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ANALYSIS OF FATAL AND INJURY CRASHES BY GEOGRAPHICAL INFORMATION SYSTEMS: A CASE STUDY OF GAZİANTEP

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By

Sevinç ÖZGÜN

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Prof. Dr. Metin BEDİR

Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Mustafa GÜNAL

Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope of quality as a thesis for the degree of Master of Science.

Assist. Prof. Dr. Yusuf Kağan DEMIR

Supervisor

Examining Committee Members:	Signature
Assist. Prof. Dr. Yusuf Kağan DEMIR	…………………
Assoc. Prof. Dr. Ali Fırat ÇABALAR	…………………
Assist. Prof. Dr. Hüsnü UĞUR	…………………

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Sevinç ÖZGÜN

ABSTRACT

ANALYSIS OF FATAL AND INJURY CRASHES BY GEOGRAPHICAL INFORMATION SYSTEMS: A CASE STUDY OF GAZİANTEP

ÖZGÜN, Sevinç

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According to General Police Department's 2013 statistics, Gaziantep ranks 10 in fatal and injury accident rankings in Turkey. The traffic accidents have became an important issue for Gaziantep as a result of the economical improvement of the city which has led to increased amounts of vehicles and immigrants. However; there is no causal relation or a model study to explain the relativity between the reasons and geographical locations of the accidents. Lack of such a study makes it harder to bring basic factors which affects fatal and injury accidents to a solution in real terms. In this study, it was aimed to identify accident hot spots according to geographical coordinates. For this purpose, information about the accidents which occur in 2013, provided by regional police department and a database created for analyze. With support of Geographical Information System (GIS), Kernel Density Estimation method used for create a model for find the parameters which is effective on accident occurrence. In order to do this, accidents were viewed on a map with locations using Geographical Information System (GIS) and were analyzed according to accident coordinates, time of accident, weather condition, type of road coat, type of road, proximity of accident areas to intersections, driver information, driver's use of alcohol, number and types of cars involved in the accident, driver, passenger, pedestrian distribution and reason of accident occurrence. As a result of the analyses conducted, it is concluded that hot spots are generally on junctures and possible solutions are offered for high risk areas.

Keywords: Traffic Accidents, Hot spot, GIS, Kernel Density Estimation

ÖZET

TRAFIK KAZALARININ COĞRAFİ BİLGİ SİSTEMLERİ YARDIMI İLE ANALİZİ: GAZIANTEP ÖRNEĞİ

ÖZGÜN, Sevinç

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Emniyet Genel Müdürlüğü'nün 2013 yılı istatistiklerine göre Gaziantep ölümlü ve yaralamalı kazalar sıralamasında ülkemizde 10. Sıradadır. Gaziantep'in gelişen ekonomisinden dolayı, alınan göç ve taşıt sayısında yaşanan artışla birlikte trafik kazaları kentin önemli bir sorunu haline gelmiştir, ancak bugüne kadar kazaların nedeni ve coğrafi konumları arasında nedensellik ilişkisi ya da bir model çalışması yapılmamıştır. Böyle bir çalışmanın eksikliği, ölümlü ve yaralanmalı kazaları etkileyen temel ögelere karşı gerçek anlamda çözümler üretmeyi zorlaştırmaktadır. Bu çalışmada Gaziantep'te 2013 yılında gerçekleşen kazalara ait raporlar Bölge Trafik Şube müdürlüğünden alınıp veri tabanına işlenmiştir. Coğrafi Bilgi Sistemleri (CBS)'nin desteği ile Çekirdek Yoğunluk Kestirim yöntemi kullanılarak istatistiki bir model kurulmuş ve kazaların lokasyonlarına göre kaza kara noktalarının belirlenmesi amaçlanmıştır. CBS desteği kazaların koordinatlarıyla harita üzerinde görüntülenmesi için kullanılmış ve sonrasında kazalar; kaza koordinatları, kaza saati, hava durumu, yol kaplama cinsi, yolun tipi, kaza bölgelerinin kavşaklara yakınlığı, sürücü bilgileri, sürücülerin alkol kullanımı, kazaya karışan araçların sayısı ve türleri, sürücü, yolcu, yaya dağılımları ve oluş sebeplerine göre analiz edilmiştir. Yapılan analizler sonrası kaza kara noktalarının genelde kavşaklarda oluştuğu belirlenmiştir ve en riskli bölgeler için uygun çözüm önerileri sunulmuştur.

Anahtar kelimeler: Trafik Kazaları, Kara Nokta, CBS, Çekirdek Yoğunluk Kestirimi

To my dearest family…

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Movement of people and goods to meet basic needs of society is defined as transportation. Every day, various transportation movements happen as part of daily life such as a family travelling another city to see their relatives or for a vacation, a fresh produce truck delivering goods to supermarkets, an ambulance providing services for injured and sick people, a salesman organizing meetings across the country to give a lecture about sales methods [1]. All these movements require a good transportation network. Also, transportation should be safe, fast and economic. Safety is the most important one of all.

Road is a preferred mean of transportation in developing countries like Turkey. This causes density on road and road safety rates fall on the inverse as to increase on road density. One of the greatest negative impact of development in transportation is accidents. It is enough to have a look at the traffic accidents to see the degree of this impact and find out about road safety [2]. Traffic accidents are among the main reasons of financial damage and deaths in developed and developing countries and we can show lack of sources on applicable precautions for this increasingly growing problem as the reason [3].

As declared by World Health Organization (WHO), the number of people killed in car crashes is much more than the number of people killed in wars until today. In 2010, 1.24 million people died on world's roads. While road traffic injury ranks eighth among other causes of deaths across the world, it is on the first rank causing deaths among young people between the ages of 15 and 29 [4]. More than one million people die each year on roads and economic costs of these accidents reach billions of dollars [5]. If traffic accidents causing deaths increase as today, in 2030 traffic injuries will be the fifth death cause unless an urgent measure is taken [6].

In 2013, there were 1 207 354 traffic accidents in Turkey of which 1 046 048 is material damaged and 161 306 is either fatal or injury accidents. As a result of these accidents 3685 people lost their lives and 274 829 people were injured. Within the borders of Gaziantep province in 2013, 3607 accidents occurred and as a result of these accidents while 79 people died, 6241 people were injured. Also since some of the people who were injured in accidents who died after they were hospitalized weren't recorded on reports, it is presumed that actual death toll is a lot more than these numbers [7]. This practice is only performed in 16 countries out of 182 in the world. Remaining countries also record people as a lost who die in 48 hours, 7 days, 30 days, 1 year or indefinite periods after the accident on reports. However; only those who lost their life on the spot of the accident were recorded on reports in Turkey and because of this actual death toll is not known [6].

Financial loss and loss of lives lead researchers and ministry of transport to work on studies that will enhance road safety [8]. For this reason, studies have been given start with Geographical Information Systems (GIS). GIS have become a very popular tool to analyze and examine accidents on roads. The GIS have become a tool to manage, explore, analyze and visualize spatial data. GIS analyze spatial data using various methods in its software's modules, which arouses more attention to GIS [9].

Aim of this study is to determine the spots which most accidents occur and bring solution to these spots and to reduce number of accidents and prevent deaths, injuries and financial loss by this way. For this reason information gathered by the examination of reports in Traffic Inspection Branch Office on 2349 accidents which occurred within the zone of responsibility of traffic police in central Gaziantep were processed in a way that will create statistical data on MS ACCESS program and then analyzed by GIS and possible solution offers was brought by determining 10 regions which accidents mostly occur and evaluating factors that leads to accidents.

CHAPTER 2

GENERAL INFORMATION

2.1 Road Safety

Road safety has become an important issue because of deaths and injuries caused by accidents. Many institutions have started to cooperate for mutual activities and mutual goals in order to ensure road safety. For this purpose, the Road Traffic Safety Strategy and Action Plan has been prepared in cooperation and coordination board was established in every province [10].

In line with goals indicated in Road Traffic Safety Strategy and Safety Plan continuation of studies were ensured and by constantly keeping road safety on agenda, providing financial support to institutions and organizations that work for this goal become compulsory. For this purpose, electronic inspection system (TEDES) was established. It is an effective system to determine traffic rule violations. Municipalities should be encouraged to ensure effectiveness in city centers as much as interurban roads [10].

In the world, Intelligent Transport Systems (ITSs) were established to improve road traffic safety and major developments were made in this matter. Intelligent transportation systems (ITSs) have been studied to solve the problems of existing physical approaches at lower costs and with higher efficiency. An ITS is a convergence of transportation technologies and information technologies, and it enhances not only traffic safety but also road use efficiency [11]. Another aim of these overall practices that were developed to support transportation is to minimize the outer environmental effects towards transport by enhancing safety and mobility. By putting these practices into action significant decrease on accidents were seen. TEDES and AUS cooperation should be enhanced and interoperability for their electronic systems should be enabled.

In addition, several analyses can be performed to determine current safety conditions of roads. Generally, there are two kinds of analysis method used; descriptive and quantitative predictive analyses. Descriptive analyses include methods of frequency, crash rate and equivalent property damage only. Data can be gathered from the history of crash occurrence by using this method that summarizes information belonging to a site. Quantitative predictive analyses can give the expected number of crashes depending on similar conditions and geometry. It can make predictions not only for present conditions but also for future. Besides these, new highway designs can also be evaluated by this method [12].

Increasing the safety level of highways depends on the applications which should be completed after the analyses. For example, after having knowledge about these reduction methods, crash frequency areas with the highest potential should be determined and the problems causing crashes should be identified, whether it is because of human factor or road geometry design faults. Then, necessary precautions should be taken. Crash reductions are also highly effective on economy. Besides, if the evaluation of the project is done precisely at the very beginning by taking into consideration of various design alternatives and the potential crash frequency is estimated, they will reduce potential crash areas greatly. [12]

When these practices that aim to enhance safety are performed, not only that they achieve this, but also they enhance the capacity of roads and provide variety of convenience to pedestrians [12].

Turkey is listed as middle income country, due to economical developments, Turkey experienced an increase in the motorization rate. Number of motor vehicles and number of vehicles per 1000 people in 2003 has respectively increased from 8 903 843 and 127 to 17 939 447 and 234 in 2013. With the increase on vehicle numbers, number of accidents in 2003 has increased from 455 637 to 1 207 354 in 2013 [13].

Statistical Information on fatal and injury traffic accidents and casualties occurred in our country can be seen on Table 2.1 which is prepared by TUIK with the help of General Police Department and General Commandership of Gendarmerie.

Table 2.1 Number of persons killed and persons injured 2003-2013 [7].

	Responsibility area of Traffic Police							Responsibility area of Gendarmerie						
Year	Total accidents	Accidents involving death and personal injury	Accidents involving death and personal injury (%)	Accidents involving material loss only	Accidents involving material loss only (%)	Number of persons killed	Number of persons injured	Total accidents	Accidents involving death and personal injury	Accidents involving death and personal injury (%)	Accidents involving material loss only	Accidents involving material loss only (%)	Number of persons killed	Number of persons injured
2003	422 272	56 103	13,29	366 169	86,71	2 811	95 607	33 365	10 928	32,75	22 437	67,25	1 135	22 607
2004	494 819	63 593	12,85	431 226	87,15	3 081	109 889	42 533	13 415	31,54	29 118	68,46	1 346	26 548
2005	570 025	72 194	12,67	497 831	87,33	3 195	123 977	50 764	15 079	29,70	35 685	70,30	1 310	30 109
2006	664 539	79 177	11,91	585 632	88,09	3 365	135 754	64 216	16 951	26,40	47 265	73,60	1 268	33 326
2007	749 434	86 947	11,60	662 487	88,40	3 462	149 814	76 217	20 047	26,30	56 080	73,70	1 545	39 243
2008	898 451	84 431	9,40	814 020	90,60	2 948	145 163	51 669	19 781	38,28	31 888	61,72	1 288	39 305
2009	1 017 940	91 279	8,97	926 211	91,03	2 993	161 719	35 406	19 392	54,77	16 014	45,23	1 331	39 661
2010	1 073 878	97 412	9,07	976 466	90,93	2 738	171 475	32 323	19 392	59,99	12 931	40,01	1 307	40 021
2011	1 195 172	110 803	9,27	1 084 369	90,73	2 582	194 149	33 756	21 042	62,34	12 714	37,66	1 253	43 925
2012	1 259 874	130 360	10,35	1 129 514	89,65	2 555	221 108	36 760	23 192	63,19	13 568	36,81	1 195	46 971
2013	1 169 377	136 033	11,63	1 033 344	88,37	2 393	224 287	37 977	25 273	66,55	12 704	33,45	1 292	50 542

2.2 Factors Affecting Road Safety

There are a number of factors that could cause road accidents, they are listed in below and deficiency in one could lead to traffic accidents.

- Human factor
- Vehicle factor
- Road factor
- Enviroment factor

2.2.1 Human Factors

Traffic accidents are not isolated incidents but also the mirror of social structure. Solution of social problems that come from the root will also help troubleshooting of traffic issues. In order to solve traffic problems, education, urban sprawl, health, distribution of income and safety matters should also be cured. Human is what forms the basis of these problems [14].

People show presence in traffic as drivers, passengers, pedestrians or traffic police however; drivers are the most influential ones for sure. When we examine traffic accidents, it's been observed that driver's personal characteristics, age, gender, health condition, habits, experience and work conditions have direct or indirect relevancy with accidents [15]. Insufficient driving training is an another factor that effects humans. In Turkey, due to lack of education drivers gets a driving license before they have sufficient experience and knowledge, in addition examination process is not compulsive to determine driving skill level of drivers.

Main reason for human factors to be examined is to reduce mistakes due to human in injury and fatal traffic accidents and to be able to design roads according to human behaviors and limits.

Even physical characteristics of a person can cause traffic accidents. As the result of researches, it has been determined that elderliness reduces eyesight and slows reaction time and young people have speed tendency and distractibility due to texting with a cell phone and similar reasons. Although sum of all these mistakes don't always cause fatal and injury accidents and can be prevented with a quick maneuver or just causes small crashes, number 1 reason of accident occurrence is driver mistakes [12]. Not only drivers but also pedestrians and passengers have faults and these were given on table 2.3, 2.4 and 2.5 together with the effects on accidents occurred in 2013.

Speed ranks number 1 in driver mistakes [13]. Effects of speed were explained influentially on the brochure that Directorate of Traffic Education and Research prepared. Since drivers are not fully aware of the risks resulted by their speed violations, speed violations are done at any moment. During a normal speed run, driver can perceive color and light changes and all sorts of movements on a wide angle, while as the speed increases, visual angle decreases [16].

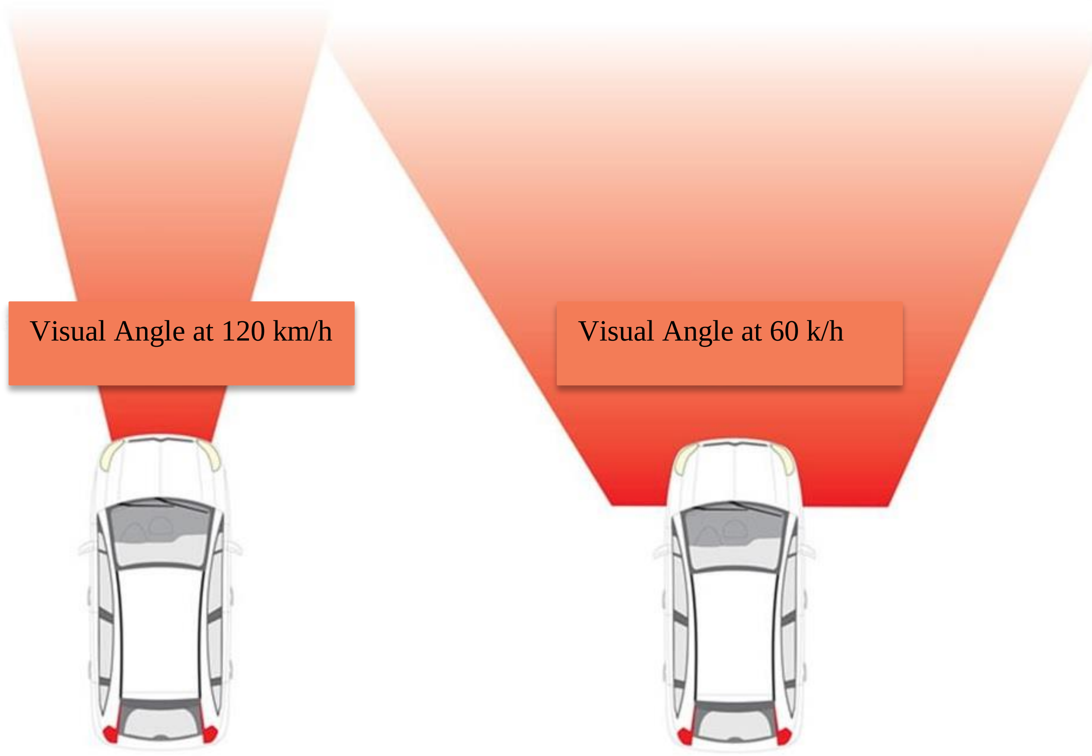


Figure 2.1 Change in visual angle according to speed [17].

Speed causes braking distance to grow longer along decrease in visual angle. Stopping distance for a vehicle that runs with 30km/h is approximately 13 meters. When the vehicle's speed is 50 km/h it is 26,77 meters and when it is 70 km/h it is 47 meters. This circumstance is also the most common reason for pedestrian accidents (Figure 2.2) [17].

In 2013 total of 67 638 vehicles had an accident because they couldn't comply their speed with necessities of weather and traffic conditions of which 51 030 were within the inhabited and 16 609 were in the uninhabited area [13].

The general formula of stopping distance given down below [18] ;

$$L_{fe} = 0{,}278 \text{x} V \text{x} t_r + 0{,}00394 \text{x} \frac{V^2}{f \mp s} \quad (2.1)$$

Where L_{fe} indicates the stopping distance while V indicates speed of vehicle; t_r is the reaction time of the driver; f is the skid resistance coefficient of surface and s is the slope. Avarage value of f is can be taken between 0,50-0,60 on dry surfaces and on the wet surfaces it decreases to between 0,20-0,30 when the surface is icy it decreases more. Changing of stopping distances according to speeds can be seen in Table 2.2.

Table 2.2 Reaction, brake, stopping lengths and brake durations for different speeds on a slopeless and dry asphalt road [18].

Speeds		Reaction Distance l_r(m)	Breaking Distance l_f(m)	Stopping Distance $L_{fe} = l_r + l_f$	Reaction Time t_r (sec.)
(km/hr)	(m/s)				
10	2,77	2,07	0,65	2,72	0,47
20	5,55	4,16	2,61	6,77	0,94
30	8,33	6,24	5,89	12,13	1,41
40	11,11	8,33	10,48	18,81	1,88
50	13,88	10,41	16,36	26,77	2,35
60	16,66	12,49	23,58	36,07	2,83
70	19,44	14,58	32,10	46,68	3,30
80	22,22	16,66	41,94	58,60	3,77
90	25,00	18,75	53,10	71,85	4,24
100	27,77	20,82	65,51	86,33	4,71
110	30,55	22,91	79,29	101,20	5,19
120	33,33	24,99	94,38	119,37	5,65

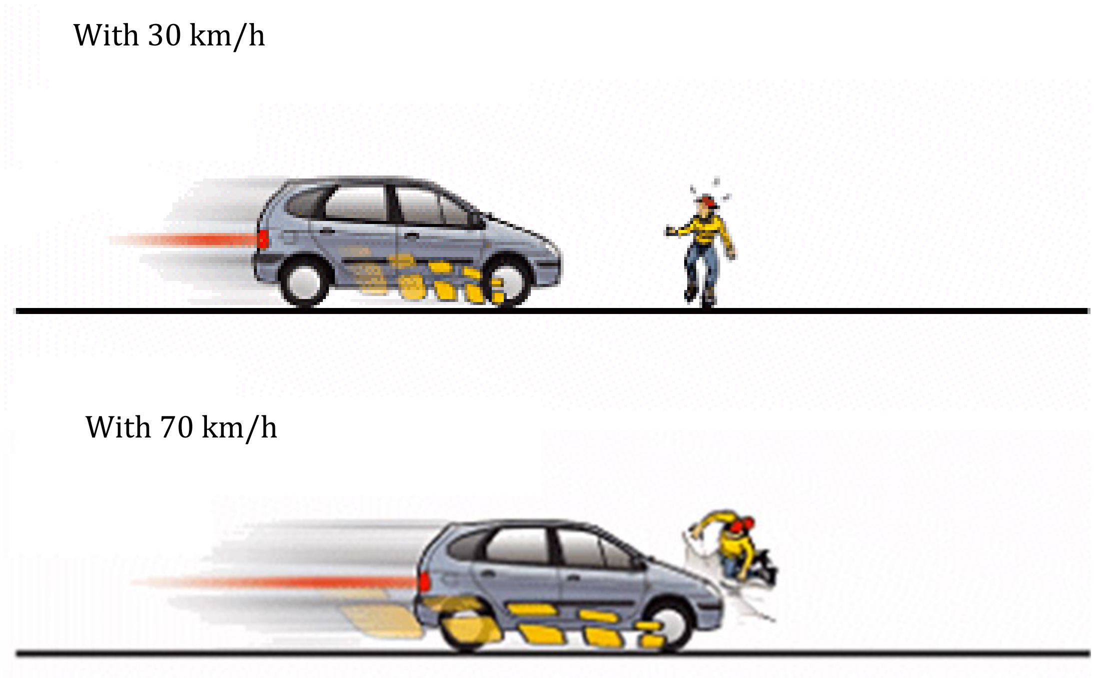


Figure 2.2 Effect of speed on situations when an immediate stop is required [17].

Accidents caused by drunk drivers are also as much as a considerable amount. In 2013, 3636 accidents were because of alcohol [13]. With use of alcohol, drivers have difficulty in understanding effects of incidents and movements while on the run and this causes reaction time, in other words response speed to incidents decrease. Possibility of accident occurrence increases in inverse proportion [19].

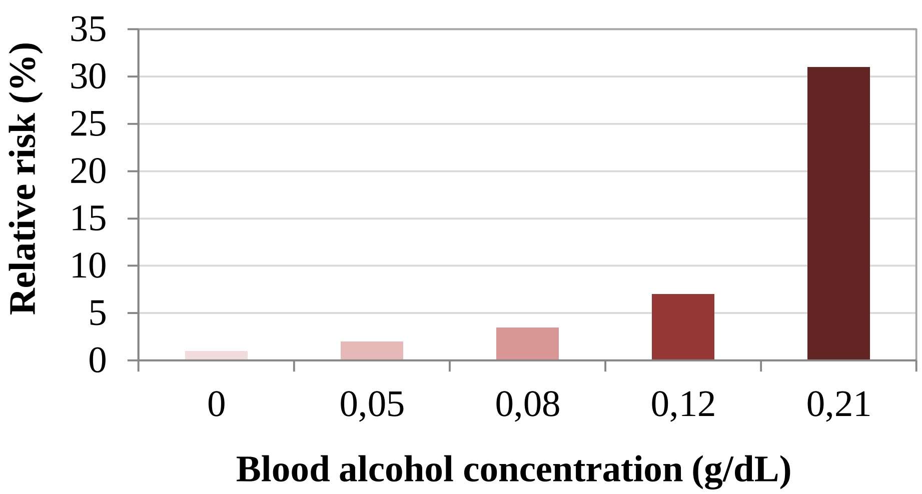


Figure 2.3 Relative risk of an accident based on blood alcohol levels [20].

Table 2.3 The fault rate of drivers, passengers, pedestrians highways and vehicles that cause to traffic accident, 2008-2013 [7]*.

Year	Total Faults	Total Faults (%)	Driver Faults	Driver Faults (%)	Passenger Faults	Passenger Faults (%)	Pedestrian Faults	Pedestrian Faults (%)	Road Faults	Road Faults (%)	Vehicle Faults	Vehicle Faults (%)
2008	167 231	100,00	151 386	90,53	713	0,43	13 995	8,37	698	0,42	439	0,26
2009	155 982	100,00	139 758	89,60	640	0,41	14 181	9,09	958	0,61	445	0,29
2010	157 970	100,00	141 728	89,72	564	0,36	14 171	8,97	992	0,63	515	0,33
2011	174 605	100,00	157 494	90,20	677	0,39	14 860	8,51	1 044	0,60	530	0,30
2012	181 266	100,00	161 076	88,86	797	0,44	17 672	9,75	1 124	0,62	597	0,33
2013	183 030	100,00	162 327	88,69	774	0,42	16 458	8,99	1 913	1,05	1 558	0,85

*: Since material damaged accidents were reported together before 2008, flaw rate of fatal and injury accidents cannot be reached.

Table 2.4 Information on driver faults that are determinant on fatal and injury accidents [13].

Driver Faults	Inhabited Area		Uninhabited Area		TOTAL	
	Number of Faults	%	Number of Faults	%	Number of Faults	%
Failure to comply speed with necessities of road, weather and traffic conditions	51.030	39,70	16.609	45,80	67.639	41,04
Failure to comply right of way at intersection	18.436	14,34	2.210	6,09	20.646	12,53
Failure to comply with general conditions of maneuver regulators	6.155	4,79	5.190	14,31	11.345	6,88
Failure to comply rules of turns	9.468	7,37	1.586	4,37	11.054	6,71
Rear-end collision	8.097	6,30	2.801	7,72	10.898	6,61
Failure to comply rules about other traffic safety	4.186	3,26	1.731	4,77	5.917	3,59
Hitting vehicles that are properly parked	4.636	3,61	301	0,83	4.937	3,00
Entering to places with signs of No Vehicle Entry	3.188	2,48	743	2,05	3.931	2,39
Drinking and driving	2.703	2,10	933	2,57	3.636	2,21
Failure to comply red light or a stop sign of officer	2.862	2,23	275	0,76	3.137	1,90
Improper lane change	2.528	1,97	567	1,56	3.095	1,88
Driving with excessive speed	1.961	1,53	698	1,92	2.659	1,61
Passing through no trespassing places	802	0,62	234	0,65	1.036	0,63
Failure to slow down at pedestrian and school crossing, failure to give right of way to	730	0,57	18	0,05	748	0,45
Improper parking or parking at no parking spots	404	0,31	341	0,94	745	0,45
Failure to comply rules of drop-off and pick-up	487	0,38	27	0,07	514	0,31
Driving with missing, broken or improper vehicle equipment	260	0,20	141	0,39	401	0,24
Failure to stop, take precautions and notify authorities at scene of accident	259	0,20	139	0,38	398	0,24
Riding bicycle, motorbike and motorcycles by violating the rules	327	0,25	27	0,07	354	0,21
Loading dangerously or excessively	233	0,18	87	0,24	320	0,19
Other	9.790	7,62	1.605	4,43	11.395	6,91
TOTAL	128.542	100	36.263	100	164.805	100

Table 2.5 Information on pedestrian faults that are determinant on fatal and injury accidents [13].

