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The Optimum Priorities In Improving The Infrastructure Of Al-Anbar Governorate Road Network Using R.S. Data, GIS And Graph Theory

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ABSTRACT

The status of the infrastructure of the transport system and then mobility in the governorate of Anbar is deplorable. Therefore, it requires two types of solutions in two phases. This study concerned with the first phase, which is represented by solving the problem of the inadequacy infrastructure in terms of availability between the cities, and work to develop it toward being maximally connected. So, generally speaking this study aimed to facilitate mobility through this network, by improving the accessibility in term of connectivity.

The analysis process in this study, have twin objectives: first, to determine how much new linkages we need for our network to be maximally connected as a first stage? Second, Building a legislative framework lends the weight for decision makers in transport agency to take tough decision built up on ranking the new proposed linkages according to their relative values in providing access to the network, and the increment in comparable nodal accessibility due to the new additions. So, there is need for more sensible decisions based on more accurate analysis for deciding the optimum priorities for the new linkages to take place in the stage of development implementation via legislative framework. Therefore, the analysis will deal with topological characteristics for a number of aspects by expressing the simple graph of the network in a matrix format. These aspects are simulated and measured through the matrices powering process and the principles of graph theory.

However, in addition to reducing the time the vehicles stays on the road, the study results will assist to divert a large proportion of the traffic volumes concurrently with the implementation process, and this in turn will pave the way to precede the solution of the second phase inside the cities. Not to mention, the legislative framework will bases for the financial framework of the transport agency.

Keywords: infrastructure inadequacy& development, accessibility and connectivity, graph theory, matrix representation &powering, new linkage, nodal accessibility , relative value ,optimum priorities (ranking) and Decision making(legislation).

Introduction

Al- Anbar is the greatest governorate in Iraq one of the developing countries, which is experiencing continuous growth and change in all dimensions. Therefore, inevitably, there is high mobility of good and passengers, which leads to high transportation demand due to the rapid economic and change. This demand requires an equivalent and effective supply represented by the infrastructure, modes and services of the network system [1].

Despite the fact that the road network infrastructure is the first element in the formation of the transport system [2], and being the extent to which a nation's landmass is covered by road network is an index of the degree of mobility of people, goods and services within a region, and the quality of the network measures, the ease and cost of that mobility [3], We find that the road network of al-Anbar region suffers from the inadequate infrastructure in terms of availability [1] (absence for many important linkages from its structure). The absence of many network links and then the shortest paths, especially those that represent a direct linkage between two adjacent cities or even the two linkages paths, restrict the level of mobility of people and goods within a certain paths across the available links. However, the taken paths represent indirect or multi-linkages paths between the origin and destination of trips and cause people travel unnecessary distances across many cities and links to reach their destinations. Thus, considering the flow as a function of capacity, most of the roads inside these cities may be assign traffic more than their capacities [1]. Not to mention that the mobility trend is for increased and longer trips mostly by private car [4], and the network that have identified, as a deplorable , and heavily congested. Thus, the current status and the poor quality of the network infrastructure in term of network density, connectivity and accessibility levels and general conditions [5], reflect inefficient infrastructure in respect to cost and time [1]. These disruptions of the transport system will cause substantial economic and social strains, and this include impairing the abilities of peoples to get to work in time, impacting the business through delayed deliveries and supplies , increased freight costs ,delayed or cancelled business , meetings , ..Etc.) [6] Thus, a wide range of negative impact and many interesting problems are present [4]. Needless to say, there will be blocking the arrival of emergency services for the event site, not to mention the negative fingerprint left by traffic conditions degraded because of the current status of road development ,along with the overall poor performance of the road infrastructure in term of overall travel time and optimized supply [5] , [1]. Therefore, any city in Al-Anbar region are a common problem today, and several attempts to solve this problem [7] by constructing new links or upgrading the existing infrastructure or considering the mass transport [1] are not feasible.

All these problems and others over all exist transport system, are due to mismatch between demand and supply, which is related directly to the inadequate infrastructure both in capacity and availability in the cities, and the availability between two adjacent cities. This in turn resulting from planning decision is made based on pure speculations.

As the transportation system aims to increase mobility and access facilities; so, it is hard to put a plan for ensuring adequate, efficient and high quality infrastructure to guarantee effective mobility of goods and people. This will ensure a usable protocol for the appraisal of this type of transport infrastructure project [8], which is to provide access within their financial and legislative framework [9] towards meeting a certain objectives of transport regarding the infrastructure development [1]; can be summarized by reducing the time the vehicle stay on the road [7]. This protocol, if successful, could save millions every year, which are lost due to time spent on the road [10] via unnecessary distances [1], as well as mitigating enormous environment impact. It could also make life safer by allowing emergency services to travel faster and avoid car accidents in the first place [10]. So, there is need for more sensible decisions based on more accurate analysis [11], which should lend weight to decision making within the field of transport system [12].

As the transportation supply complexity has uniform sequence for its generation; and the first generation focuses on supporting basic connectivity between nodes and how to scale network to support growing number of trips. Therefore, we will handle analyzing the network connectivity indices in order to follow the logic progression of analyzing the requirement of accessibility, which flow into network architecture, which in turn forms the basis for the network design [2]. This study aims at assessing road infrastructure development in study area, taking in consideration the road connectivity as an index for accessibility requirement for the existing roads using data obtained from map analysis and evaluation by graph theory as theoretical background [5]. Then, Identifying the best new connection to implement in the network, identifying where the absence of structure having the most significant impact on the accessibility enhancement, [13] Ranking of each linkage as to its importance to the system. This ranking provides a useful input into the decision process for any future additions or improvements to the existing network infrastructure [14].

Permeable:

The analysis process helps us understand the forces and changes at work within the system. However, the analysis process can be achieved, where sets of options are developed including architecture, design, topologies, mechanisms and mobility, and then prioritize and achieve all the fundamental services and requirements, which form the basis for customer expectation and satisfaction through building a complete and successful network system.

The connectivity requirement can be provided through the first function of architecture, which is (addressing / routing) .this function describes the capability in providing robust and suitable connectivity between nodes.

Our study will regard analyzing the requirement of accessibility and the connectivity of the network. Viewing the network as part of a system provides a tool to help us for describing, analyzing, and evaluating the characteristics of the network structure, and then its capabilities in connectivity and accessibility between its origins and destinations (nodes) [2].

