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Development an Accessibility Approach to Rank the Transportation Network Components During the Occurrence of Flood Crisis (Golestan Province Case Study)

Ali Mansour Khaki, Afshin Shariat Mohaymany, Seyyed Hossein Sadati Baladehi

[1,2]Associate Professor of Civil Faculty, Iran University of Science & Technology
[3]PHD candidate of transportation engineering, Iran University of Science & Technology
Phone: 00989111532072

Abstract: One of the most paramount problems after occurrence the flood crisis is the prioritization of reconstructing the components of roads network. One of the characteristics which have important role in this matter is accessibility index. It means that the more important role to accessibility to whole of the network, the more significance for reconstructing after flood crisis. At present study, it has been tried that with using of accessibility index the reconstruction of roads network of Golestan province is prioritized. For this reason at first the roads network of Golestan province was modeled by EMME2 software and then the modeled network was loaded based on the daily traffic volume at current statue. According to previous researches, the accessibility index includes two main parameters, parameter of volume traffic and parameter of distance dimension. At present study it has been tried that composed of these two mentioned parameters, were used as an accessibility index. At next step, with supposing that each of the roads network components was disrupted under flood crisis, the accessibility index was calculated before and after disrupting the links for whole of the network. The difference between two accessibility indexes was used as a significance degree of disrupted link for reconstruction after flood crisis. The higher degree of significance for disrupted link, the higher prioritization for reconstructing.

Key words: accessibility index, link disruption, loaded network, origin-destination matrix

INTRODUCTION

Natural disasters leave destructive and adverse effects on human communities. Some of these natural disasters include flood, cyclones, hurricanes as well as earthquakes. In our country, Iran, around 70% of the budget allocated for unexpected and natural disasters, is directed to flood. Among the destructive and disastrous effects of flood, some would be concerning the road network transportation which leads to destruction of arterials in the network. Destruction of these arterials in the network lengthens the trip time and creates several problems for transportation of goods and passengers. Some of the network components enjoy a very significant importance whose destruction due to flood considerably increases the trip time and fuel cost as well as other factors in the network.

In the present study, in order to determine the significance of each of the components of road networks, the accessibility index has been utilized based on the length of the trip distance and traffic volume. To do this, Golestan province road network has been selected for the case study.

Methodology:

According to the above-mentioned ideas, the research method is divided into different stages.

- First Step: Modeling the road network of Golestan province
- Second Step: Loading the road network of the province
- Third Step: Determining the accessibility index for the existing condition
- Fourth Step: Determining the accessibility index for different scenarios (after occurrence the flood)
- Fifth Step: Determining the difference of accessibility before and after link-loss for each of the components
- Sixth Step: Prioritization of reconstruction of different components of the network after flood

Corresponding Author: Ali Mansour Khaki, associate professor of civil faculty, Iran University of Science & Technology

Determining the Accessibility Index:

There are two effective and influential parameters in determining the accessibility index. The first is the distance between zones which has a reverse relationship. The second parameter is the traffic volume which has a direct relationship with the accessibility index. Various investigations have been conducted considering the two parameters both singly and together, as well as simultaneously to determine the accessibility index. Chang and Nojima(2001) proposed an index in which both parameters were simultaneously considered: (Chang and Nojima, 2001).

$$A_i = 4*\left[\alpha\frac{P_j}{\sum_{K=1}^{24}P_K}\sum_{j=1}^{23}\left(\frac{P_j}{\sum_{K=1}^{24}P_K}\frac{d_{ij}^{-\beta}}{\sum_{K=1}^{24}d_{ik}^{-\beta}}\right)+(1-\alpha)\frac{P_j}{\sum_{K=1}^{24}P_K}\sum_{j=1}^{23}\left(\frac{P_j}{\sum_{K=1}^{24}P_K}\frac{t_{ij}}{\sum_{K=1}^{24}t_{ik}}\right)\right]$$

In which

A_i: accessibility of zone i

α: Weighted coefficient (0<α<1)

P_j: The population of zone 1

β: 0.446632 (experimental coefficient)

d_{ij}: the shortest path between *i and j zones* in different scenarios

d_{ij}: the shortest path between *i and j zones* in the existing conditions

$t_{ij} = \frac{\sum_{m=1}^{n} AADT_m . d_m}{d_{ij}}$: the average traffic volume between *i* and *j* zones