Pedestrian Faults	Inhabited area		Uninhabited area		TOTAL	
	Number of Faults	%	Number of Faults	%	Number of Faults	%
Failure to comply crossing rules where crosswalk or intersection don't exist	6 709	42,98	299	33,52	7 008	42,47
Taking actions on vehicle roads that will endanger the traffic	1 569	10,05	70	7,85	1 639	9,93
Failure to comply traffic lights and signs	1 547	9,91	49	5,49	1 596	9,67
Failure to comply traffic rules while crossing	1 264	8,10	64	7,17	1 328	8,05
Entering roads	965	6,18	145	16,26	1 110	6,73
Failure to use left side on roads	499	3,20	44	4,93	543	3,29
Failure to take precautions that will prevent crashing during night and day when there is lack of sight	451	2,89	47	5,27	498	3,02
Violating other traffic safety rules	44	0,28	2	0,22	46	0,28
Failure to take precautions at the scene of accident	42	0,27	2	0,22	44	0,27
Throwing, pouring, or taking similar actions to road that will complicate traffic	18	0,12	6	0,67	24	0,15
Heading out intoxicated	6	0,04	5	0,56	11	0,07
Other	2 495	15,98	159	17,83	2 654	16,08
TOTAL	15 609	100	892	100	16 501	100

Table 2.6 Information on passenger faults that are determinant on fatal and injury accidents [13].

Passenger Faults	Inhabited area		Uninhabited area		TOTAL	
	Number of Faults	%	Number of Faults	%	Number of Faults	%
Disuse of helmet	83	14,80	41	17,45	124	15,58
Disuse of seatbelt	42	7,49	34	14,47	76	9,55
Throwing, pouring, or taking similar actions to road that will complicate traffic	32	5,70	29	12,34	61	7,66
Getting on and off the vehicles without control	37	6,60	1	0,43	38	4,77
Violating other traffic safety rules	7	1,25	26	11,06	33	4,15
Travelling intoxicated	10	1,78	9	3,83	19	2,39
Failure to take precautions at the scene of accident	5	0,89	2	0,85	7	0,88
Other	345	61,50	93	39,57	438	55,03
TOTAL	561	100	235	100	796	100

2.2.1.2 Effects of Driver's Duty on Accidents

Drivers have 3 main duties during traffic flow [12].

- Control: Vehicle must be used with proper speed and lanes shouldn't be violated
- Guidance: Vehicle must be careful about following distance and overtaking. Being in communication with other vehicles shouldn't be forgotten and others should be warned via signals before taking action.
- Navigation: Should pay attention to road signs and be able to find direction from the start point to the end.

These operations require variety degrees of decision making mechanism. Hierarchical relation among them can be seen at figure 2.4 [12]

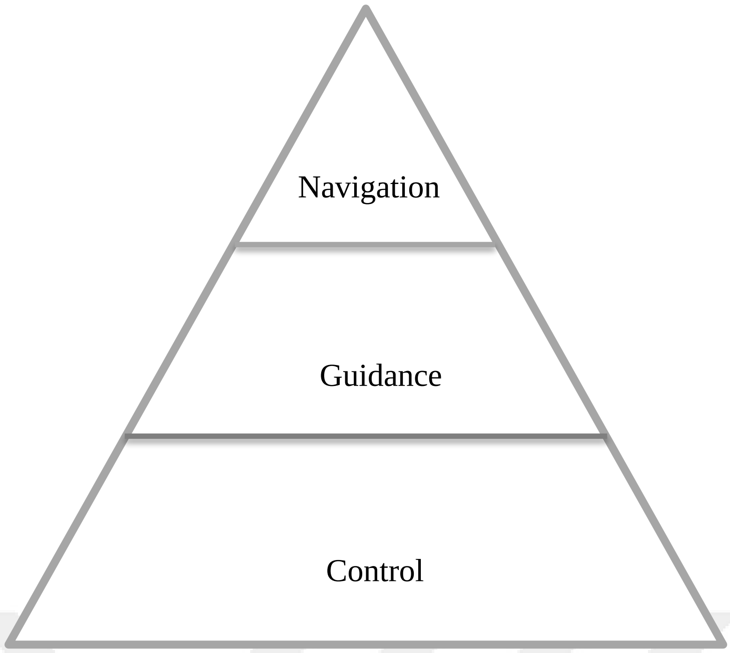


Figure 2.4 Driver task hierarchy [21].

Harmony between these three duties is key to a successful driving experience. Driver should follow these duties while driving without losing attention. Navigation stage is the most complicated one, starts with determining the route (highway A or B) and it also requires critical decision making while driving (left turn, right turn, exit on next exit). As driving experience enhances, it is determined that driver ensures improvement at this stage [22-23].

Driver takes action based on 3 main basis which are information based, rule based and skill based. For example, it is encountered that experienced drivers hesitate too when they come across an unknown area. A driver who drives on dessert for the first time may not know what to do and how the vehicle will react. For this reason, driver performs actions such as shifting gears on basis of skill while turning on intersections and determining routes on rule basis. As the driver gets used to the environment, his actions would proceed according to a base that is one stage below. In other words, a driver who has always used an automatic transmission vehicle would use a manual transmission vehicle on rule basis when they start using one since he is not used to using gear. This incident was explained on Figure 2.4 and Table 2.6 [24]. A mistake that will occur during this whole mechanism of decision making would result driver's to have an accident.

Table 2.7 Relation between task hierarchy and the skill, rule, and knowledge framework [24].

Driver’s Skill	Knowledge based	Rule based	Skill based
Navigation level	Navigation in unfamiliar environment	Choosing between two familiar routes	Daily way to work
Manuevering level	First time driving in the desert	Overtaking of other vehicles	Turning at a familiar intersection
Control level	First lesson in driving school	Driving a new car	Driving curves, shifting

2.2.2 Vehicle Factor

Vehicles are the second element that would come to mind when we talk about accidents. Vehicle factor caused accidents are 0.92% in our country according to 2013 statistics. Main reasons of vehicle caused accidents are break failure, flat tire and rear light failure. All faults are given on Table 2.8 [13].

Table: 2.8 Information on vehicle faults that are determinant on fatal and injury accidents - 2013 [13].

Vehicle Faults	Inhabited area		Uninhabited area		TOTAL	
	Number of Faults	%	Number of Faults	%	Number of Faults	%
Brake	331	35,25	140	18,16	471	27,54
Flat Tire	114	12,14	297	38,52	411	24,04
Rear Lights	41	4,37	44	5,71	85	4,97
Door	69	7,35	14	1,82	83	4,85
Rod	38	4,05	36	4,67	74	4,33
Wheel	42	4,47	28	3,63	70	4,09
Axle	41	4,37	26	3,37	67	3,92
Headlight	30	3,19	20	2,59	50	2,92
Leaf Spring	31	3,30	10	1,30	41	2,40
Shaft	31	3,30	9	1,17	40	2,34
Turn Signal	20	2,13	7	0,91	27	1,58
Transmission	10	1,06	7	0,91	17	0,99
Windshield Wiper	6	0,64	3	0,39	9	0,53
Horn	6	0,64	2	0,26	8	0,47
Other	129	13,74	128	16,60	257	15,03
TOTAL	939	100	771	100	1710	100

First purpose of vehicles was just to transport people from one place to another and because of that they were manufactured in a way just to ensure this technical competence however; as fatality rates in traffic increased variety of safety precautions started to be taken on vehicles. Vehicle safety systems that are named to be luxury are now considered as a must. Competence in the automotive sector and advertisements on media have raised expectations and caused new technologies to develop [25]. Vehicles are not only designed to prevent vehicle faults but also to support driver’s decision making mechanism and prevent driver based faults. These systems can be seen on Figure 2.5.

Although vehicles are fault-free when first purchased, as time passes by vehicle systems may break down because of usage, road conditions and time. Therefore care should be given to maintenance times, vehicle inspection shouldn't be ignored and it should be made sure that it is in the condition to run in traffic. If these operations are not done it might be a threat for road safety [26]. Because of this reason legal regulation and mandatory periodic inspections have emerged.

2.2.3 Road Factor

Besides vehicle and human factors, road factor is also effective on accident occurrence. Though rates for causing accidents are lower than other factors, it should be paid attention to since it affects human behaviors [25].

Reasons for roads to be an effect on accidents:

- Road surface
- Lack of traffic signs and signalization
- Road geometry

Number of accidents caused by road faults can be seen on table 2.8.

Table 2.9 Information on road faults that are determinant on fatal and injury accidents [13].

Road Faults	Inhabited area		Uninhabited area		TOTAL	
	Number of Faults	%	Number of Faults	%	Number of Faults	%
Loose Material on Road Surface	252	33,92	458	66,47	710	49,58
Collapse of a Lane	212	28,53	59	8,56	271	18,92
Craters on Road	150	20,19	83	12,05	233	16,27
Partial or Discrete Downfall	51	6,86	38	5,52	89	6,22
Sitting of Tire Mark	56	7,54	24	3,48	80	5,59
Low shoulder	22	2,96	27	3,92	49	3,42
TOTAL	743	100	689	100	1432	100

2.2.3.1 Road Surface

Maximizing driving comfort and lowering vehicles road based expenses and providing smooth surfaces are among the basic principles of road coatings. For safety purposes, road surface should enhance skid resistance and minimize wearing out caused by weather conditions and traffic load. Importance of skid resistance is avoiding situations like hanging back on road surface caused by tire locking [27].

Measuring road surface and identifying boundaries are necessary for determining value for skid resistance. Roads split in two as adoption stage and service stage. Skid friction coefficient that are measured on roads should not be lower than 0,5 for 50 km/h in all countries. During the service stage road pavements are showing lower performance than expected because of increasing vehicle speeds along with developed technology. Factors such as comfort, silence, economy and safety could not show much development because road construction technology has fallen behind other developments. Evenness and smoothness are characteristics that belong to road surface. In order to achieve permanent geometric evenness on surface, necessary resistance should be supplied first [28].

Surface roughness split in two as macro and micro texture. Macro roughnesses are formed of spaces that come off during settlement between aggregates. It is responsible of water drained between tires and coating surface and providing enough adherences. Macro roughness may be deformed due to excess rate of heavy vehicles in the traffic stream. Whereas micro roughnesses are formed by pores and roughness on aggregate particles and have an effect of enhancing skid resistance [27]. While micro roughnesses are effective up to 50 km/h, macro roughnesses are effective on greater speeds [29]. In order for adherence to be maximum, tires must be smooth and contact area must be at maximum. Also even if the water that comes to road doesn’t freely collect on axe it would form a water film and when macro textures are not sufficient enough to break this up micro textures would step in. Disadvantage of micro textures are that they wear out tires [30].

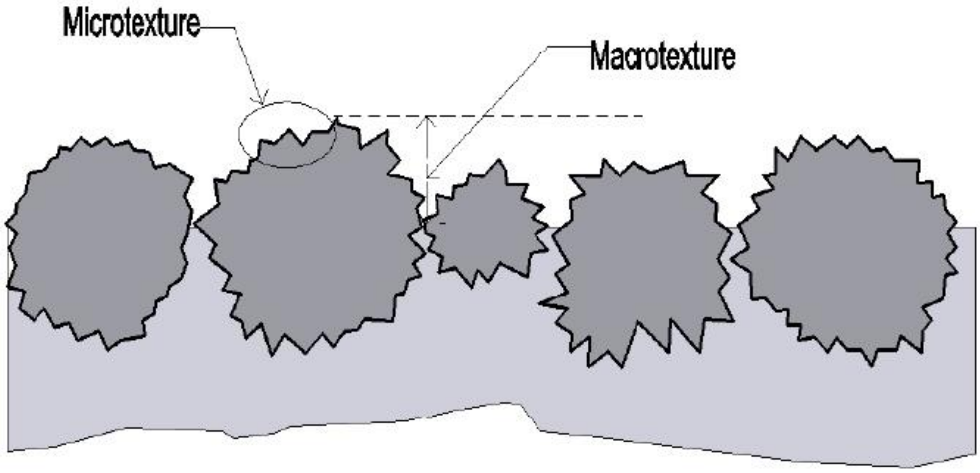


Figure 2.5 Details of road roughness [31].

2.2.3.2 Traffic Signs and Signalization Effect

In order to organize traffic flow and ensure safety at intersections there are traffic control elements like traffic lights and signs. These elements ensure pedestrian safety and vehicles to use roads restrained using right of way system. Basic principle of signalization is to ensure effective timing according to needs of pedestrians and vehicles and field sharing [32].

Joining to traffic flow and delays that occur while joining are depending on driver skill and experience at intersections signalization implementation was not done. With signalization, joining a flow becomes automatic and in a way, decision making mechanism cuts out and instead performing what is already decided comes to place. Pre-calculated favors to be gained and after a signalization that is decided to be true to do, road delay and volume diminishes and general decrease on traffic accidents will be seen. This downfall can be seen on table 2.9 when distribution of accident data in 2013 according to traffic lights is examined.

Table 2.10 Number of road traffic accidents and results by traffic lighting [7].

Traffic light	Total Accidents	Number of persons killed	Number of persons injured
Present	17 299	204	29 790
Absent	136 826	3 383	233 432
Out of order	7 181	98	11 607
Total	161 306	3 685	274 829

2.2.3.3 Road Geometry

While a road is being designed, traffic safety must definitely be among geometry criteria. Radiuses of horizontal and vertical curves, super elevation, longitudinal and transverse slope values form the geometric standards of a road [18].

- Radiuses of horizontal and vertical curves: Diameter of horizontal curves are very important for traffic safety because during the transition to a curve centrifugal force will arise and in the cases when diameter is small while speed is high this force will ruin the vehicle's balance and may cause an accident. Whereas on vertical curves sudden changes of slope will shorten sight distance in a way that will cause accident and also will reduce driving comfort by causing vertical acceleration [18]. Accidents caused by curves can be seen on table 2.10.

Table 2.11 Fatal and injury traffic accidents and its rates according to road's geometric characteristic – horizontal alignment [7].

Horizontal Alignment	Inhabited Area		Uninhabited Area		Total	
	Accidents	%	Accidents	%	Accidents	%
Straight and level road	106 602	88,82	27 271	66,17	133 933	83,03
Curve	11 643	9,70	9 342	22,67	20 985	13,01
Dangerous Curve	1 787	1,49	4 601	11,16	6 388	3,96
Total	120 092	100	41 214	100	161 306	100

Table 2.12 Fatal and injury traffic accidents and its rates according to road's geometric characteristic – vertical alignment [7].

Vertical Alignment	Inhabited Area		Uninhabited Area		Total	
	Accidents	%	Accidents	%	Accidents	%
Level	94 355	78,57	26 186	63,54	120 541	74,73
Inclined	24 433	20,35	13 511	32,78	37 944	23,52
Dangerous Slope	937	0,78	1 106	2,68	2 043	1,27
Top hill	367	0,31	411	1,00	777	0,46
Total	120 092	100	41 214	100	161 306	100

- Super elevation: During the transition to a curve, centrifugal force that will endanger traffic safety may occur , if this force is faced with transverse slope, transverse acceleration will not occur and driving comfort will not fail, however; if super elevation's upper limit 8-10% is exceeded then vehicles might skid into curve and tip over [18].

Traffic safety drops down as the numbers of heavy vehicles increase since these vehicles have limited maneuver ability and failure to speed. If slope on a runaway truck ramp is high, effects of these vehicles would be at maximum. For this reason climbing lane must definitely be added to double lane roads or else other vehicles will form long lines behind heavy vehicles and will have to overtake unsafely [28].

Rate of accidents caused by roads in 2013 is 1.05%. This rate goes up to 20% in European countries [33]. It is known that road standards in European countries are not lower than the road standards in our country. Starting from this point of view it came to a conclusion that determination of accidents caused by road's geometry cannot be made. Primary reason for this is technical insufficiency of institutions concerning accident determination and the regulation that is in force. An example to this would be inserting speed reducer traffic signs on roads that actually allows 90 km/h speed because of the mistake on road geometry and indicating driver's failure to comply signs is the reason for accident [34].

Another aspect that should be given attention to is that because geometric characteristics of an intersection is directly related with traffic safety, while designing an intersection caution should be warranted to these characteristics.

2.2.3.3.1 Geometric Characteristics of Intersections

Geometric characteristics of intersections may also cause accidents. Intersection design and calculations should be made carefully. Factors that will cause accidents:

- Intersection ways: Accidents at three-way intersections are less than those at four-way intersections [18]. Decrease on accidents is seen at four-way intersections that were converted into two three-way intersections because the first reason is that at three-way intersections, intersections are seen better and the second reason is that while at a three-way intersection has 9 overlap points this number at a four-way intersection is 32 [35]. Accidents that happened in Turkey in 2013 distributed according to intersection geometry can be seen on Table 2.13.

Table 2.13 Number of road accidents and results by geometric characteristics of intersections [13].

Intersections	Total Accidents	Accidents involving death	Accidents involving personal injury	Number of persons killed	Number of persons injured
Tree-leg intersection(T)	17 320	165	17 155	181	26 561
Tree-leg intersection(Y)	3 768	58	3 710	62	6 380
Four-leg intersection	23 603	124	23 479	142	39 241
Round about	7 583	90	7 493	112	14 499
Interchanges	578	11	567	15	1 018
Other intersections	5 516	76	5 440	101	9 387
Level crossing	352	20	332	24	578
Without intersections	102 586	2 488	100 098	3 048	177 165
Total	161 306	3 032	158 274	3 685	274 829

- Angle between intersection arms: Intersections can be considered safe as long as see-and-be-seen takes places within the intersections. Angle between the ways is the most important factor. Right or close to right angle (70°-110°) is ideal for a good sight [36].

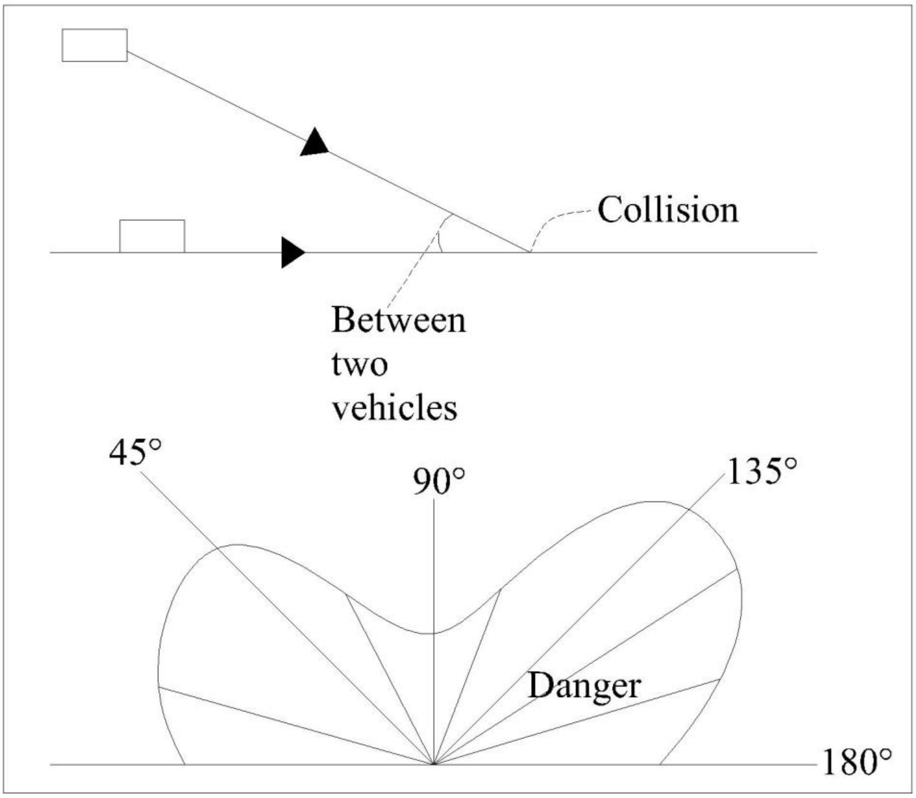


Figure 2.6 Effects of angle between intersection arms on crashes [37].

- Sight distance and objects that block sight: Providing stopping sight distance also means providing safety. There shouldn't be an intersection on a horizontal curve [38]. Triangle sights are the most important elements of intersections because drivers who are getting close to an intersection need these sights to see other vehicles and avoid crashing [39]. Also, there shouldn't be any objects blocking sights in these areas.

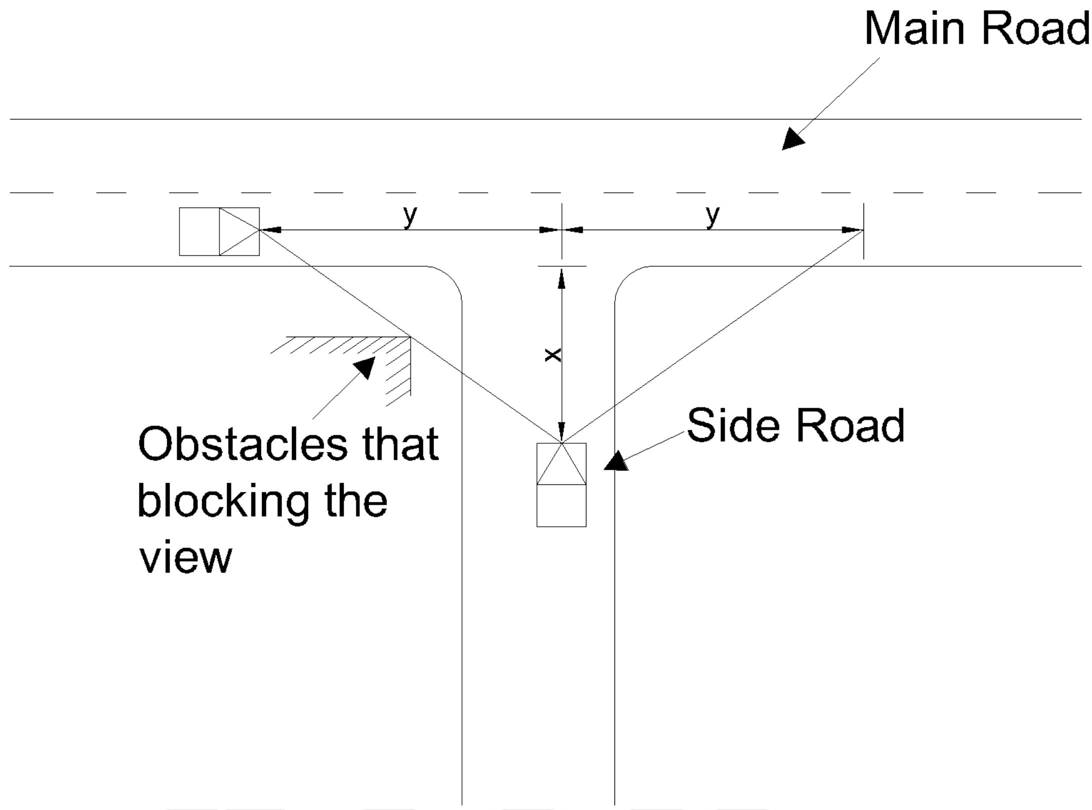


Figure 2.7 Sights at intersections [40].

- Ideal security x distance is identified as 20 meters in Turkey however; it is almost impossible to apply in local traffic [41]. This value which usually varies between 3 meters and 5 meters, will decrease road safety when it is below 3 meters since it will sight an obstacle like building and etc. [42].

2.2.4 Environmental Factor

Another reason that causes accidents on roads is the environment. We can consider seasonal changes, weather conditions and road lightning as environmental factors.

2.2.4.1 Seasonal Effects

As the result of researches, when traffic accidents are examined based on seasons, it is seen that most of the accidents occur during summer season where the following season is fall and most accident expected season winter is the last one of accident rate sorting [43].

Because of the summer vacation that starts beginning the summer season, there is an increase in vehicles on traffic and operating vehicles on long distances require extreme attention and it has an effect on accident numbers since it tires the driver [43].

The reason for an increase in accidents during fall can be explained as the increase in road flow because of returns from summer vacation, peak of school bus and shuttle numbers in traffic following the start of schools and with the effect of dusting remained from summer roads to become slippery because of raining [43].

Winter season falls behind summer and fall despite the bad conditions and the reason for this can be shown as that drivers enhance their attentions because of bad conditions and high penalties for disuse of winter tires. Most affected vehicles by winter are the ones that did not carry out maintenance during mid seasons and hitting the road with inadequate equipment [43].

Rates and numbers of accidents occurred in 2013 in Turkey according to months and seasons can be seen on Table 2.14.

Table 2.14 Information According to Months and Seasons that are Determinant on Fatal and Injury Accidents [13].

MONTHS	Accidents	%	Number of persons killed	%	Number of persons injured	%	Seasons	Accident Ratio (%)
December	11 003	6,82	267	7,25	18 392	6,69		
January	9 810	6,08	205	5,56	16 800	6,11	Winter	18,35
February	9 180	5,69	211	5,73	15 260	5,55		
March	11 294	7,00	242	6,57	18 297	6,66		
April	12 670	7,85	240	6,51	20 631	7,51	Spring	22,93
May	14 495	8,99	302	8,20	24 081	8,76		
June	15 367	9,53	393	10,66	26 674	9,71		
July	15 382	9,54	347	9,42	26 329	9,58	Summer	31,76
August	18 267	11,32	495	13,43	34 268	12,47		
September	16 067	9,96	339	9,20	26 940	9,80		
October	15 161	9,40	367	9,96	26 523	9,65	Autumn	26,96
November	12 610	7,82	277	7,52	20 634	7,51		
Toplam	161 306	100	3 685	100	274 829	100	Total	100

2.2.4.2 Weather Conditions

As a result of surveys conducted, it is observed that accidents are affected by weather conditions. Weather conditions have psychological and physical impacts on drivers. Effective parameters are as below:

- Air temperature: As the temperature increases in summer, sunlight grows stronger, which has a direct impact on road safety. If vehicles are in direct sunlight, it can cause reduced vision and the driver may not see the road completely because of reflection. In addition, high temperature may cause engine to overheat and catch fire [44].

- Average wind speed: It is observed that especially inexperienced drivers have difficulty in controlling the vehicle and wind speed makes the vehicle prone to skidding. Weather phenomena at high wind speeds, such as storms and tornadoes etc., can pose a great danger to vehicles as the possibility of blowing off of rocks and roofs around, increases [44].

- Precipitation: There are also cases in that an increase in accident rates during rain and snow is observed. However, as drivers are much more careful in the cases of excessive rain or snow and reduce their speed, it has been noticed that there is a decrease in accident rates, not increase [44].

- Fog: Even if accident rates are thought to increase due to poor visibility in foggy conditions, it is observed that there has not been a noticeable increase in the number of accidents since drivers generally reduce speed, give more of their attention and use warning systems (fog lamps, 4-way flasher etc.) in those cases. However small the number of accidents caused by foggy conditions are, still some safety measures must be taken on roads [44].