One of the most important mutually dependent elements with the transportation system is its accessibility [14]. The concept of accessibility is a key element in urban, regional and transportation planning, and it generally considered as a one of the most important determinates of land use patterns that has a strong impact on accessibility through the spatial distribution of urban and regional activities [15]. Therefore, the accessibility can be defined as the ease of reaching goods, services, activities and destinations, which together are called opportunities [16]. However, the traditional access measures can be broadly classified into three categories:

1. Reach or distance-based measures.
2. Gravity-based measures.
3. Opportunity-based measures [17].

Generally, these categories deals with two major indicator (topological and economic indicators).each of these indicators consist many measures of indices for accessibility which related by one or more than theoretical background. This complexification of accessibility concept can be summarized by a conceptual development [18] as in table (1):

Any one of the above measures may be estimated in quantitative or qualitative approach, in order to analyze and evaluate the accessibility of the transportation system. And through it we will be able to handle the existing problems and then giving the suitable enhancements, as well as taking it onto account to avoid it in the future development of the transportation system [19].

Thus, because the limitation in space of our research and due to lack in time, the considered measurements tend to be either come topological characteristics for the network elements and has direct impact to the network accessibility which is a component in network environment. [1], [17], [2].

The network analysis and evaluation.

- The external structure.

The conventional indices for describing the network structure and measuring its connectivity, are α, β and γ [20], [21]. Where α index represents (the network circuitry), and showed the loop percentage in the network; β index is (edge-node ratio, average linkage for each node [19], it indicates the complexity of the network) and it is simply equal to the "number of links" divided by the "number of nodes" or L/N [20]. γ index is (network connectivity , percent of connectedness [19].

Considering the network connectivity, the transporters classify the network configuration into three categories are spinal, grid and delta [14]. This sequence is arranged from the minimally connected network (spinal) to the maximally connected network (delta). The relative connectivity of the different configuration can be evaluated by γ index , which is simply the ratio between the number of edges actually in the network and the maximum number possible in that network. Generally, the ranges of values for the three classical network configurations are:

Spinal $1/3 \le \gamma < 1/2$ where $V > 4$

Grid $1/2 \le \gamma < 2/3$ where $V > 4$

Delta $2/3 \le \gamma < 1$ where $V > 3$

Where V= vertices = number of nodes [14].

Considering that the higher value for each of the three indices represents a more connected network [22], so, what do these indices tell us about the existing network? The values of the three indices, the adopted formulas and the mapped exist network are shown in figure (1).

In reality, networks are highly complex spatial system. We must therefore substantial simplification of these systems. This permits us to express any system, however complex, as a relatively simple graph [14]. In our study, we will depend a space image for al – Anbar governorate, and through which we will obtain the spatial characteristics for the regional network in this region. Through This manipulated image, the network will have been expressed as a simple graph by digitizing it by using the arc GIS 9.0, as shown in figure (1) By comparing these results with the limitation we find that:

From the mapped network and the specified formulas, we have diameter of 5, this means that it takes 5 steps to connect all spaces.

Alpha= 0.067, which means that there are 6.7% of all possible circuits. As the α ranges from (0) percent (no. circuits) to (100) percent (a completely interacted network)[23], our network is needed for adding new linkages by 93.3% for α index to be completely interconnected.

Beta= 1, as the β ranges from β= 1(minimal connected network), and the greater value of β, the greater connectivity [23]. $\gamma = 0.409$. The index γ ranges from 0 (no connection between nodes to 1(the maximum number of connections, with direct linkages between all nodes [23]. So, our network is about 59.3 ways to being maximally connected. It is relatively weakly connected, and there is high isolation for many cities. [Lec. i]

By these indices, we able to treat only the topological properties of a network and then we will be able to describe the structure in a relatively simple fashion [14]. As these practical indices used to measure connectivity must be able to empirically quantify differences of complexity between network patterns, such an index, therefore serve as a performance standard in the development or act as a comparative measure [20] for different networks, as well as to trace more precisely the development of a practical network through the time. Therefore, we will develop a series of matrices for direct connection, accessibility, the Shimbel distance, and valued graph [22], [14]. These permit us by graph theory [14] to conduct network analysis that cannot be effectively treated by single- number full- network measure [22] and, to critically examine its internal structure [14]. On the other hand, as the matrices that we will derive, are fundamentally descriptive in nature and are designed to provide more precise measurements of network structure and comparative accessibility of nodes within them [14]. To this extent, we cannot diagnose missing links in the network, but decide any of them more influential on the connectivity and thus the accessibility of the network.

The internal structure.

- The network as a matrix:

When a simple network is abstracted as a graph, the analyst is able to examine a transport network for evidence of spatial organization of an area; he is by no means limited to considering only full-network characteristics of network. In this case, many aspects of network analysis will be neglected because of being not effectively treated by single-number full network such as gamma (γ) index. Sometimes a new linkage of network is added or an old one is improved, this make it is possible that these changes will be reflected by changes in nodal accessibility. Therefore, emphases require to be placed on the identification of the internal spatial structure by examine linkage and flows between centers or we may look at the nodes themselves in terms of their functions and their accessibility to the rest of the network. By graph theory, we have a convenient means of measuring and recording these changes in nodal accessibility.in order to identify and monitoring the internal spatial structure and decision making for solving any question. For adding and improving any linkage and evaluate the existing network, we must consider aspects of network analysis that are absence in full-network topological measures:

Placement of the linkage with respect to each other.-

Both direct and indirect linkages.-

-Attenuation: the difference between single-step and multi-step linkages.

- Redundancies or meaningless round-trips.

These aspects will be handled to evaluate the internal structure of the network and its connectivity through expressing the network in a matrix format. The network as a matrix will consider the direct connection linkages as a first step through looking more carefully at the internal structure of the network and begin to evaluate the accessibility using the connectivity index of the individual nodes. Through estimating this measure in matrix format as shown in figure (2), this matrix will be called a connection matrix and formed by C1 as it deals with number of direct or one-step connections to the other nodes.

Matrix cell entries record the absence or presence of direct linkage between nodal pairs. A zero cell means that there is no linkage between that particular origin node, i, and destination node, j, while the cell entry a one in C123 indicated that you can go directly from V2 to V3 in one step, and a one for C134 an indication that you can go directly from V3 to V4 in one step. The row sums (∑Cij) could be referred to as the degree of a node (DON), it tell us more than gamma index (γ) because it does take into account the placement of the linkages and nodes with respect to other some in the network system, and then provides a measure of accessibility for each node, namely, the number of direct connections it had to the other nodes.

