Analysis of Roads Network Connectivity in Al-Qassim Region - Saudi Arabia

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Abstract: Network analysis is an important aspect of transport geography because it involves the description of the disposition of nodes and their relationships and line or linkage of distribution. It gives measures of accessibility and connectivity and also allows comparisons to be made between regional networks within a country and between other countries. Road connectivity is measured with help of graph theory, Alpha, gamma and beta index. The main objective of the present paper is to identify the Al-Qassim region transport network connectivity.

Keywords: Transport roads network, Connectivity*, and Saudi Arabia.*

Introduction

The road network is made up of single roads which link together two or more points or centers of movement. It may therefore be regarded as a set of inter-connected roadways along which movement takes place. Different modes of transportation form prominent landscape features and indeed roads, railway tracks, waterways and electricity structures form imposing features on the landscape and in well-populated, industrial and urban areas there is usually a dense pattern of transportation lines (Bamford and Robinson, 1978). Network analysis is considered an important feature in geographical studies of transportation network (FitzGerald, 1974). However, to understand the broad skeleton of the road network it is useful to reduce the actual network to a topological network.

A topological map or graph, as it is commonly called, reduces a transport network into its simplest form to help us to understand the characteristics of transportation networks more easily (Bamford and Robinson, 1978). Briggs (1972:9) has said:

"Topology is a form of geometry concerned with the positions and relationships between points and lines and areas and not with the distance between points, the straightness of lines or the size of areas". The elements of topological networks consist of a series of points, usually called as ' Nodes' or 'Vertices' which are usually linked together by lines,   usually referred to as 'Links', 'Edges', and 'Arcs' which often enclose areas of space (Haggett and Chorley, l969). After the transport system is reduced to a topological network several measures and indices are used to analyze the network efficiency, the connectivity of a network is one of them. The main aim of this paper is to identify the Al-Qassim region transport network connectivity.

The Study Area

The Al-Qassim Region, which is the target of this research, is located in the heart of the Kingdom of Saudi Arabia (see figure 1). It lies approximately 330 kilometres northwest of the capital, Riyadh, and occupies an area of about 78,500 square kilometres or nearly 4% of the total area of Saudi Arabia. It is geographically located between E40°. 00, E45°. 00 longitude and N23°. 30, N28°. 00 latitude. Furthermore, the Al-Qassim Region consists of 10 sub-provinces and 155 local centres. According to the estimate (2000) Al-Qassim's population totalled nearly 980,000, which gives a population density of 12.6 people per square kilometre, while KSA density is 9 people per square kilometre. Moreover, the Al-Qassim Region comes 7th out of 13 provinces in terms of population and the main economic activity is agricultural.

Compared to other provinces in the Kingdom of Saudi Arabia, the Al-Qassim Region has a good road network of approximately 4289 kilometres linking its cities, towns and villages. The agricultural nature of the region requires an adequate road system in order to enable farmers to transport their products to market. Furthermore, the highway system in the Al-Qassim Region was greatly expanded during the 1980s due to its geographical position in the Kingdom, as well as its importance as a prime agricultural area, and the region was given special attention in respect of road construction. As a result of its location it became the hub of the road network with roads from the east linking with those from the west of Saudi Arabia. For example, the highway linking Dammam in the eastern part of Saudi Arabia with Ynbuh in the western part passes Riyadh, Al-Qassim and Madinah. Also as a result of its

geographical location, the road network of the Al-Qassim Region plays an important role in the movement of pilgrims, especially those from Gulf countries.

