SAFETY ANALYSIS OF U-TURNS IMPLEMENTED IN TEHRAN HIGHWAYS BASED ON EFFECTIVE INDICES

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ABSTRACT

Traffic accident is one of the most important reasons of fatality and has enormous influence on the society, culture and economy. Nowadays, in some countries U-turns implementation is one of the short term methods of access management. Traffic and pedestrian safety are the main characteristics of effective transportation systems, therefore it is necessary to analyze safety condition of U-turns and related weaving areas based on effective indices. For this purpose, geometrical, physical and traffic indices that have determinant influence on safety performance of U-turns and weaving areas, have been introduced in this study. For safety evaluation of U-turns, various indices such as median dimensions, turning radius and traffic signs have been considered. Safety evaluation of weaving areas carried on indices such as traffic signs, pavement condition, lighting and drainage system. In this research, based on case study that has been done in Tehran, safety performance of U-turns that used in Sa'idi highway has been evaluated. Sa'idi highway is located in southwest of Tehran with high traffic volume of vehicles. Safety performance of U-turns and weaving areas has been evaluated by using Analytic Hierarchical Procedure (AHP). In addition, level of service has been determined for weaving areas by HICAP software. Safety number has been calculated by Simple Additive Weighting method (SAW) and based on this number, safety performance of U-turns and weaving areas has been categorized. Safety performance classification could be useful for prioritization of improvement operation. Safety analysis showed that the most U-turns have inappropriate safety conditions because of their certain indices such as traffic separator, turning radius and safety equipments

Keywords: U-turns, Traffic Safety, Effective indices, Weaving areas, Analytic Hierarchical Procedure (AHP)

1- INTRODUCTION

U-Turns are considered as one of the cost-effective, practical, fast and effective solutions to facilitate traffic flow and a quite suitable alternative for the junctions which may decrease the delay resulted from traffic intensity. However, failure to observe the issues relevant to traffic safety of vehicles results in decreasing the safety factor and consequently, decreasing the useful effects of the U-Turn construction results. The main purpose of organizing U-Turns is to increase their capacity and throughout, decreasing the potential and collision among vehicles, facilitating traffic, providing comfort and tranquility for the U-Turn users and eventually, efficiency, capacity and safety of connecting network. Organizing U-Turn shall be appropriated to the speed, volume, traffic flow characteristics, area topography, development of U-Turn bounds region and rating streets of U-Turn area. What will be studied in this article shall be analyzing the safety status of U-Turns implemented in Saeidi Highway between 45 Metri Zarand and Shahid Kazemi Junction [1]

2- STATEMENT OF PROBLEM AND IMPORTANCE OF ISSUE

High frequency of turning left at the junctions results in increasing the delays, and interferes with the vehicles in the other directions. One of the methods to decrease delays in such type of junctions is prohibiting turning left and taking benefit from U-Turns to transfer left-turning movements. In this article, the safety status of U-Turns implemented within the area under study as well as the Weaving areas of direct movements of those vehicles exiting U-Turn which tend to turn right has been studied considering the defined safety indicators and a certain method has been presented to assess and compare the safety issue of its different types. Studies indicate that through analyzing the safety indicators of U-Turns and Weaving areas, e.g. geometrical, physical and traffic indicators, the implemented U-Turns may be categorized based on their safety performance and safeguard the same considering their levels of performance [1].
It should be mentioned that constructing U-Turns requires comprehensive investigating the issues affecting the safety of the vehicles movements. Therefore, it is essential to fulfill integrated studies per case and considering the local conditions and compare the advantages and disadvantages of the implemented plans [2].

3- METHODOLOGY OF ANALYZING THE SAFETY STATUS OF U-TURNS AND WEAVING

Generally speaking, analyzing the safety status of the U-Turns and Weaving areas depends on a variety of factors and parameters which affect assessment of safety factor. Considering the variability of the effective indicators as well as the level of importance of each of these indicators and in order to categorize the U-Turns and Weaving areas in terms of their safety indicator, the Analytical Hierarchical Processing (AHP) has been used in this article.

3-1- Case Study

The U-Turns implemented throughout Tehran are mainly located along the inter-urban highway paths. In a certain study performed in this article, the safety issue of U-Turns implemented in Highway between 45 Metri Zarand and Shahid Kazemi Junction has been focused. The U-Turns existed within this area include six U-Turns, implemented in two-by-two (back to back) manner. Besides studying the aforementioned U-Turns, the safety performance of vehicles Weaving areas generated within the area of these U-Turns has also been studied. In Table No. 1 the specifications of the U-Turns have been given. Meanwhile, the specifications of Weaving areas and their level of service (found by taking benefit from HiCAP software) have been given in Table No. 2 [1].