On the other hand, the DON permit us to rank the cities more actually than was possible simply by visual inspection of a map, because it is difficult visually to compare how well each city is connected to the others in the network. But when the network is expressed as a matrix, however, and sums for each two vector are tabulated, the cities may be ranked according to the DON.

From the gamma index (γ) we already can estimate the number of times that the total accessibility can be doubled through the network improvement with time, while by the DON measure (V2, V3 and V9) cities are ranked as the most accessible cities or the best connected cities, since they have a direct connection to more major Anbar cities than did any other city. In spite of being the DON or direct linkages as a meaningful indicator of relative accessibility, but it is remain a poor discriminator , because of being all major cities are connected to each other major cities by indirect linkage and these must be taken into account to be interested in knowing any evaluation of comparative accessibility which involves more than the direct connections between nodal pairs ,through taking into account both direct and indirect linkage, the second of the five important characteristics. However, this involves producing a total accessibility matrix or T-matrix which provided measures of accessibility involving both direct and indirect linkages.

T-matrix is the summation of summing nc-matrices for multistep connections could be calculated by powering the connection matrix C1 to Cn, where n is the diameter of network or the number of steps between the most remote nodes of the network. In the following procedure we will see the powering process for a matrices of multistep connections of Anbar cities and their total accessibility matrix, and how it will be recognized from γ index and the DON measures in help us as a planners or decision makers for deciding the manner of nodal accessibility improvement and what is the best new between nodal pairs can be made to give the suitable optimum priority for the consequence of new linkages addition regarding the improvement of the network and its nodal accessibility .

At first, we will consider that the matrix –powering process is as feasible for system with many nodes and it's quite possible to rank nodal accessibility with relative precision with the help of computer, while as the network become more complex, it quickly becomes impossible to make such judgment simply by visual inspection.

At beginning of considering the inclusion of both direct and indirect linkage in order to provide a measure of accessibility involving them, and then evaluate the network connectivity, we will firstly multiply the connectivity matrix C1 by itself and then getting the indirect of two-step connection matrix. Therefore, the produced matrix called C2 as it provides complete enumerations of the two-linkage paths in the network. The powering or multiplication process is illustrated in figure (3).

In matrix C2 , all direct or one-step connections such as those between V1 and V2 are represented by zeros , and any positive entry indicates that a two-step connection does exist between that nodal pairs such as that between V1 and V3, where the entry of one refers to that there is a one way of going between V1 and V3 in exactly two step, thus the c2 matrix shows only those linkages with exactly two step .

The main diagonal entries represents a round trips from Vi to Vi with two step entries represent the number of a two- step a round-trips from Vi to Vi, for example , the number of three in cell C222 indicates that there are three ways of going from node V2 back to itself via V1, V3 and V9.

Until this stage we have not considered all the indirect linkages between some nodes, for example there is a three step linkage between V1 and V5, therefore, we must produce a three step connection matrix, C3 by multiplying the C1 matrix by the C2 matrix. The multiplication process involves the element-by-element multiplication of the rows in C1 matrix by the columns in C2 matrix, as it is illustrated in figure (4).

The non-zero entry between any nodal pair in C3 matrix represents the number of ways to move between the node Vi and Vj. Any non-zero entry for a cell C3ij is exists when there is a non- zero entry for a cell C1ij and non- zero entry for a cell C2ij and just if the j of a cell C1ij is equal to the i of a cell C2ij. For example, the C315 entry is the sum of multiplying each entry in row I in the C1 matrix by its corresponding entry in column 5 in C2 matrix. However, the C315 entry of 1, indicating that there is one way to move between V1 and V5 in exactly three steps. In addition, the entry number of any C3ij refers to the number of ways to move between the node Vi and the node Vj in exactly three-step linkages. Note that there a round-trips are to be found in the off diagonal elements as some redundant ways of moving from I to j. For example, there three ways to go from V1 to V2 in three steps: V1to V2, V2 back to V1 and V1 toV2. Again, V1 to V2, V2 to V3 and V3 back to V2. Again, V1 to V2, V2 to V9 and V9 back to V2. This will provide measures over all degree connectedness of the network of meaningless round-trips as they are clearly related to the general accessibility of the individual nodes. The same way we get the matrix C4 shown in figure (5).

Deciding whether or not to keep on powering the matrix, depend on the value of all cells, the process continue until all zero cells are removed in one of the powered matrices at least for any cell. i. e. we should power the matrix until to reach the n matrices. And as the network of our study is of four step diameter, we will produce C4 by multiplying the C1 matrix by the C3 matrix as shown in figure (6) (C1 XC2 =C4).

After completing the matrix powering , the nodal accessibility measures is become distributed in five separated matrices, but we can add these matrices to provide this measure in a useful single summary matrix that does take into account an accessibility measure for both direct and indirect linkages . The summary matrix is called the total accessibility matrix or T-matrix, which has any entry cell indicated to the number of way there are of going from i to j in n steps or fewer. The total connectivity values can then be mapped to help in determine the theoretical isolation or accessibility level (lec. ?). The T-matrix of our network and the mapped total connectivity values are illustrated in figure (7) below.

T-matrix represents the sum of Vi to Vj entries in the five connection matrices. For example, the sum of V1 to V2 in the T-matrix is: one in C1 (one way of single step connection between V1 and v2), zero in C2(no way in two step), three in C3 (three ways for three step connection between V1 and V2 involving the round trips), zero in C4(no way for four step connection between V1 and V2), and 13 in C5(13 way for four step connection) ,thus , the entry T12 indicates that there are 17 ways of moving between V1 and V2 in five steps or fewer.

Row sums indicate the number of ways of going from Vi to all nodes (including i itself). The larger this row sum, is the more accessible that node. Thus, the most accessible node in figure (7) is therefore, V2 as it has the larger row sum represented by 145 ways of moving from V2 to all nodes in the network in four steps or fewer.