$AADT_m$: The average annual daily traffic in link *m*

d_m : the length of link *m*

In the first part of the above-mentioned relationship, the distance parameter has been considered in determining the accessibility indicator. In the second part, traffic volume indicator determines the accessibility index between origin and destination. The α coefficient in this relationship is the coefficient whose change, could change the percentage of effects of the two-mentioned parameters in determining the accessibility could be either increased or decreased. For example, α=1 means that only distance has been utilized in determining the accessibility index, α=0 demonstrates that the accessibility index is determined solely based on the parameter of traffic volume.

Modeling the Road Network of Golestan Province:

In order to calculate the accessibility index of different zones, it is necessary to model the road network of Golestan Province (case study) along with the trip production and attraction zones in this province. To do this EMME2 Software was selected. EMME2 is a software which has been increasingly utilized in transportation planning. There are 3 types of databases in the understudy area, Golestan Province Road Network, (Advanced EMME/2 2003)

1. Network (province road network)
2. Matrix (origin-destination matrix)
3. Functions (the mathematical formula of accessibility index)

The road network of Golestan province has been illustrated in figure 1. (Advanced EMME/2 2003; Correia *et al.,* 199b) and (JICA, 2006).

Having modeled the road network of Golestan Province in the Software of EMME2, the origin-destination matrix of daily trips throughout the province was assigned to the network. The loaded network in the existing situation has been illustrated in figure 2. (Traffic, 2004).

RESULTS AND DISCUSSIONS

5-1. Assessment of the Accessibility Index in the Existing Conditions:

In this stage, the manner of calculation of accessibility index, presented in the previous section, was determined by QBasic Programming Language. Then, using the programming language of Macro net, the existing characteristics in the province road network system, trip production and attraction zones were determined as the input of the program of QBasic and the accessibility index in the existing condition was calculated. (Advanced EMME/2 2003).