In addition, weather conditions have an impact on roads as well. Superstructures of roads are directly affected by weather conditions. For instance, there may occur poor road conditions such as potholes caused by heavy rain. If the compression is not good enough on roads where bituminous material is used or the type of asphalt is not chosen regarding road properties, deterioration of the asphalt pavement will be inevitable. Puddles may form on roads due to poor drainage and cause accidents [44].

Even if there is no frost on a road when the temperature is below zero, frost and black ice may be encountered on bridges and viaducts, which means invitation to an accident as it will cause vehicles to slide. Therefore, there must be road icing warning signs before entering a bridge or a viaduct. When air temperature is high, asphalt may melt. Because of that wheels leave traces on roads, roads get slippery and sliding resistance reduces [44]. For these reasons, as a country with four seasons, Turkey must give high importance to road construction conforming to the standards. Distribution of accidents by weather conditions can be seen from Table 2.15.

Table 2.15 Number of persons killed or injured with respect to the weather condition [13].

Weather conditions	Accidents			Number of persons killed	Number of persons injured
	Total accidents	Accidents involving death	Accidents involving personal injury		
Sunny	143 730	2 704	141 026	3 274	274 829
Rain	13 006	229	12 777	287	23 905
Hail	37	3	34	3	85
Snowy	1 639	34	1 605	46	3 779
Strong wind	242	7	235	7	462
Fog/smoke	2 208	45	2 163	57	4 238
Sleet	302	7	295	8	566
Blizzards	114	3	111	3	287
Dust and sand storm	28	-	28	-	55
Total	161 306	3 032	158 274	3 685	274 829

2.2.4.3 Effects of Road Lighting

Darkness is an important factor that affects road safety. The surveys conducted in USA confirms that it is better to make measurements at night time because of that the number of night time accidents is 2.5 times as much as daytime accidents [45].

Therefore, lighting system on roads is a must. Even though one of the reasons why lighting systems are not built on roads is related to costs, it has been seen that the cost of lighting is the same as the amount paid for only 15 percent of accidents. A good lighting system creates road safety and comfort [46].

2.3 Literature Review

(Khan et al., 2004) developed a GIS-based management and analysis system in order to gather and store data on traffic accidents in Abu Dhabi correctly. They noticed that there is a margin of error around 100 m. when GPS devices are utilized to locate accident scenes and the people who fills in the forms are not able to transfer the information on the device to official reports correctly. The best solution was determined to be a GPS receiver that operates with GIS map of Abu Dhabi. In this way, the data marked on the map had only a 5-meter margin of error and would be used for future analysis. Also, he states that 99 different variables can be obtained from an accident report and emphasizes the importance of using GIS as it is hard to fill in all the information by hand and it may lead to missing information.

Tuncuk (2004), formed a database based on accidents between 1998 and 2002 in Isparta, identified accident hot spots using GIS and offered suggestions to improve them. Making clear the importance of GIS, this study also indicates that GIS is an indispensable part of accident analysis studies, for it can store data as geographical reference data and can link them to map coordinates. In addition, it is noted that GIS should be used with GPS in order for accident location information to be displayed on maps accurately and for accurate analysis. As a result of the study, information on intersections of streets and avenues and the number of accidents is provided on charts. It is observed that in order to discover what causes accidents at located hot spots by examining layers as a whole is more feasible instead of examining data one by one.

(Valverde et al.,2006) made an analysis of accidents with casualties (killed and injured) by obtaining data on the accidents that occurred in Pennsylvania between 1996 and 2000 and by comparing full hierarchical Bayesian model to traditional negative binomial method. As a result of the study it is observed that full Bayesian method is more consistent compared to negative binomial method as it uses spatial correlation in data analysis. It is concluded that spatial correlation should be preferred especially for analysis of accidents that occur at any road segment or junction. As no correlation was found for fatal accidents because of insufficient data, they underlined the importance of studying with more data.

Bilim (2006) examined the crashes occurred between 2004 and 2005 in order to identify the hot spots where the accidents occur at most in Konya. Upon locating these spots, he worked on what causes the accidents for the first 10 place and provided solutions to minimize accident rate. It is observed that the factors causing accidents most are breaking the speed limit, narrow sidewalks for pedestrians, violation of the traffic rules, errors in the design of junctures, and excessive number of parked vehicles at roadside.

In his/her study Loo (2006) analyzed whether it is necessary to correct accident locations prior to analysis. For this purpose, he examined crashes that occurred in Hong Kong from 1993 to 2004. After processing accident data on database and visualizing it on GIS, he was able to see most of the errors on the map and found that accuracy of data provided by the police was about 65-80%. It is found out that accuracy of GPS devices is not high in crowded cities. Therefore, stating that not only coordinates but also information about road classes, number of lanes, lane widths and types of junctures can be obtained using GIS, he underlines the importance of expanding GIS' areas of use. With GIS, the accuracy, precision and reliability of the crash information will also increase. He emphasizes that researchers should check the accuracy of data in case of possible errors since GIS is not commonly used while writing accident reports.

(Li et al., 2007) analyzed five-year crash data of city of Harris through Bayesian Method with the aid of GIS and sought for solutions to find road segments with high risk of accidents and prevent them. As a result, they found out the segments with high risk of accidents and prepared a risk map using GIS in order to help drivers choose safe routes. In addition, result of the analyses indicate that it is not possible to determine why some roads have more risks and what should be done to reduce risks without knowing traffic volume, road characteristics and environmental factors.

(Erdoğan et al. 2008) analyzed the data, collected by department of traffic safety; of 7634 crashes occurred on Afyonkarahisar road from 1996 to 2006 using poisson distribution and kernel density methods in order to identify high risk areas. The results show that crash rate is higher in summer and winter, that crashes occur at weekends most, and that junctures are the most risky areas when geometric properties of roads are regarded. The study is essential in that it uses GIS not only to make visualization but also to make analysis.

Anderson (2009) used road accident data from 1999 to 2003 in London collected by Metropolitan Police Service to find out hot spots for the purpose of reduction of high density accident areas then transferred the data on GIS and identified 15 hot spots using kernel density analysis. Even though making analysis using kernel density method is not new, focusing on high density areas of accidents, this study associates crashes with the data and reaches different results. For instance, an analysis on a hot spot indicates that most pedestrian crashes happen between midnight and 3 am and at early hours of Sunday mornings since there are a lot of bars and pubs around the area and drunk pedestrians cause accidents while crossing the road.

In order to find out the influence of geometrical standarts of road in traffic accidents and instantly measuring the acceleration values on a particular route in Afyonkarahisar, Tuncel (2010) tried to detect influences of lateral acceleration created by centrifrugal force in bends. To achieve this, he placed a GPS and an accelerometer in a vehicle, made measurements moving with the vehicle and gathered data. Consequently, he detected faults in geometrical designs of bends. Subsequent to examinations on accident data, it is understood that the main reason for accidents is actually inappropriate transition curve joints of successive bends. In the data acquired from accident reports in Turkey it is indicated that roads are generally defect-free, however, while road defect percentages are high even in European countries, these data seem nonrealistic. This is the reason why a study like this was needed. Emphasis is laid on the need for necessary steps to be taken and the importance of training report makers so as to detect road defects.

(Kaygisiz et al., 2010) carried out an analysis on 1619 accidents that took place between 2006-2008 in Southern Anatolian Highway in order to find out spatial distribution of accidents and to detect hotspots. Subsequent to non-spatial analyses, it is seen that the number of accidents increase in summer months and take place mostly in daytime. In order to carry out spatial anaylses, kernel density method is used with GIS and accidents are not analyzed according to their number but their severity. Coefficients are taken 3 for accidents involving death and 1 for accidents involving injuries. Furthermore, this study is important for it takes density of traffic in accident regions as a parameter. As a result, hotspots are detected for each year and hotspot changes are pointed out on maps annually.

In his study, Durduran (2010) created a data set from the information about accident day and month, temperature, humidity, and weather conditions then transferred the information on GIS platform to predict crashes occurring on Konya-Afyonkarahisar road. Creating a decision making mechanism with support vector machine or artificial neural network classifier algorithm that choose properties on correlation basis, for made predictions of traffic accidents. The data was visualized on GIS and correlation analysis was made through kernel methods. It is observed that the results obtained when decision making mechanism is started, by using only one of the two methods have less accuracy than the ones obtained when both of them are used at the same time. It is concluded that predictions of real accidents can be made by more data and using decision making mechanism in this way.

In his study, Gündoğdu (2010) gathered crash data that occurred between 2007 and 2008 in Adana in order to identify accident hot spots. He analyzed the accidents by days of week, seasons, air temperature, holidays and time zones then examined their direct relations with accidents. He identified accident hot spots by making kernel density analysis and found what causes accidents on those spots and also offered solutions to reduce risks at accident hot spots. As a result, he underlines the importance of using GIS in traffic accident analyses and indicates that a GIS which is developed for accident analysis will help make analyses in a faster and more reliable way.

In order to reveal hotspots formed by accidents on 7 main arterial roads in Konya, Gundogdu (2010) analyzed 3586 accident data of the last decade with GIS-supported Getis-Ord Gi* method. Analysis is carried out segmenting the roads in 1 km pieces. The main purpose is to find out the regions with frequent accident occurences and the influence of physical conditions of roads, coating materials and bends. This study is a first in terms of identification of potential future hotspots. Within the scope of this study, spots with %95 probability of being future hotspots are identified and included in the study in order to take measures in time. As a consequence, 38 hotspots and 22 potential future hotspots are detected.

(Keskin et al., 2011) in this study, to be able to understand traffic accidents and analyze them, examined 459 traffic accident data in METU campus which took place between 2003-2008. In order to reveal in which region accidents clustered, they used kernel density estimation and nearest neighbor distance methods and compared hotspots found through each method. This study, which analyzes accidents occuring in a university campus, is a first in Turkey. As a result, when the accidents are analyzed by their occurence time, it is found out that these accidents occur between 12:00-19:00 when there is a heavy traffic and that most of them take place on Mondays. After visualizing accident spots on map, it is ascertained that accidents generally occur on main roads and also cluster around shopping and cultural centers which draw pedestrians and vehicles to themselves. 4 hotspots are identified within the campus and solution offers are made for these spots. Especially, emphasis laid on the need for signalization.

In his study, (Somenahalli, 2011) in order to determine the insecure bus stops in Adelaide, Australia, examined the pedestrian accidents that took place between 1996 and 2008 and, in order to find hot spots, made a GIS based spatial autocorrelation analysis. In determining hot spots, the number of accidents are not regarded, instead the accidents are multiplied with weighting coefficients and the study is carried out according to these figures. Coefficients are taken 3 for accidents involving death, 1.8 for accidents resulting severe injuries, 1.3 for accidents resulting injuries and 1 for accidents resulting in material damage. A spatial model is established using Moran's I method, and by means of Getis-Ord Gi* hotspots are specified on map according to their index values. As a result, it is concluded that hotspots generally take place at intersections and mid-blocks and also that bus stops without a pedestrian crossing are more secure. Solution suggestions are made for bus stops which are identified to be insecure. Only, no statement is made about the effects of bus drivers in accidents for no interrelation could be established during the study.

In his study, (Saha, 2012) found hotspots formed as a result of accidents which took place at Elk Mountain Corridor. After the evaluation, it is understood that the %71 of accidents arose from overspeeding. For this reason, it is decided to apply variable speed limit, however, it is decided to determine the hotspots in the region in order to detect critical spots which are to be practiced. To be able to determine these hotspots, analyses made on GIS. Beside Kernel Density Method Getis-Ord Gi*, Moran’s I and sliding scale, which is a former non-GIS analysis, are used. In conclusion, it is decided that GIS-based methods give more consistent results owing to spatial autocorrelation approach of GIS and that kernel density method is good at catching hotspots but should be supported with other test methods if statistical significance is needed.

In his study, (Chainey, 2013) made a research inquiring the effects of cell size and bandwith on analysis which are parameters of the most popular hotspot detecting method of the recent years – the kernel density method. The reason why Kernel Density method is popular is that visually it presents spatial distribution of accidents and occurences so good and that it is the most accurate method in detecting hotspots on maps. However, the effects of cell size and bandwith, which are inputs of kernel density analysis, are not well understood. This study is carried out in order to satisfy this need. Maps are obtained keeping bandwidth stable and exercising analysis on different cell sizes; and it is seen that cell size has so little effect in detecting hotspots and it has a direct effect on visual clarity. Nonetheless, it is concluded that when bandwidth is changed, it is quite a contributing factor in detecting hotspots. It is observed that as the bandwidth value increases, the success of the kernel density analysis method in detecting hotspots and finding spots of possible accidents goes down. Yet, at the same time, extremely low bandwidth values causes the evaluation of so small regions as hotspots and it fails to reveal spots which demand strategical attention. That’s why, there must be an equilibrium in bandwidth choice. As a practical method, he suggested an analysis with a second and a lower bandwidth parameter to detect hotspots focusing on hot regions found subsequent to high bandwidth value analysis.

Bil et. al. (2013), worked on data of accidents that occurred between 2007-2010 in Southern Moravia, Czech Republic and made clustering analysis to identify hazardous road locations. The difference from other studies is that it evaluates each cluster by its force to find the most dangerous spots in an area. The force of cluster was found by evaluating the number of accidents in a cluster and in an area and path length of the cluster and the area. In this way, 840 potential hot spots were identified in kernel method while the most dangerous 39 hot spots were identified when cluster density was arranged as 0.6. Since what is required to complete this analysis is nothing but the position of traffic accidents in the area and area length, this method is defined to be a fast identifying method in finding the most dangerous spots in a transportation network.

In the study of Zhixiao (et al., 2013), after traffic accident data was visualized on GIS, it was analyzed using kernel density and network kernel density methods to identify high density areas of accidents. However, because of computational imperfections in statistical evaluations, once again an analysis of nearest neighbor at a scale of 100 m was made using Moran's I method after the density was found. As a result of the study it is observed that by using the methods in this way one can reach improved results that are more accurate and have statistical precision. It is also stated that such observations are valuable in terms of preventing future accidents and improving safety. On the other hand, traffic volume was taken as stable and not taken into consideration while making the analysis even though more crash rate is expected at locations where traffic volume is high. If it is not taken into consideration, density analyses may not reflect the truth. Therefore, it is concluded that traffic volume must be considered prior to real practices.

Liu (2013) examined the impact of weather conditions on traffic accidents using crashes that occurred between 2007 and 2010 in Maryland. The results indicate that accidents are affected by weather conditions and high temperature, high speed winds and precipitation have increasing impacts on crash rates.

CHAPTER 3

MATERIAL AND METHODS

3.1 Material

3.1.1 Study Area

With 1 889 466 population by 2014, Gaziantep ranks first in Southeastern Region of Anatolia and sixth across Turkey in terms of industry and development [64]. One of the richest provinces in Turkey, Gaziantep owes its wealth to the wide range of transportation facilities and its proximity to seaports.

It has 9 districts; Araban, İslahiye, Karkamış, Nizip, Nurdağı, Oğuzeli, Şahinbey, Şehitkamil and Yavuzeli. Şahinbey and Şehitkamil constitute the center of Gaziantep. The population in the center is 1 556 381, which means the population is densely accumulated in the center. It is surrounded by Kahramanmaraş in the North and Northwest, Yavuzeli in the Northeast, Nizip in the East, Oğuzeli in the Southeast, Kilis in the South, İslahiye in the Southwest and Nurdağı in the West [65].

Due to its geographical position Gaziantep is under the influence of both Mediterranean and Continental climates. While the weather is quite hot especially in June, July, August and September, it is very cold in December, January and February. The highest temperature measured in Gaziantep is 44 °C and the lowest is -17.5 °C in the last 50 years. It receives the least rainfall between June and September and the most between December and February. There is a huge temperature difference between night and day during seasonal change. Rate of humidity is quite low because it is landlocked, which is why weather conditions are not severe [66].

As it is located between Anatolia and Mesopotamia, Gaziantep has always been on trade routes throughout history, the most important of which is Silk Road. For this reason, air and land transportation has been very advanced in the city [67].

Especially E-24 highway that enables transit from Europe to Asia and Africa plays a crucial role in the development of the city. However, the most important route is Gaziantep-Adana-Tarsus Highway. It has train services every day to Adana, Ankara, Bilecik, Elazığ, İstanbul, Kahramanmaraş, Karkamış, Malatya, Nizip, Nusaybin and Osmaniye. Put into service in 1954, the railway station has an important position. In 2001 another station was opened [68].

Some steps have been taken for rail transportation as well. Although there is not a subway system yet, the city has 3 active tram lines. In 2008, construction works began for tram line route 1, from Railway Station to University, and it started operating in June, 2010. Then second route, Karataş tram line was built. After that, third one, İbrahimli tram line, was built and started operating in 2014.

City of Gaziantep has three fundamental transportation problems [69]:

1) Pedestrian problems: Ensuring pedestrian safety is the most important of all since foot traffic comprises %50 of traffic flow. It is observed that uncontrolled pedestrian crossing on the rails of tramline, public transportation vehicles' stopping at places other than bus stops, narrow sidewalks, and warning signs that spoil the continuity of sidewalks endanger pedestrians. That is firstly because most people ignore traffic rules in the city causing a lot of problems. For instance, public transportation vehicles, risk pedestrian safety by stopping at places other than bus stops and other vehicles occupy bus stops for short stops or parking and put them into trouble. Since very few people use signals, and lots of people violate the signalization, lateral collisions happen very often [69].

2) Problems with Intersections: On the same level signalized and unsignalized intersections are examined in terms of traffic safety and continuity, it is seen that intersections pose a risk for traffic as it is difficult to open byways to turn right due to unplanned structuring and geometric design of intersections are not as required. In addition, vehicle parking in impact area of intersections cannot be prevented in spite of warning signs and tickets. Not obeying traffic rules is observed to reduce intersection safety as well [69].

3) Problems with Parking Lots: Due to unplanned structuring, old houses and workplaces cannot have parking lots. Therefore, parked vehicles on roads narrow them and risk traffic safety. Parking garages are excessively full and used above their capacity due to shortage of parking spaces, which has a risk of causing loss of life and property in the event of a fire and so forth [69].

In addition, 'asphalt of poor quality used in road construction causes deformation of roads and forms craters. Poor quality materials used on sidewalks may cause puddles on the surface and water accumulation under tiles and they reduce road comfort. Sidewalks may not be preferred for such reasons and all of these are among the factors that reduce traffic safety [69].

In this study, accident data of city of Gaziantep in 2013 is examined and analyzed using kernel density model on GIS in an attempt to identify hot spots and make statistical analysis. As a result, accident hot spots are identified and solutions are offered to remove accident risks at hot spots.

3.1.2 Dataset

In this study, with the permission of Gaziantep Traffic Agency, data of year 2013 on accidents involving death or personal injury has been read from the accident reports in this division and a database has been created on MS ACCESS. Then the data has been transferred on Excel format and prepared for analysis.

Before analysis, data was examined, the faults in recording coordinates after reading from GPS device were detected. Generally, due to x-y coordinate confusion or no x-y coordinate specification at all on accident reports, the coordinates were obtained through Google Maps depending on address information recorded on accidents reports. For 940 of 2351 accident data, coordinates were examined one by one, and after the examination, an analysis was conducted with the aim of locating accident hot spots. As Khan (2004) and Tuncuk (2004) indicate in their study, using a system developed with GIS-GPS integration keeps accident reports will prevent such faults.

With the aim of collecting statistical data, some information has been obtained from the reports such as date, road, type of road, type of paving, class of road, weather conditions, vertical and horizontal routes on a road, type of junction, type of accident, number of cars involved, number of dead and injured, birth year and sex of driver, type of car, part of car which has been affected by accident.

Other missing data on the accident reports were not taken into consideration in assessment as information on pavement width; platform and lane width was not recorded on the most reports. In addition, in 99% of the accidents, the road problems section was filled as ‘there was nothing wrong with the road’, which implies that even if there had been a road problem, the reports were presumably filled by someone who was incapable of identifying any road problem. That’s why, road problems were examined after accident hot spots were located.

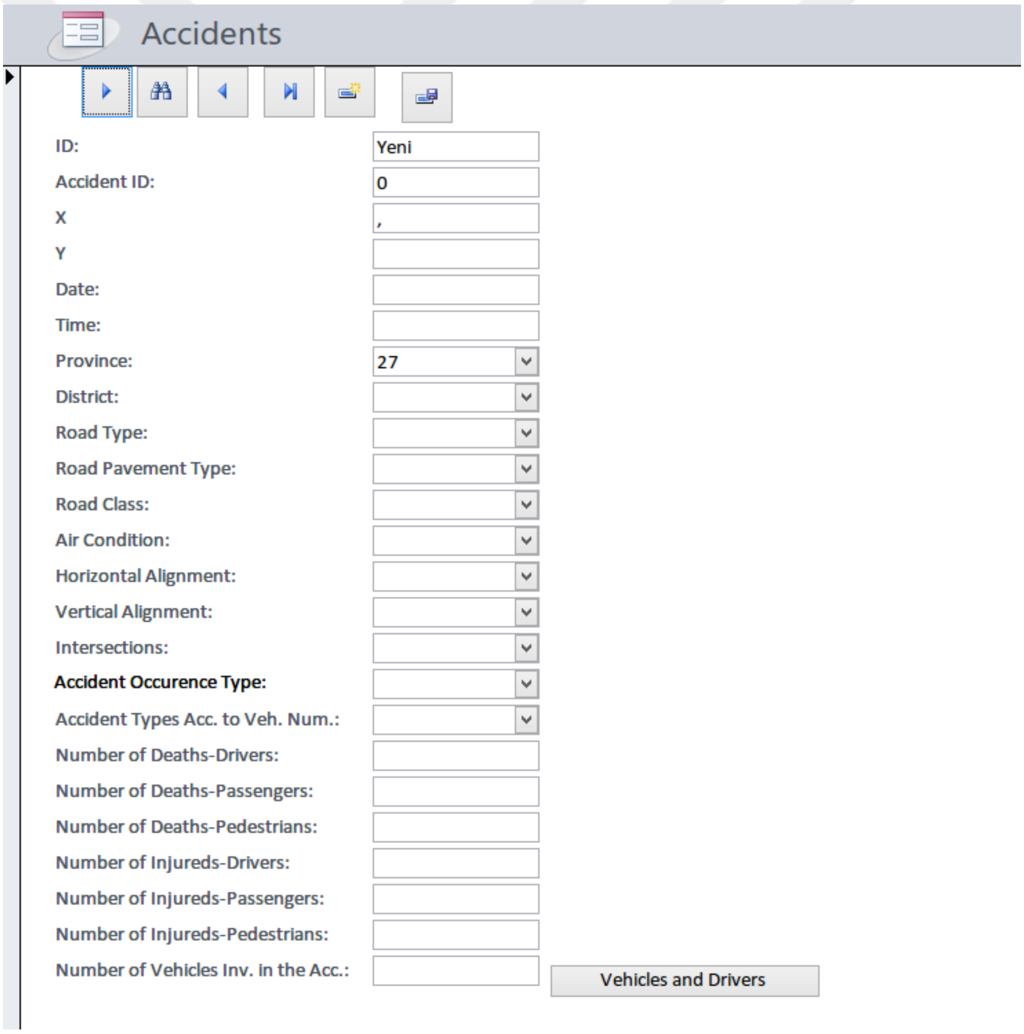
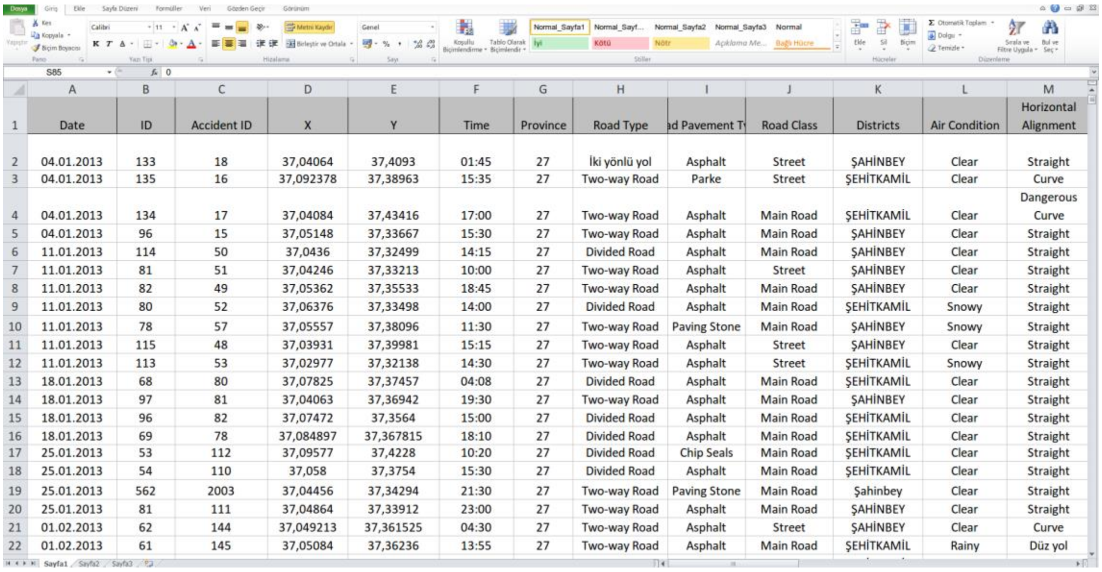


Figure 3.1 MS ACCESS database creation screen



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Date	ID	Accident ID	X	Y	Time	Province	Road Type	ad Pavement T	Road Class	Districts	Air Condition	Horizontal Alignment
2	04.01.2013	133	18	37,04064	37,4093	01:45	27	İki yönlü yol	Asphalt	Street	ŞAHİNBEY	Clear	Straight
3	04.01.2013	135	16	37,092378	37,38963	15:35	27	Two-way Road	Parke	Street	ŞEHİTKAMİL	Clear	Curve
4	04.01.2013	134	17	37,04084	37,43416	17:00	27	Two-way Road	Asphalt	Main Road	ŞEHİTKAMİL	Clear	Dangerous Curve
5	04.01.2013	96	15	37,05148	37,33667	15:30	27	Two-way Road	Asphalt	Main Road	ŞAHİNBEY	Clear	Straight
6	11.01.2013	114	50	37,0436	37,32499	14:15	27	Divided Road	Asphalt	Main Road	ŞAHİNBEY	Clear	Straight
7	11.01.2013	81	51	37,04246	37,33213	10:00	27	Two-way Road	Asphalt	Street	ŞAHİNBEY	Clear	Straight
8	11.01.2013	82	49	37,05362	37,35533	18:45	27	Two-way Road	Asphalt	Main Road	ŞAHİNBEY	Clear	Straight
9	11.01.2013	80	52	37,06376	37,33498	14:00	27	Divided Road	Asphalt	Main Road	ŞEHİTKAMİL	Snowy	Straight
10	11.01.2013	78	57	37,05557	37,38096	11:30	27	Two-way Road	Paving Stone	Main Road	ŞAHİNBEY	Snowy	Straight
11	11.01.2013	115	48	37,03931	37,39981	15:15	27	Two-way Road	Asphalt	Street	ŞAHİNBEY	Clear	Straight
12	11.01.2013	113	53	37,02977	37,32138	14:30	27	Two-way Road	Asphalt	Street	ŞEHİTKAMİL	Snowy	Straight
13	18.01.2013	68	80	37,07825	37,37457	04:08	27	Divided Road	Asphalt	Main Road	ŞEHİTKAMİL	Clear	Straight
14	18.01.2013	97	81	37,04063	37,36942	19:30	27	Two-way Road	Asphalt	Main Road	ŞAHİNBEY	Clear	Straight
15	18.01.2013	96	82	37,07472	37,3564	15:00	27	Divided Road	Asphalt	Main Road	ŞEHİTKAMİL	Clear	Straight
16	18.01.2013	69	78	37,084897	37,367815	18:10	27	Divided Road	Asphalt	Main Road	ŞEHİTKAMİL	Clear	Straight
17	25.01.2013	53	112	37,09577	37,4228	10:20	27	Divided Road	Chip Seals	Main Road	ŞEHİTKAMİL	Clear	Straight
18	25.01.2013	54	110	37,058	37,3754	15:30	27	Divided Road	Asphalt	Main Road	ŞEHİTKAMİL	Clear	Straight
19	25.01.2013	562	2003	37,04456	37,34294	21:30	27	Two-way Road	Paving Stone	Main Road	Şahinbey	Clear	Straight
20	25.01.2013	81	111	37,04864	37,33912	23:00	27	Two-way Road	Asphalt	Main Road	ŞAHİNBEY	Clear	Straight
21	01.02.2013	62	144	37,049213	37,361525	04:30	27	Two-way Road	Asphalt	Street	ŞAHİNBEY	Clear	Curve
22	01.02.2013	61	145	37,05084	37,36236	13:55	27	Two-way Road	Asphalt	Main Road	ŞEHİTKAMİL	Rainy	Düz yol

Figure 3.2 A dataset profile

3.2 Methods

3.2.1 GPS

Working in any weather conditions economically and constantly, GPS works to determine location on a common coordinate system through satellite [70]. It is prominent with its significant abilities in military, civil and commercial use. GPS was working with only 24 satellites at the beginning then it became fully operational in 1995 [71].

