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Investigation of Road Geometry-Based Weaving Area Problems on Urban Roads

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Driver behavior,
Road geometry.

Abstract

Traffic chaos in weaving areas with merging or diverging bay is a general problem encountered across the world. There are studies in the literature to find solutions to this problem and to develop calculation methods. When studies on weaving problems are examined in Turkey and World, no study has been found to evaluate vehicle movement types in the weaving areas by considering all vehicle types. Especially, a study is needed to examine vehicle movement types and suggest new geometries for the solution of the problem with such an evaluation. In this study, weaving confusion in three different weaving points in two metropolitan areas and the effect of many different parameters for the solution of weaving confusion were examined in detail with a diagnostic-based approach. In the study, total 7 different vehicle movement types were determined and it was tried to reveal how large the distribution of movement types caused by the confusion in the weaving areas. It was determined that the most common movement type was Type-1 with 39.2%, and the least common movement type was Type-6 with 3.1%. As a result, depending on the improvements in the traffic flow with the help of new geometry arrangements in three different weaving points, traffic safety will increase and complexity in the weaving areas will reduce on urban roads.

1.Introduction

Weaving confusion in urban traffic is defined as the intersect or overlap of two or more traffic streams moving in the same direction along a certain section of the highway due to lane changes on the road sections (HCM, 2010). According to the literature, weaving area problems are seen more commonly merging and diverging roads or intersections with uninterrupted flow. Particularly, the short distances between the merging and diverging roads can lead to traffic accidents by not providing the necessary distance so that the vehicles do not affect each other in case of lane changes for merging and diverging behaviors. In many countries, there are many problems related to weaving area complexity on roads that are not made in accordance with a certain standard or scientific study (Dağlı, 2020). Especially, a certain standard or scientific findings are not obtained in the planning and construction of urban road geometries. Therefore, many merging and diverging problems observed in urban road network. The most common geometric design problems observed in urban arterials caused by irregularity in the width and number of lanes, deficiency or excess in the number of lanes, excessive length or shortness of the diverging and merging roads, etc. These existing problems lead to negative behaviors on roads resulted from indiscipline in lane use, tendency to avoid the queue as much as possible in case of congestion, fast driving, illegal lane changing, unsafe overtaking, not obey to the rules, aggressive behavior. All these negative behaviors of drivers result many accidents in main arterial roads in cities.

In many countries around the world, traffic chaos in weaving areas with merging or diverging bay are commonly observed during the peak hours of traffic due to many different reasons such as driver and road characteristics, traffic flow demand, weather conditions, etc. All complexity in traffic flow may create bottleneck and weaving areas, and cause long queues, unnecessary lane changes, delays and traffic accidents. Therefore, the main purpose of this research is to examine and analyze the reasons of weaving area problems in the two selected pilot cities in Turkey. In this study, weaving area confusion types in two different regions in two metropolitan cities and the effect of many different parameters for the solution of weaving confusion were examined in detail with a diagnostic-based approach in urban roads. Thus, new geometries were suggested to fix the observed problems and reasons of the weaving confusion were tried to be determined by evaluation many different effective parameters.

2.Literature Review

It can be seen from the current literature that weaving confusion generally observed in road arterials where a diverging lane close to a merging lane or merging lane connecting to a main arterial road. If there is not enough distance between the merging lane and the diverging lane to enable vehicles to change their current lanes without affecting each other, the weaving chaos are commonly observed in entry and exit roads of cities. According to the findings from the previous studies, there are three important parameters (length, width and type of the weaving area) that affect the operating characteristics of the weaving area, and they directly affect the critical lane changing behavior of vehicles (HCM, 2000; HCM, 2010; Aydin, 2018; Dağlı, 2020). Many studies have been carried out and still continue to be done in order to model and develop solution proposals by examining the traffic problems on the road sections where weaving areas are seen commonly. For example, the first study on this subject was carried out within the scope of the preparation of HCM (1950). After this date, many studies have been carried out to develop the model proposed by HCM (1950) and related studies still continue. For example, in HCM (1965), a new model is proposed in relation to weaving area length, total weaving area volume and level of service in these road sections. In HCM (2000), a new model is proposed which is estimated to determine the current or expected level of service (LOS) by converting vehicle speed to overall density and evaluating weaving area type and operating characteristic. In their study, Roess and Ulerio (2009) developed a new model that gave better results in field tests compared to the model proposed by HCM (2000). Then, the model proposed by Roess and Ulerio (2009) was further developed in HCM (2010) as a new method for estimating the level of service based on the density of the weaving area. According to this newest method proposed by HCM (2010), the density is determined by evaluating the average speeds of vehicles during the lane changing behaviors or not and the current traffic volumes observed in the weaving area.