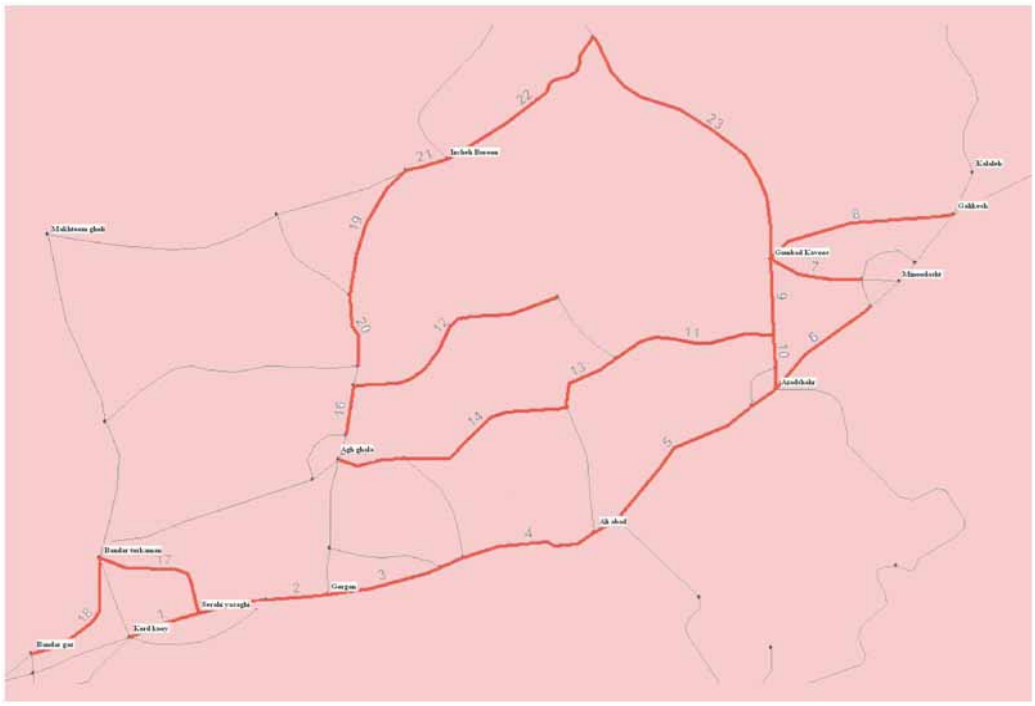


Fig. 1: The Modeled Road Network of Golestan Province

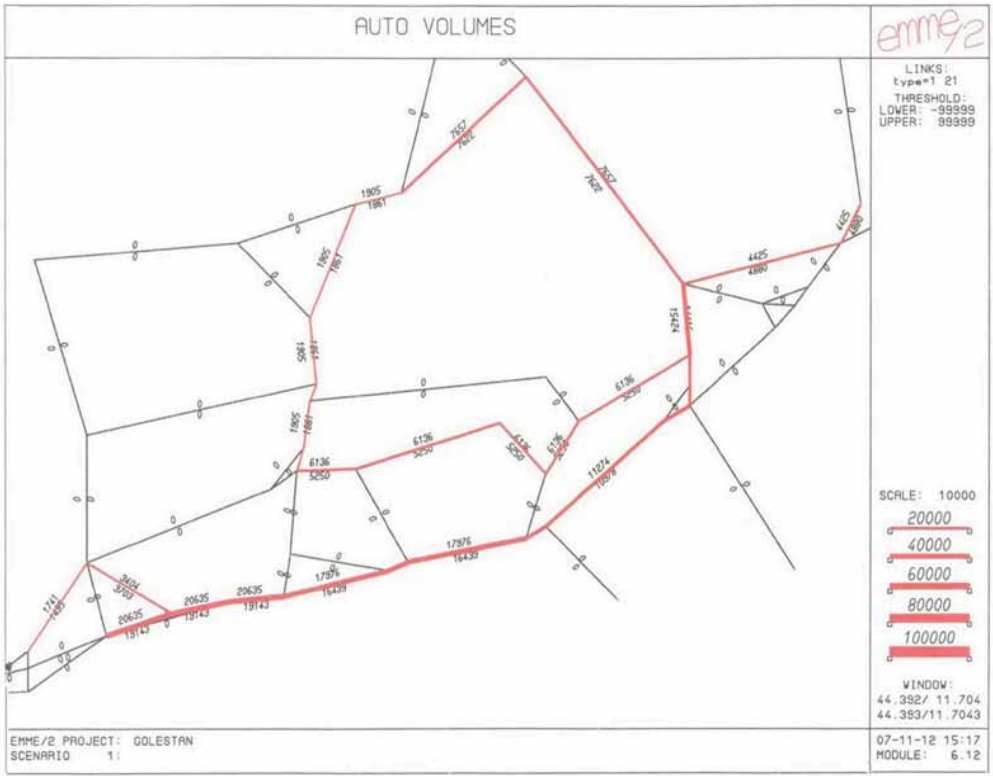


Fig. 2: The Loaded Network of Golestan Province in the Existing Condition

5-2. Assessment of Accessibility Index in the Different Link-disruption Conditions in the Network:

In this section, assuming the flood occurrence in the road network of the province, and loss of each of the existing links of in the network, 14 scenarios were defined and developed. After that the origin-destination matrix was assigned to the new network, after the link-loss for each of the scenarios, the amount of the new accessibility index for all production and attraction zones was assessed. In figure 3, the loading of the province road network in the link-loss condition between Ali-abad and Azadshahr has been illustrated. (Chang and Nojima, 2001; Correia *et al.,* 1999a) and (Kim *et al.,* 2002).