The T-matrix can also be used to evaluate the accessibility of the entire network by adding up all the row sums, which indicates the total number of going from each to each nodes in the network. From figure (7) there are 1024 ways in which the eleven nodes are connected to all the nodes in the network in five steps or fewer. This measure can be made somewhat more meaningful by subtracting the main diagonal cells values that represent a redundancies or meaningless round-trips .for example, the row sum of 58 for V4 includes 4 ways of going from V4 to V4 in five steps or fewer. After subtracting the diagonal cells values, the total indicates the number of ways of going from every node in the network to every other node in the network. Thus, we will get a new total of 918 as a measure of the total connectivity of the entire network, this say that in the network there are 918 ways in which we can move from each node to each other node in the network in five step or fewer. The results show us that the nodes have different ranking in term of connectivity and then their accessibility. Places with high connectivity are often being considered important since they are the best connected and most accessible. The nodes importance ranked from the least accessible, highest isolation node v4, v7, and v11 with 54 connections to the most accessible, lowest isolation node v2 with 129 connections (lectures).

In T-matrix the attenuation is not completely removed [14] because of being the impact of a given link is inversely related to the number of preceding links. For eliminate both attenuation and redundancy from analysis of the network is to use shimbel distance or D-matrix [14]. Shimbel distance-topologic network analysis that is restricted to the shortest paths between nodes . The shortest path involving the fewest linkages and recording the number of linkages involved in that bath, so the D-matrix elements represent the shortest path and indicate it as a distance in "number of linkages" between each nodal pair &[14]. Our D-matrix is illustrated in figure (8).

Not that larger circle represents lower shimbel distance and therefore more accessible. According to D-matrix results, the most accessible node is V2, which takes 16 steps to connect to all other nodes .

Generally, as the network is not completely connected network, it is need for sequences of new linkages between the pairs of nodes to enhance the existing network nodal accessibility in term of adequate infrastructure. However, the question is remaining “what is the optimum new linkage that takes the first step in sequence of additions to be added to the network before another?". The priorities in selection the better-proposed addition as a new linkage cannot be distinguished by any measure, the planners have no decision by using the γ index, and the degree of node is not useful since it simply provides the sum of direct linkages for each node and it does not consider the many indirect linkages in the system. While T-matrix provides a better means of evaluating the effect of the different placements of a proposed new linkages on both direct and indirect linkages.

The T-matrix represents the first step that helps us as planners or decision makers to decide what would be the best new linkages for adding to the existing network, and then give it the priority in sequence of the implementation process before another. This can be done through identifying the optimum result among all other T- matrices for the network of all others proposed additions. As we know, the transport system development is passing through over all its functions to achieve its requirements, but when we consider the network accessibility, the network system development process takes many stages can be described in term of their connectivity to transfer from systems that have a minimal connection or more than that to system of maximal connection.

In our study, the network infrastructure improvement and accessibility enhancement will begin with the proposed linkages additions. Because the limitations due to lack in space of the research, we will consider only seven proposed new linkages in developing process, and these are: (V1- V3), (V2- V4), (V4- V5), (V4- V9), (V5- V9), (V6- V9), and (V7-V9). For each proposed new addition to the exist network infrastructure, the network has been expressed in a matrix format, and powered again and the whole process is repeated until all (zero) cells are filled (lec.), and result in T-matrix for the network with each proposed addition.

The results of the different proposed linkages to decide the first optimum addition to the infrastructure are illustrated and summarized in figure (9) below. The results will give us the ability to decide any of the new proposed addition will take the optimum priority during stage of the infrastructure improvement. However, according to the T-matrix characteristics, the higher total, and the better connected the network is considered to be. The (V5 –V9) addition would have the greatest effect, which gives a network have maximum relative value, with high Connectivity, low isolation, and overall high accessibility, compared with the others proposed additions. It result in a 12.38 percent increase of T-matrix totals in the number of ways of going from each node to each other node in the system as compared with a 8.22, 6.17, 5.48, 4.11, 3.43 and 2.74 percent for (V4 –V9) , (V7 –V9) , (V6 –V9), (V2 –V4), (V1 –V3) and (V4 –V5) addition respectively.

Therefore, the (V5 –V9) addition is the optimum new linkage, that give the optimum increasing in network accessibility over others , and this reason will take it the logical priority to be the first new addition that must be implemented before the others for improving the network infrastructure. A (V5-V9) addition would move V2 as the most accessible node in the network, V2 would fall behind V9 and V5 which becomes the highest connective, lowest isolated, and the most accessible node, and V6 would fall behind all other nodes to be lowest connective, highest isolated, and the lowest accessible node.Thus, by the continuous comparing between the T-matrix for the original network and the T- matrix for the network after adding the (V5 –V9) addition, we can identify a new ranking for the system nodes. However, the developing process continues by repeating the same preceding procedure, powering new matrices for each next addition for the development process. Not that with each new addition, we consider the network with the preceding decided addition as an exist network and dropping the preceding decided addition from the proposed additions of the next stage of the development process. The whole development process results, the relative values and decision making for its priorities are summarized and illustrated in table (2).

Discussion:

With the implementation of each new linkage providing a direct connectivity between the adjacent cities and enhancing their nodal accessibility; the individuals will have the linkages of all alternative routes to their destinations, and they will select those routes that minimize total travel time (shortest path) ( ). This implies that the network is closer to the main goal of transport system, which is reducing the time the vehicle stays on the road, and then reducing its effect on the environment, and quickly navigate to pay to become less costly, either in money or time ( ) saving millions.

It is hard to say that with new connectivity, we will repeat the traffic assignment rapidly overall the network and not so much that cities become attractive for through traffic to avoid congestion and delay (st. conn.). The diverted trips from the exist paths to the new linkages; will leave the cities (that stay between origin and destination) indirect the new linkages and then enhancing the traffic conditions inside these cities through reducing the traffic over the infrastructure that exists but has low capacity. Inevitably, this will pave the way for the traffic agency to legislate with putting the solution of the second phase (either by upgrading the roads needed to meet the remaining traffic inside these cities or by traffic management) to the network, and with lower cost.

Not to mention, the high difference in nodal accessibility, unequal spatial accessibility due to absence of the direct linkages between many of the adjacent cities, this in turn, created unbalanced attractiveness between nodes (cities) and deteriorated the distribution of the economic activities in most cities.

