164	172	188	192	148	158	161	129	148	152	146	155	165	159	151	166	-	191
Jafr	66	60	54	87	91	91	99	102	95	89	93	87	96	106	100	92	107	191	-
Total	**745**	**1120**	**1242**	**1107**	**1149**	**777**	**771**	**781**	**775**	**685**	**645**	**673**	**755**	**876**	**805**	**909**	**1161**	**2870**	**1706**
Rank	**4**	**14**	**17**	**13**	**15**	**8**	**6**	**9**	**7**	**3**	**1**	**2**	**5**	**11**	**10**	**12**	**16**	**19**	**18**

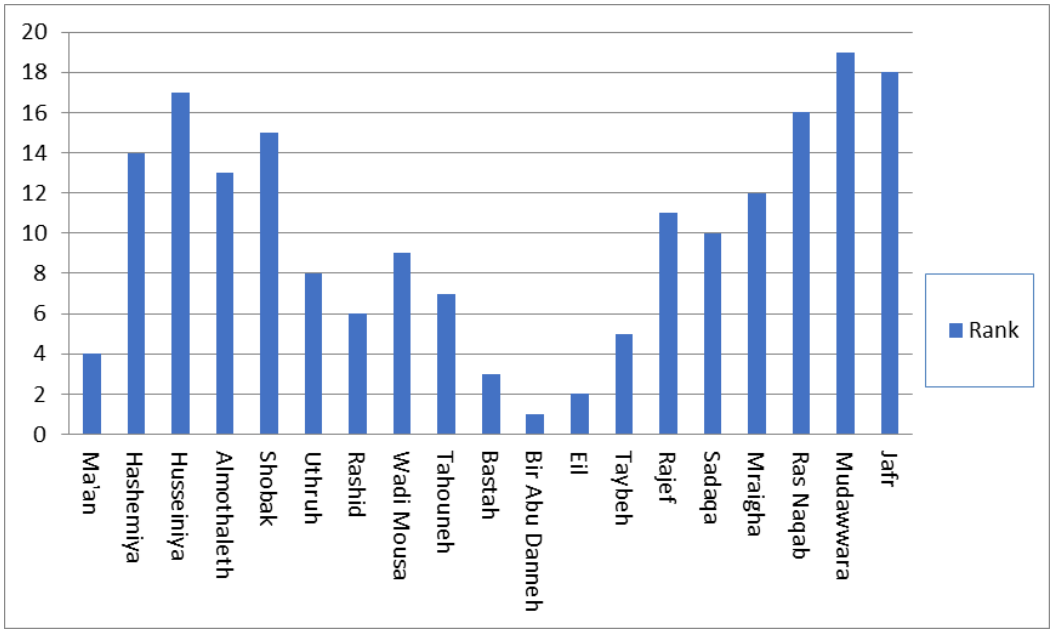

Figure 6: Nodes Ranks according to the length of connections between them

4.3 Accessibility According to the Length of Connections between the Nodes (Distance)

The node that is connected to the rest of the network nodes via the least total of connections lengths is the most accessible to the rest of the network nodes. The general rule states that travelers prefer taking the shortest routes to the rest of the network nodes (Muhammad, 2003).Based on the number of nodes in the study area, the variable used requires the creation of a matrix showing the distances between nodes, as shown in Table 3. Based on the accessibility matrix according to the length of connections between the nodes, we found the following (Figure 6):

1. The connections between the nodes in Ma'an governorate are characterized by being long, which confirms the wide spread of the nodes or urban clusters in the region due to the large area occupied by Ma'an governorate compared to other Jordanian governorates.
2. The lengths of the connections between the nodes range between 645-2870km. The node of Bir Abu Danneh (645 km) ranked first in accessibility based on the lengths of connections between the nodes (distance) with an average distance of about (34 km), followed by Eil, Bastah and Ma'an nodes which ranked second, third and fourth (673 km, 685 km, 745 km), respectively.
3. Mudawwara node (2870km) ranked last in accessibility based on the lengths of connections between nodes with an average distance of (151 km.). This is due to its location on the road network having no direct connections with the rest of the other nodes.
4. It can be noted that the importance of the nodes according to the distance between them in accessibility is not consistent with the population, urban and economic importance. Ma'an node came in the fourth place, although it represents the population and economic weight in the study area. This is due to the large spatial area of the governorate, which is reflected in the lengths of the distances between the nodes.