Table 1 – Specifications of U-Turns within the Studied Area [1]

U-Turn Name			U-Turn Location	Entrence Storage		Exit Storage	
				Length (m)	No. of Lines	Length	No. of Lines
BACK TO BACK	North to north	A	Between Yadegar St. and Yaftabad Cross Road	40	1	Continuous	1
	South to south	B		No Entrence storage		Continuous	1
	North to north	C	Between Yaftabad Cross Road and Banaei St.	70	1	Continuous	1
	South to south	D		45	1	Continuous	1
	North to north	E	Between Vafaeinejad and Tabaei St.	45	1	Continuous	1
	South to south	F		70	1	Continuous	1

Table 2 – Specifications of Weaving areas within the Area under Study

Name of Weaving area	Location of Weaving area	Length (m)	Level of service
1W	Between Yadegar St. exit and A U-Turn	60	F
2W	Between exit from B U-Turn and Moallem St. entrance	110	F
3W	Between exit from Moallem St. and C U-Turn	215	F
4W	Between D U-Turn and Banaei St.	100	F
5W	Between Vafaeinejad St. and E U-Turn entrance	185	F
6W	Between F U-Turn and Tabaei St. entrance	135	F
7W	Between Tabaei St and slow lane of Pazand St.	30	C
1E	Between Yaftabad St. exit and B U-Turn entrance	90	F
2E	Between C U-Turn exit and Yaftabad St. entrance	220	C
3E	Between C U-Turn exit and Yaftabad St. entrance	65	D
4E	Between C U-Turn exit and Taghizadeh St. entrance	180	B
5E	Between E U-Turn exit and Asgari St. entrance	340	C

In Figure. No. 1 the position of A, B U-Turns and Weaving areas of 1W, 2W has been shown as sample. As it may also be seen in Figure. No. 1, A, B U-Turns have been implemented in back-to-back manner. Meanwhile, Figure. No. 1 shows that the 1W Weaving area is due to

the interference of movement of vehicles passing Saeidi Highway with vehicles entering into A U-Turn, while 2W Weaving area is the result of interference of the vehicles passing through Saeidi Highway with the vehicles exiting B U-Turn. In figure. No. 2 the level of service of 1W Weaving area calculated by taking benefit from HiCAP software, has been shown

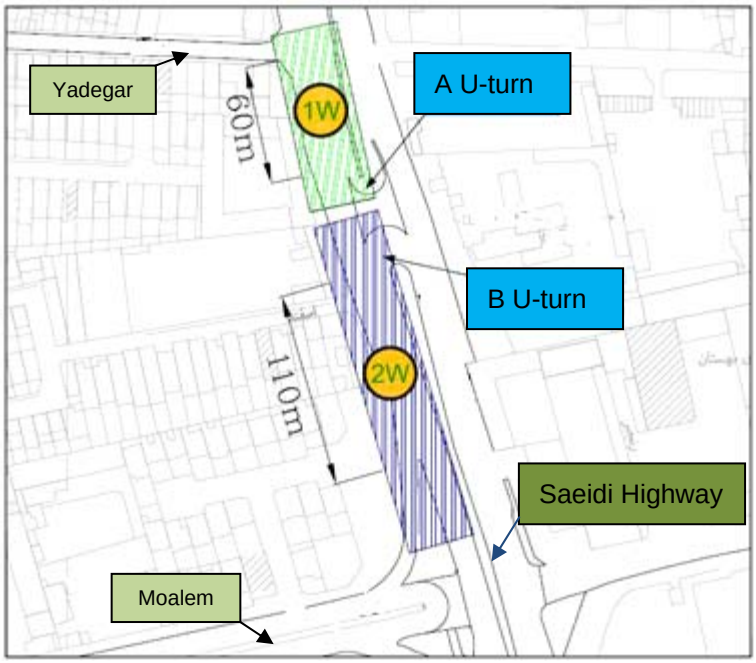

Figure 1 –Positions of A, B U-Turns and 1W, 2W Weaving areas within the area of study [1]