As the opportunities of the cities are a measure for their attractiveness for the trips from other cities, but it play as an impedance force when exists in the cities situated between the origin city and a given destination city ,the traveler considers the spatial sequence of possible opportunities that is offered on his path. This has a large impact on the traveler decision, inevitably, opportunities with the closest city being evaluated and considered first. The attractiveness of cities has been affected to high limit by the deplorable and inadequate infrastructure which represented by absence for many important linkages. So, the exists infrastructure created different gabs between the cities, and created unbalanced attractiveness between nodes (cities) and deteriorated the distribution of the economic activities in most cities.

However, the study results will reduce the gabs in nodal accessibility, and repeat the distribution of the economic activities, : change in nodal accessibility after adding the proposed linkages. This in turn will encourage using the public transport as the activities will become closer and the shortest is available, and then providing wide options for the decision makers in transport agency to take sensible decisions between the development, upgrading, and traffic management to achieve most of the transport requirement.

Recommendations:

It is very necessary, that is the adoption of this study and its results as a source for the development of the network infrastructure; will provide guidelines for the decision makers to make tough decisions and encourage the specialists in transportation agency to work according a useable protocol, as a base for the other stages of development and for all the components of the transportation system. However, for more benefits in addition to the implementation the optimum priorities of the infrastructure development, we recommend with the following:

1. For more attention, there are traffic volumes diverted with constructing the new linkages and other generated as additional traffic due to the new road space. So, there is hint to take it as a traffic volume for the base year in design the new linkages.

2. As the network analysis means putting thought and time into preparing for architecture and design; so, considering the developed infrastructure that will be implemented according to the optimum and logical progression results of our study, inevitably will encourage the others to take in ac-

count other requirements and other components of the system in their studies both in analysis and design [2].

3. Coinciding with the infrastructure development, there is possibility for shifting mobility to soft transportation modes to public transport, notably for long- distance travel [4].

4. The adoption of the results of the study paints what financial dependence required for implementing process improvement with each addition according to optimum priorities in improving the system perfect.

5. There is big importance for take in consideration the principles of decision making, the principles of graph theory and computer techniques in academic studies, notably for those concerning the transportation field, for more accurate and sensible decision making, when there is a payoff for that.

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Table (1): conceptual development of the accessibility

1-step of requirements	**Requirement selection**					
2- step of indicator type	**Topological indicators**				**Economic indicators**	
3-step of measuring type	**Measurements selection**				**Measurements selection**	
	distance	**time**	**Transport cost**	**connectivity**	**Spatial interaction(attraction function / impedance function)**	**Utility function (net utility :gross utility of transport cost)**
4- **theoritical process**	***Theoretical background***				***Theoretical background***	
	Euclidean space	**Euclidean space**	**Graph theory**	**Graph theory**	**Gravity model**	**Neo-classical theory of consumer behavior**

Figure (2): abstracted a
number of r
number of r
presence o

α =(L-V+P)/(2V-5)

α =(11-11+1)/(20-5)=0.06

β =(L/V)=11/11=1

γ=L / L max. =L/3(V-2)

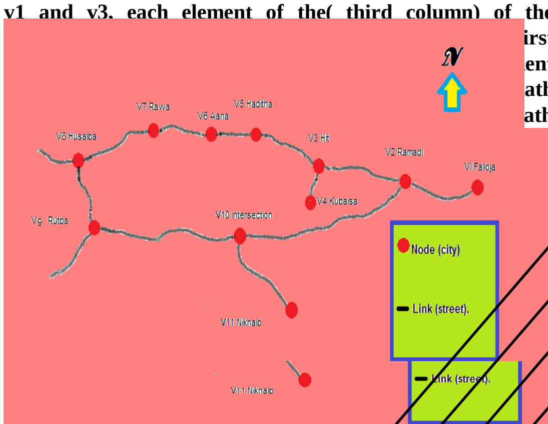
γ=11/3(11-2)=0.407

where L=11 ,V=11

				V4	V5	V6	V7	V8	V9	V10	V11	DON
				0	0	0	0	0	0	0	0	1
				0	0	0	0	0	0	1	0	3
				1	1	0	0	0	0	0	0	3
				0	0	0	0	0	0	0	0	1
				0	0	1	0	0	0	0	0	2
V6	0	0	0	0	1	0	1	0	0	0	0	2
V7	0	0	0	0	0	1	0	1	0	0	0	2

Figure (1): the road network of Al- Anbar governorate.

Figure (3): **matrix multiplication to determine if a two linkage path exist between any nodal pair, such as between v1 and v3. each element of the(third column) of the** irst ent ath ath



tween v1 and v3, each element of the(third column) of the connection matrix c1 is multiplied by each element in the first row of the matrix c1 . The sum of the element-by element product is enumeration of the number of two- linkage path between that nodal pairs. In this example, one such path

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	0	1	0	0	0	0	0	0	0	0	0
V2	1	0	1	0	0	0	0	0	0	1	0
V3	0	1	0	1	1	0	0	0	0	0	0
V4	0	0	1	0	0	0	0	0	0	0	0
V5	0	0	1	0	0	1	0	0	0	0	0
V6	0	0	0	0	1	0	1	0	0	0	0
V7	0	0	0	0	0	1	0	1	0	0	0
V8	0	0	0	0	0	0	1	0	1	0	0
V9	0	0	0	0	0	0	0	1	0	1	0
V10	0	1	0	0	0	0	0	0	1	0	1
V11	0	0	0	0	0	0	0	0	0	1	0

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	0	1	0	0	0	0	0	0	0	0	0
V2	1	0	1	0	0	0	0	0	0	1	0
V3	0	1	0	1	1	0	0	0	0	0	0
V4	0	0	1	0	0	0	0	0	0	0	0
V5	0	0	1	0	0	1	0	0	0	0	0
V6	0	0	0	0	1	0	1	0	0	0	0
V7	0	0	0	0	0	1	0	1	0	0	0
V8	0	0	0	0	0	0	1	0	1	0	0
V9	0	0	0	0	0	0	0	1	0	1	0
V10	0	1	0	0	0	0	0	0	1	0	1
V11	0	0	0	0	0	0	0	0	0	1	0