However successful GPS is in determining location, its accuracy was quite low at the beginning. Even if margin of error decreased at around 3.5 m after recent studies, it may increase at around 7.8 m in the worst-case scenario because of atmosphere problems and receiver quality. Military GPS works with higher accuracy. That is because while civil GPS broadcasts on one frequency, military GPS broadcasts on two frequencies, which means ionospheric correction, a system which reduces radio degradation coming from the atmosphere, can be used by military users [72]. As we cannot use military GPS for civil processes, using the version of GPS which is integrated into GIS will provide more accurate and precise information.

3.2.2 GIS

Geographical Information Systems (GIS), is a set of methods that works in order to process, manage, and provide data; to use it for spatial analyses and visualize it on maps after collecting and storing geographical data of large amounts. Collecting geographical data is necessary for the solution of social, economic and environmental problems [73]. GIS is essential to figure out what is happening and will happen in a geographical area.

GIS is a set of systems that involves different technologies, processes and methods. A great many of operations on engineering, planning, management, transportation, insurance and telecommunication can be managed by GIS. Essential to analysis and visualization, GIS can be used to carry out many applications based on location [74].

Any data that includes location and coordinates shall be used by GIS. There are many ways to express the location like latitude and longitude, address or ZIP code. GIS can be used to compare and contrast variety of information. Data regarding people such as population, income or education level is included in the system. Land information such as the location of streams, variety of vegetation and variety of soil can be included in it. Information on sites of factories, farms, and schools or storm drains, roads and electric power lines can also be included [75].

Data in many different forms can be entered into GIS. Data that are already in map form can be included in GIS. This includes such information as the location of rivers and roads, hills and valleys. Digital, or computerized, data can also be entered into GIS. An example of this kind of information is data collected by satellites that show land use—the location of farms, towns, or forests. GIS can also include data in table form, such as population information. GIS technology allows all these different types of information, no matter their source or original format, to be overlaid on top of one another on a single map [75].

In order to use GIS efficiently, designed so as to work with a database that is prepared by location data; necessary information for the project and studying area should be determined, data on the area should be obtained, a database should be set and a new model should be developed. The analysis should be done after the data is transferred to GIS. There are some methods of analysis such as kernel density, distance matrix and nearest neighbor [76].

In order to understand better, GIS' working discipline can be explained by a case study on insurance. For example, there is a hurricane which is going to happen 72 hours later in Florida. In order to identify the insurance company's risk status and the policy owners who will suffer a loss, the policy owners can be viewed on the map using GIS. With the help of GIS, the number of policy owners living in risk areas can be identified by forming a density map, total insurance value in the risk areas can be viewed, and evacuation of the people living in those areas would be possible before the hurricane hits [77].

In this study, GIS is used to determine what causes traffic accidents and to offer solutions for the factors that cause accidents due to road conditions. There are a lot of software of GIS that are open-source or can be purchased. In this study, 2.8 version of Quantum GIS, an open-source software, is used. Gaziantep's road network downloaded from Open Street Map and get transferred to GIS by coordinating it using WG8 84 system then the accident data, obtained from Distric Traffic Agency, is processed. In this way, the accident locations can be viewed and the system becomes ready for hot spot analysis studies.

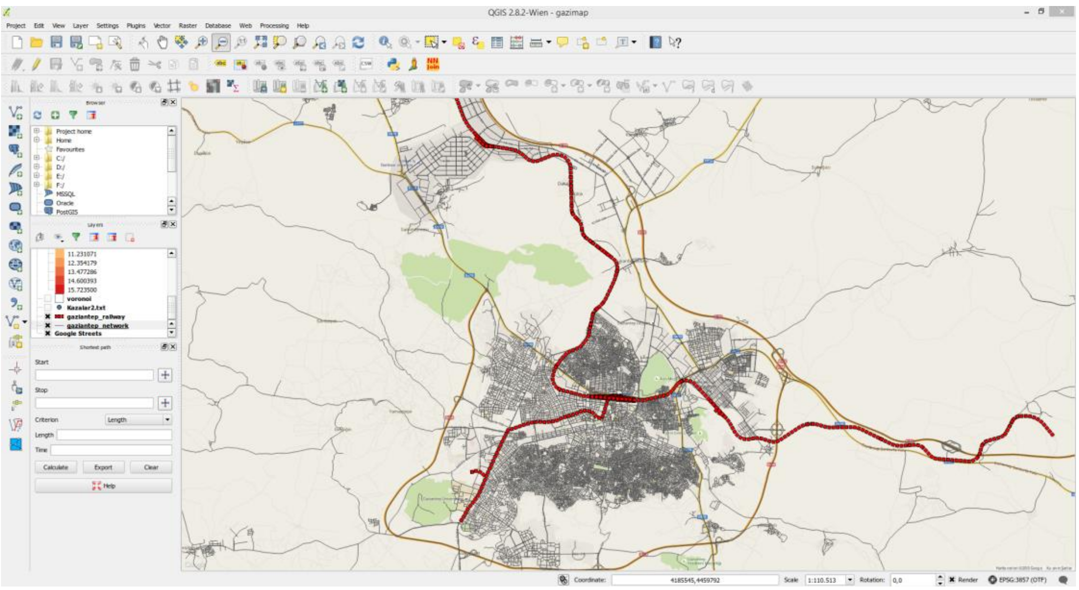


Figure 3.3 The map of Gaziantep viewed on GIS

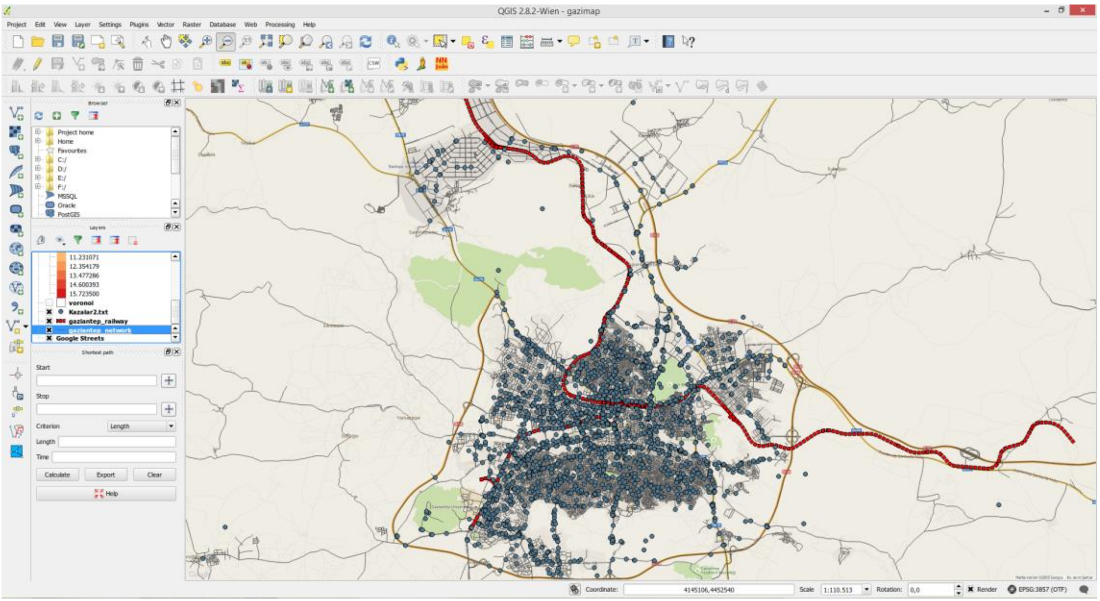


Figure 3.4 Accident coordinates viewed on Gaziantep map.

3.2.2.1 Features of GIS

On GIS, data can be processed in a map in the formats of vector and raster; in raster format, data are presented on cells which are comprised of pixels. Resolution depends on the pixel size, which determines the data sensitivity. Each pixel has an assigned value. In vector format, data are processed based on x, y coordinate values; lines represent lakes and roads; spots represent electric poles, traffic lights, accident locations on roads; and field property represents lands and parcels. A raster based GIS is analytically stronger than vector based GIS [78].

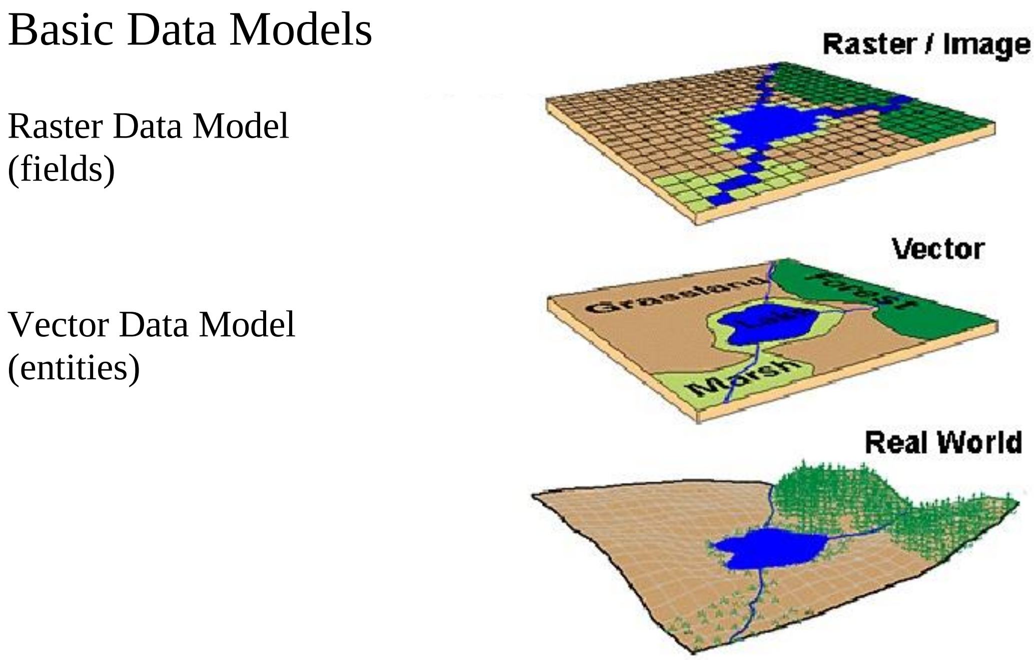


Figure 3.5 Vector and raster data models [79]

Once all of the desired data have been entered into a GIS system, they can be combined to produce a wide variety of individual maps, depending on which data layers are included. For instance, using GIS technology, many kinds of information can be shown about a single city [75]. Layer system can be applied in this context. For example, data on buildings, roads, and green areas in a city can be added individually in layer format, which allows us to study the particular layer we wish to study on a single file. In addition, assuming that coordinate data of roads and traffic lights in a city are entered on GIS and two separate layers are created, we can locate the traffic lights on roads by cross-analysing the layers.

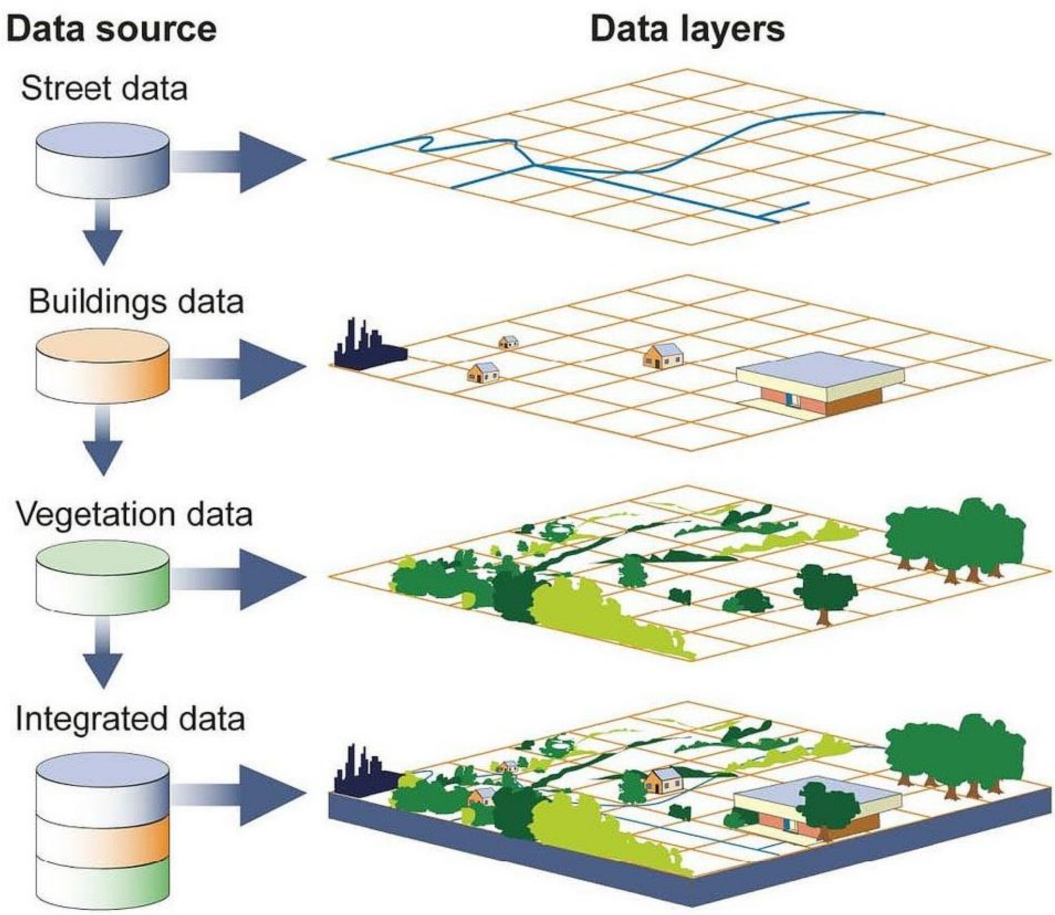


Figure 3.6 Display of GIS layers [75]

3.2.3 GIS-GPS Integration

Originally, GIS use was limited to offices, while in field only GPS could be active. However, with the recent development of light and portable computer technology, the desire to extend the utilisation area of GIS to field has become prominent, and the interest in GIS-GPS integration has increased. Another reason is that GPS is not adequately accurate on its own [80].

There are three key methods in which GIS-GPS can co-operate. These are;

- Data- focused integration
- Position-focused integration
- Technology-focused integration

3.2.3.1 Data-Focused Integration

It is the most common method but it is truly more of an interaction rather than an integration. In outdoor conditions, only GPS device is used, then in office, it is transferred on computer [81]. This method is not efficient enough as it cannot eliminate the faults which may be caused by the inaccuracy of GPS device. As this study has adopted this method, it is observed that it is ineffective in eliminating faults on its own and requires manual control (Figure 3.7).

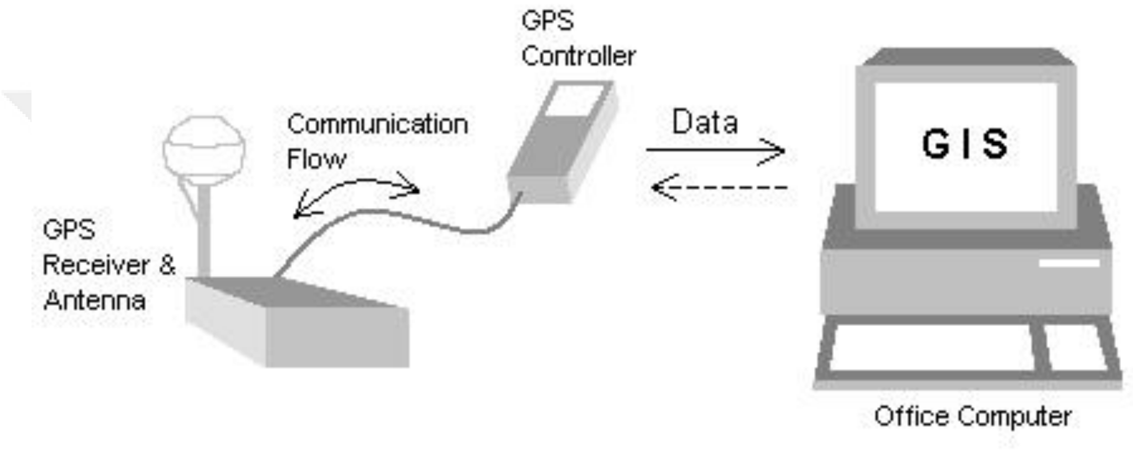


Figure 3.7 Conceptual view of data-focused integration [81].

3.2.3.2 Position-Focused Integration

In position-focused integration, as in data focused integration, a field-operable GIS device is used in addition to a GPS device. The former device has no control over GPS, this device just provides an interface that is designed well for image display and spatial query [81]. For example, as one who fills accident report can see the location and coordinate data obtained through GPS on GIS at the same time, the accuracy of the data can be checked (Figure 3.8).

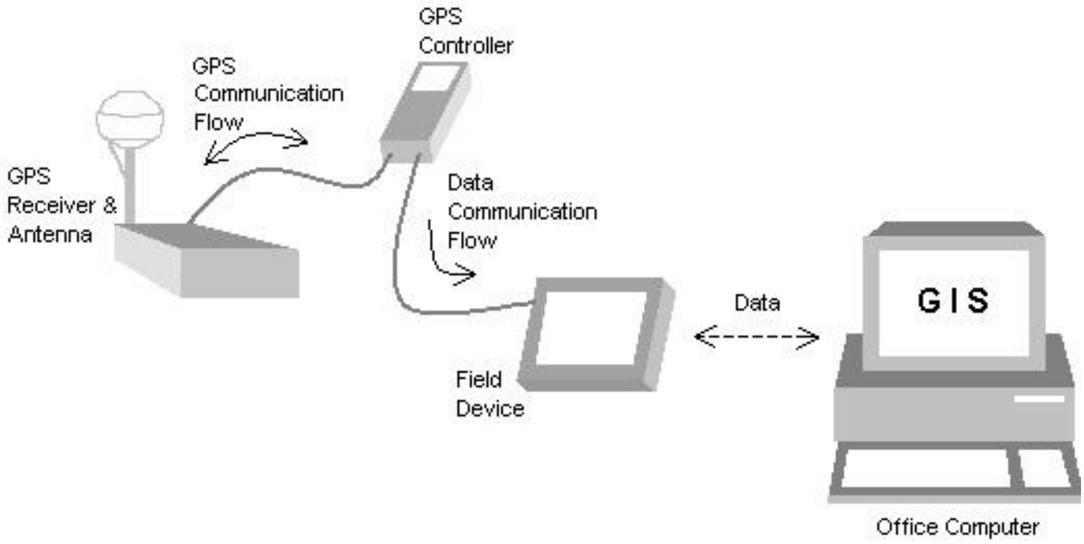


Figure 3.8 Conceptual representation of position-focused integration using two field devices [81].

3.2.3.3 Technology-focused Integration

In technology-focused integration which is a step forward from position-focused integration, GPS is entirely controlled by GIS. There is a bilateral data flow and GIS is ready to be used on field with its full capacity without requiring any external GPS device support. This method causes no fault and allows direct coordinate and location determination [81]. Also field device can help to fill the reports (Figure 3.9).

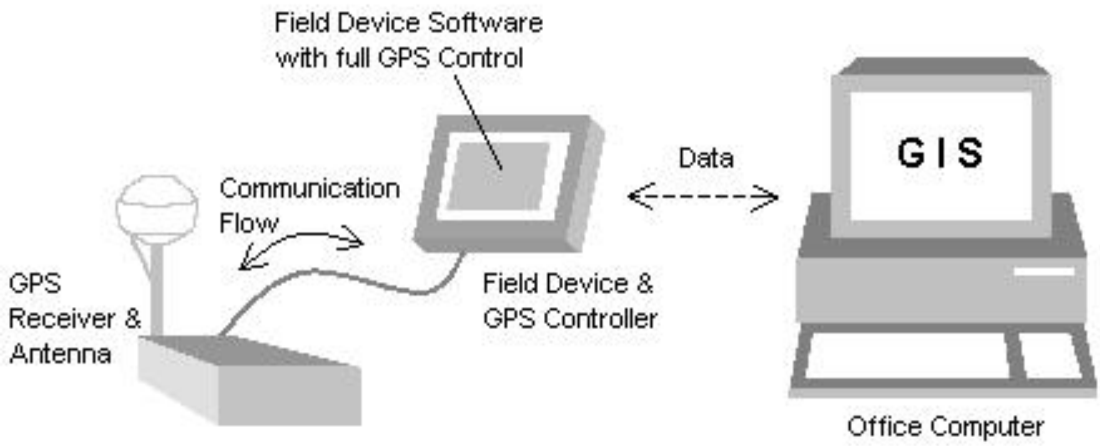


Figure 3.9 Conceptual representation of technology-focused integration [81].

3.2.4 Accident Hot Spot Analysis

3.2.4.1 Hot spots

When incidents which have occurred in a particular area and in a particular time period are evaluated by a particular geographical area, it is observed that in some spots in this area, accidents are more frequently occur compared to the other spots. The spots with higher accident frequency are called hot spots [60].

In accident analysis, the spots where accidents are intensely occurring are also called hot spots. The fact that there hot spots means that there are also cool spots. For example, when we conduct a hot spot analysis on a map on which accident data are entered, we see spots are indicated with colours going from lighter to darker. While lightest colour indicates the spot with lower accident frequency, the darkest colour indicates the spot with higher accident frequency, which allows us to demonstrate hot spots on a map.

The analysis methods chosen are Sliding Scale Analysis, Kernel Density Estimation, Morans I and Getis-Ord Gi*. The existences of a number of softwares to conduct KDE analysis have contributed to the popularity of this method. In addition a kernel density estimation output allows for an easier interpretation of where crimes cluster in comparison to point, geographic area thematic, and grid thematic maps. The maps area thematic, and also reflect more accurately the location, relative scale and spatial distribution of crime hot spots in comparison to these other methods. The kernel density estimation method also considers concentrations of crime at all event levels, rather than grouping som ecrime events into clusters and discounting others [82]. For this reason, Kernel Density Estimation method has been choosen.

3.2.4.2 Analysis Methods

3.2.4.2.1 Sliding Scale Analysis

In accordance with sliding scale analysis, road is divided into segments in pre-determined lenghts and accident density is calculated for each segment. Segment length is determined according to daily traffic average. Generally, it is taken as 1 km. Its drawbacks; it has no statistical significance, a change in start point also changes the results, it cannot evaluate the data effectively and the number of softwares for anaylsis is limited [83].

3.2.4.2.2 Anselin Moran's I Method

Using Moran's I method, GIS determines spatial autocorrelation of accident locations in accordance with accident coordinations and accident frequency in areas. It shows result according to closeness of areas and similarity of attributes. Similarity between two different locations means that the accident frequency of these two different locations are similar. The Moran Index can be calculated using the following equations [59].

$$I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}(x_i - \overline{x})(x_j - \overline{x})}{(\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij})(\sum (x-\overline{x})^2)} \tag{3.1}$$

$$Z = \frac{I - E(I)}{\sqrt{VAR(I)}} \tag{3.2}$$

Where w_{ij} indicates the spatial weight in between location *i* and location *j*; n expresses the total number of vehicle crash locations; x_i denotes the total number of crashes at location *j* and $\overline{x}$ gives the global mean value. The standardized Z-score can be calculated using the expected value of calculated Moran's Index *(E(I))* and the variances *(VAR(I)).*

To be able to evaluate results, GIS makes calculations according to Z-score and P-value figures. In case index has a positive value, it is concluded that this area is surrounded by other areas which have similar accident densities. Existence of this kind of an area implies that the area is a hot spot. If the result is negative value, that area is surrounded by areas which have dissimilar accident densities. In this case, the area is named as outlier [84].

3.2.4.2.3 Getis-Ord Gi* Metodu

Getis-Ord Gi* analysis method is a local statistic method and calculates local spatial statistics separately according to each location. It is used in order to determine hot or cold areas, in other words, hot spots. It achieves this through deciphering the clustering of indexes at high or low values. High Gi* results show hot spots as Z-score value; and low Z-score value shows cold spots. Not all spots with statistically high values can be named as hot spot. To be able to name a spot as a hot spot, it should be surrounded by other areas with high values, at the same time. The formulation of the Getis-Ord Gi* statistic is given is as follows [85]

$$G_i^* = \frac{\sum_{j=1}^{n} W_{(ij)} x_j - \overline{X} \sum_{j=1}^{n} W_{ij}}{S\sqrt{\frac{\sum_{j=1}^{n} W_{ij}^2 - \left(\sum_{j=1}^{n} W_{ij}\right)^2}{n-1}}} \tag{3.3}$$

Where x_i is the value of location, w_{ij} is the spatial weight between location i and j, n is the total number of locations.