When the studies on weaving area problems on roads with merging/diverging in Turkey and the world are examined, no study found that evaluates all parameters (road geometry and characteristics, lane change behavior, spot/average speed, traffic flow, driver/vehicle characteristics, etc.) in the weaving area together. In particular, it is necessary to propose a model that calculates capacity and/or service level with such an evaluation, or to develop new proposals for the solution of the problem in weaving areas and there is a need for such a study in the literature. Existing literature in Turkey is examined, the studies mostly reveal the weaving areas form due to the turns at intersections (Aydemir, 2006; Tanyel and Yayla, 2010; Saplıoğlu and Karaşahin, 2010; Alçelik, 2010; Kaygısız and Şenbil, 2011) or model complexity in the merging/diverging region where congestion, shockwave queuing, and irregular lane change or indiscipline of lane use problems (Ceyhan, 2011; Yaslan, 2012; Demir vd., 2014; Abuamer vd., 2016).

It is seen from the previous studies on weaving formation are examined, there are many studies conducted to explain weaving formation to develop various calculation methods and to find solutions to this problem. However, when these studies are examined in detail, it has been determined that there is no study that examines all weaving area formations and proposes a solution by evaluating many external parameters, especially road geometry and lane change behavior. It has also been determined that it is necessary to propose a model that develop new proposals for the geometric solution of the problem in weaving areas to solve the above-mentioned problems. In this direction, the effects on the formation of weaving were examined by taking into account the road geometry, driver characteristics a vehicle type. Additionally, many related sub-parameters, and geometric arrangements and operational improvements were tried to be made with the findings.

3.Material and Method

3.1. Study Site Determination

In the scope of the study, the effects on the formation of weaving confusion were examined by taking into account the road geometry, traffic flow characteristics, driver characteristics, many related sub-parameters, and geometric arrangements and operational improvements were tried to be made using the findings. During the study site determination, candidate road sections were limited as follows:

• Located on the main arterials,

• Divided two lanes with merging and diverging road sections,

• Irregular lane widths,

• Not designed in accordance with certain standards,

• High queue and delay problems caused by the weaving problems.

In the study, two study sites in two pilot cities (Antalya and Trabzon) were found to be appropriate (Fig. 1).

Figure 1. Locations of examined two cities in Turkey.

Steps for the study site selection, data collection and extraction process can be summarized as given flow chart in Figure 2.

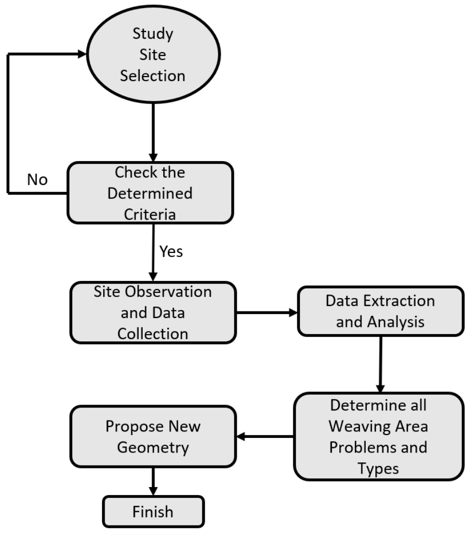

Figure 2. Methodology of the study and determination of sites.

Within the scope of the study, two different points were determined in an examined region where the weaving problem is seen intensely in Antalya city. The locations and real site visuals of these two points are shown in Figure 3.

(a)

(b)

Figure 3. Determined weaving areas in Antalya city (a) Point 1 and (b) Point 2.