C1

C1

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	0	1	0	0	0	0	0	0	0	0	0
V2	1	0	1	0	0	0	0	0	0	1	0
V3	0	1	0	1	1	0	0	0	0	0	0
V4	0	0	1	0	0	0	0	0	0	0	0
V5	0	0	1	0	0	1	0	0	0	0	0
V6	0	0	0	0	1	0	1	0	0	0	0
V7	0	0	0	0	0	1	0	1	0	0	0
V8	0	0	0	0	0	0	1	0	1	0	0
V9	0	0	0	0	0	0	0	1	0	1	0
V10	0	1	0	0	0	0	0	0	1	0	1
V11	0	0	0	0	0	0	0	0	0	1	0

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	0	1	0	0	0	0	0	0	0	0	0
V2	1	0	1	0	0	0	0	0	0	1	0
V3	0	1	0	1	1	0	0	0	0	0	0
V4	0	0	1	0	0	0	0	0	0	0	0
V5	0	0	1	0	0	1	0	0	0	0	0
V6	0	0	0	0	1	0	1	0	0	0	0
V7	0	0	0	0	0	1	0	1	0	0	0
V8	0	0	0	0	0	0	1	0	1	0	0
V9	0	0	0	0	0	0	0	1	0	1	0
V10	0	1	0	0	0	0	0	0	1	0	1
V11	0	0	0	0	0	0	0	0	0	1	0

C1

C2

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	1	0	1	0	0	0	0	0	0	1	0
V2	0	3	0	1	1	0	0	0	1	0	1
V3	1	0	3	0	0	1	0	0	0	1	0
V4	0	1	0	1	1	0	0	0	0	0	0
V5	0	1	0	1	2	0	1	0	0	0	0
V6	0	0	1	0	0	2	0	1	0	0	0
V7	0	0	0	0	1	0	2	0	1	0	0
V8	0	0	0	0	0	1	0	2	0	1	0
V9	0	1	0	0	0	0	1	0	2	0	1
V10	1	0	1	0	0	0	0	1	0	3	0
V11	0	1	0	0	0	0	0	0	1	0	1

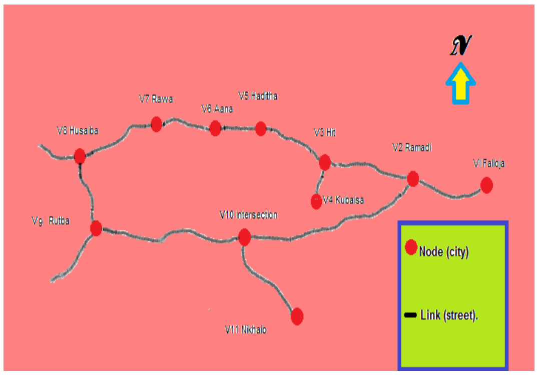
O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	0	3	0	1	1	0	0	0	1	0	1
V2	3	0	5	0	0	1	0	1	0	5	0
V3	0	5	0	3	4	0	1	0	1	0	1
V4	1	0	3	0	0	1	0	0	0	1	0
V5	1	0	4	0	0	3	0	1	0	1	0
V6	0	1	0	1	3	0	3	0	1	0	0
V7	0	0	1	0	0	3	0	3	0	1	0
V8	0	1	0	0	1	0	3	0	3	0	1
V9	1	0	1	0	0	1	0	3	0	4	0
V10	0	5	0	1	1	0	1	0	4	0	3
V11	1	0	1	0	0	0	0	1	0	3	0

C2

C3

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	0	3	0	1	1	0	0	0	1	0	1
V2	3	0	5	0	0	1	0	1	0	5	0
V3	0	5	0	3	4	0	1	0	1	0	1
V4	1	0	3	0	0	1	0	0	0	1	0
V5	1	0	4	0	0	3	0	1	0	1	0
V6	0	1	0	1	3	0	3	0	1	0	0
V7	0	0	1	0	0	3	0	3	0	1	0
V8	0	1	0	0	1	0	3	0	3	0	1
V9	1	0	1	0	0	1	0	3	0	4	0
V10	0	5	0	1	1	0	1	0	4	0	3
V11	1	0	1	0	0	0	0	1	0	3	0

C3



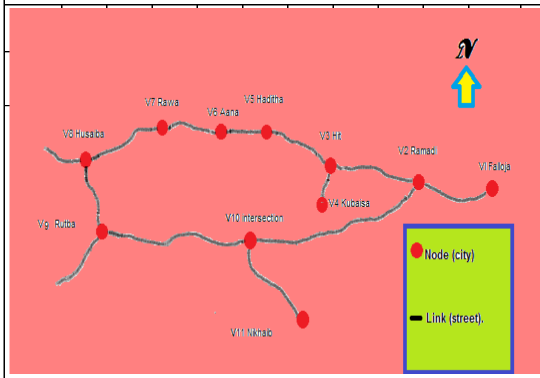
Figure(5): determination the number of four- linkages paths between nodal pairs ,the results are shown in the C4 matrix , which is derived by multiplying the C3 matrix by the original connection matrix C1

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	0	1	0	0	0	0	0	0	0	0	0
V2	1	0	1	0	0	0	0	0	0	1	0
V3	0	1	0	1	1	0	0	0	0	0	0
V4	0	0	1	0	0	0	0	0	0	0	0
V5	0	0	1	0	0	1	0	0	0	0	0
V6	0	0	0	0	1	0	1	0	0	0	0
V7	0	0	0	0	0	1	0	1	0	0	0
V8	0	0	0	0	0	0	1	0	1	0	0
V9	0	0	0	0	0	0	0	1	0	1	0
V10	0	1	0	0	0	0	0	0	1	0	1
V11	0	0	0	0	0	0	0	0	0	1	0

C2

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	3	0	5	0	0	1	0	1	0	5	0
V2	0	13	0	5	6	0	2	0	6	0	5
V3	5	0	12	0	0	5	0	2	0	7	0
V4	0	5	0	3	4	0	1	0	1	0	1
V5	0	6	0	4	7	0	4	0	2	0	1
V6	1	0	5	0	0	6	0	4	0	2	0
V7	0	2	0	1	4	0	6	0	4	0	1
V8	1	0	2	0	0	4	0	6	0	5	0
V9	0	6	0	1	2	0	4	0	7	0	4
V10	5	0	7	0	0	2	0	5	0	12	0
V11	0	5	0	1	1	0	1	0	4	0	3

C4



Figure(6): **determination the number of four- linkages paths between nodal pairs ,the results are shown in the C4 matrix , which is derived by multiplying the C3 matrix by the original connection matrix C1**