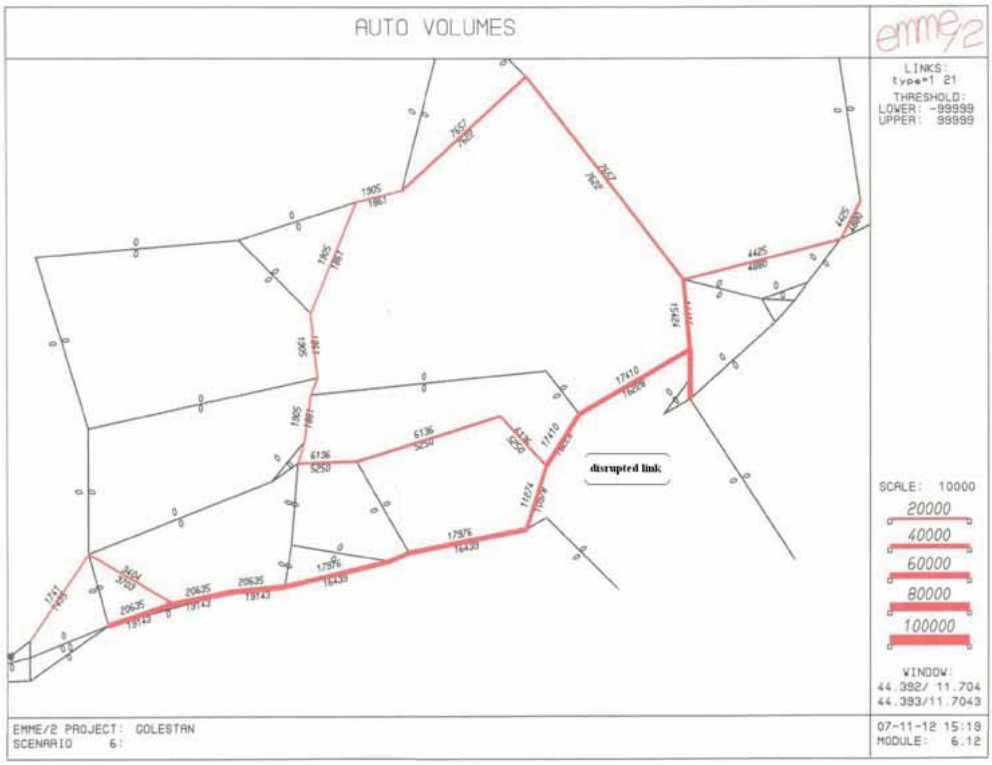


Fig. 3: The Loaded Road Network of Golestan Province in the condition of link-loss between Ali-abad and Azadshahr.

5-3. Prioritization of Reconstruction of Road Network Components after Flood:

According to what was mentioned earlier, the accessibility index was assessed, both before and after the occurrence of flood and consequently the destruction of each of the network components. The bigger the difference of the index before and after flood, the higher the significance of the disrupted link, and naturally it needs to be granted a higher priority in reconstruction after flood. Determining the degree of importance of each of the network components is presented via the following relationship. (Chang and Nojima, 2001) and (McAllister *et al.,* 2000).

$$A^j = \sum_{i=1}^{24} A_i - \sum_{i=1}^{24} A_i^j = \sum_{i=1}^{24} (A_i - A_i^j)$$

In which:

A^j : the degree of importance of link j

A_i : the accessibility of zone i before the disruption of link j

A_i^j : the accessibility of zone i after the disruption of link j

In table 1, the results of prioritization in case α=0.5 (i.e. the effects of two parameter of distance and traffic volume in determining the accessibility index are equal) is presented. In graph no. 1, these results are illustrated for different volume of α.