3.2.4.2.4 Kernel Density Estimation

A standard planar Kernel Density Estimation (KDE) produces a continuous density of spatial points over a 2-D surface. This method has been used widely for identifying accident hazardous location and analysis. Since traffic accidents occur in a 1-D linear space, planar KDE might not be appropriate for the representation of density depending on the network characteristics such as large roadway network, small roadway network, a particular segment of a roadway. The general form of KDE in a 2-D space is given down below [61].

$$f(x,y) = \frac{1}{nh^2} \sum_{i=1}^{n} k\left(\frac{d_i}{h}\right) \tag{3.4}$$

Where f(x,y) indicates the location of (x,y) while n is the density value of accidents and h indicates the radius(bandwidth) of Kernel Density Estimation; k is the weight of i spot; d_i is the distance from (x,y) spot to i spot [61].

Basically, on the model where KDE is used, the longer the distance from the spot is, the lower the weight coefficient is used for total density estimation. Kernel Density calculates a magnitude per unit area from point or line features using a kernel function to fit a smoothly tapered surface to each point or line [83].

Let’s design a transportation network and assume that 10 accidents occurred on different areas in this network; in order to conduct analysis with kernel density estimation method, a bandwidth -i.e. radius- value of 1 km is adopted. As a result, as is seen on the Figure 3.10, we see that within this radius, there occurred 6 accidents. In addition, kernel density estimation method develops a hot spot map by estimating density based on the distance of these 6 spots within this radius.

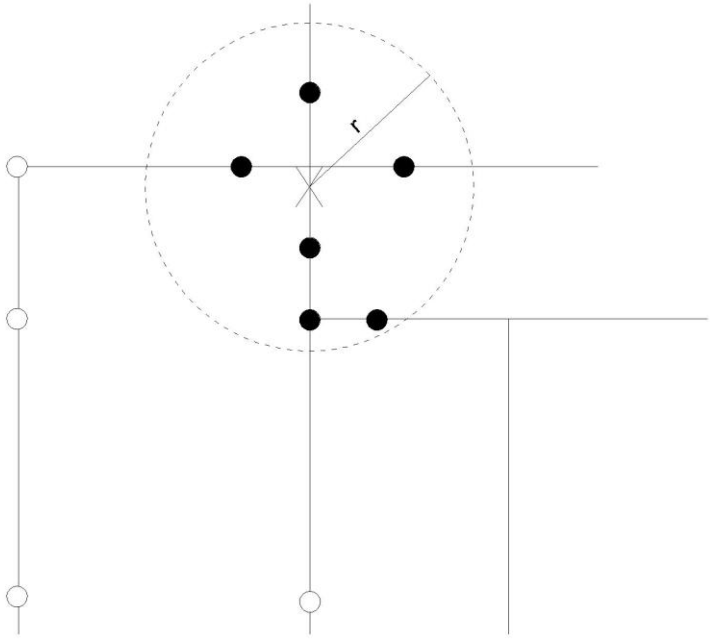


Figure 3.10 Planar KDE [60].

To be able to conduct a hot spot analysis with KDE, we need to know the cell size and bandwidth values. Cell size is use to set the spatial resolution of the output density raster and bandwidth is the radius of the search neighborhood. The effect of cell size on hot spot estimation accuracy is quite low and only allows obtaining files with high definition [60].

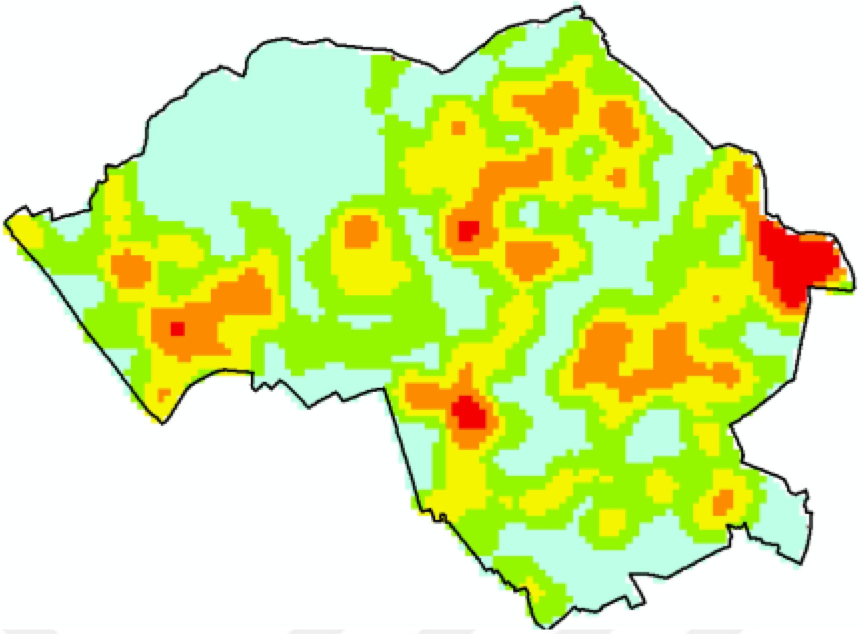


Figure 3.11 Hot spot map using KDE (cell size: 75m and bandwidth: 440 m.) [86].

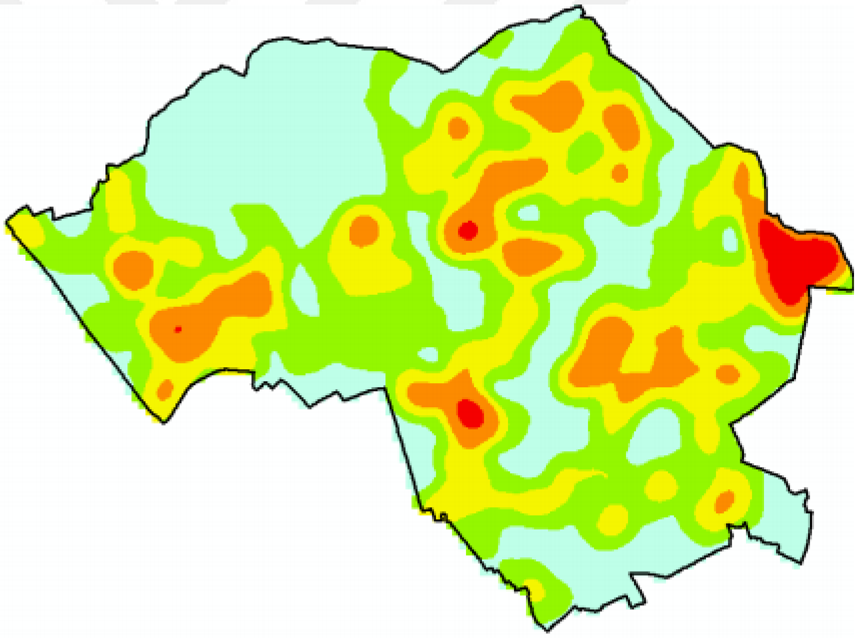


Figure 3.12 Hot spot map using KDE (cell size: 15m and bandwidth: 440 m.) [86].

The lower the bandwidth -i.e. radius- is, the higher the hot spot accuracy tends to be. However, this is not certain. Thus, analysis tool is repeated a few times to find the ideal bandwidth. As is seen on Figure 3.13 and 3.14, changing bandwidth has enabled to locate hot spots from hot regions.

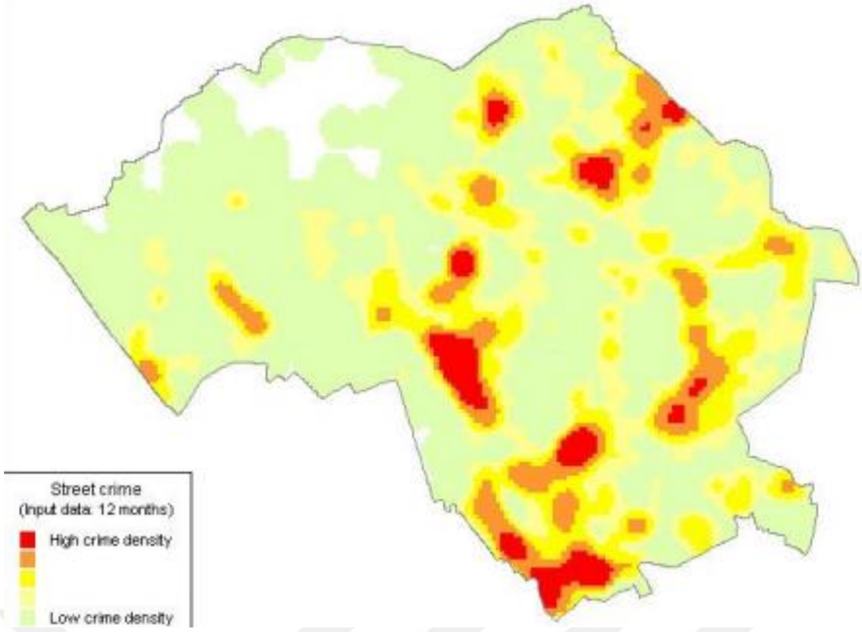


Figure 3.13 Hot spot map using KDE (cell size: 50 and bandwidth: 225 m.) [86].

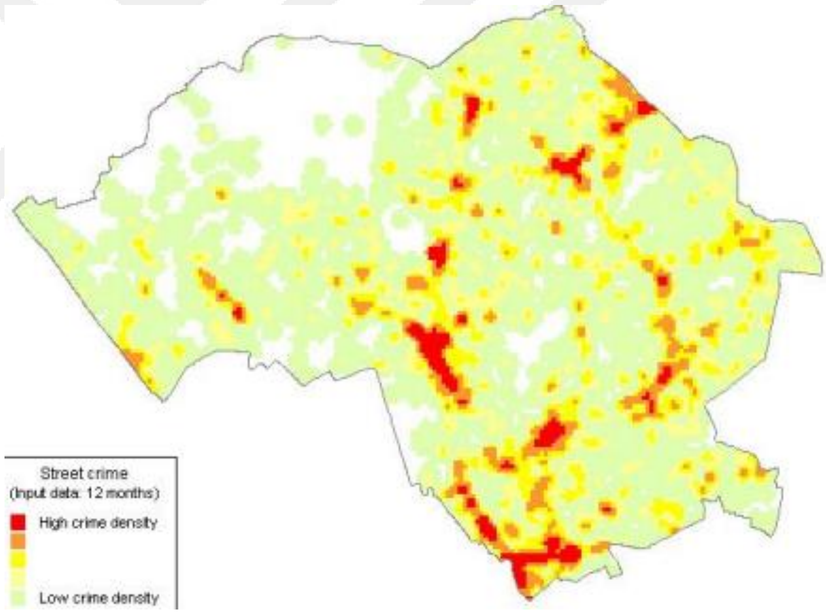


Figure 3.14 Hot spot map using KDE (cell size: 50m and bandwidth: 125 m.) [86].

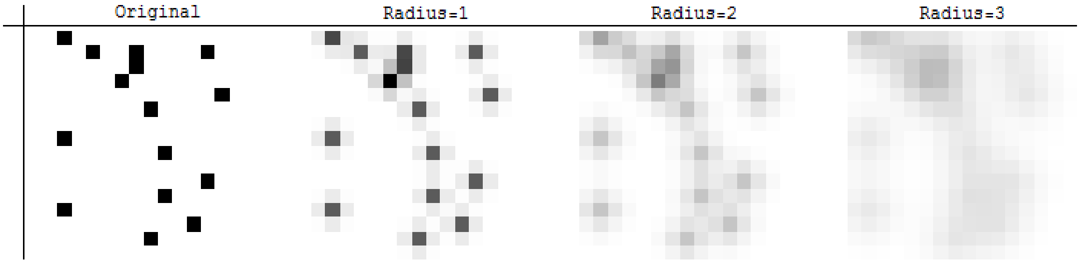


Figure 3.15 Changes observed on the map by varying radius values [87].

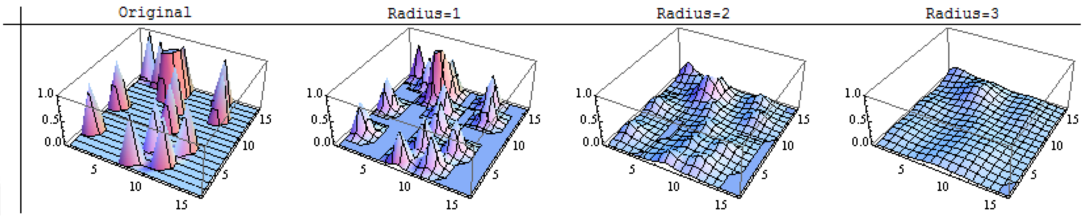


Figure 3.16 Map smoothing by varying Radius [87].

The quartic kernel density estimation method creates understandable grid cell value outputs that relate to crime and requires fewer parameters to be set than those required for many other methods. The parameters entered can relate to the spatial distribution of the points being analyzed. The method also has the advantage of deriving accident density estimates based on calculations performed at all locations [88], and retains some practical flexibility in map design.

The issue over which thematic range to choose to represent the different thematic thresholds remains a problem. One method that has been suggested to help standardize the thematic threshold settings of kernel density estimation hot spot maps is the application of incremental multiples of the grid cells' mean [89]. Calculations for the mean are applied only to grid cells that have a value of greater than 0 and that are within the study area boundary. From this grid cell set, the mean can easily be calculated within a geographic information system (GIS) with grid cell thematic thresholds set at:

- 0 to mean.
- Mean to 3 mean.
- 3 mean to 4 mean.
- 4 mean to 5 mean
- Greater than 5 mean

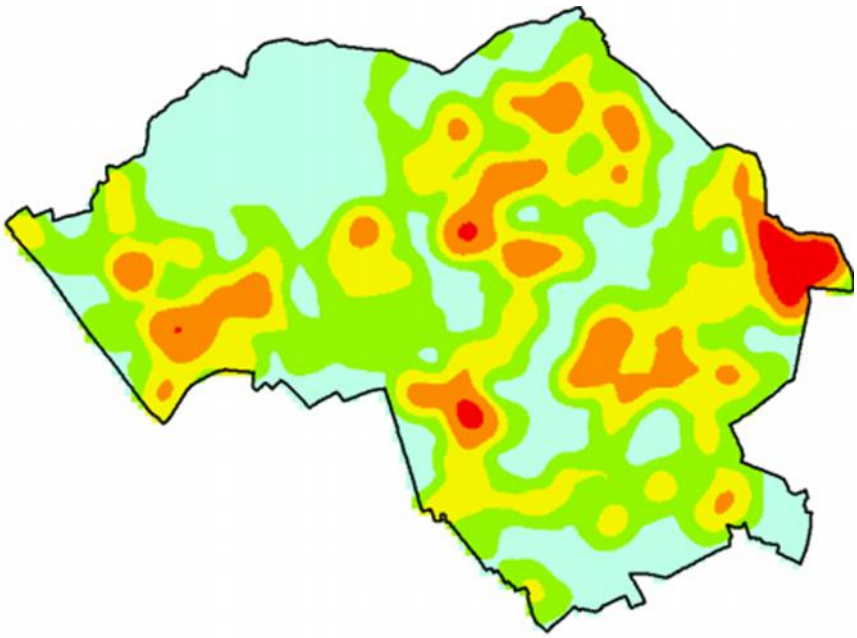


Figure 3.17 Quartic kernel density estimation surface and threshold values (cell size: 15m and bandwidth: 440 m.) [82].

In this study, the analysis has been conducted based on varying bandwidhts –i.e. radius- values of 250 m., 500 m., 750 m. and 1000 m.

CHAPTER 4

FINDINGS

4.1 Aspatial Analyses

The study includes statistical information on traffic accidents resulting in deaths and injuries that occurred in the city of Gaziantep in 2013 with regard to the district where accidents occur; days, seasons, and hours of accidents, whether they occur on weekdays or weekends; whether there is a juncture in the area of accident and the types of junctions; types of accidents by their occurrence; vertical and horizontal curves in the area of accident; weather condition at the time of accident; drivers, passengers, pedestrians and vehicles involved in the accidents.

4.1.1 Accident Analysis by districts

The center of the city of Gaziantep consists of two districts; Şehitkamil and Şahinbey, the area of which is 1250 and 960 km^2 respectively. As understood from Figure 4.1, it is found that 53% of accidents in Şahinbey and 47% of them occurred in Şehitkamil although the district of Şahinbey has smaller area. That is because settlement is higher and roads are patchier in Şahinbey as a consequence of old structuring.

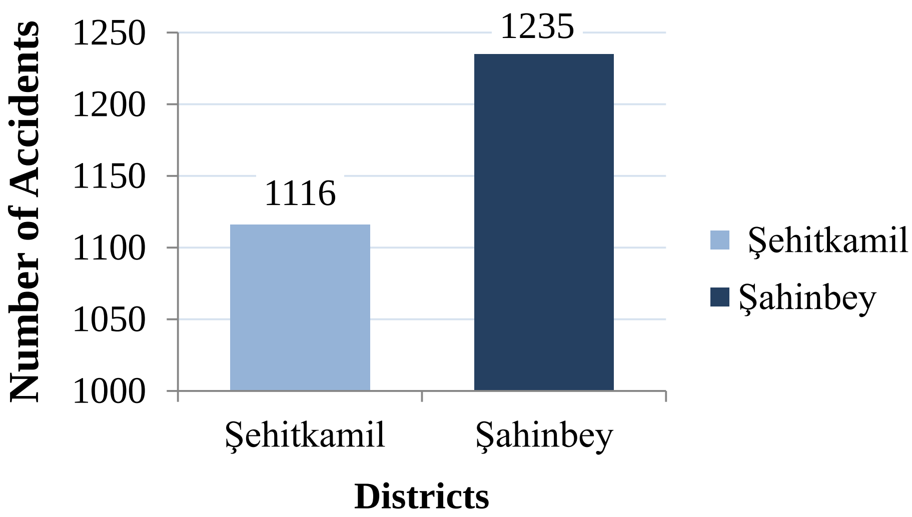


Figure 4.1 Accident Distributions by Districts.

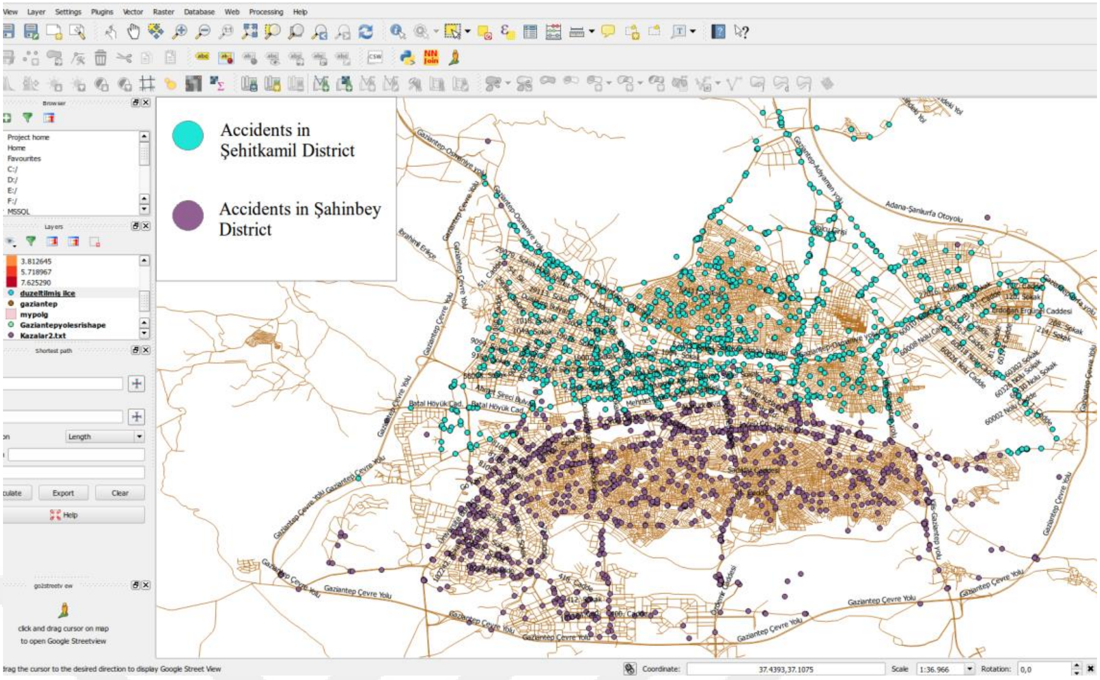


Figure 4.2 Accidents by districts viewed on maps.

4.1.2 Accident Analysis by Seasons and Months

When the accidents analyzed by seasons, it is seen that 17% of accidents occurred in winter, 25% in spring, 30% in summer, and 28% in fall. The number of accidents occurred are given according to seasons on Figure 4.3. Besides, as can be seen on table 2.12, the accidents occurred in Gaziantep has the same rates as the ones occurred in the whole country, when examined by seasons. For more detailed observations it has been analyzed by months as well. The accidents are observed to have occurred most in October and least in December. While the number of accidents shows decrease in winter months, it tends to increase as of spring months as soon as the weather gets better (Figure 4.4).

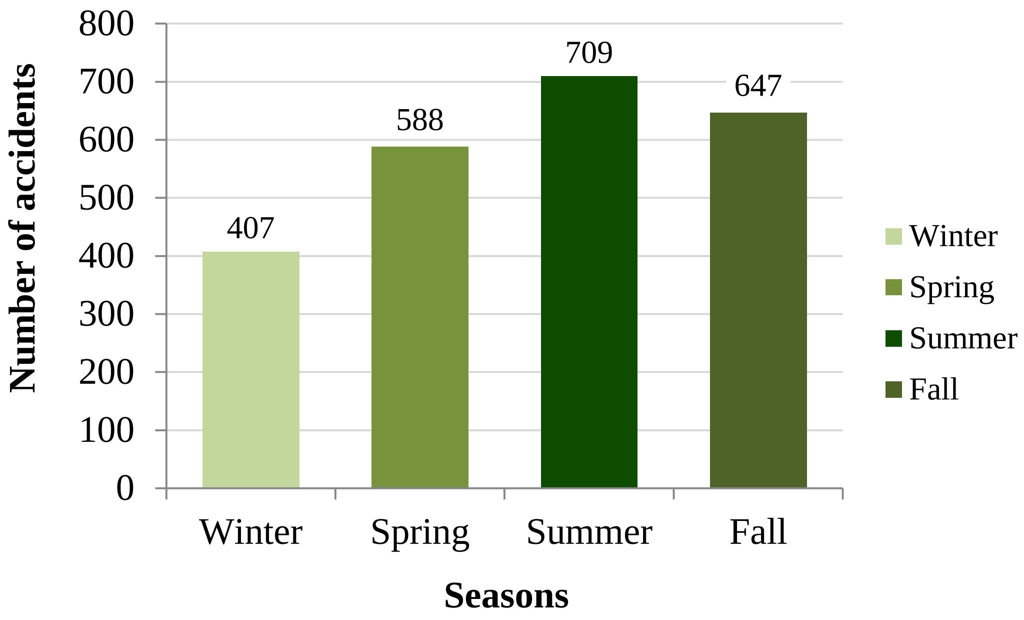


Figure 4.3 Accident Distributions by Seasons.

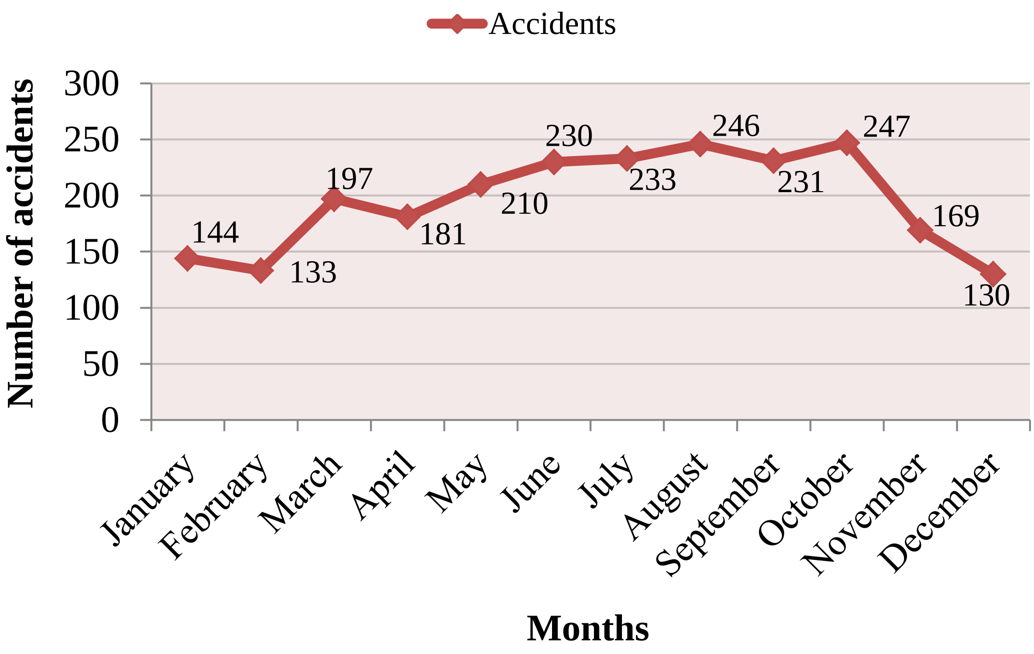


Figure 4.4 Accident Distributions by Months.

4.1.3 Accident Analysis by the Days of Week

When the accidents are analyzed by days and separated as weekdays and weekends, it is observed that accident occurrence rate is 70% on weekdays and 30% on weekend (Figure 4.5). As there are 5 days on weekdays and 2 days on weekends, the distribution of accidents is not understood clearly. Therefore, the accidents are analyzed by days and it is observed that they occurred on Saturdays most frequently, followed by Monday and Friday, the first and last working days (Figure 4.6).