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	1	0	1	0	0	0	0	0	0	1	0

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	3	0	5	0	0	1	0	1	0	5	0
V2	0	13	0	5	6	0	2	0	6	0	5
V3	5	0		12	0	0	5	0	2	0	7	0
V4	0	5	0	3	4	0	1	0	1	0	1
V5	0	6	0	4	7	0	4	0	2	0	1
V6	1	0	5	0	0	6	0	4	0	2	0
V7	0	2	0	1	4	0	6	0	4	0	1
V8	1	0	2	0	0	4	0	6	0	5	0
V9	0	6	0	1	2	0	4	0	7	0	4
V10	5	0	7	0	0	2	0	5	0	12	0
V11	0	5	0	1	1	0	1	0	4	0	3

C4

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	0	1	0	0	0	0	0	0	0	0	0
V2	1	0	1	0	0	0	0	0	0	1	0
V3	0	1	0	1	1	0	0	0	0	0	0
V4	0	0	1	0	0	0	0	0	0	0	0
V5	0	0	1	0	0	1	0	0	0	0	0
V6	0	0	0	0	1	0	1	0	0	0	0
V7	0	0	0	0	0	1	0	1	0	0	0
V8	0	0	0	0	0	0	1	0	1	0	0
V9	0	0	0	0	0	0	0	1	0	1	0
V10	0	1	0	0	0	0	0	0	1	0	1
V11	0	0	0	0	0	0	0	0	0	1	0

C2

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	0	13	0	5	6	0	2	0	6	0	5
V2	13	0	24	0	0	8	0	8	0	24	0
V3	0	24	0	12	17	0	7	0	9	0	7
V4	5	0	12	0	0	5	0	2	0	7	0
V5	6	0	17	0	0	11	0	6	0	9	0
V6	0	8	0	5	11	0	10	0	6	0	2
V7	2	0	7	0	0	10	0	10	0	7	0
V8	0	8	0	2	6	0	10	0	11	0	5
V9	6	0	9	0	0	6	0	11	0	17	0
V10	0	24	0	7	9	0	7	0	17	0	12
V11	5	0	7	0	0	2	0	5	0	12	0

C5

V2	1	0	1	0	0	0	0	0	0	1	0
V3	0	1	0	1	1	0	0	0	0	0	0
V4	0	0	1	0	0	0	0	0	0	0	0
V5	0	0	1	0	0	1	0	0	0	0	0
V6	0	0	0	0	1	0	1	0	0	0	0
V7	0	0	0	0	0	1	0	1	0	0	0
V8	0	0	0	0	0	0	1	0	1	0	0
V9	0	0	0	0	0	0	0	1	0	1	0
V10	0	1	0	0	0	0	0	0	1	0	1
V11	0	0	0	0	0	0	0	0	0	1	0

C1

+

V2	0	3	0	1	1	0	0	0	1	0	1
V3	1	0	3	0	0	1	0	0	0	1	0
V4	0	1	0	1	1	0	0	0	0	0	0
V5	0	1	0	1	2	0	1	0	0	0	0
V6	0	0	1	0	0	2	0	1	0	0	0
V7	0	0	0	0	1	0	2	0	1	0	0
V8	0	0	0	0	0	1	0	2	0	1	0
V9	0	1	0	0	0	0	1	0	2	0	1
V10	1	0	1	0	0	0	0	1	0	3	0
V11	0	1	0	0	0	0	0	0	1	0	1

C2

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	0	3	0	1	1	0	0	0	1	0	1
V2	3	0	5	0	0	1	0	1	0	5	0
V3	0	5	0	3	4	0	1	0	1	0	1
V4	1	0	3	0	0	1	0	0	0	1	0
V5	1	0	4	0	0	3	0	1	0	1	0
V6	0	1	0	1	3	0	3	0	1	0	0
V7	0	0	1	0	0	3	0	3	0	1	0
V8	0	1	0	0	1	0	3	0	3	0	1
V9	1	0	1	0	0	1	0	3	0	4	0
V10	0	5	0	1	1	0	1	0	4	0	3
V11	1	0	1	0	0	0	0	1	0	3	0

C3

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	3	0	5	0	0	1	0	1	0	5	0
V2	0	13	0	5	6	0	2	0	6	0	5
V3	5	0	12	0	0	5	0	2	0	7	0
V4	0	5	0	3	4	0	1	0	1	0	1
V5	0	6	0	4	7	0	4	0	2	0	1
V6	1	0	5	0	0	6	0	4	0	2	0
V7	0	2	0	1	4	0	6	0	4	0	1
V8	1	0	2	0	0	4	0	6	0	5	0
V9	0	6	0	1	2	0	4	0	7	0	4
V10	5	0	7	0	0	2	0	5	0	12	0
V11	0	5	0	1	1	0	1	0	4	0	3

C4

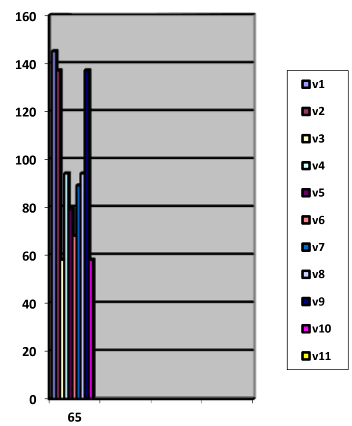
O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V4	5	0	12	0	0	5	0	2	0	7	0
V5	6	0	7	0	0	11	0	6	0	9	0
V6	0	8	0	5	1	0	10	0	6	0	2
V7	2	0	7	0	0	10	0	10	0	7	0
V8	0	8	0	2	6	0	10	0	11	0	5
V9	6	0	9	0	0	6	0	11	0	17	0
V10	0	24	0	7	9	0	7	0	17	0	12
V11	5	0	7	0	0	2	0	5	0	12	0

C5

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	0	1	2	–	–	–	–	–	–	2	–
V2	1	0	1	2	2	–	–	–	2	1	2
V3	2	1	0	1	1	2	–	–	–	2	–
V4		2	1	0	2						
V5	–	2	1	2	0	1	2	–	–	–	–
V6	–	–	2	–	1	0	1	2	–	–	–