In examined another pilot city (Trabzon city), a point was determined where the weaving area problem is seen intensely.

Figure 4. Determined weaving area in Trabzon city.

3.2. Data Collection

After determining the urban road sections that have weaving area problems in the pilot cities, the geometric features (lane width, platform width, lateral clearance and line width) and characteristic features (problems observed according to the number of lanes and merging/diverging types) of the road sections were determined in detail. The geometric lengths of the determined road sections were determined by taking the average of five different measurements made from the same point. From the field measurements, the line width of the lanes was measured as 15 cm on an average value. The data obtained regarding the geometric properties of the examined road sections are given in Table 1.

Table 1. Geometric properties of examined roads.

City	Point No	Lane No	Lane Width (m)	Lateral Clearance (right–left) (m)	Platform Width (m)
Antalya	1	1	3.00	0.25–0.25	14.50
		2	3.60		
		3	3.60		
		4	3.80		
Antalya	2	1	4.30	0.25–0.25	14.70
		2	3.30		
		3	3.30		
		4	3.30		
Trabzon	3	1	3.50	0.15–1.10	11.55
		2	3.40		
		3	3.40		

Note: According to the direction of vehicles, Lane no 1 is defined as the right lane.

Site data of three examined points in two different regions in two different pilot cities were collected considering the traffic flow characteristics (for 5 different situations from least density to most density) and weather conditions (rainy and non-rainy). For this purpose, vehicle movements in the examined regions were recorded with video cameras on weekdays a during peak hours when the weather is bright (08:00-09:30 and 17:00-18:30). As mentioned in previous, in order to examine the effect of weather conditions on weaving area formation in addition to driver psychology, the days when the weather was rainy and dry were especially taken into account and the data were collected accordingly. Thus, a comprehensive data set was tried to be obtained by taking into account the driver characteristics, traffic flow characteristics and weather conditions in different regions of two pilot cities (Fig. 5).

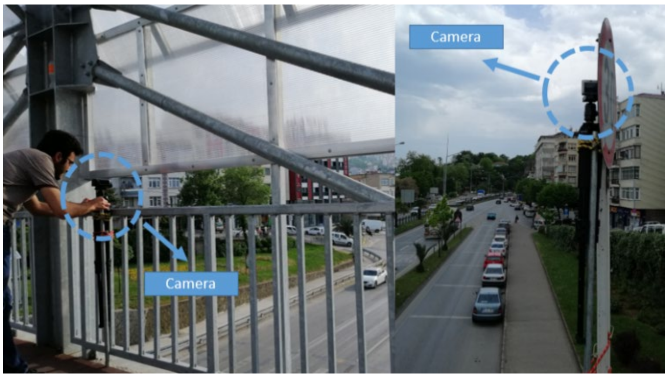

Figure 5. Video recordings and data collection visuals from the study sites.

3.3. Data Extraction

After video recordings, the recorded videos were transferred to the computer and then the counts were made with the help of the counter program. For a detailed analysis of all the activity and the problems in the selected weaving area regions during the digitization of the data, all lanes were examined on a lane-based evaluation. The data given in below have been obtained from video recordings:

- Vehicle types and total number of vehicles,
- Traffic volume for entry and exit zones (vehicle/hour),
- Lane number and width,
- Movement types of vehicles,

Obtained data from the video recording for three cities as summarized in Table 2.

Table 2. Obtained traffic flow data in weaving areas.

Pilot City	No	Location	Lane No	Total Vehicle Observation Number (vehicle)	Volume (veh/hr)
Antalya	1	Weaving Area Entry	1	4605	1116
			2		1511
			3		1955
		Weaving Area Exit	1	4632	1257
			2		313
			3		1246
			4		1815
Antalya	2	Weaving Area Entry	1	4255	1051
			2		410
			3		865
			4		1173
		Weaving Area Exit	1	4289	497
			2		595
			3		773
			4		1370
Trabzon	3	Weaving Area Entry	1	1221	276
			2		457
			3		488
		Weaving Area Exit	1	1206	319
			2		403
			3		484

4. Data Analysis and Findings

4.1. Vehicle Movement Types in Weaving Areas

The observed vehicle movement types in the weaving areas at three different points were examined in detail. In analysis, all movement types caused by weaving forming have been determined by considering traffic congestion, confusion, irregular lane changing etc. From the analysis, total seven different movement types observed at examined three road points as shown in Fig. 6.