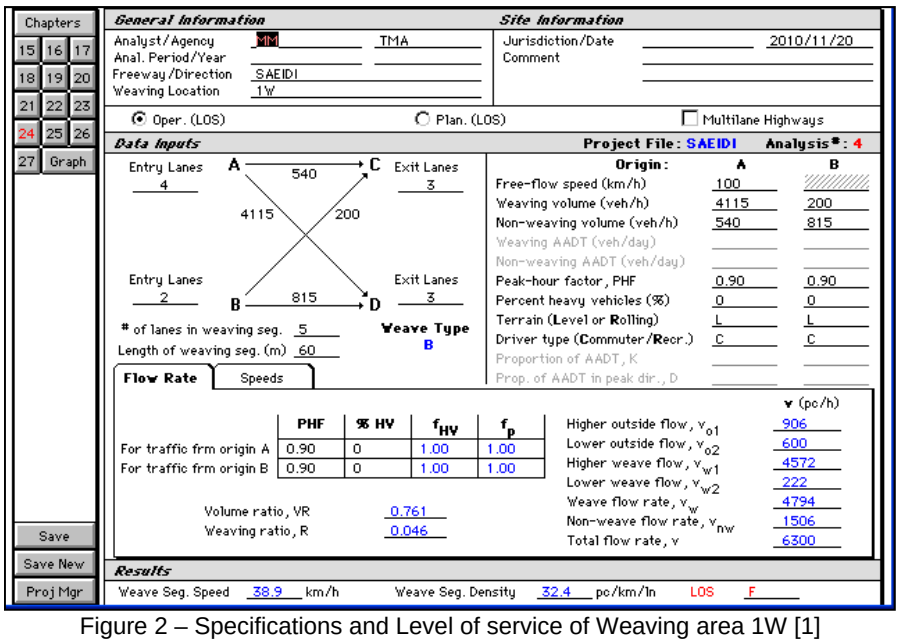

Figure 2 – Specifications and Level of service of Weaving area 1W [1]

3-2- AHP

The AHP is considered as one of the common methods which results in choosing the final option with linear viewpoint. Considering all the issues addressed to it, this method has been used for years. This method enjoys frequent applications concerning economic and social issues and has also been applied in managerial affairs within the recent years. One of the most important parts of AHP is the hierarchical structuring, which include the following three phases:
-Structuring hierarchy,
-Relative weight of criteria,
-Final weight of options

3-2-1-Structuring Hierarchy

The first step in the AHP is structuring hierarchy which includes three main hierarchies, e.g. purpose, criterion and option. In the highest level, there is the purpose of decision-making and in the lowest level of decision-making. In the middle level, there are criteria which may include one or more levels [3].
In Figure. No. 3, the hierarchy of categorizing the safety performance of U-Turns and Weaving areas in Saeidi between 45 Metri Zarand and Shahid Kazemi junction (studied area) has been presented. As it may be seen in the figure, in the first hierarchical level, the final target which is categorizing the safety of the U-Turns and Weaving areas exited within the studied area has been shown. In the second hierarchical level, the indicators affecting the safety status of the U-Turns and Weaving areas (considered criteria) have been given; generally speaking, such indicators include the following:

a-Geometrical indicators,
b-Physical indicators,
c-Traffic indicators.
And finally, in the third hierarchical level, the U-Turns and Weaving areas existed within the studied area have been given

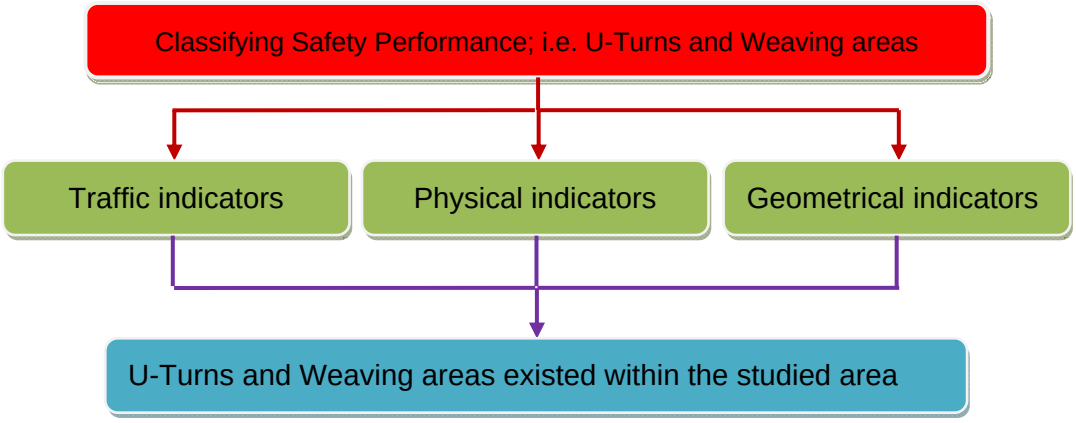

Figure 3 – Hierarchy of Categorization of Safety Performance of U-Turns and Weaving areas of studied area [1]

3-2-2- Weight of Criteria

Investigating the motion maneuvers of the vehicles within the U-Turn area indicates that studying the U-Turn safety shall be focused in two sections. The divergent movement location, known as the U-Turn location; and a certain area as the Weaving area where the interfered movements of the vehicles are performed. Therefore, the safety indicators have been studied for each of the U-Turns and Weaving areas sections separately.