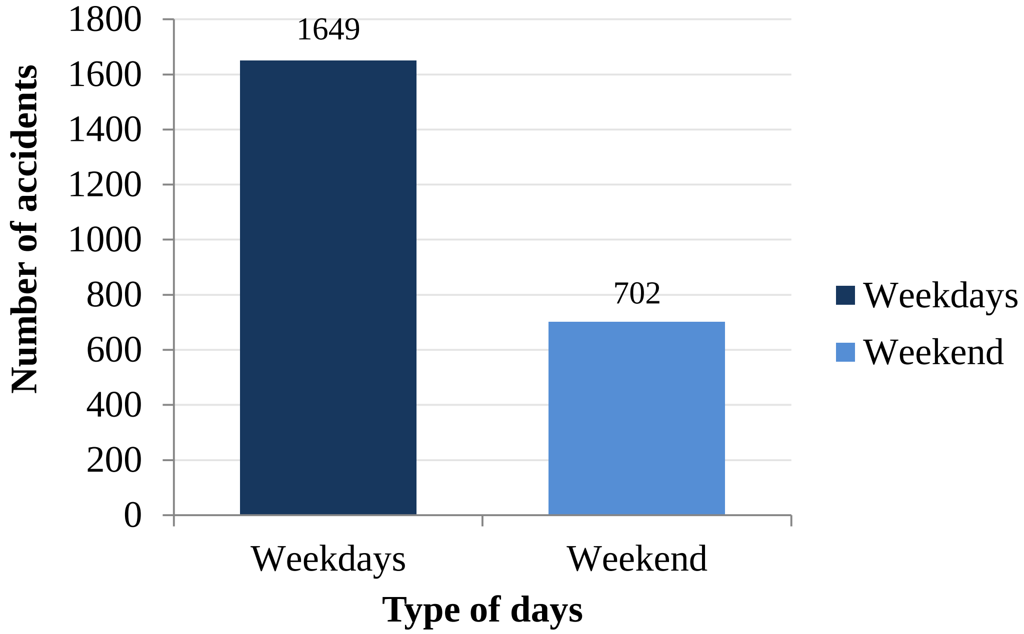


Figure 4.5 Accident distributions by weekdays and weekend.

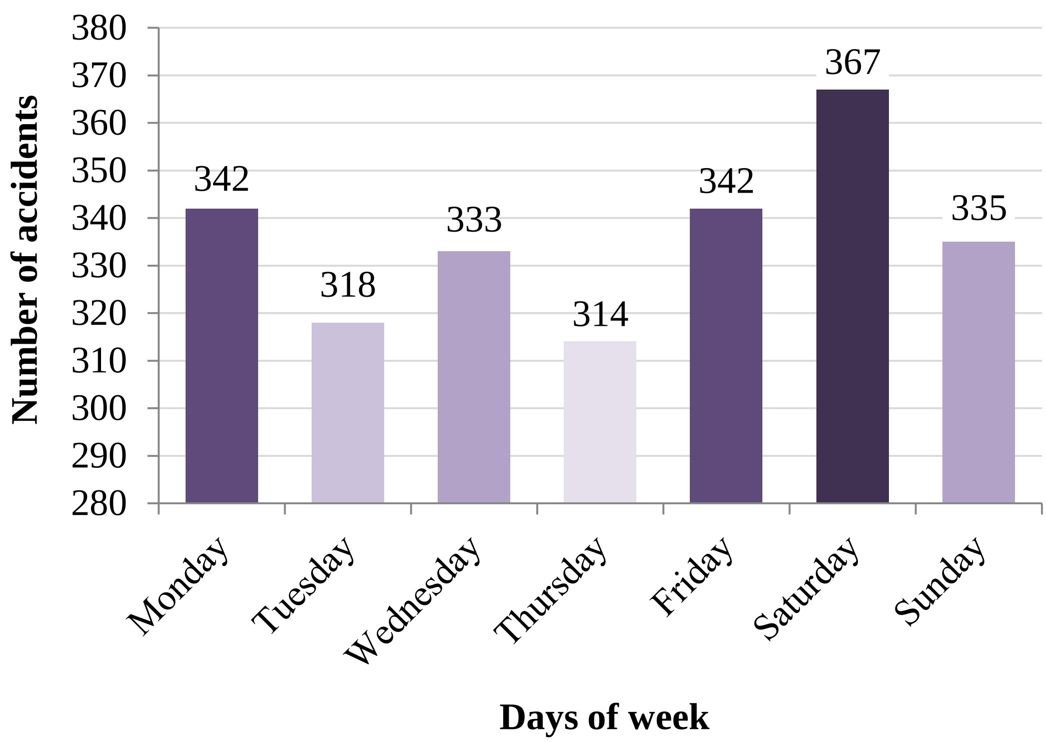


Figure 4.6 Accident distributions by days of the week.

4.1.4 Accident Analysis by Parts of the Day and Hours

When analyzed by daytime and night time, it is seen that accidents occurred most during daytime (Figure 4.7).

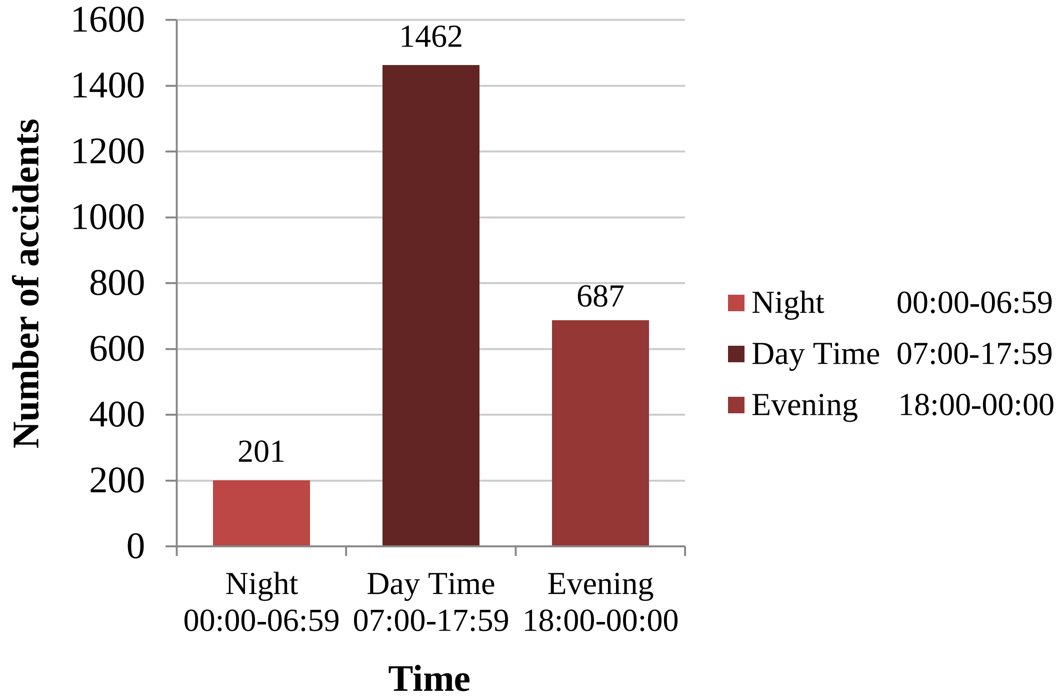


Figure 4.7 Accident distributions by parts of the day.

When examined by hours, it is observed that the peak hours are 13:00-14:00 and 17:00-18:00. The number of accidents decreases from 19:00 to 07.00 and then increases until it reaches at peak points (Figure 4.8).

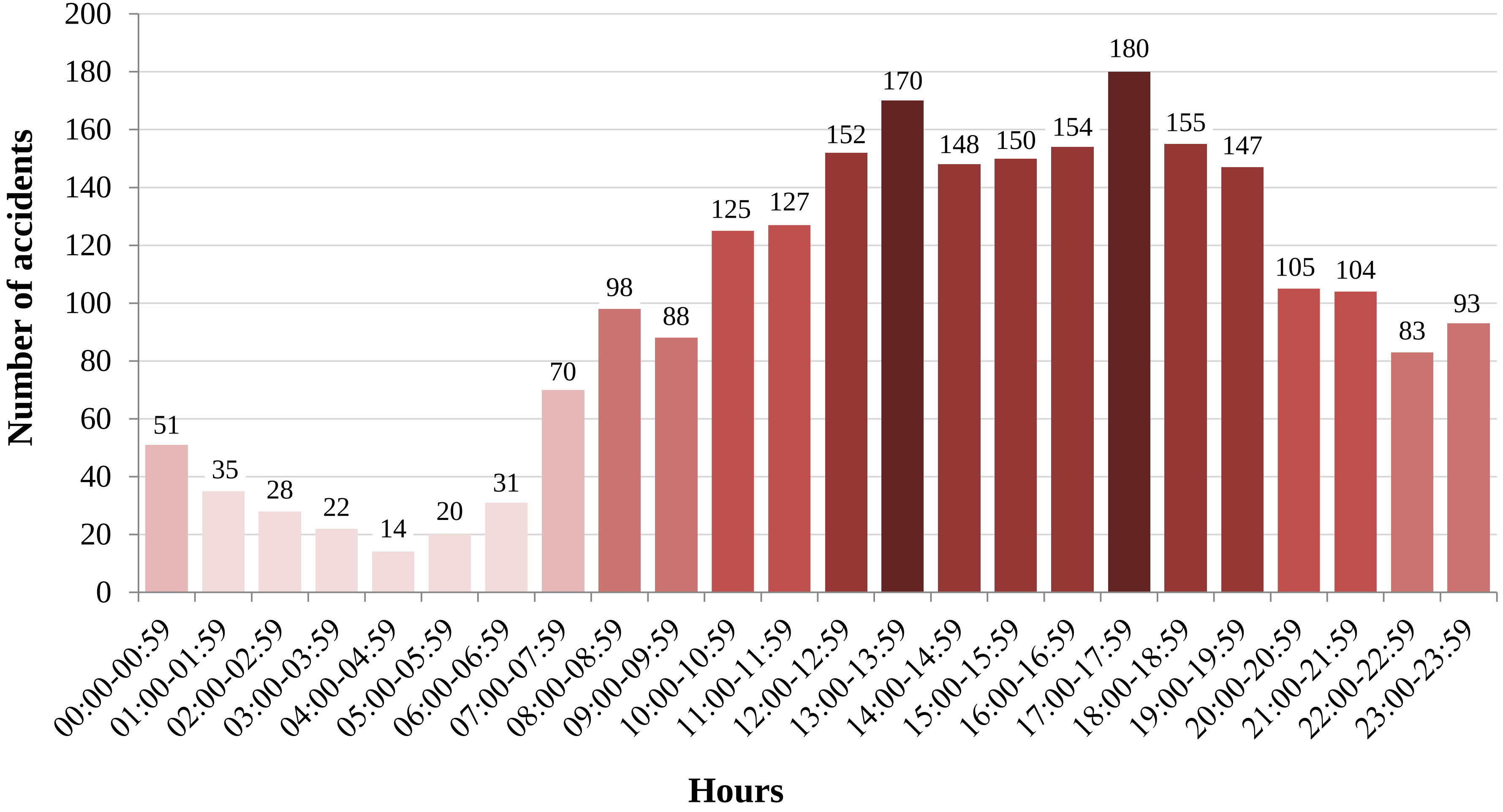


Figure 4.8 Accident distributions by hours of the day.

If Saturdays and Mondays, when accidents are observed to have occurred most frequently, are analyzed by hours, it is seen that on Mondays accidents occur mostly during daytime while they occur more during night time on Saturdays. That is because on Saturdays the number of people working is small and the number of vehicles outside is more compared to Mondays (Figure 4.9).

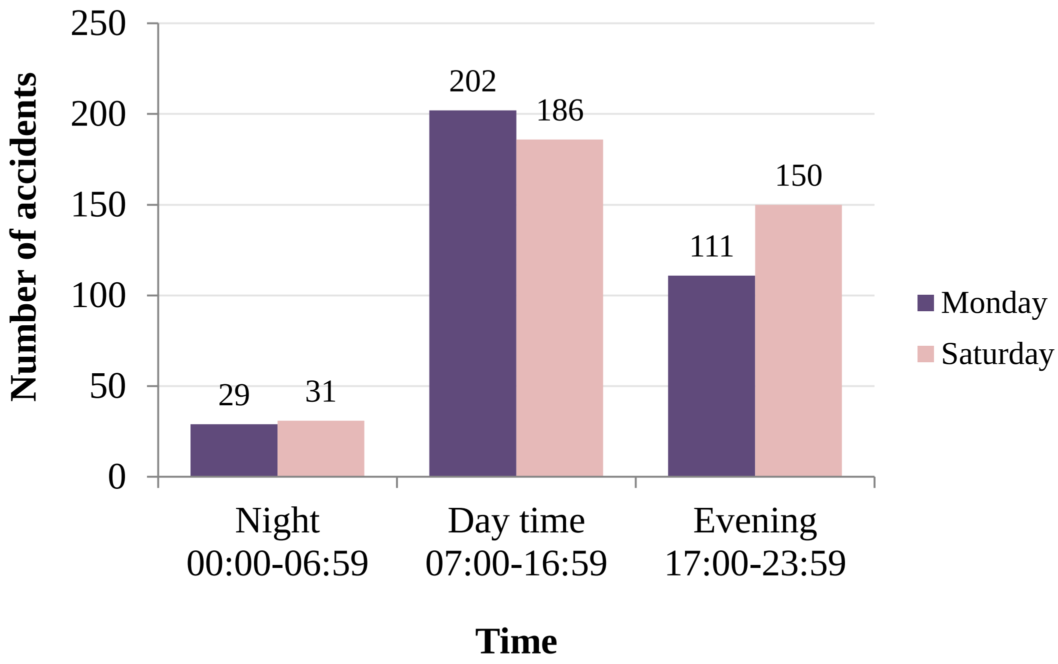


Figure 4.9 Accident distributions by hours on Mondays and Saturdays.

4.1.5 Accident Analysis by Types of Occurrence

When accidents are classified by how they occur, lateral and vehicle-pedestrian collisions are seen as the most common ones. With the rate of 41%, lateral collisions come in first, followed by vehicle-pedestrian collisions with 21%, rear-end collisions with 11%, rollover, overturning and skidding with 7%, head-on collisions with 6%, collisions with an obstructing object with 5%, crashing into a parked vehicle with 3%, side to side collision with 1%, and other causes with 1% (Figure 4.10).

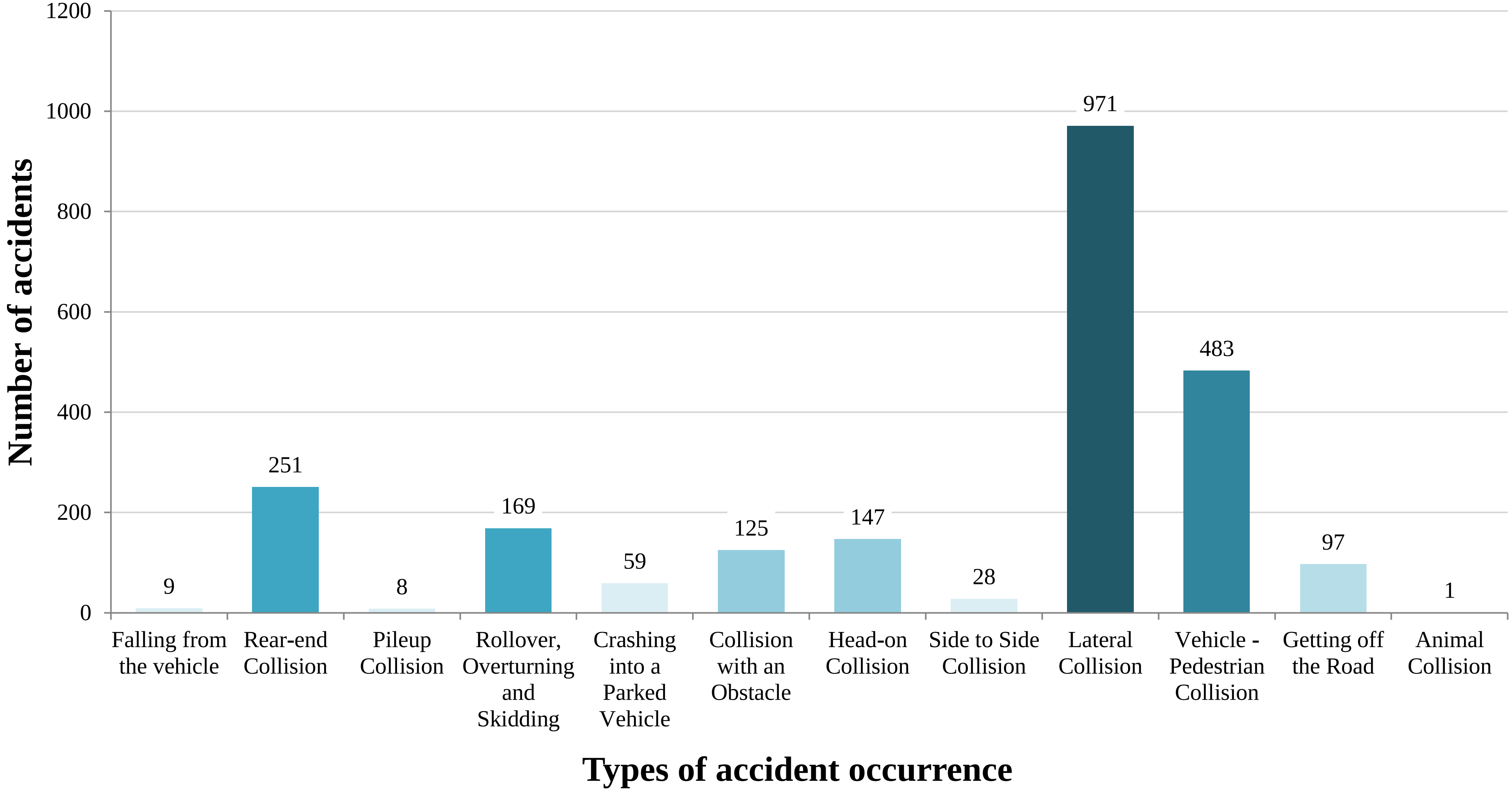


Figure 4.10 Accident distributions by types of occurrence.

4.1.6 Accident Analysis by Types of Vehicles Involved

When vehicle distribution is examined by all accident occurrence types, it is seen that the vehicles involved in accidents are 46% automobiles, 24% motorcycles, 17% light trucks, 5% buses, 5% minibuses, 2% trucks, 2% bicycles, 1% tow trucks and 1% other types of vehicles (Figure 4.11).

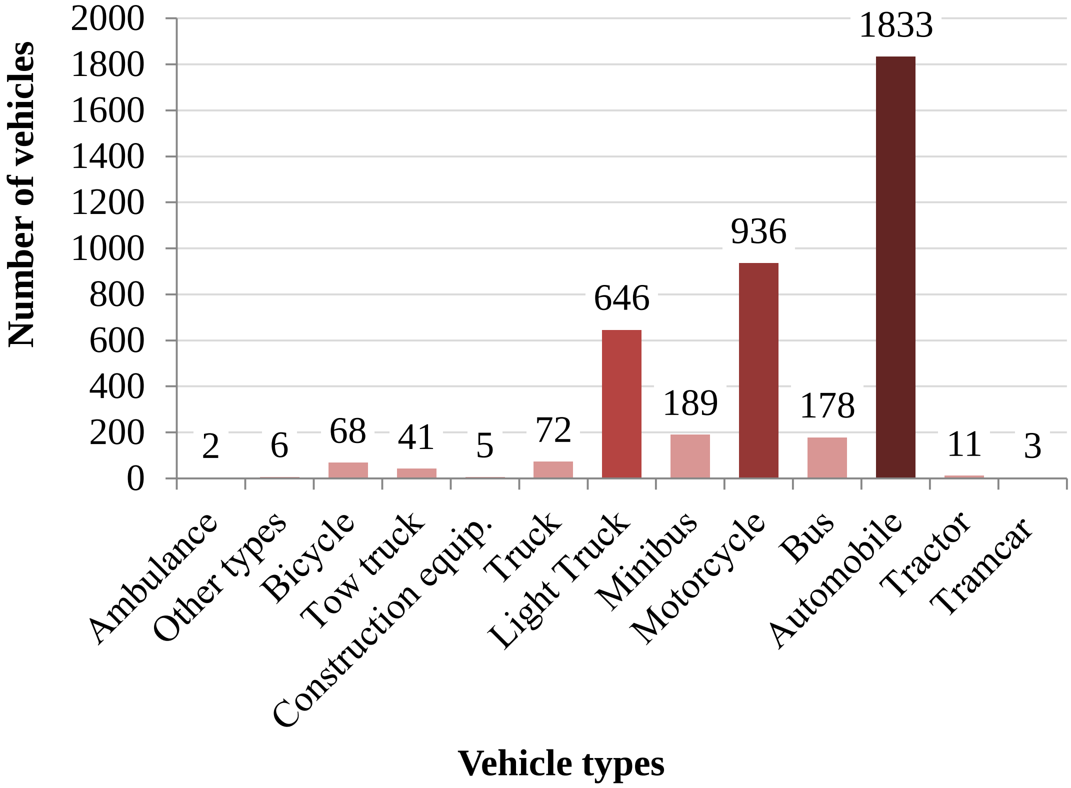


Figure 4.11 Distribution of types of vehicles involved in accidents.

Table 4.1 Motor land vehicles registered by years in Gaziantep [90].

Years	Automobile	Minibus	Bus	Light Truck	Truck	Motorcycle	Tractor	Special Purpose Vehicles
2009	116 554	11 105	2 611	41 578	14 465	91 836	19 887	512
2010	127 324	11 106	2 906	46 619	14 382	96 470	20 677	546
2011	141 142	11 284	3 314	52 851	15 102	102 757	22 173	516
2012	155 052	11 543	3 768	59 448	16 028	106 126	23 695	484
2013	171 055	12 207	4 053	65 030	16 497	110 458	25 230	638

As seen on Table 4.1, the number of registered automobiles and motorcycles in Gaziantep is 171 055 and 110 458 respectively. Due to their numbers, these two are the most frequently seen vehicle types in accidents. In order to prevent injuries in the accidents, controlling must be increased. Not fastening seatbelts is what drivers violate most frequently. In addition, according to the information obtained from accident reports, motorcycle accidents increase because motorcyclists get on side roads from main roads more carelessly, they use direction indicator lamps and signals less, which are situated to warn other vehicles, and they are not noticed by other vehicles while turning right or left. As motorcyclists do not wear helmets and other special protective gear, they are prone to injuries after an accident occurs. In order to prevent this, drivers must be trained as required and controlling on roads must be increased.

4.1.7 Analysis of Types of Accident Occurrence by Types of Vehicles Involved in Accidents

The types of accidents that occur most frequently, lateral, vehicle-pedestrian, rear-end, head-on collision and rollover, overturning and skidding, are analyzed by types of vehicles involved in accidents.

4.1.7.1 Lateral Collision Accidents

The types of vehicles that are involved in lateral collisions most are automobiles with the rate of 46%, motorcycles with 26% and light trucks with 16%. Lack of attention, less using of direction indicator lamps and red light violation are the main causes of lateral collisions (Figure 4.12).

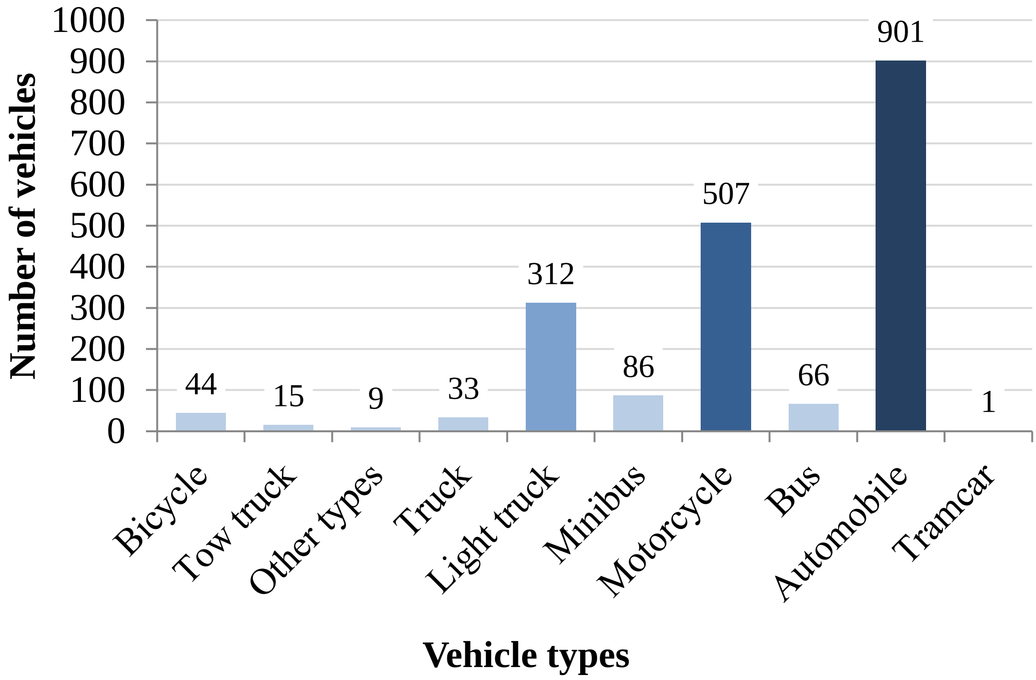


Figure 4.12 Distribution of vehicles in lateral collisions.

4.1.7.2 Pedestrian Collision Accidents

44% of the vehicles involved in pedestrian collisions are automobiles, 21% motorcycles, 17% light trucks, 8% buses, 6% minibuses, 2% trucks, 1% bicycles, and 1% other vehicles. Even though pedestrian accidents is the second cause of accidents, the number of vehicles involved in pedestrian collisions is 506. The reason why there are few numbers of vehicles involved in pedestrian collisions, is that 98% of pedestrian collisions is single-vehicle ones. Although tramline was completed in 2010, it still caused pedestrian collisions, resulting in high rates of fatality. That is why more measures must be taken (Figure 4.13).

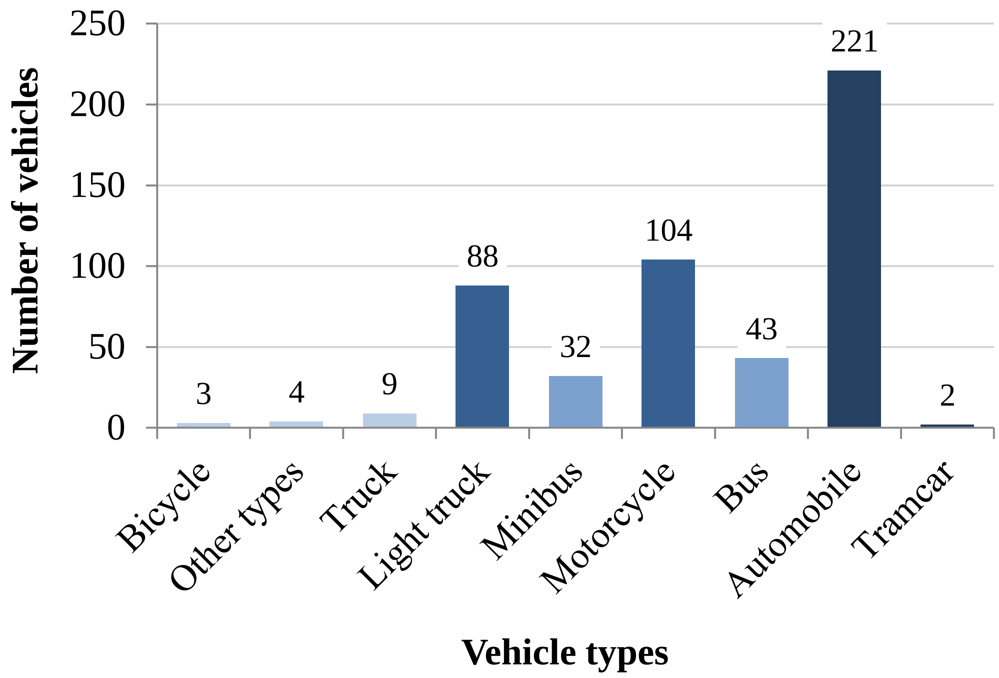


Figure 4.13 Vehicle type distributions according to crashing pedestrian accidents.