4.4 Accessibility According to the Number of Nodes between Each Two Nodes

This variable is based on the assumption that the most accessible node is the one that is connected directly to other nodes without the need to change stations. (Al-Ruwaythi, 1992). On this basis, the matrix can be configured to determine points of change (inter-nodes) between every two nodes on the road network. Thus, the node that registers the lowest number of inter-nodes is the most accessible, as shown in Table 4.We conclude the following from the Accessibility Matrix according to the number of nodes between every two nodes (Figure 7):

1. The number of inter-nodes between each two nodes ranges between34 to 59 nodes. The difference between these two values represents the intermediate node in its

position with reference to the road axes in the study area.

2. Ma'an node is ranked first (34 nodes) in terms of accessibility according to the number of inter-nodes, indicating its central position compared to other nodes in the region.
3. Husseiniya node ranked last (59 nodes) in terms of accessibility according to the number of inter-nodes. This result corresponds to the result of accessibility according to the number of connections between the nodes, which confirms the relatively distant location of this node from the rest of the other nodes.

4.5 Overall Accessibility of the Road Network

This variable is based on the combination of two or more variables in order to eliminate the defects of each variable. It can be measured by combining two related variables such as the number of inter-nodes and the length of the connections between the nodes. To combine the two variables, we assume that each change in pathway from one node to another is equivalent in cost and effort to an average of 10 km (Muhammad, 2003). Table 5 shows the overall accessibility between network nodes.Although the overall accessibility variable is based on the lengths of the connections variable and the number of inter-nodes variable, it is an important indicator of accessibility between the road network nodes in Ma'an Governorate.

Table 4: Accessibility Matrix according to the number of nodes between every two nodes

Nodes	Ma'an	Hashemiya	Husseiniya	Almothaleth	Shobak	Uthruh	Rashid	WadiMousa	Tahouneh	Bastah	Bir Abu Danneh	Eil	Taybeh	Rajef	Sadaqa	Mraigha	RasNaqab	Mudawwara	Jafr
Ma'an	-	1	2	2	2	2	3	3	1	2	3	1	2	3	2	1	2	1	1
Hashemiya	1	-	1	1	2	2	3	3	2	3	4	2	3	4	3	2	3	2	2
Husseiniya	2	1	-	2	3	3	4	4	3	4	5	3	4	5	4	3	4	3	2
Almothaleth	2	1	2	-	1	1	2	2	2	3	3	3	3	4	5	4	5	3	3
Shobak	2	2	3	1	-	2	2	1	3	2	3	3	2	3	4	5	4	4	4
Uthruh	2	2	3	1	2	-	1	2	1	2	2	3	3	4	4	3	4	3	3
Rashid	3	3	4	2	2	1	-	1	2	4	1	3	2	3	4	4	4	4	4
WadiMousa	3	3	4	2	1	2	1	-	3	1	2	2	1	2	3	4	3	4	5
Tahouneh	1	2	3	2	3	1	2	3	-	3	2	2	3	4	3	2	3	2	2
Bastah	2	3	4	3	2	2	4	1	3	-	1	1	2	3	2	3	4	3	3
Bir Abu Danneh	3	4	5	3	3	2	1	2	2	1	-	2	3	4	3	4	5	4	4
Eil	1	2	3	3	3	3	3	2	2	1	2	-	1	2	1	2	3	2	2
Taybeh	2	3	4	3	2	3	2	1	3	2	3	1	-	1	2	3	2	3	3
Rajef	3	4	5	4	3	4	3	2	4	3	4	2	1	-	3	2	1	4	4
Sadaqa	2	3	4	5	4	4	4	3	3	2	3	1	2	3	-	1	2	3	3
Mraigha	1	2	3	4	5	3	4	4	2	3	4	2	3	2	1	-	1	2	2
RasNaqab	2	3	4	5	4	4	4	3	3	4	5	3	2	1	2	1	-	3	3
Mudawwara	1	2	3	3	4	3	4	4	2	3	4	2	3	4	3	2	3	-	2
Jafr	1	2	2	3	4	3	4	5	2	3	4	2	3	4	3	2	3	2	-
Total	**34**	**43**	**59**	**49**	**50**	**45**	**51**	**46**	**43**	**46**	**55**	**38**	**43**	**56**	**52**	**48**	**56**	**52**	**52**
Rank	**1**	**3**	**13**	**7**	**8**	**4**	**9**	**5**	**3**	**5**	**11**	**2**	**3**	**12**	**10**	**6**	**12**	**10**	**10**