Table 1: the results of prioritization in case α=0.5

Scenario	zone center	amount of accessibility	Scenario	zone center	amount of accessibility	Scenario	zone center	amount of accessibility
1	serahi yasaghi	0	6	serahi yasaghi	0	11	serahi yasaghi	0
1	bandar gaz	9.43E-03	6	bandar gaz	9.41E-03	11	bandar gaz	9.42E-03
1	bandar torkaman	1.37E-02	6	bandar torkaman	1.37E-02	11	bandar torkaman	1.36E-02
1	kalaleh	0.026717456	6	kalaleh	2.64E-02	11	kalaleh	2.67E-02
1	agh ghala	2.34E-02	6	agh ghala	3.34E-02	11	agh ghala	2.35E-02
1	incheh boroon	1.54E-03	6	incheh boroon	1.54E-03	11	incheh boroon	1.57E-03
1	gombad kavoos	4.76E-02	6	gombad kavoos	5.27E-02	11	gombad kavoos	4.75E-02
1	azadshar	2.97E-02	6	azadshar	3.55E-02	11	azadshar	2.97E-02
1	ali abad	5.73E-02	6	ali abad	5.80E-02	11	ali abad	5.73E-02
1	kord kooy	4.78E-02	6	kord kooy	4.77E-02	11	kord kooy	4.78E-02
1	gorgan	9.37E-02	6	gorgan	9.26E-02	11	gorgan	9.37E-02
total		0.350882362	total		0.37090396	total		0.35079
2	serahi yasaghi	0.00E+00	7	serahi yasaghi	0.00E+00	12	serahi yasaghi	0.00E+00
2	bandar gaz	9.16E-03	7	bandar gaz	9.43E-03	12	bandar gaz	9.43E-03
2	bandar torkaman	1.37E-02	7	bandar torkaman	1.37E-02	12	bandar torkaman	1.34E-02
2	kalaleh	2.67E-02	7	kalaleh	2.66E-02	12	kalaleh	2.67E-02
2	agh ghala	2.34E-02	7	agh ghala	2.34E-02	12	agh ghala	2.34E-02
2	incheh boroon	1.54E-03	7	incheh boroon	1.54E-03	12	incheh boroon	1.54E-03
2	gombad kavoos	4.75E-02	7	gombad kavoos	4.75E-02	12	gombad kavoos	4.76E-02
2	azadshar	2.97E-02	7	azadshar	2.97E-02	12	azadshar	2.97E-02
2	ali abad	5.72E-02	7	ali abad	5.73E-02	12	ali abad	5.73E-02
2	kord kooy	4.97E-02	7	kord kooy	4.78E-02	12	kord kooy	5.06E-02
2	gorgan	9.39E-02	7	gorgan	9.37E-02	12	gorgan	9.48E-02
total		3.52E-01		total		3.51E-01	total	3.54E-01
3	serahi yasaghi	0.00E+00	8	serahi yasaghi	0.00E+00	13	serahi yasaghi	0.00E+00
3	bandar gaz	8.87E-03	8	bandar gaz	9.39E-03	13	bandar gaz	9.42E-03
3	bandar torkaman	1.26E-02	8	bandar torkaman	1.35E-02	13	bandar torkaman	1.37E-02
3	kalaleh	2.67E-02	8	kalaleh	2.67E-02	13	kalaleh	2.67E-02
3	agh ghala	2.34E-02	8	agh ghala	2.67E-02	13	agh ghala	2.34E-02
3	incheh boroon	1.54E-03	8	incheh boroon	1.53E-03	13	incheh boroon	1.50E-03
3	gombad kavoos	4.75E-02	8	gombad kavoos	4.73E-02	13	gombad kavoos	4.76E-02
3	azadshar	2.96E-02	8	azadshar	3.09E-02	13	azadshar	2.97E-02
3	ali abad	5.72E-02	8	ali abad	5.69E-02	13	ali abad	5.73E-02
3	kord kooy	4.62E-02	8	kord kooy	4.77E-02	13	kord kooy	4.78E-02
3	gorgan	9.06E-02	8	gorgan	9.28E-02	13	gorgan	9.37E-02
total		3.44E-01	total		3.54E-01	total		3.51E-01
4	serahi yasaghi	0.00E+00	9	serahi yasaghi	0.00E+00	14	serahi yasaghi	0.00E+00
4	bandar gaz	9.38E-03	9	bandar gaz	9.43E-03	14	bandar gaz	9.43E-03
4	bandar torkaman	1.36E-02	9	bandar torkaman	1.37E-02	14	bandar torkaman	1.37E-02
4	kalaleh	2.65E-02	9	kalaleh	2.67E-02	14	kalaleh	2.67E-02
4	agh ghala	2.76E-02	9	agh ghala	2.08E-02	14	agh ghala	3.04E-02
4	incheh boroon	1.54E-03	9	incheh boroon	1.53E-03	14	incheh boroon	2.01E-03
4	gombad kavoos	4.82E-02	9	gombad kavoos	4.23E-02	14	gombad kavoos	5.28E-02
4	azadshar	2.91E-02	9	azadshar	2.54E-02	14	azadshar	3.44E-02
4	ali abad	5.76E-02	9	ali abad	5.70E-02	14	ali abad	5.73E-02
4	kord kooy	4.77E-02	9	kord kooy	4.78E-02	14	kord kooy	4.78E-02
4	gorgan	9.26E-02	9	gorgan	9.32E-02	14	gorgan	9.37E-02
total		3.54E-01	total		3.38E-01	total		3.68E-01
5	serahi yasaghi	0.00E+00	10	serahi yasaghi	0.00E+00	15	serahi yasaghi	0.00E+00
5	bandar gaz	9.37E-03	10	bandar gaz	9.42E-03	15	bandar gaz	9.30E-03
5	bandar torkaman	1.36E-02	10	bandar torkaman	1.36E-02	15	bandar torkaman	1.36E-02
5	kalaleh	2.65E-02	10	kalaleh	2.67E-02	15	kalaleh	2.67E-02
5	agh ghala	3.85E-02	10	agh ghala	3.91E-02	15	agh ghala	2.34E-02
5	incheh boroon	1.54E-03	10	incheh boroon	1.54E-03	15	incheh boroon	1.54E-03
5	gombad kavoos	5.12E-02	10	gombad kavoos	5.35E-02	15	gombad kavoos	4.76E-02
5	azadshar	2.91E-02	10	azadshar	2.72E-02	15	azadshar	2.97E-02
5	ali abad	6.16E-02	10	ali abad	6.55E-02	15	ali abad	5.73E-02
5	kord kooy	4.76E-02	10	kord kooy	4.78E-02	15	kord kooy	4.78E-02
5	gorgan	9.53E-02	10	gorgan	9.81E-02	15	gorgan	9.37E-02
total		3.74E-01	total		3.82E-01	total		3.51E-01