4.1.7.3 Rear-end Collision Accidents

Vehicle types that are most involved in rear-end collision accidents; 43% automobile, 17% light truck, 16% motorcycle, 8% bus, 8% minibus, 3% truck, %3 tow truck and %2 bicycles (Figure 4.14).

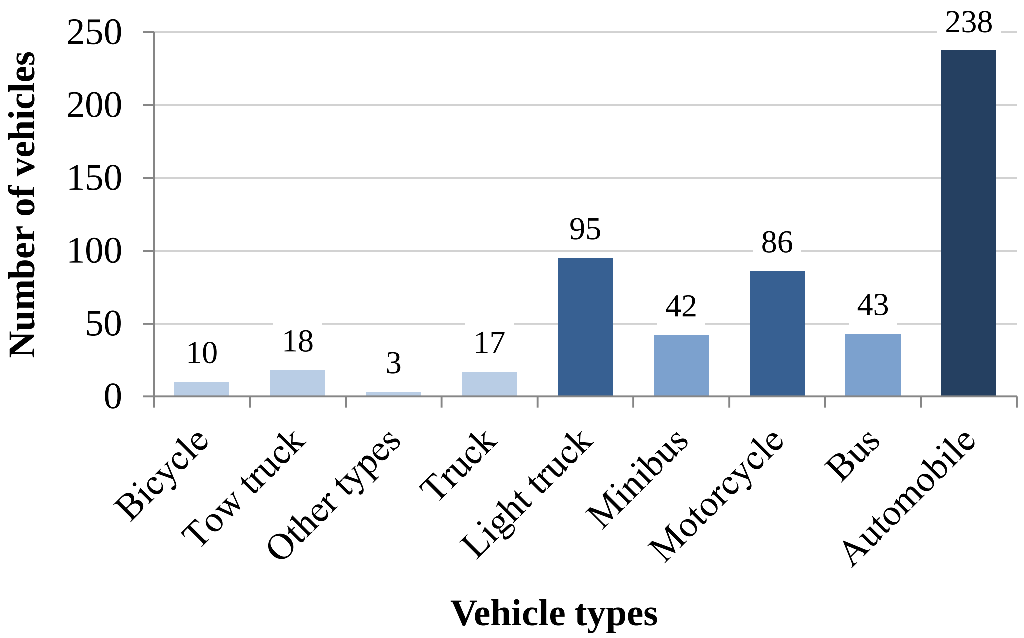


Figure 4.14 Vehicle type distribution according to rear-end collision accidents.

4.1.7.4 Rollover, Overturning and Skidding Accidents

Types of cars involved in rollover, skidding and tumbling accidents are 48% motorcycle, 32% automobile, 11% light truck, 3% bus, 3% minibus and 2% other types of vehicles. The reason for motorcycles to be in first place is that because of its physical structure it is more vulnerable against rollover and skidding compared to other vehicles (Figure 4.15).

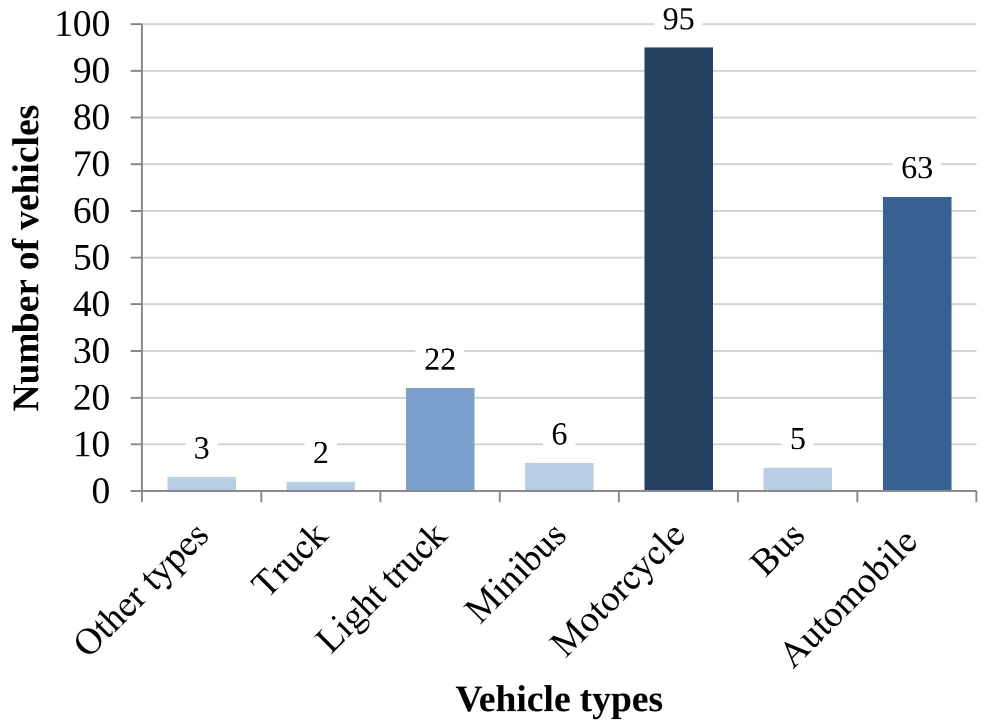


Figure 4.15 Vehicle type distributions according to rollover, skidding and tumbling accidents.

4.1.7.5 Head-on Collision Accidents

Types of vehicles involved in head-on collision accidents are 46% automobile, 26% motorcycle, 16% light truck, 4% bus, 4% minibus, 2% bicycle, 2% other vehicles and 1% trucks (Figure 4.16).

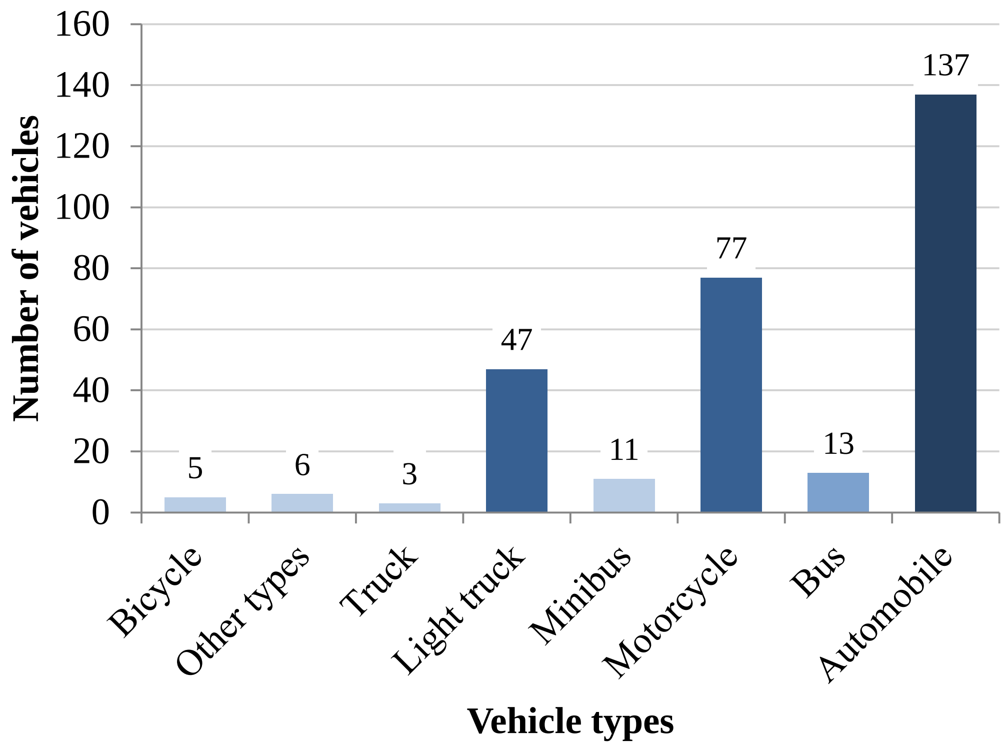


Figure 4.16 Vehicle type distributions according to mutual collision accidents.

4.1.8 Analyzing Accidents According to Weather Conditions

If we look at the accidents according to weather conditions we see that most of the accidents occur at clear weather. The reason for this is that drivers are more careful during rainy, snowy and foggy weather compared to clear weather (Figure 4.17).

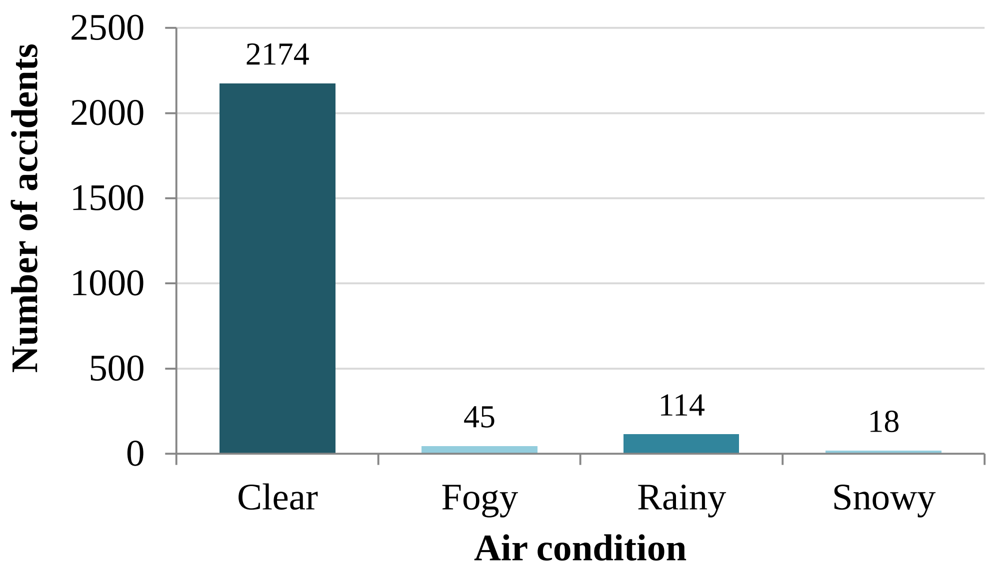


Figure 4.17 Accident occurrences according to weather condition.

4.1.9 Analyzing Accidents According to Geometric Characteristics of Road

As seen on figures 4.18 and 4.19, most of the accidents occur at straight roads without slope.

Figure 4.18 Accident distributions according to slope status.

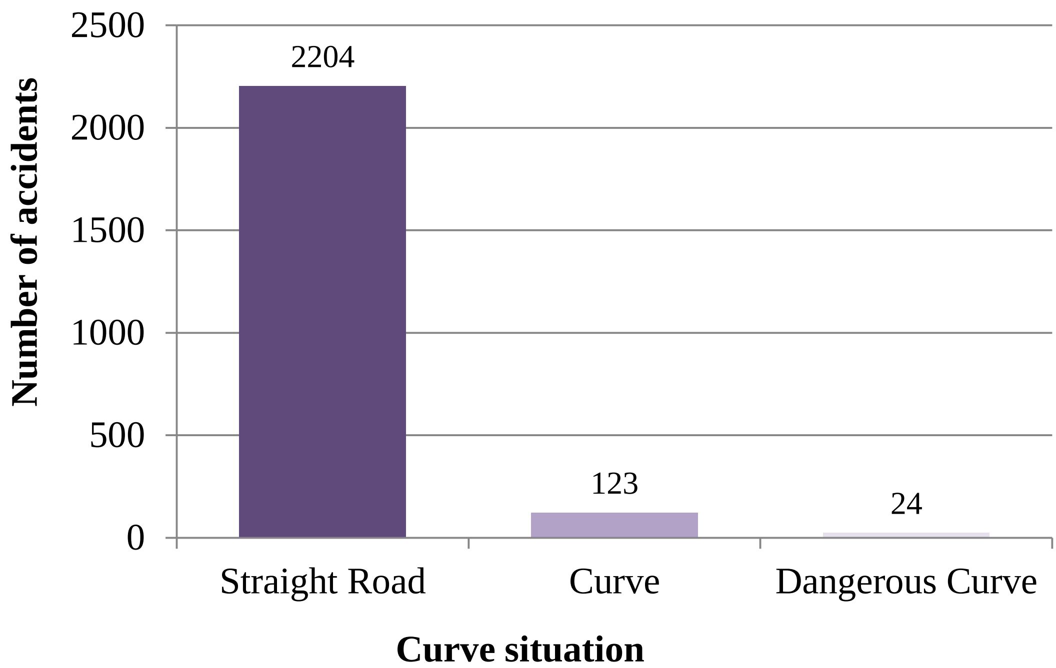


Figure 4.19 Accidents according to horizontal curve status.

4.1.10 Analyzing Accidents According to Intersections

Out of 2351 accidents that occurred at Gaziantep city center in 2013, 58% of it occurred at intersections whereas 42% of it occurred at main roads or streets (Figure 4.20). Solutions that will solve the issues at intersections are no doubt the most important steps of the steps that must be taken to ensure traffic safety. When we look at the accidents according to intersection types it is seen that 51% of it at four-way intersections, 34% of it at three-way (T)s, 5% of it at roundabouts, 1% of it at three-way (Y)s, and 5% of the accidents occur at other types of intersections (Figure 4.21). Four-way intersections are the ones that should be given priority to in order to prevent accidents at intersections. Although converting four-way intersections into two three-way intersections as a solution has the potential to decrease accident rates, the fact that city plan wasn't done previously and location of buildings prevent this. For this reason, other solutions should be headed out to the city of Gaziantep.

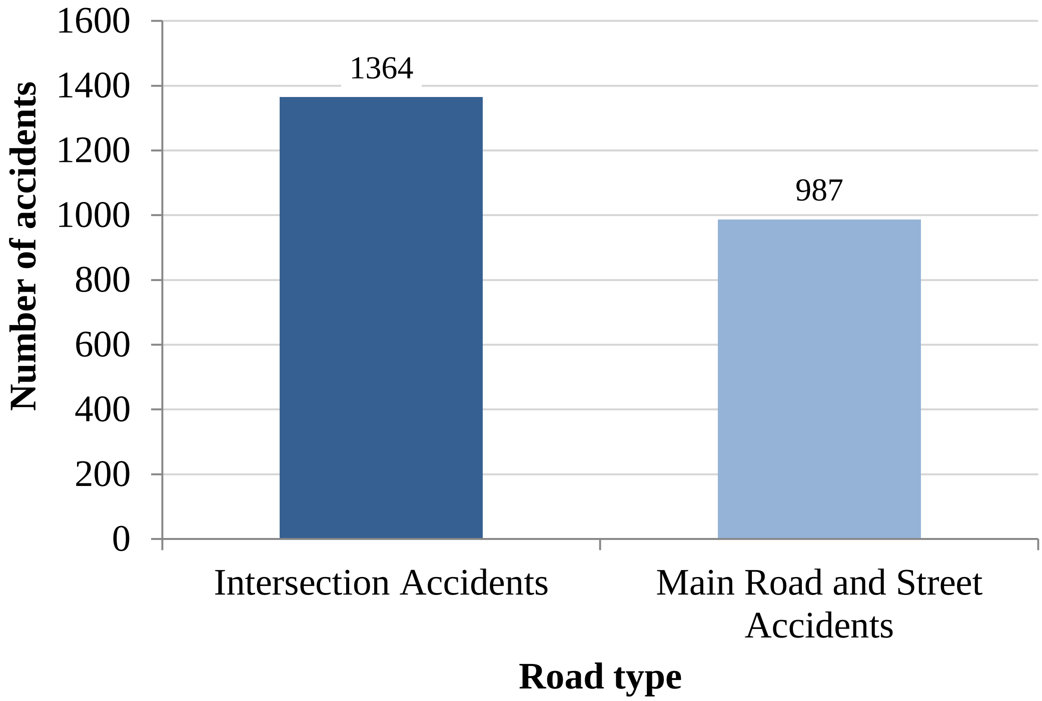


Figure 4.20 Gaziantep province intersection and main road-street accidents.

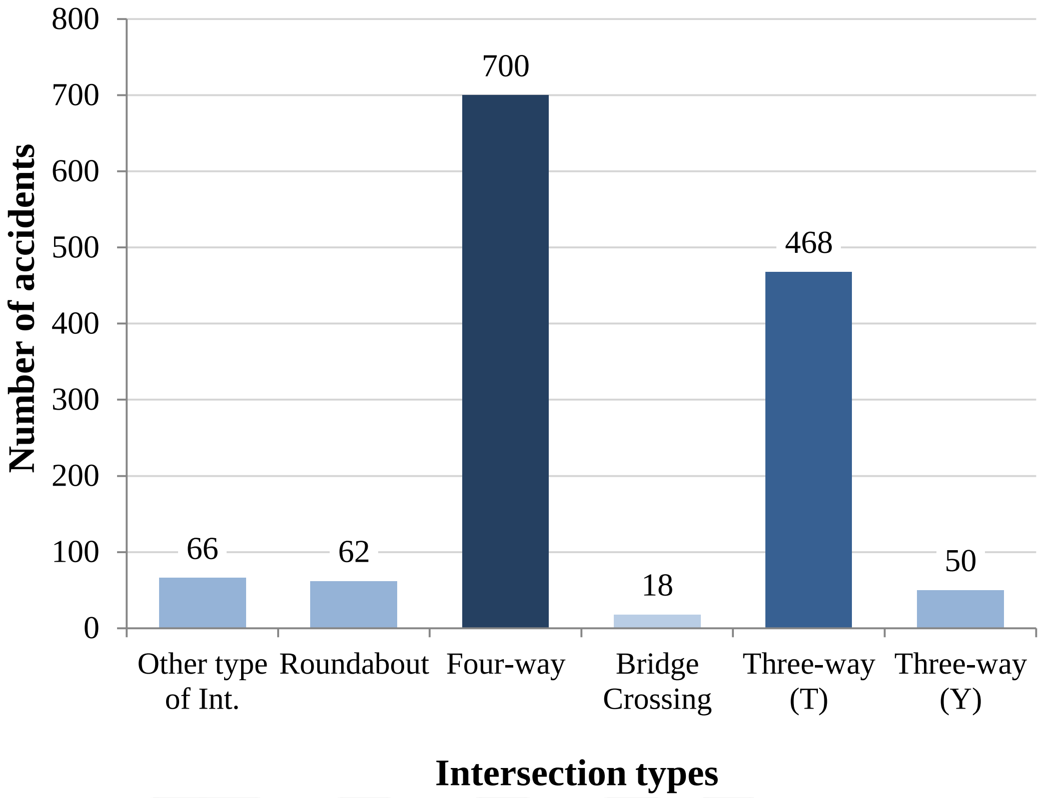


Figure 4.21 Accident distributions according to intersection types.

4.1.11 Analyzing Accidents According to Number of Vehicles Involved in the Accident

Accidents occurring on roads consist 58% of double vehicled, 35% of single vehicled, and 7% of multi-vehicled accidents. Also, 56% of single vehicled accidents are pedestrian collision accidents (Figure 4.22).

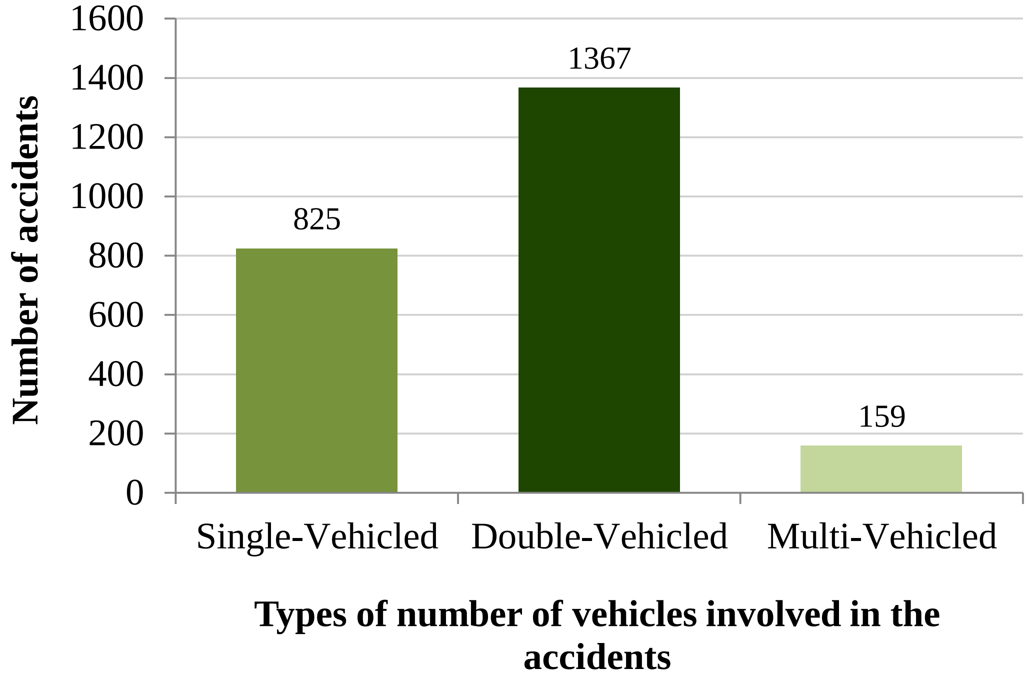


Figure 4.22 Accident-vehicle number relations.

4.1.12 Analyzing Accidents According to Age of Vehicles

Ages of vehicles involved in accidents are as follows; 37% between 0-4 years, %30 between 5-9 years, 12% between 10-14 years, 19% between 25-34 years, and 3% between 25-34 years old (Figure 4.23).

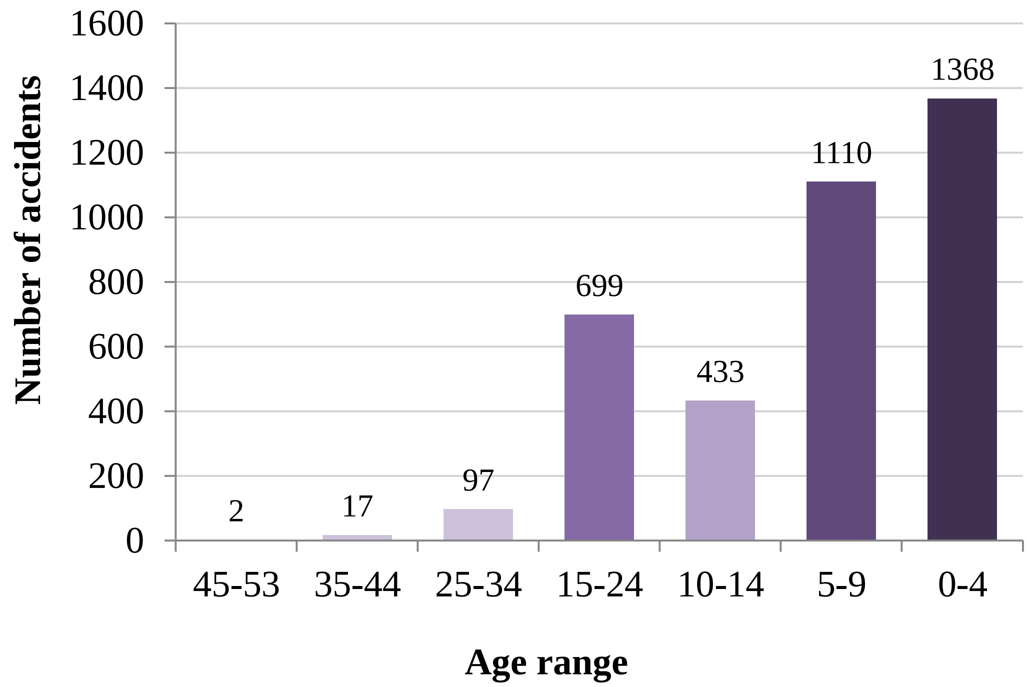


Figure 4.23 Relation between accident numbers and vehicle ages.

4.1.13 Analyzing Deaths and Injuries after Accidents

As a result of accidents 99% of people involved in accidents were injured and 1% of them has died (Figure 4.24).

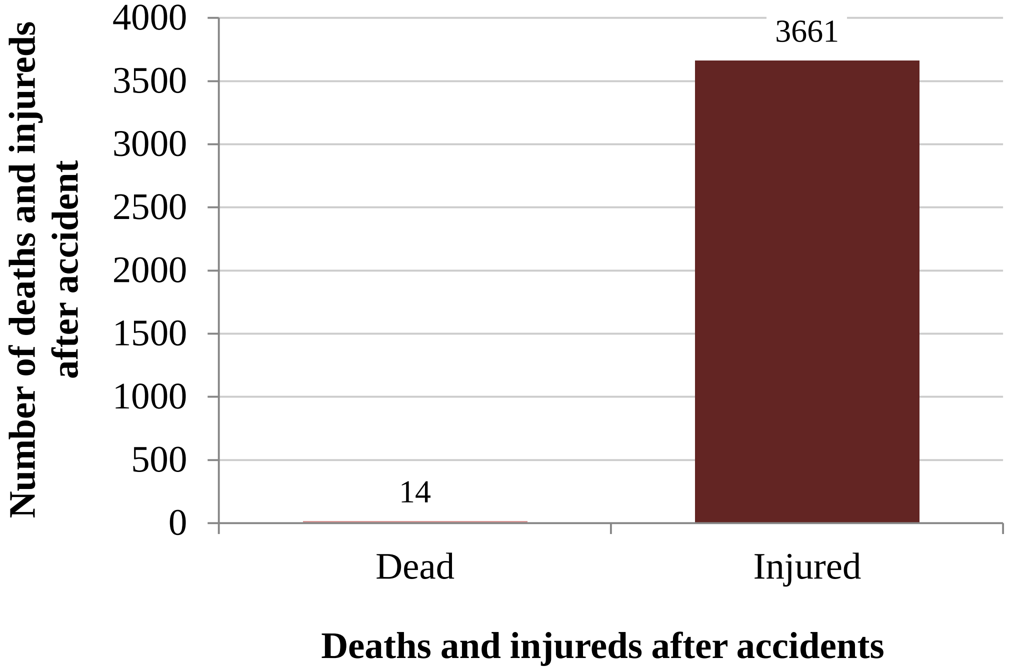


Figure 4.24 Number of deaths and injureds as a result of accident.

Affected people from an accident can be analyzed under three sub-categories as driver, passenger and pedestrian.

4.1.13.1 Analyzing Drivers Involved in Accident

54% of drivers who were involved in accident weren't injured whereas 0.2% lost their lives, 39% were injured and 3.8% weren't at the scene of the accident (Figure 4.25).