Figure 8 shows the following:

1. Eil node preserved the first place of accessibility to the rest of the network nodes with an index of (1.053 km), which confirms its central location and ease of communication with other nodes in the network.
2. It was found that Ma'an node also retained the second position with an index of (1.085 km), which indicates that it has an intermediate position between the nodes of the network. Bastah and Taybeh also came in third and fourth places respectively.
3. It is noted that there is a slight difference in the levels of accessibility of the network nodes according to this variable compared to the other variables.
4. Jafr and Mudawwara nodes retained the 18th and 19th places with (2.226 km) and (3390 km) respectively. These nodes are therefore having the lowest accessibility, indicating that they have marginal locations that are far away from the other nodes of the network.

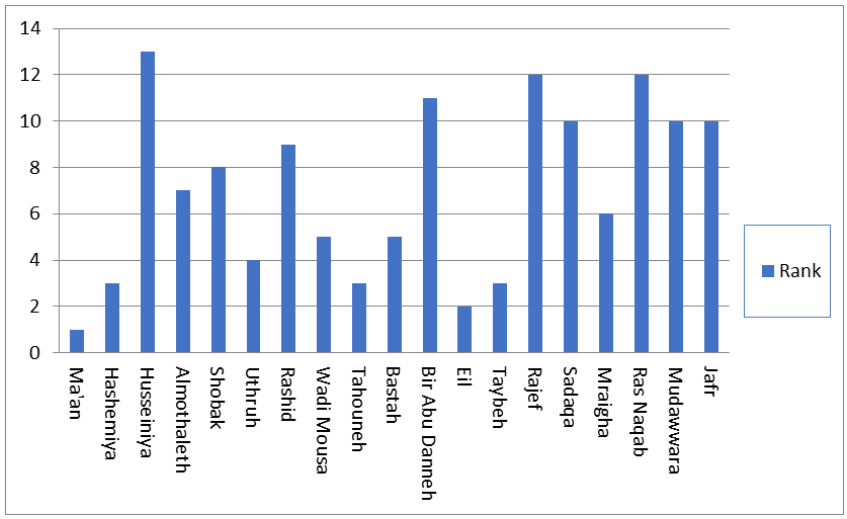

Figure 7: Nodes Ranks according to the number of nodes between every two nodes

Table 5: Overall accessibility of the road network

Nodes	Variables in km. No. of nodes X 10 (1)	Actual distance (2)	Accessibility	
			Total (1 + 2)	Rank
Ma'an	34 x 10 = 340	745	1085	**2**
Hashemiya	43 x 10 = 430	1120	1550	**13**
Husseiniya	59 x 10 = 590	1242	1832	**17**
Almothaleth	49 x 10 = 490	1107	1597	**14**
Shobak	50 x 10 = 500	1149	1649	**15**
Uthruh	45 x 10 = 450	777	1227	**7**
Rashid	51 x 10 = 510	771	1281	**9**
WadiMousa	46 x 10 = 460	781	1241	**8**
Tahouneh	43 x 10 = 430	775	1205	**6**
Bastah	46 x 10 = 460	685	1145	**3**
Bir Abu Danneh	55 x 10 = 550	645	1195	**3**
Eil	38 x 10 = 380	673	1053	**1**
Taybeh	43 x 10 = 430	755	1185	**4**
Rajef	56 x 10 = 560	876	1436	**12**
Sadaqa	52 x 10 = 520	805	1325	**10**
Mraigha	48 x 10 = 480	909	1389	**11**
RasNaqab	56 x 10 = 560	1161	1721	**16**
Mudawwara	52 x 10 = 520	2870	3390	**19**
Jafr	52 x 10 = 520	1706	2226	**18**