Figure 1: The Location of Al-Qassim Region.
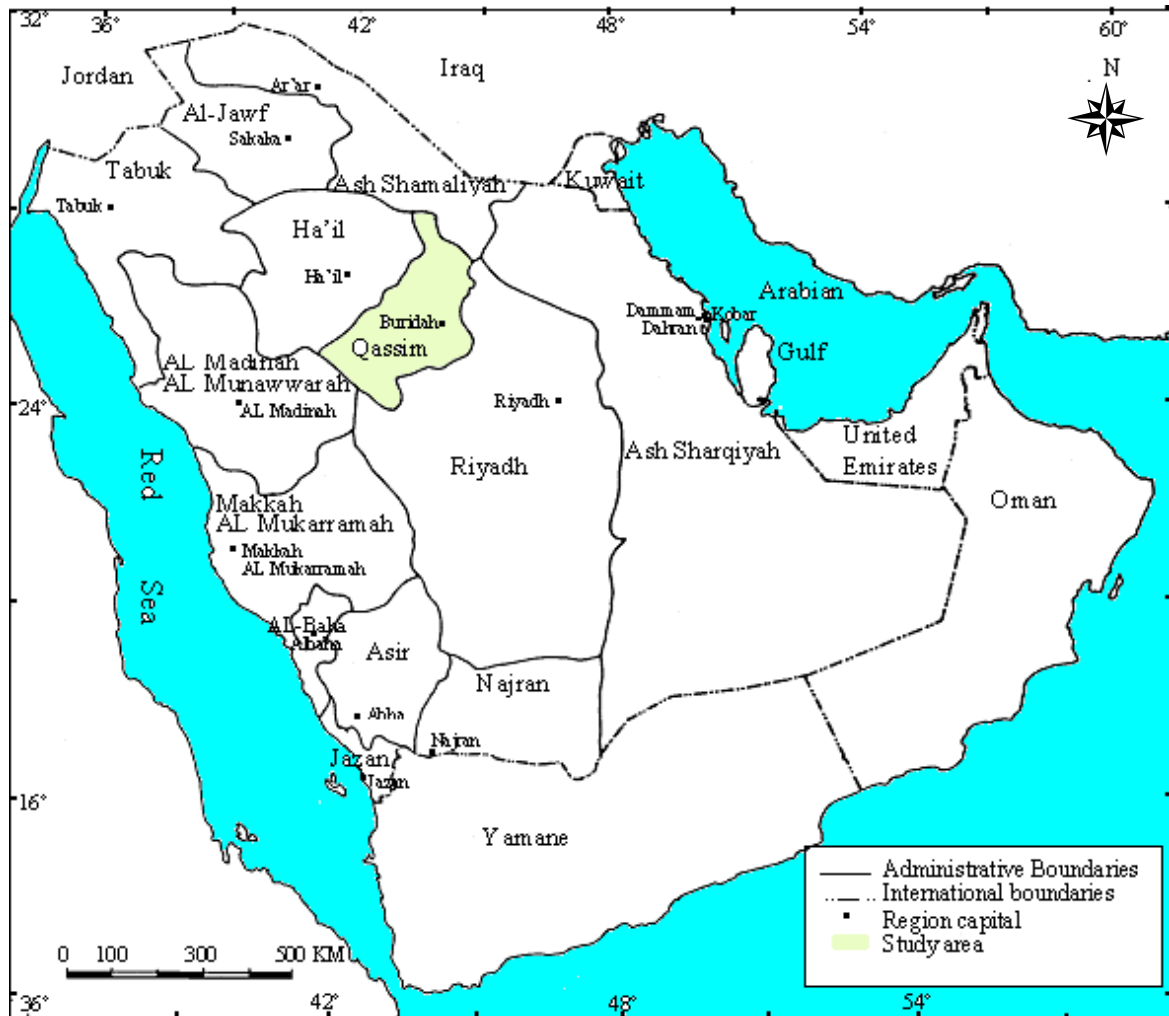
Source: Modified Higher Education Ministry 1999.

Analysis of Roads Network Connectivity

The connectivity of a network may be defined as the degree of completeness of the links between nodes of a network which are directly connected to each other. Also, it means that the connectivity of a network may be defined as the degree of connection between all vertices by arcs 'links' (Robinson and Bamford 1978). The concept of connectivity is particularly useful where a given network is either (1) compared with other networks or (2) its growth is viewed through time (Taaffe and Gauthier, 1973).

Davis stated (1974) that the connectivity of a network is considered to be of a great importance in a discussion of network geography, specially as there may be some significant relationship between connectivity and the extent of degree of development of a country.

Kansky (1963) has studied the structure of transportation networks, and has provided a number of indices which can be used for this purpose. There are several methods that can be used to measure the degree of connectivity; including Beta, Gamma and Alpha indices (Taaffe and Gauthier, 1973 and Davis, 1974). These may be calculated as follows.

- **The Beta Index**

The measure of the level of connectivity in a graph and is expressed by the relationship between the total number of arcs (e) over the total number of Vertices (v).

$$B = \frac{arcs}{nodes}$$

This index is designed so that any network with a beta index less than 1 will be composed largely of branches, while a ratio of exactly 1 indicates the presence of one complete circuit and a ratio of over 1 indicate the presence of more than one complete circuit. So, it is clear the higher number indicates greater connectivity.

- **The Gamma Index**

Gamma is a measure of connectivity that considers the relationship between the number of observed links and the number of possible links. The value of gamma is between 0 and 1 where a value of 1 indicates a completely connected network, which would be unlikely in reality.

$$G = \frac{arcs}{3(nodes-2)}$$

This index always lays between 0, for a null graph, and 1 for a complete graph, a range of values being more acceptable for purposes of placing on the axis of a graph.