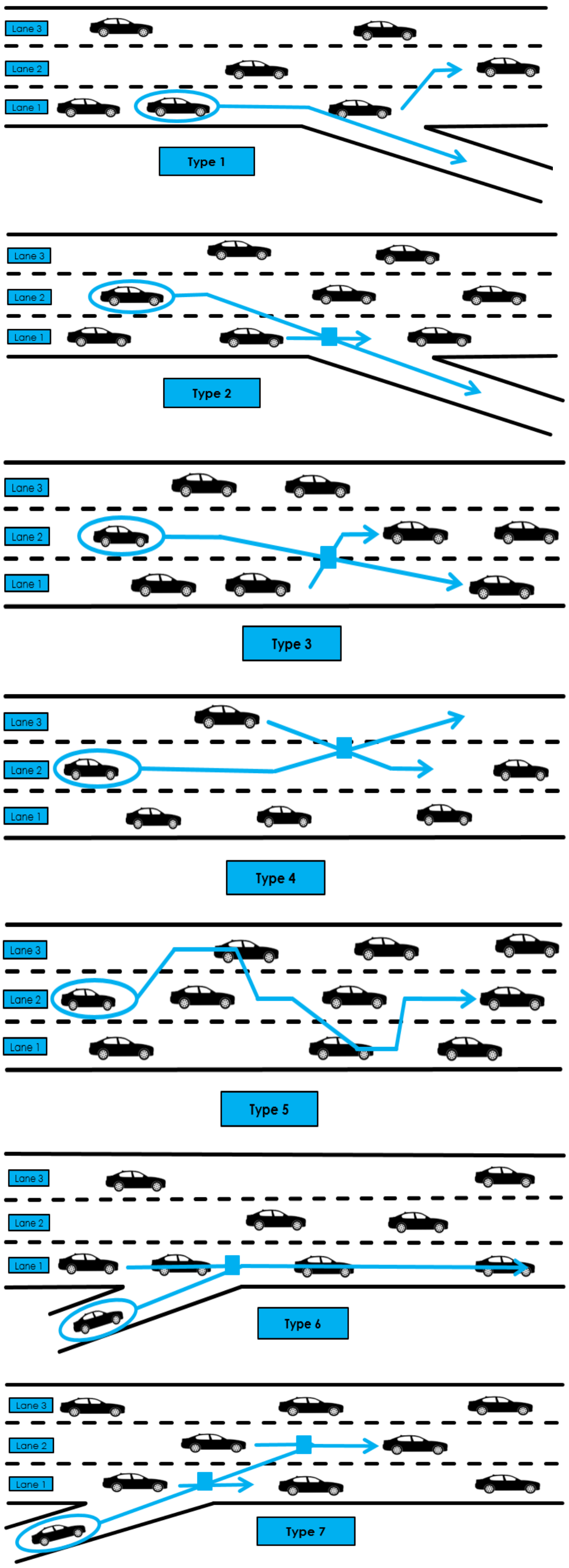

Figure 6. Observed seven different vehicle movements in weaving areas.

Total seven different vehicle movements that cause weaving chaos in three different weaving points examined within the scope of the study. Obtained movement types are summarized in Table 3.

Table 3. Detailed explanation of observed seven different vehicle movements.

Movement No	Movement Property
1	Diverging of a vehicle from the exit lane
2	Diverging of a vehicle from exit lane by changing lanes.
3	Changing lanes to the right with the intent or effect of diverging
4	Changing lanes to the left with the intent or effect of merging
5	Changing lanes due to diverging/merging movements
6	Movement from the entry lane by merging
7	Move to other lanes by merging from the entry lane

From the data analysis, total seven different vehicle types (Passenger Car, Minibus, Midibus, Bus, Van, Truck and Lorry) were observed on the examined road sections within the scope of the study. In order to facilitate the examinations and the proposal of calculation methods, these vehicles have been reduced to four different main categories (1-Passenger Car, 2-Minibus & Van, 3-Midibus & Bus, 4-Truck & Lorry) according to their dimensions and characteristics. From the analysis, the distribution of seven different vehicle movement types, which cause weaving confusion, were determined and summarized in Table 4 from the detailed examination of the video camera recordings according to the vehicle type.