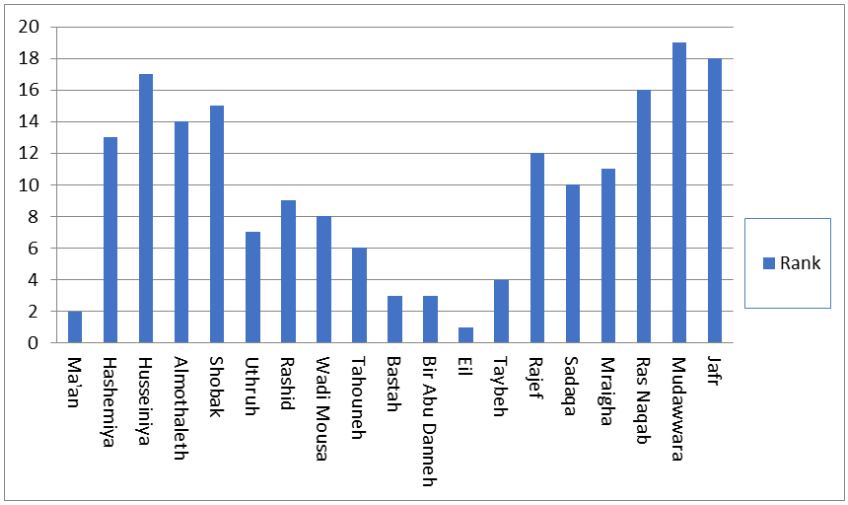

Figure 8: Nodes Ranks according Overall accessibility

Finally, based on the results of the analysis, it was found that Ma'an city node obtained the first place according to most of the scales and variables that were relied upon in this study. On the other hand, the other nodes' accessibility levels varied according to the variable used, but this variation was to a limited extent as some nodes have maintained the same rank in more than a variable. The overall accessibility variable is a true average of the nodes 'ranks of accessibility as it depends on more than one variable and thus can be relied upon in the overall ranking of accessibility.

5. Conclusions

The construction of matrices in geographical research and studies is an important means to obtain precise and accurate results, especially in the analysis of road networks. Ma'an node retained its position in the first place in accessibility according to almost all variables and scales adopted in the study, due to its central position from other nodes in the network. Ma'an node ranked fourth in accessibility according to the lengths of the connections variable (distance) with a total of 745 km, due to the wide spread of the nodes in Ma'an governorate and the vast area of the governorate. Al-Mudawwara, Al-Jafr, Ras Al-Naqab and Al-Husseiniya nodes suffer from difficulty in accessibility, as these nodes occupied the last places of accessibility according to the variables used, due to their marginal location on the road network.

In addition to that, Husseiniya node ranked last according to the number of connections between the nodes and the number of inter-nodes due to its peripheral location in the far north of Ma'an Governorate. Mudawwara node ranked last according to the length of connections between the nodes and the overall accessibility variable as a result of its marginal location in the far south-east of Ma'an governorate, the same goes for Al-Jafr and Ras Al-Naqab nodes. The other nodes ranks varied according to the variable used but to a limited extent, so that some nodes maintained the same rank in more than one variable or index such as Eil, Sadaqa and Rashid nodes. The overall accessibility variable is a true average of the node's ranks in accessibility as it is based on more than one variable.