- **The Alpha Index**

Alpha is a measure of connectivity which assesses the number of cycles in a network in comparison with the maximum number of cycles.

$$A = \frac{a-n-1}{2n-5}$$

The range of the index is from a value of 0 for a minimally connected network to a value of 1 for a maximally connected one. For convenience, the numerical value may be expressed as a percentage of circuitry in a network.

The road transport network in the Al-Qassim Region links all the main settlements. Therefore, the purpose of this section is to analyze the present distribution of the main network of asphalted roads i.e. inter-city and principal rural roads, but not feeder roads or intra-city roads. To understand the broad structure of the road network, it is useful to reduce the actual network to a topological network, which looks at a transport network in its simplest form. The topological map of the road network in the Al-Qassim Region consists of 34 Nodes (see Table 1) connected with each other by 46 Edges. The nodes include most of the urban centers in the Al-Qassim Region with more 2000 people, and they connect with other centers of the network by paved roads, both direct and indirect (Figure 2).

Table 1: The Nodes of the Topological Map

	City (Node)	Number of node
1	Buraidah	V1
2	Unaizah	V2
3	Ghmas	V3
4	Al Busser	V4
5	Mulaida	V5
6	Ashugah Sufla	V6
7	Al Garha	V7
8	Aiwon Aljwa	V8
9	Algoarh	V9
10	Gussaiba	V10
11	Aeen Ibnfheed	V11
12	Alkhussabh	V12

13	Gaebh	V13
14	Arbaheh	V14
15	Ashmaseh	V15
16	Al Badaeh	V16
17	Al Methnb	V17
18	Al Ammar	V18
19	Kharma	V19
20	Arass	V20
21	Qasser Ibn Hugael	V21
22	Dukhnah	V22
23	Adhalh	V23
24	Smhoodeh	V24
25	Dhreh	V25
26	Alkhabra	V26
27	Riyadh Alkhabra	V27
28	Al Graen	V28
29	Adlamih	V29
30	Atheebih	V30
31	Al Foarh	V31
32	Auglat Al Ssqur	V32
33	Al Bukarih	V33
34	Al Foalig	V34

Figure 2: The Nodes and Edges of Al-Qassim Road Network
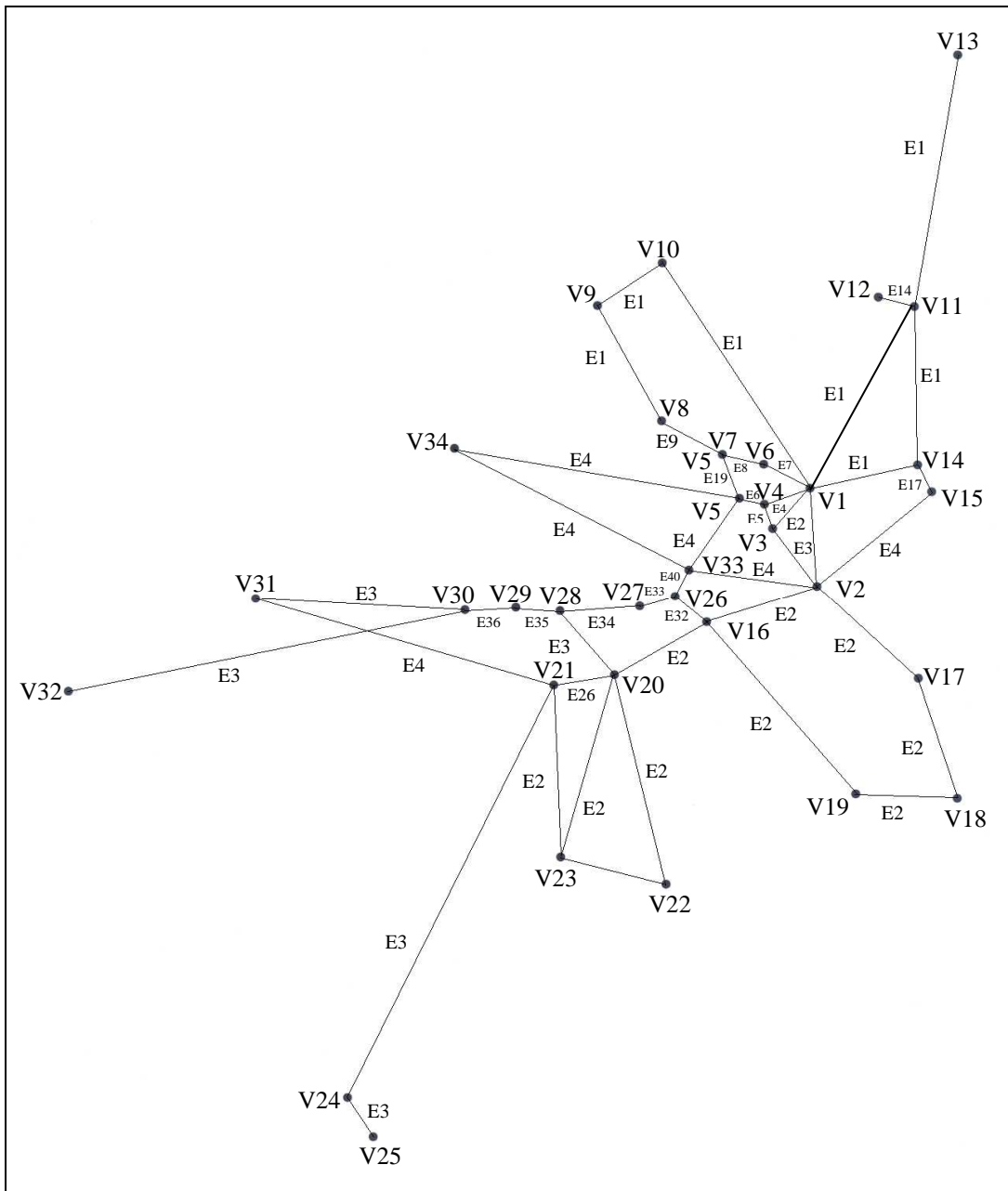
The connectivity of a network is considered to be of great importance in the measurement of networks, particularly as there may be a significant relationship between connectivity and the extent of degree of development of a region, for instance the Al-Qassim Region. Therefore, there are a number of indices that can be used to measure the degree of connectivity as follows:

- **The Beta Index**

As mentioned before, it is clear that the higher number indicates greater connectivity. By applying the Beta Index to the road network of the Al-Qassim Region, the value of this measure equates to 1.35, in that the number of arcs in the Al-Qassim network is 46 and the number of nodes 34. This means that the road networks of the Al-Qassim Region have, at present, a high degree of connectivity. In addition, this value indicates the presence of more than one complete circuit. To compare with other regions in Saudi Arabia, the value of this measure is 1.21 in the Al-Madinah Region (Alruwithy, 1991), and 1.11 in the Eastern Region (Al-Qaraawi, 1996).

- **The Gamma Index**

The value of the Gamma Index is between 0 and 1 where a value of 1 indicates a completely connected network and the value of 0 indicates that there is no connected network. By applying the Gamma Index to the road networks of the Al-Qassim Region, a value of 0.48 is arrived at. This means that the road network of the Al-Qassim Region is considered a quasi-connected network, but not a completely connected network. To compare with other regions, the Index measures 0.59 in the Al-Madinah Region and 0.38 in the Eastern Region.

- **The Alpha Index**

The Alpha Index consists of the ratio of the number of fundamental circuits to the maximum possible number of circuits that may exist in a network. The value of the Alpha Index ranges from 0, which is considered a minimally connected network, to 1, which is considered maximally connected. By applying the Alpha Index to the road networks of the Al-Qassim Region, a value of 0.19 is arrived at. This means that the Alpha Index value of the network in the Al-Qassim Region is indicating a weak network vis-a-vis the values of Gamma Index and Beta Index. Also, to compare with the other regions, the values of the Alpha Index in the Al-Madinah Region is 0.12 and in the Eastern Region 0.06.

From the foregoing analysis of the connectivity of the road transport network in the Al-Qassim Region by Beta, Gamma and Alpha indices, the road network is considered to be a connected network. Furthermore, the Gamma Index is considered an optimal index to apply on the Al-Qassim road network, because the network is nearly a connected network.

Conclusion

With regard to the connectivity of the network, the road transport network of the Al-Qassim Region might be considered as having a high degree of connectivity. By applying the Beta Index (with a result of 1.3) it has good connectivity. Also, it has quite good connectivity by applying the Gamma Index (with a result of 0.4) but the value of connectivity by the Alpha Index was quite low (0.19). In general, the road transport network of the Al-Qassim Region, when compared with other road networks in the Kingdom of Saudi Arabia, is considered a connected network and has more than one complete circuit.

Through the assessment and the analysis of the connectivity roads network in the Al-Qassim Region in this paper, the transport road network might be able to facilitate the movement of both people and commodities. Also, it is an important element in the transfer of production both within the region and further afield. In addition, this search conclude that, the transport road network might be able to contribute to regional and economical development in the Al-Qassim Region.

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