3-2-2-1- Introducing the Indicators affecting the Safety Performance of U-Turns

The problems resulted from failure to observe the regulations and standards on design and implementation results in decreasing the capacity and safety of U-Turn. On the other hand, the designing and implementing problems result in intensifying the behavioral problems of drivers and pedestrians and failure to observe the traffic rules, which intensifies interference of the U-Turn performance. The features which play a role in determining capacity and safety of traveling of vehicles within the U-Turns area include general geometrical, physical and traffic indicators.
However, in studying such general indicators, some more detailed indicators shall be analyzed which affect the safety performance discussion of the U-Turns. According to the studies, field visits and studies made by Tarh Mandegar Aria Consulting Engineers, scoring the indicators affecting the safety of studied U-Turns has been made while the conditions of the U-Turns and Weaving areas of Saeidi Highway have been assessed and analyzed [1].

3-2-2-2-Weighing Indicators

Along with analyzing and comparing the studied U-Turns, each of the indicators affecting their safety performance has been weighed relying on the engineering judgment. In Table No. 3, those effective indicators studied and analyzed in case study together with the scores allocated to each of the same as well as the weighted assigned to them have been given. In the fulfilled scoring, the most suitable and unsuitable safety indicators relevant to each U-Turn are given 1 and 10 points, respectively. For instance, in A U-Turn, the separating islands and changing turning radius are most unsuitable and length and number of output storage is the most suitable indicator affecting safety. As it may also be seen in Table No. 3, in weighing assigned to U-Turns, certain indicators such as separating islands, safety equipment, changing turning radius and output storage length have the highest effects, while drainage, superstructure and warning signs have the least effects on the analysis of U-Turns safety performance.

Table 3 – Scoring and Weighing Indicators Affecting U-Turns Safety [1]

Effective Indicators	Assigned Weight	Scores Assigned to U-Turns					
		A	B	C	D	E	F
Directing islands	7	9	10	3	3	2	3
Separating islands	10	2	8	2	2	2	3
Changing turning radius	9	9	5	2	2	2	2
Opening width	5	2	4	4	4	4	4
Entrance storage length	5	7	10	2	4	3	2
Number of lanes of entrance storage	4	5	10	3	2	2	2
Length of exit storage	9	1	5	1	1	1	1
Number of lanes of exit storage	7	1	5	2	2	2	2
Widening U-Turn entrance bound	4	5	2	3	3	3	3
Widening U-Turn exit bound	7	2	5	3	3	3	3
Continuous horizontal signs (lining)	4	7	7	4	4	4	4
Non-continuous horizontal signs	4	7	7	4	4	4	4
Information boards	5	3	2	2	2	2	2
Disciplinary boards	5	5	2	2	2	2	2
Warning boards	2	5	5	2	2	2	2
Signs	4	7	2	2	2	2	8
Drainage	1	4	3	2	2	2	2
Pavement	2	2	2	2	2	2	2
Lighting	4	2	2	2	2	2	5
Sight angle	7	7	1	1	1	1	1
Safety equipment	10	7	5	3	3	3	5

3-2-2-3- Introduction of Indicators affecting Safety Performance of Weaving areas

There have been defined certain indicators in order to assess the safety of the Weaving areas in this case study, which may be analyzed with their performance through weighing and scoring the indicators. In Table No. 4, the effective indicators, scoring and weighing relevant to the same have been given.

As it has also been shown in Table No. 4, the method of weighing indicators affecting the Weaving areas safety is in a way that the indicator of manner of interference with the approach and the indicators of warning sing and signs have the highest and lowest importance, respectively.