In which:

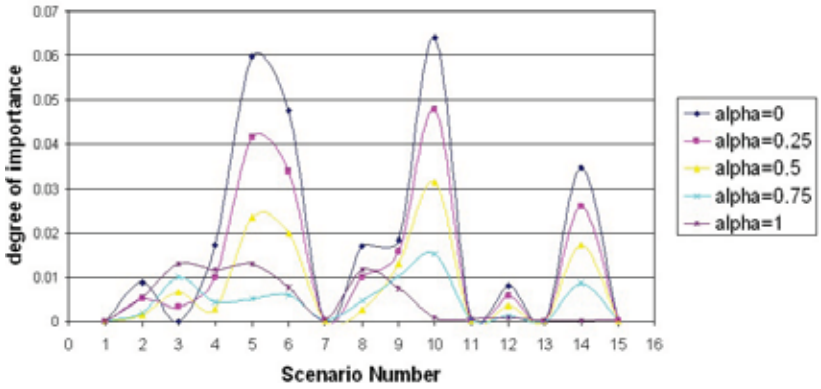
Scenario number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Disrupted link	---	1	2	3	4	5	8	9	10	11	14	17	19	23	18

Base on table 1, the prioritization of links disruption scenarios in Golestan province is:
Scenario number: 10, 5, 6, 14, 9, 3, 12, 4, 8, 2, 15, 7, 11, 13, 1
Link number: 11, 4, 5, 23, 10, 2, 17, 3, 9, 1, 18, 8, 14, 19,

Conclusion:

According to the results of graph one, as the α coefficient nears 1(The condition in which only distance is the influential factor in assessing and determining the accessibility index), the amount of changes in the accessibility in relation to the existing conditions will decrease. This is owing to the little sensitivity of accessibility index in defined mathematical relationship to the distance parameter.

In conditions in which the traffic volume parameter play a role in determining the accessibility index (i.e, α=0, α=0.25, α=0.5 and α=0.75), those links in the network have great level of importance whose disruption will lead to considerable increase in traffic volume in the substitute links for example scenario no. 5,6,10 and 14. (links no. 4,5,11 and 23.)



Graph 1: Results of Prioritization of Network Components of Golestan Province after the occurrence of flood

In conditions in which distance parameter is the only influential factor in determining the accessibility index α=1, Those links in the road network enjoy greater significance which are the only accessibility links in their zones and their disruption will cause that the substitute links in other zones and with longer distance transfer the traffic volume. For example scenario no. 3,4,5 and 8 (links no. 2,3,4 and 9.)

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