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	∑
V1	4	19	6	6	7	1	2	1	7	6	6	65
V2	19	16	32	6	7	9	2	9	7	32	6	145
V3	6	32	15	18	24	6	8	2	10	8	8	137
V4	6	6	18	4	5	6	1	2	1	8	1	58
V5	7	7	24	5	9	17	5	7	2	10	1	94
V6	1	9	6	6	17	8	16	5	7	2	2	79
V7	2	2	8	1	5	16	14	16	5	8	1	68
V8	1	9	2	2	7	15	16	8	17	6	6	89
V9	7	7	10	1	2	7	5	17	9	24	5	94
V10	6	32	8	8	10	2	8	6	24	15	18	137
V11	6	6	8	1	1	2	1	6	5	18	4	58
T-matrix												1024

C1 +C2 +C3 +C4 +C5 = ∑ Cn= T-matrix



Nodal accessibility

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V7	_	_	_	_	_	1	_	1	_	_	_
V8	_	_	_	_	_	_	1	_	1	_	_
V9	_	_	_	_	_	_	_	1	_	1	_
V10	_	1	_	_	_	_	_	_	1	_	1
V11	_	_	_	_	_	_	_	_	_	1	_

D1

+

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V7	_	_	_	_	2	1	0	1	2	_	_
V8	_	_	_	_	_	2	1	0	1	2	_
V9	_	2	_	_	_	_	2	1	0	1	2
V10	2	1	2	_	_	_	_	2	1	0	1
V11	_	2	_	_	_	_	_	_	2	1	0

D2

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	0	1	2	3	3	_	_	_	3	2	3
V2	1	0	1	2	2	3	_	3	2	1	2
V3	2	1	0	1	1	2	3	_	3	2	3
V4	3	2	1	0	2	3	_	_	_	3	_
V5	3	2	1	2	0	1	2	3	_	3	_
V6		3	2	3	1	0	1	2	3		
V7	_	_	3	_	2	1	0	1	2	3	_
V8	_	3	_	_	3	2	1	0	1	2	3
V9	3	2	3	_	_	3	2	1	0	1	2
V10	2	1	2	3	3	_	3	2	1	0	1
V11	3	2	3	_	_	_	_	3	2	1	0

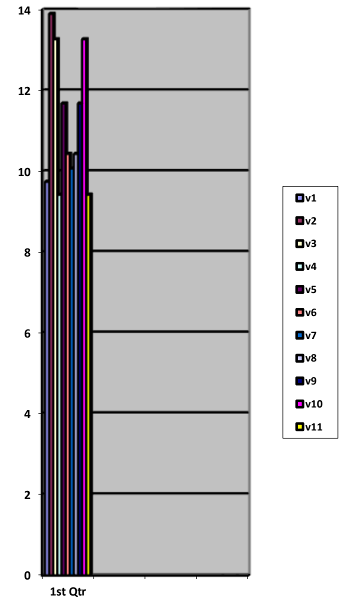
D3

O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	0	1	2	3	3	4	_	4	3	2	3
V2	1	0	1	2	2	3	4	3	2	1	2
V3	2	1	0	1	1	2	3	4	3	2	3
V4	3	2	1	0	2	3	4	_	4	3	4
V5	3	2	1	2	0	1	2	3	4	3	4
V6	4	3	2	3	1	0	1	2	3	4	_
V7	_	4	3	4	2	1	0	1	2	3	4
V8	4	3	4	_	3	2	1	0	1	2	3
V9	3	2	3	4	4	3	2	1	0	1	2
V10	2	1	2	3	3	4	3	2	1	0	1
V11	3	2	3	4	4	_	4	3	2	1	0

D4

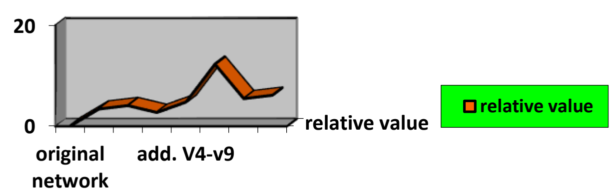
O/D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	∑	rank
V1	0	1	2	3	3	4	5	4	3	2	3	30	6
V2	1	0	1	2	2	3	4	3	2	1	2	21	1
V3	2	1	0	1	1	2	3	4	3	2	3	22	2
V4	3	2	1	0	2	3	4	5	4	3	4	31	7
V5	3	2	1	2	0	1	2	3	4	3	4	25	3
V6	4	3	2	3	1	0	1	2	3	4	5	28	4
V7	5	4	3	4	2	1	0	1	2	3	4	29	5
V8	4	3	4	5	3	2	1	0	1	2	3	28	4
V9	3	2	3	4	4	3	2	1	0	1	2	25	3
V10	2	1	2	3	3	4	3	2	1	0	1	22	2
V11	3	2	3	4	4	5	4	3	2	1	0	31	7

Relative value =total ∑/∑

D5	**292**		
D1+ D2+ D3 + D4+ D5 = $\sum$Dn			
Figure (8): shimble distance or D-matrices measures for the exits network.			

V7	6	5	11	6	11	8	8	6	6	5	6	5	8	6	2	3
V8	4	4	9	6	9	6	9	5	5	4	5	4	7	5	4	5
V9	3	3	7	4	6	4	7	4	1	1	1	1	1	2	1	2
V10	2	2	4	2	4	2	5	2	3	2	4	2	2	1	2	1
V11	8	7	10	8	10	9	4	8	7	6	7	5	9	6	8	6
total accessibility	1024	292	1290	282	1326	280	1375	284	1224	268	1364	256	1344	276	1302	274

Figure (9): the relative value for deciding the optimum priority to select the first addition for the network development process.



R. V. =[(original D value- the addition D value)/ original D value]*100

City/addition	***Original network***		***V1 _v3 addition***		***V2 _v4 addition***		***V4 _v5 addition***		***V4 _v9 addition***		***V5 _v9 addition***		***V6 _v9 addition***		***V7_v9 addition***	
City/Matrix	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
V1	7	6	3	4	7	8	10	7	7	6	8	6	10	7	9	6
V2	1	1	2	1	1	1	3	1	3	2	3	3	4	2	3	1
V3	2	2	1	1	2	3	1	2	2	1	2	2	5	8	5	2
V4	8	7	6	7	3	5	4	5	4	3	7	5	11	3	10	7
V5	3	3	5	3	5	5	2	3	5	4	1	1	6	4	7	3
V6	5	4	8	5	8	7	6	5	6	5	5	4	2	3	6	4