Table 4 – Scoring and Weighing Indicators Affecting Weaving areas Safety [1]

Effective Indicators	Assigned Weight	Scores Assigned to U-Turns											
		1E	2E	3E	4E	5E	1W	2W	3W	4W	5W	6W	7W
Continuous horizontal signs (lining)	6	7	4	4	4	4	7	2	4	4	4	4	4
Non-continuous horizontal signs	5	7	4	4	4	4	7	2	4	4	4	4	4
Information boards	7	3	2	2	2	2	3	2	2	2	2	2	2
Disciplinary boards	4	5	2	2	2	2	5	6	2	2	2	2	2
Warning boards	2	5	5	2	2	2	5	2	3	2	2	2	2
Signs	2	6	2	2	2	2	7	2	2	2	2	10	10
Drainage	3	5	2	2	2	2	5	5	2	2	2	2	2
Pavement	4	4	2	2	2	2	3	3	2	2	2	2	2
Lighting	4	2	2	2	2	2	2	2	2	2	5	5	5
Sight angle	5	3	2	2	2	2	3	3	1	2	1	2	2
Safety equipment	5	4	3	3	3	3	6	5	2	3	3	5	5
Manner of interference with approach	10	7	3	8	5	3	7	4	5	7	6	3	7

3-3- Weighed Safety Indicator

In order to compare the U-Turns and Weaving areas in terms of safety performance, the safety indicator is defined, which is in fact an effective weighed indicator, whose weight is resulted from a certain weight determined considering engineering judgment. Considering the fact that the method of scoring the effective indicators has been in a way that more score indicates unsuitability of the safety status of such indicator, therefore, higher weighed safety indicator (quantitatively speaking) indicates the improper status of such indicator on the studied location [1].
Safety indicator is calculated through the following relationship:

Safety indicator = indicator weight × indicator assessment score

Where indicator weight is determined through engineering judgment and also indicator assessment score is determined through field visits.

Figure No. (4) indicates comparative comparison of weighed safety indicator relevant to each U-Turn. By taking benefit from such chart Saeidi U-Turns may be compared considering their safety performance.
In figure No. (5) the weighed safety indicator of Weaving areas and also the comparative comparison chart of safety indicator of the Weaving areas have been presented.