6. Recommendations

Considering the findings of the study of the accessibility to the road network in Ma'an Governorate, the Planning for new alternative and shortcut roads that will increase accessibility to the nodes that is difficult to access such as Al-Jafr, Mudawwara, Husseiniya and Ras Al Naqab.And Working on achieving a spatial balance between the levels of accessibility of the accessible nodes as well as the inaccessible nodes. And Increasing the attention to the importance of accessibility to the city of Petra in Wadi Musa; as it recorded medium levels of accessibility according to the variables used in the study, given its touristic and economic importance in the region. and Establishing an integrated road database in Ma'an governorate to address accessibility in a scientific way away from guessing and speculating. And Paying more attention to the use of modern technologies such as geographic information systems GIS by government institutions; and the use of road network analysis in the studies of accessibility due to the precise and accurate results provided by these technologies. Finally, The expansion of such studies and generalizing this study to other governorates; and conducting comparison between these governorates

in order to guide development projects and regional planning.

References

Abdo, S., 2007, *Geography of Transport and its Implications*, Egypt: Anglo-Egyptian Library.

Abdo, S., 1989, Road Network in the UAE: Quantitative and Analytical Study. *Arabic Geographic Journal*, Vol. 21, 109-142.

Abu Assi, I, E., 2011, *Transport Planning and Policies: Geographical Study*, Egypt: Dar Al-Ma'rifah Al-Jami'yya.

Abu Radi, F., 1989, *Spatial Distributions: A Study on Statistical Description and Methods of Numeric Representation*, Egypt: Dar Al-Ma'rifah Al-Jami'yya.

Aldagheiri, M., 2014, Accessibility Analysis of Roads Network in Al-Qassim Region.*Journal of Arabic and Human Sciences*, Vol. 8, 1-21.

Al-Dosari, N., 2011, *Traffic Congestion and Accessibility to Kuwait City, Center for Studies and Research.*Naif Arab University for Security Sciences, Saudi Arabia.

Al-Fanatsah, A., 2015, *Educational Services in Ma'anGovernorate.Unpublished PhD Thesis*. Egypt: Cairo University.

Al-Hussein, S. N., 2011, The Effect of Connectivity in Public Transport on the Development of Tourism Areas in Saudi Arabia. *Journal of Gulf and Arabian Studies*, Vol, (37)142, 387-432.

Al-khashman, A., 2013, *Geography of Transport*, Jordan: Dar Wael.

Al-Ruwithi, M. A., 1992, The Road Network in Al-Madinah Al-Munawwarah Region: An Analytical Geographical Study. *Scientific Book of Geographical Symposium of Geography Departments in Saudi Arabia*, Part 1, Umm Al-Qura University, Makkah, Saudi Arabia.

Al-Zouka, M. K., 2005, *Geography of Transport*. Egypt: Dar Al-Ma'rifah Al-Jami'yya.

Department of Statistics., 2015, General Population and Housing Census**.**

Ghallab, M. A., 2014, Geographic Evaluation of Spatial Accessibility to Health Services in Rural Areas of Kafr El Dawar Center Using Geographical Information Systems. *Arab Journal of Geographic Information Systems, Saudi Geographical Society*, Vol. 8, 1-59.

Ighraieb, A., 2010, Assessing Access to the Nodes in Urban Road Network and the Degree of Centrality in the Hebron Governorate. *Islamic University Journal*, Vol. 18, 525-545.

Li, P. and Lu, Y., 2005, Review and Prospection of Accessibility Research. *Progress in Geography*, Vol. (24)3. 69-78.

Mohamed, E, M., 2003, *Land Transportation in Suhaj Governorate: Geographical Study*. unpublished PhD Thesis, Egypt: South Valley University.

Rodrigue, J., 2020, *The Geography of Transport Systems*, 5th Edition, New York: Routledge.

Scheurer, J. and Curtis, C., 2007, *Accessibility Measures: Overview and Practical Applications*. Curtin University, Working Paper, No. 4.

Thatcher, W., 1958, *Economic Geography*. London: English Universities Press.

Vandenbulcke, G., Steenberghen, T, and Thomas, I., 2009, Mapping accessibility in Belgium: A Tool for Land-Use and Transport Planning?.*Journal of Transport Geography*, Vol. 17, 39-53.

Wazi', T., 2012, Developmental Evaluation of Accessibility in Sana'a City by Isochron Maps Using GIS.unpublished PhD thesis, Egypt: Assiut University.