Table 4. Observed vehicle movements according to vehicle types.

No	Veh. Type	Movement Type							Total Veh. Numb.
		1	2	3	4	5	6	7	
1	1	99	73	3	21	15	0	0	211
	2	17	8	1	0	7	0	0	33
	3	4	0	0	0	1	0	0	5
	4	1	1	0	1	0	0	0	3
2	1	0	2	41	0	2	17	106	168
	2	0	1	7	0	3	0	12	23
	3	0	0	4	0	1	3	0	8
	4	0	0	0	0	1	0	2	3
3	1	121	1	15	9	9	0	0	155
	2	14	0	14	11	5	0	0	44
	3	1	0	0	1	0	0	0	2
	4	0	0	0	0	0	0	0	0
Total (∑)		257	86	85	43	44	20	120	655

When Table 4 is examined in detail, it was determined that total 655 vehicles caused weaving forming in examined road points. In the study, total seven different vehicle movement types were determined and it was tried to reveal how large the distribution of movement types caused by the confusion in the weaving areas. When the number of seven different movement types were examined numerically, it was determined that the most common movement type was Type-1 with 39.2%, and the least common movement type was Type-6 with 3.1%. It has been determined that the percentage distribution of the other five different movement types is distributed between the percentage values of these two movement types.

4.2. New Geometry Design Suggestion

As stated in the aims of the study, new geometric arrangements that will prevent the formation of weaving have been proposed instead of irregularity in the examined three points. Since the existing road geometries are located on the urban road networks and there is no possibility to go beyond the existing boundaries in terms of geometry. The suggestions were made by considering the existing geometric boundaries, number of lanes and lane widths as given Table 5.

Table 5. Proposed new geometry for the examined road sections.

City	Point No	Entry Lane No	Exit Lane No	Lane Width (m)
Antalya	1	1	1	3.50
		2	2	3.50
		3	3	3.50
		—	Extra Side Lane 1	3.20
		—	Extra Side Lane 2	3.20
Antalya	2	1	1	3.50
		2	2	3.50
		3	3	3.50
		Extra Side Lane 1	Extra Side Lane 1	3.20
		Extra Side Lane 2	Extra Side Lane 2	3.20
Trabzon	3	1	Extra Side Lane 1	4.50
		2	1	3.20
		3	2	3.20

5. Conclusions and Suggestions

Increasing traffic safety and flow performance by reducing complexity in weaving areas is a very important issue for authorities and researchers. In this study, the road sections with weaving confusion problems on urban roads in two metropolitan cities of Turkey with different driver characteristics were examined in detail. For this purpose, firstly, the traffic flow characteristics in these regions were examined. When the lane changes made by the drivers in order to diverge or merge a road section are examined, it is seen that the drivers mostly move in the lanes close to the merging or diverging bays. Therefore, it has been determined that drivers mostly change their lanes for the purpose of diverging or merging from these lanes. When the data obtained from the recordings made with the video camera are analyzed quantitatively, it is seen that the majority of the vehicles that will diverge or merge the most suitable lane just before the weaving confusion regions. The following results were obtained from the observations and analyses made in the study:

• Unfortunately, there are geometrical problems that have an effect on the complexity on the road sections in Turkey with weaving area complexity. The results obtained for the two metropolitan cities confirm this judgment for three points in two different regions.

• It has been observed that most of the drivers are in the right lane for the diverging/merging movement when entering and exiting the weaving confusion zones, however, a significant number of drivers triggered the accidents by making a sudden lane change when they were not in the appropriate lane during the diverging/merging movement.

It is expected that the researches on the roads, where there is weaving, will reduce the complexity in the weaving areas on urban roads and reduce the stress on the drivers. Thus, it will make a significant contribution to road safety. In addition, such studies will encourage the authorities in road planning and construction to design and build roads that do not have geometric indiscipline.

Declaration of Conflict of Interests

The authors declare that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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