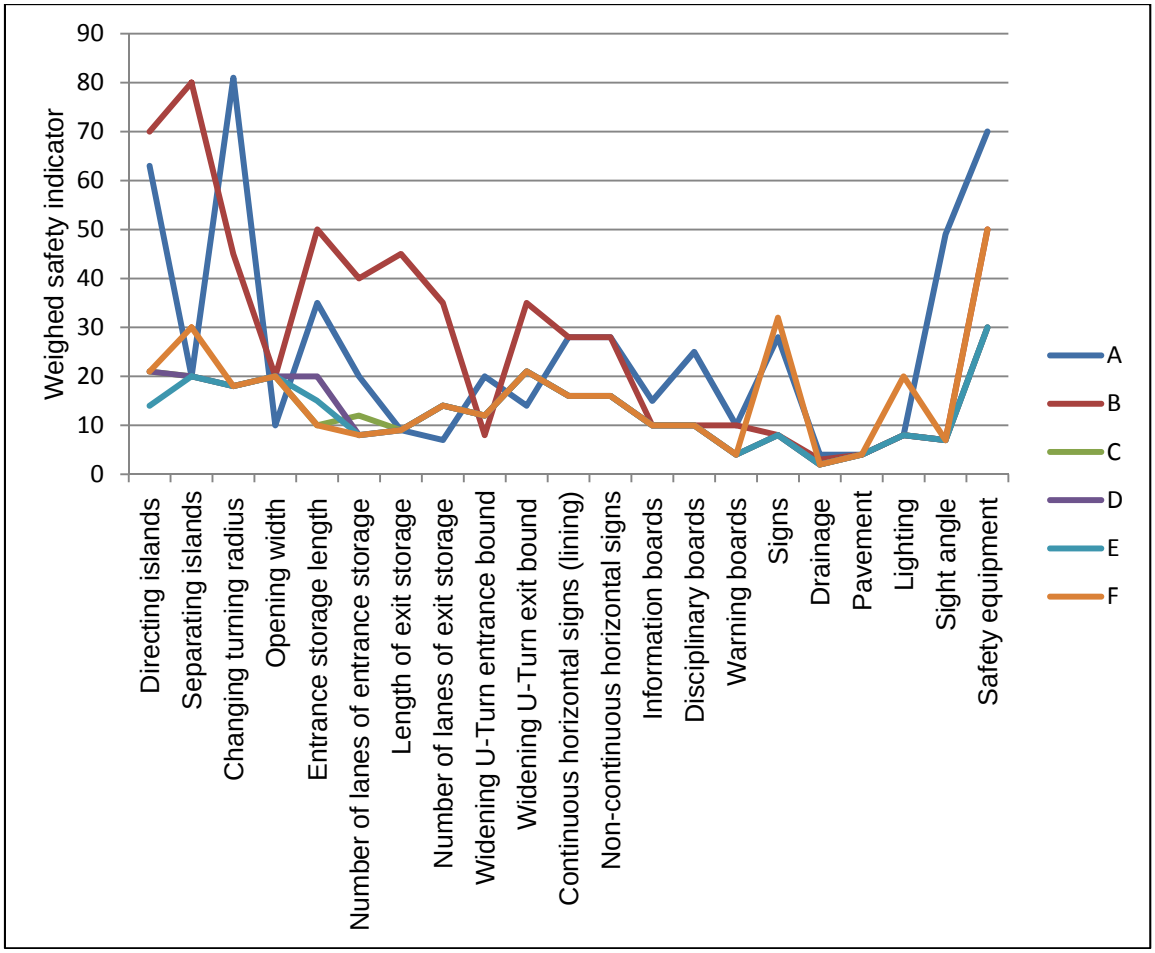

Figure 4 – Comparative Comparison of studied U-Turns in Saeidi Highway

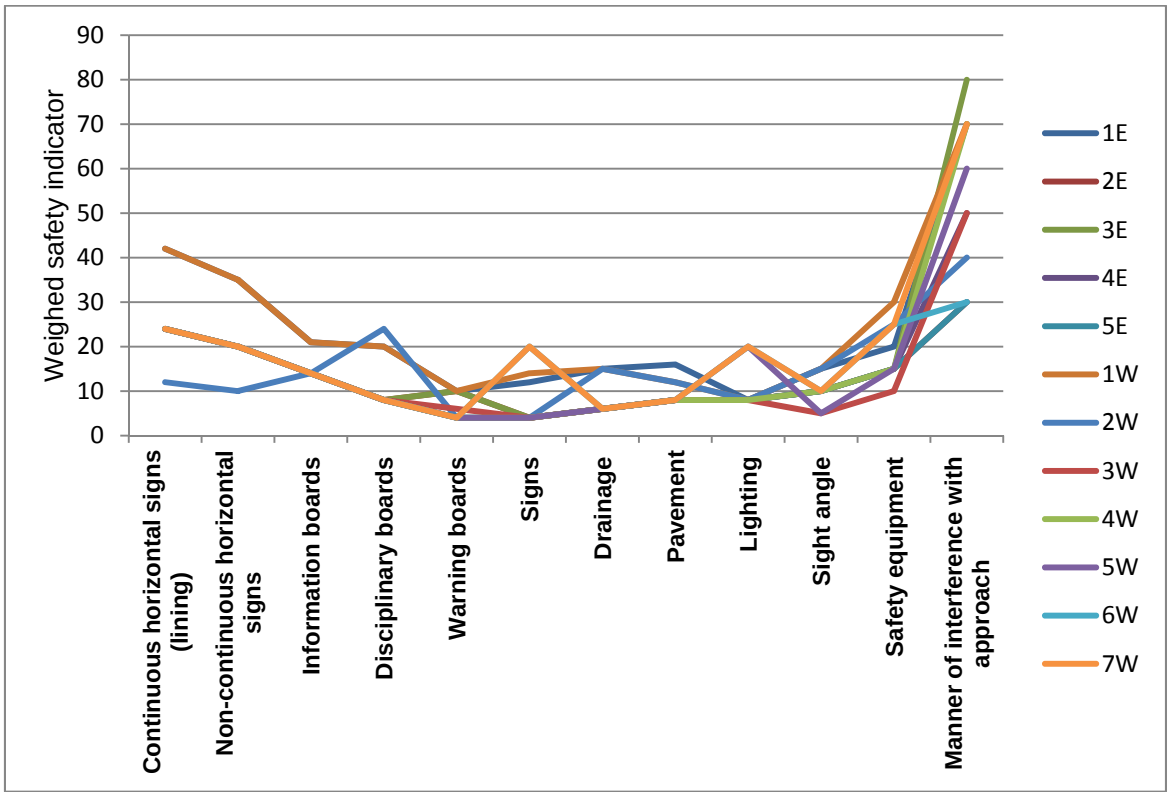

Figure 5 – Comparative Comparison of studied Weaving areas in Saeidi Highway

As it may be seen in figure No. (4), in comparing the status of the safety indicators of studied U-Turns, most of the studied U-Turns have improper conditions as per the indicators of separating islands, changing turning radius as well as safety equipment, however, they are under better conditions concerning certain indicators such as information, warning and disciplinary boards, horizontal signs, and drainage and superstructure status. It may be understood fro, the investigating and comparing the defined safety indicators in Weaving areas and considering the results existed in figure No. (5) that the studied Weaving areas of this study are of suitable status regarding the indicators of the manner of interference with the approach and continuous horizontal sings, while they are of relatively good conditions in terms of certain indicators such as warning boards, drainage status, superstructure status and signs status.

3-3-1- Safety Number

By taking benefit from the weighed simple sum through summation the multiplication of each of assessed scores in the relevant weight, the U-Turn safety number shall be calculated. This number shall be within 21 to 2,100 interval and its bigger value indicates less safety of the U-Turn.

4- CATEGORIZATION OF SAFETY PERFORMANCE

In order to analyze the safety performance and realizing safest and least safe U-Turns and Weaving area as well as their prioritizing in terms of effective safety indicators, they have been focused with their categorization by taking benefit from calculated safety number in the above clause.

4-1- Categorization of Safety Performance

By comparing the safety number calculated by using the weighed simple summation of the U-Turns implemented in Saeidi Highway have been categorized, while its results have been presented in figure No. 6

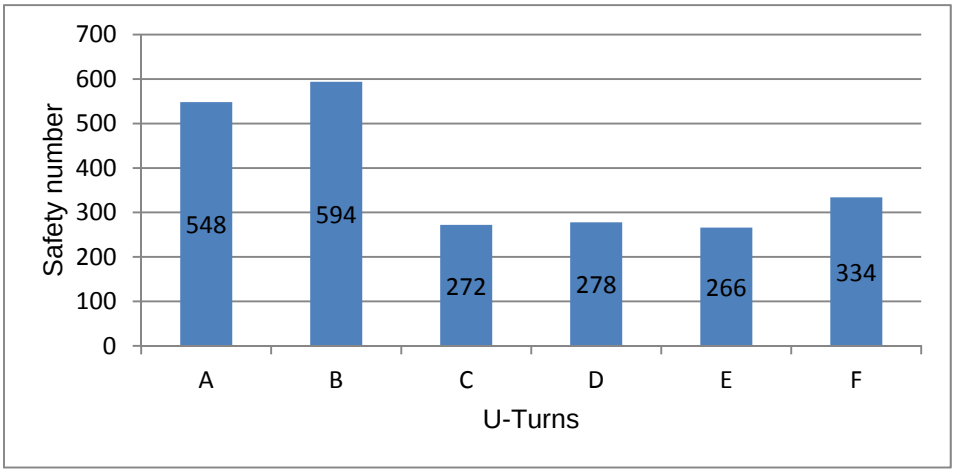

Figure 6 – Comparison of the Safety Number of the Studied U-Turn

As it is seen, B U-Turn with safety number of 594 is assessed as the least safe U-Turn. Meanwhile, A U-Turn is placed as the next one with safety number of 548. One of the reasons based on which B U-Turn has been recognized as the least safe U-Turn within the studied area is that the status of separating islands, directing islands, length of entrance storage and number of lines of entrance storage of this U-Turn has been assessed as very improper. On the other hand, C, E U-Turns with 272, 266 safety numbers, respectively, are considered as the safest U-Turns of Saeidi Highway. Of the reasons of E U-Turn safety, the suitable status of separating islands, changing turning radius and length of exit storage may be mentioned.

4-2-Categorization of Safety Performance of studied Weaving areas

By taking benefit from the resulted safety numbers, the safety performance of Weaving areas studied were compared with each other, of which the relevant results have been given in figure No. 7.

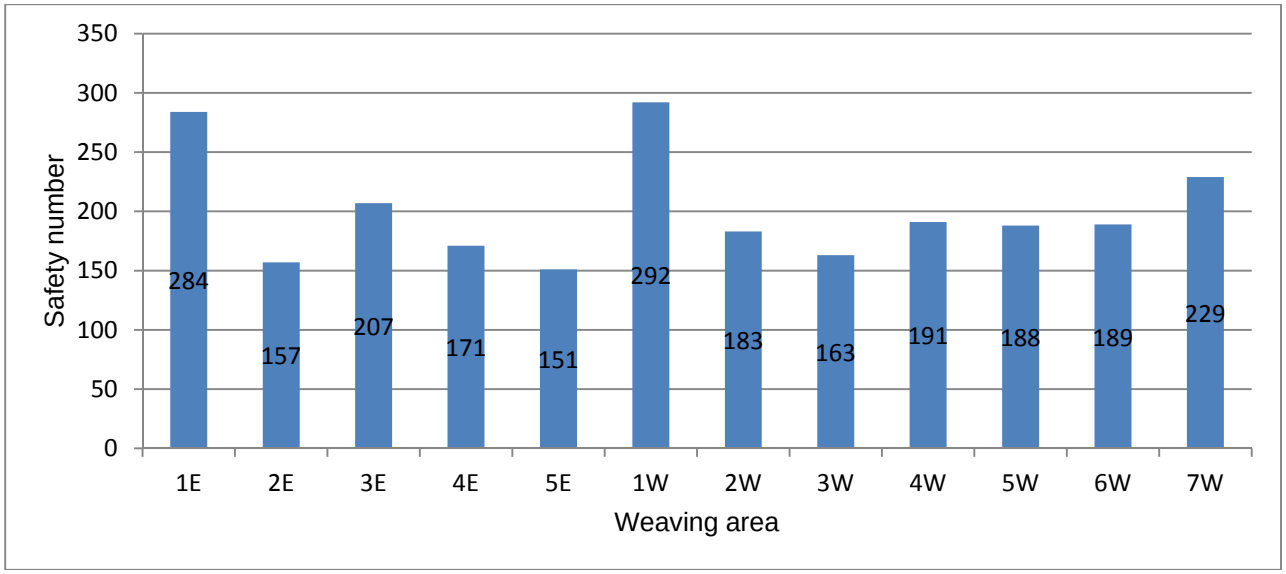

Figure 7 – Comparison of the Safety Number of the Studied Weaving areas

As it may also be seen in figure No. (7), 1W Weaving area (first western) with safety number 292 is recognized as the least safe Weaving area. Of the reasons the unsafe nature of this Weaving area, improper status of manner of interfere with the approach and continuous horizontal sings (lining) may be mentioned. On the other hand, 5E Weaving area (fifth eastern) with safety number of 151 is recognized as the safest Weaving area of Saeidi Highway, which is due to the suitable status of manner of interfere with the approach and information boards [1].

5- CONCLUSION

1- A high volume of turning left movements in the junctions result in increased delay and interference with the vehicles in other directions. One of the methods to decrease the delay in such types of junctions is prohibition of turning left and taking benefit from U-Turn for turning left movements' transmission.
2- By analyzing the safety indicators of U-Turns and Weaving areas, such as geometrical, physical and traffic indicators, the implemented U-Turns may be categorized based on their safety performance and safeguard the same considering their performance level.
3- Considering the variability of the effective indicators to categorize U-Turns Weaving areas in terms of their safety indicator, in this article the AHP method has been used.
4- Those features which play a role in determining the capacity and safety of traveling vehicles within the area of U-Turns include general geometrical, physical and traffic indicators.
5- In weighing assigned to the U-Turns, certain indicators such as separating islands, safety equipment, changing turning radius and length of exit storage have the highest effects, while the indicators of drainage, pavement and warning signs have the least effects on the analysis of the U-Turns safety performance.
6- Method of weighing the indicators effective on the safety of the Weaving areas is in a way that the indicator of the manner of interference with the approach has the highest importance, while the indicators of warning sign and signs have the least importance.
7- Most of the studied U-Turns are of improper status considering separating islands, changing turning radius as well as safety equipment, while they are of better conditions in terms of certain indicators such as information, warning and disciplinary boards, horizontal signs, drainage and superstructure status.
8- The studied Weaving areas in this articles are of suitable status concerning the manner of interfere with the approach and continuous horizontal sings, while enjoying relatively suitable conditions in terms of certain indicators such as warning boards, drainage, superstructure status and signs status.
9- B U-Turn has been recognized as the least safe U-Turn within the studied area, while its separating islands, directing islands, length of entrance storage and number of entrance storage line have been assessed as quite improper; on the other hand, of the reasons of safety reasons of E U-Turn, the suitable status of separating islands, changing turning radius and length of exit storage may be mentioned.
10- Due to the improper status of manner of interfere with the approach and continuous horizontal signs (lining), W1 Weaving area is the least safe Weaving area and 5E Weaving area is considered as the safest studied Weaving area due to the suitable status of the manner of interfere with the approach and information boards.

6- ACKNOWLEDGEMENT

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7- REFERENCES:

[1] Tarh Mandegar Aria Consulting Engineers, revision and safeguarding of Saeidi Highway U-Turns, between 45 Metri Zarand and Shahid Kazemi Highway, Tehran Organization of Transportation and Traffic, Summer 2010.

[2] Shahi Jalil, Naderan, Ali, the effect of U-Turn on the safety of traffic. 1st international conference on driving and road incidents, year 2005.

[3] Asgharpour, Mohammad Javad, multi-standard decision making, Tehran University Press, 3rd edition, 2004.