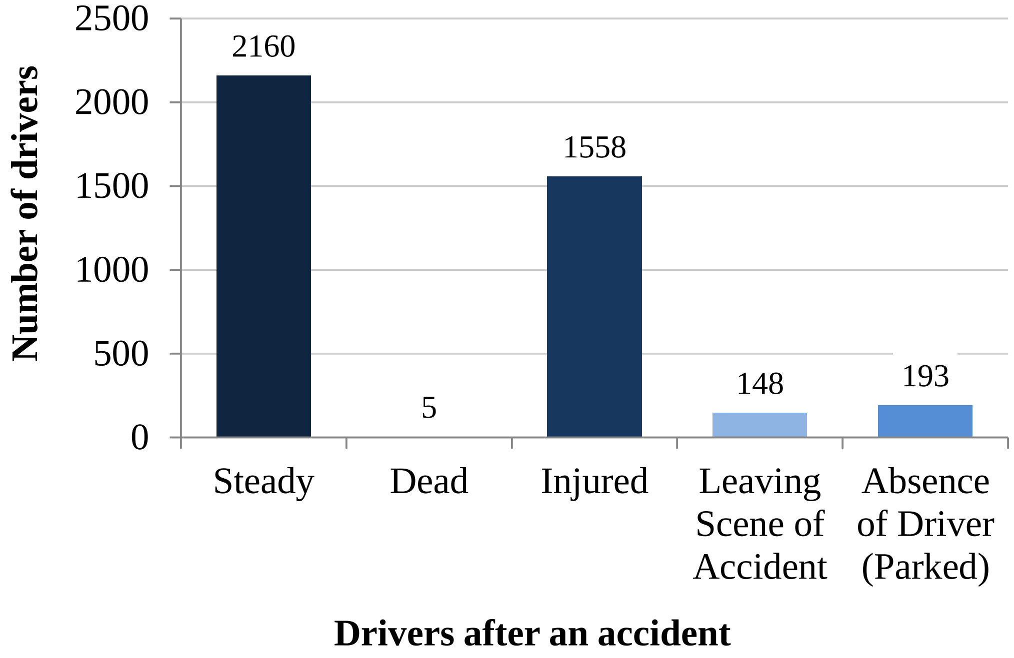


Figure 4.25 Distribution of drivers' condition after an accident

After the accident some of the drivers weren't able to be identified since there are drivers who leave the scene of the accident and in cases crashing into parked vehicles there are no drivers in the vehicle. Analyses on drivers from now on are according to identified numbers of drivers and information.

4.1.13.1.1 Analyzing Drivers Involved in an Accident According to Gender

When accidents are analyzed according to driver's gender it is noticed that rate of women drivers being involved in an accident is much lower than men drivers and it is identified that 95% of drivers who were involved in accidents are men where only 5% of drivers are women (Figure 4.26). The number of women and men drivers in Gaziantep is 79 779 and 316 350, respectively. According to that information, the rate of women drivers is 20%, the rate of men drivers is 80%.

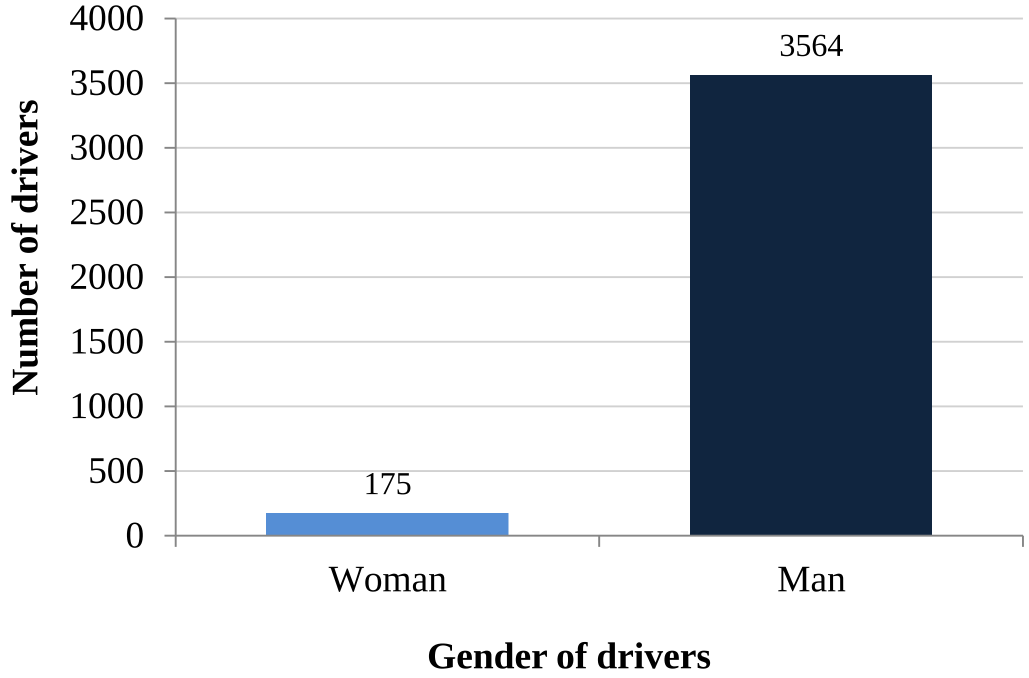


Figure 4.26 Driver number-gender relations.

4.1.13.1.2 Analyzing Age Range of Drivers Who Were Involved in an Accident

When age range of drivers who were involved in accidents were analyzed it is determined that drivers between the ages of 20-29 are the ones who have accident most frequently with a share of 35%, which is followed by 30-39 years old with 27%, 40-49 years old with 17%, 0-19 years old with 10%, 50-59 years old with 7% and 60-69 years old with 3%. When 0-19 year old drivers are analyzed separetly, it is determined that drivers under 18 are 23% is bicycle rider, 20% is motorcycle license holder and 57% operates motor vehicles without a valid driver’s license (Figure 4.27).

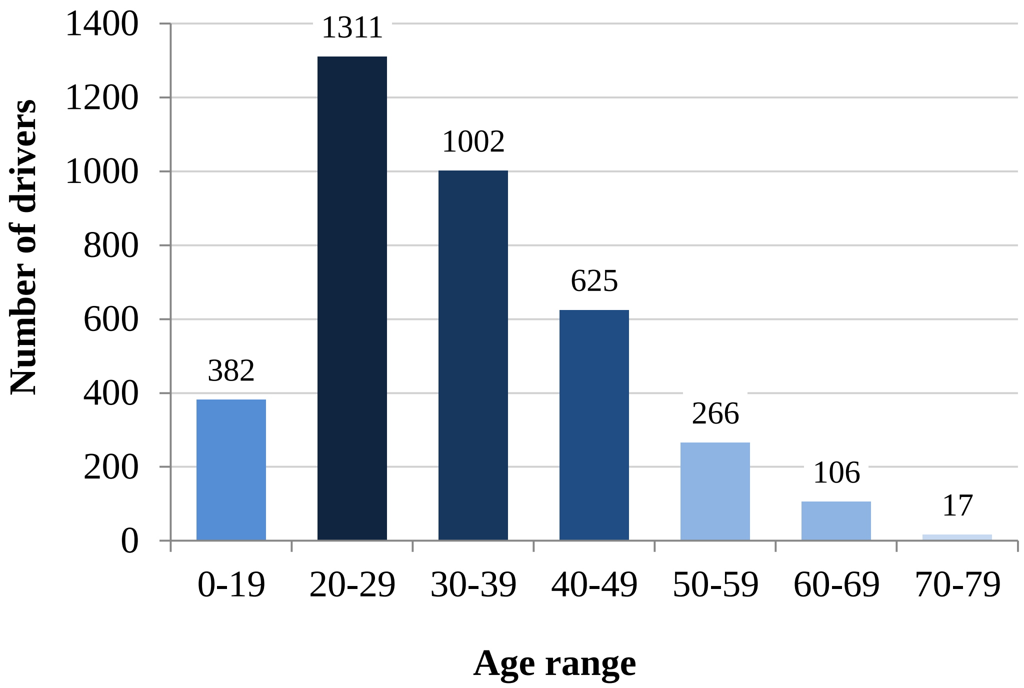


Figure 4.27 Drivers involved in an accident according to their ages.

4.1.13.1.3 Analyzing Alcohol Condition of Drivers Involved in an Accident

Rate of intoxicated drivers involved in an accident is 2% while alcohol free drivers are 98% (Figure 4.28).

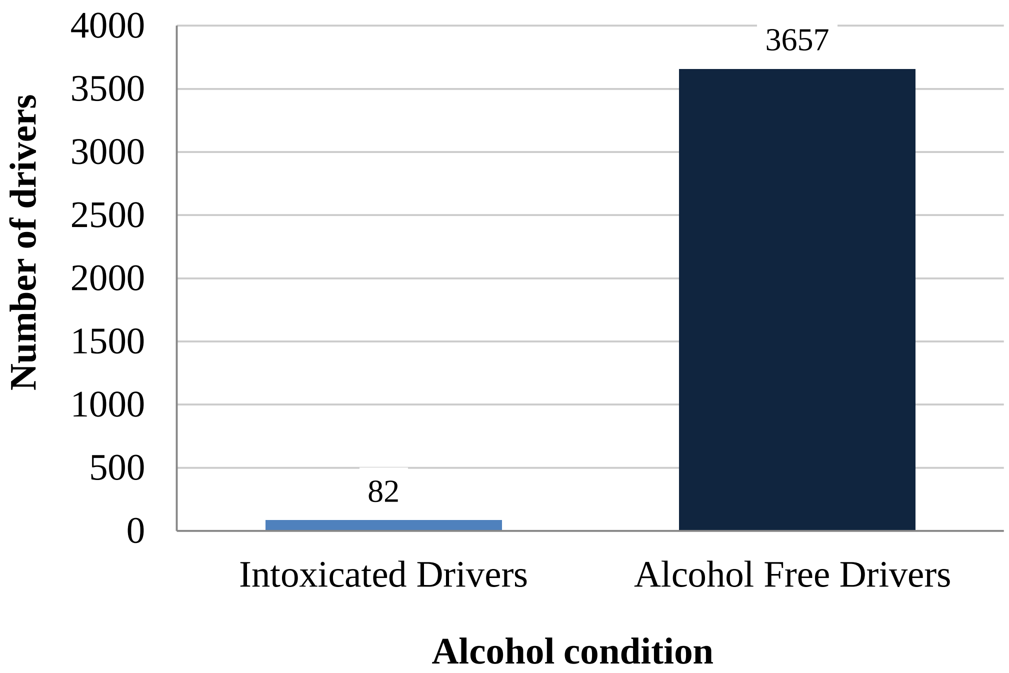


Figure 4.28 Number of alcohol usage in accidents.

There might be a connection established between intoxicated vehicle operating and accident occurrence time. It is identified that most of the intoxicated driver accidents occur between 8:00pm – 9:00pm and 7:00pm – 8:00pm and at night mostly between 03:00am – 04:00am (Figure 4.29).

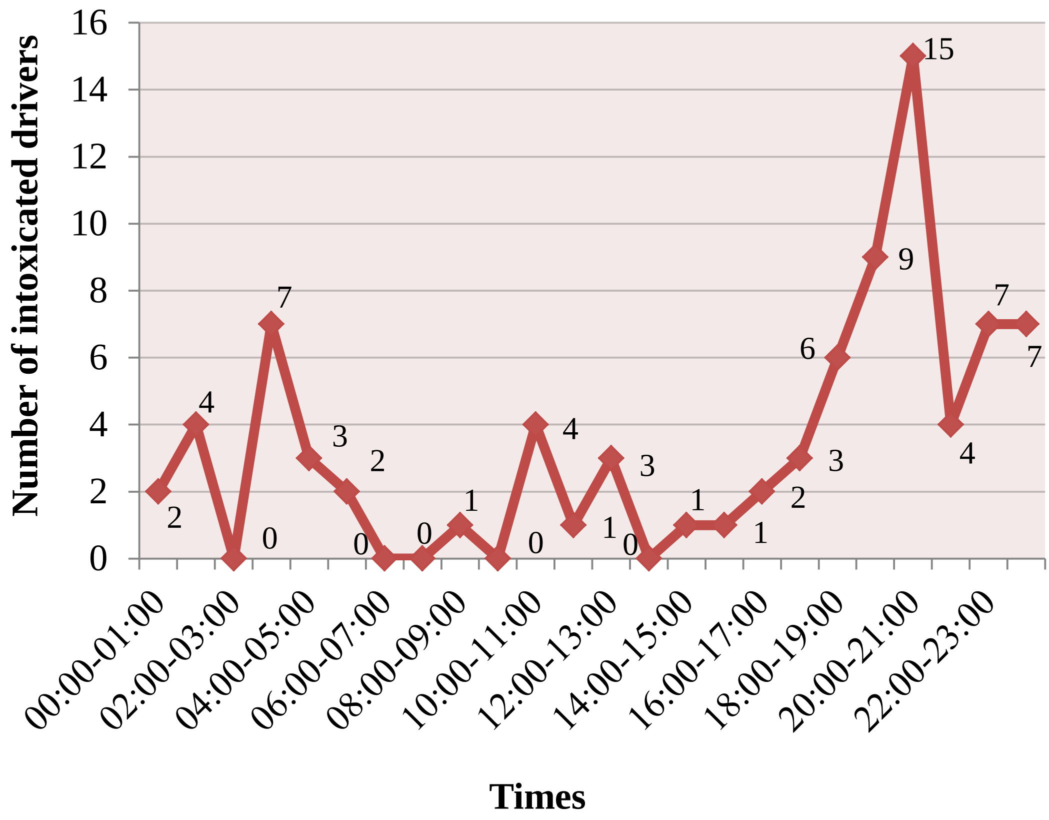


Figure 4.29 Intoxicated driver involved accidents-time relations.

4.1.13.2 Analyzing Passengers Involved in an Accident

0.30% of passengers involved in an accident lost their lives while 99.70% of them were injured (Figure 4.30). Disuse of helmet is the most common one among passenger injuring causes.

Figure 4.30 Condition distributions of passengers involved in an accident.

4.1.13.3 Analyzing Pedestrians Involved in an Accident

0.50% of pedestrians involved in an accident lost their lives while 99.50% of them were injured (Figure 4.31).

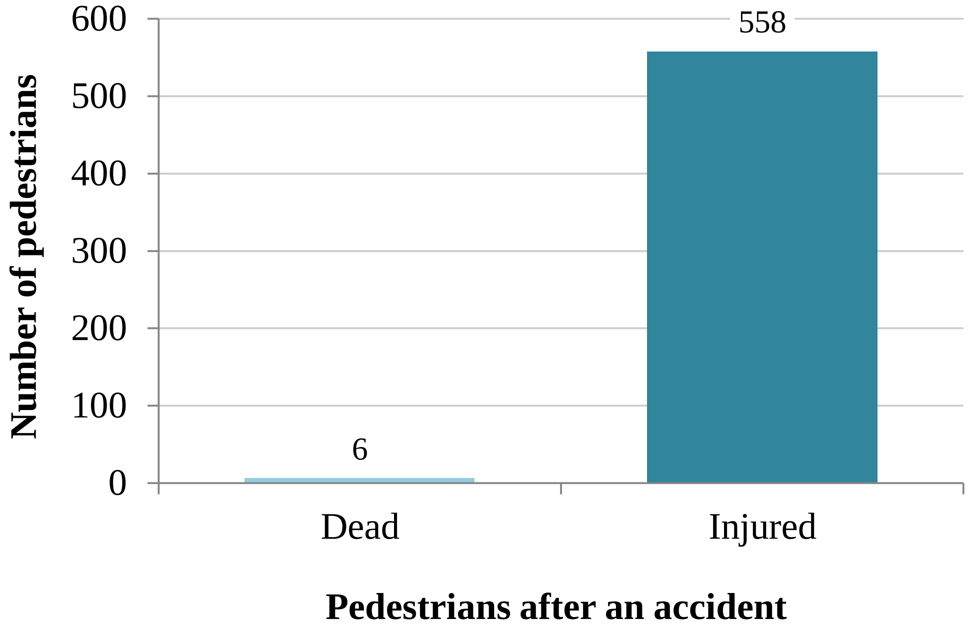


Figure 4.31 Condition distributions of pedestrians involved in an accident.

4.1.13.3.1 Analyzing Age Distribution of Pedestrians Involved in an Accident

When ages of 509 out of 558 pedestrians involved in accidents were identified and it is determined those 1-9 years old pedestrians are the ones mostly involved in accidents with 25%. Number one reason for this is that children are less careful than adults. 10-19 years old youths follow children with the rate of 22%. Lack of attention and use of cell phones on road has effects on youth pedestrians being involved in accidents (Figure 4.32).

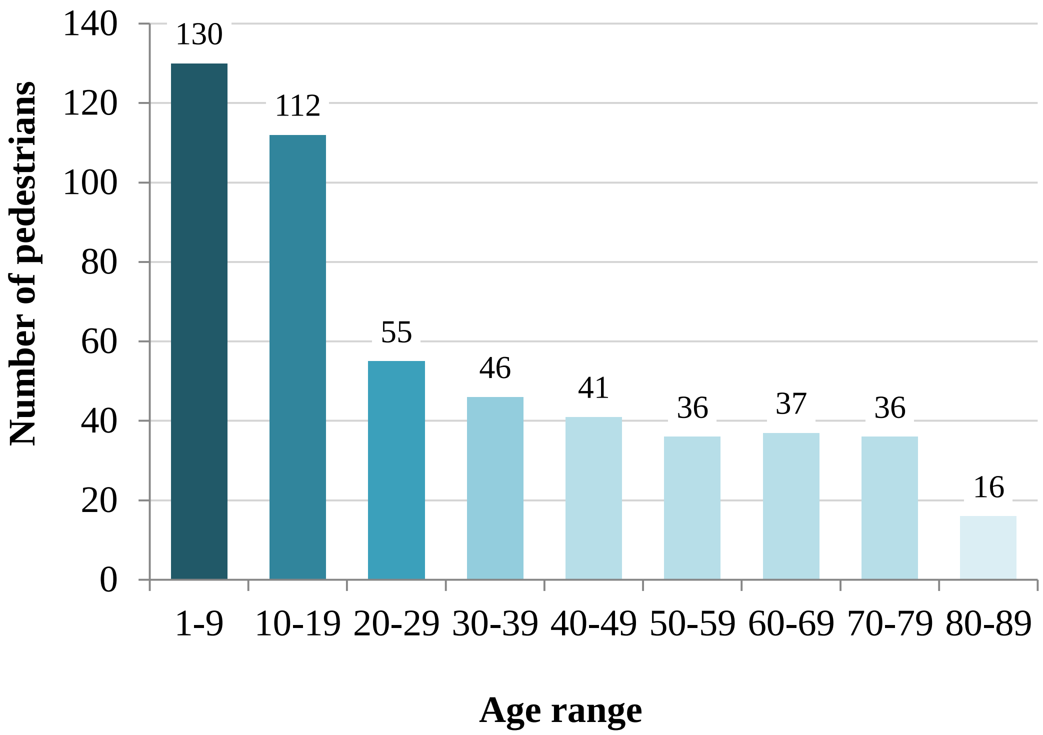


Figure 4.32 Age range of pedestrians involved in an accident.

4.1.14 Analyzing Conditions of Driver Involved in an Accident According to Vehicle Types

When conditions of drivers are examined in order to understand vehicle safeties it was split in two as motorcycles and other vehicles and it is seen that 84% of motorcycle riders were injured and 0.2% of them lost there lives whereas 26% of other vehicle drivers were injured and 0.1% of them lost their lives. Lack of protecting equipment and clothes of motorcycle riders is the number one reason of high injury rates of them (Figure 4.33).

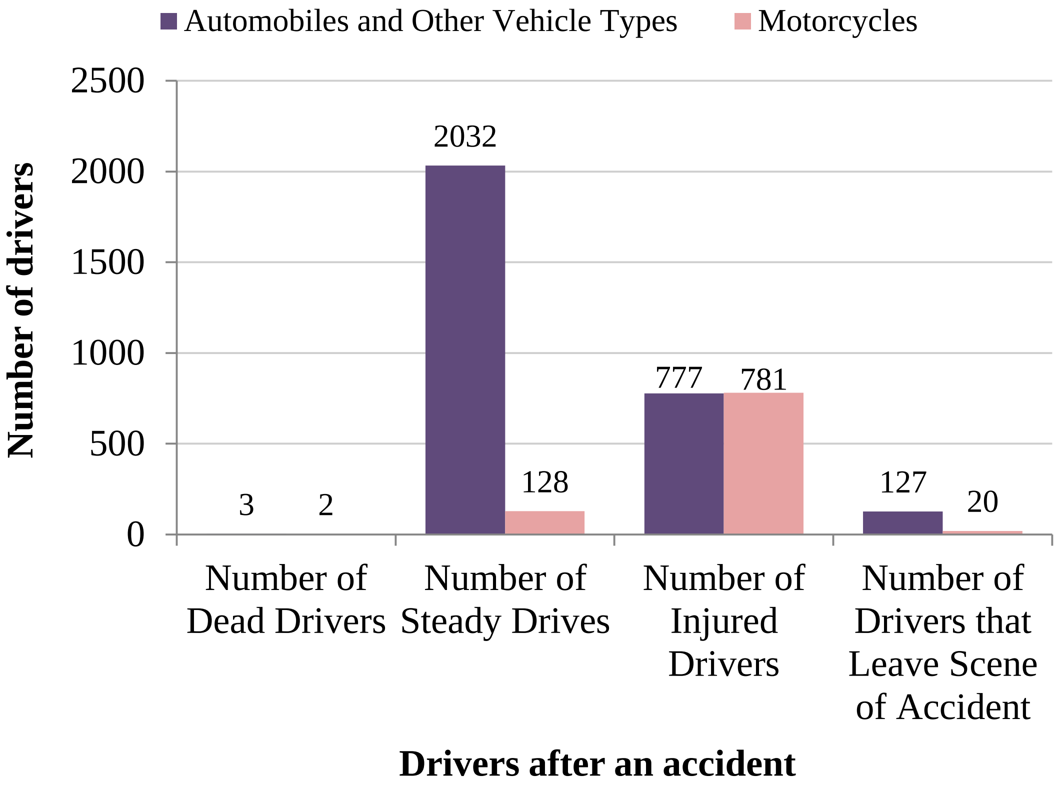


Figure 4.33 Distribution of driver conditions according to motorcycles and other vehicles.

4.2 Hot Spot Analysis using Kernel Density Estimation

In this study, kernel density estimation method is used to make density analysis of the accidents that occurred in the center of Gaziantep in 2013. Choosing threshold value is important in terms of displaying hot spots in density analysis approach. In this study we used the method that has been suggested to help standardize the thematic threshold settings of kernel density estimation hot spot maps is the application of incremental multiples of the grid cells' mean [89]. Calculations for the mean are applied only to grid cells that have a value of greater than zero, this method also retains flexibility in map design by allowing the user to apply different K order bandwidths. From this grid cell set, the mean is calculated easily in GIS.

For density estimates of accident data in 2013, quartic kernel function is used. At first, analyses are made for radius of 250 m., 500 m. and 750 m. in order to find the most appropriate band width, that is the survey's radius. Then, average magnitude value for each (πx0,25^2) km^2, (πx0,5^2) km^2 and (πx0,75^2) km^2 area is calculated by raster calculator tool in QGIS. As a result, it is observed that as band width increases, distributions expand and the number of accidents included in hot spots increases. In other words, different threshold values are found in each band width. It is concluded that the analysis works best at 250 m. band width to locate hot spots (Figure 4.34, 4.35, 4.36).

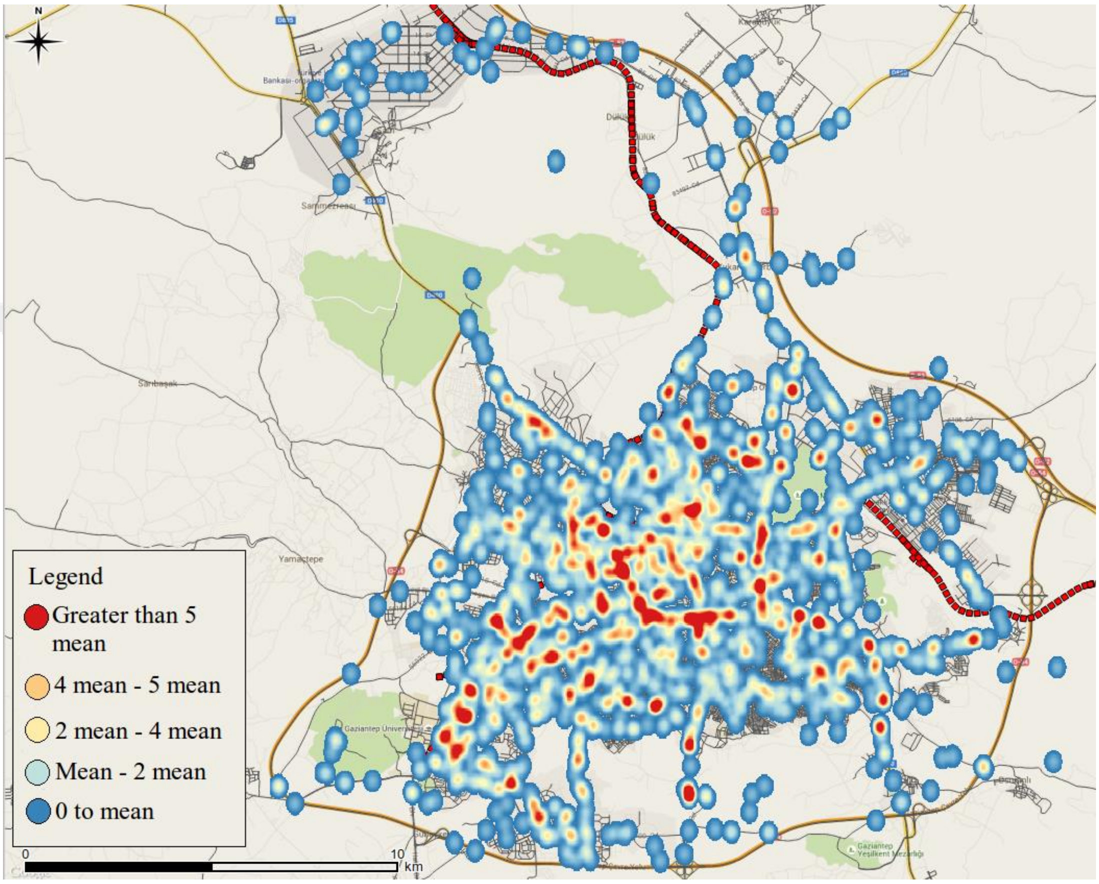


Figure 4.34 Kernel density map by the number of accident repetition with 250 m bandwidth.

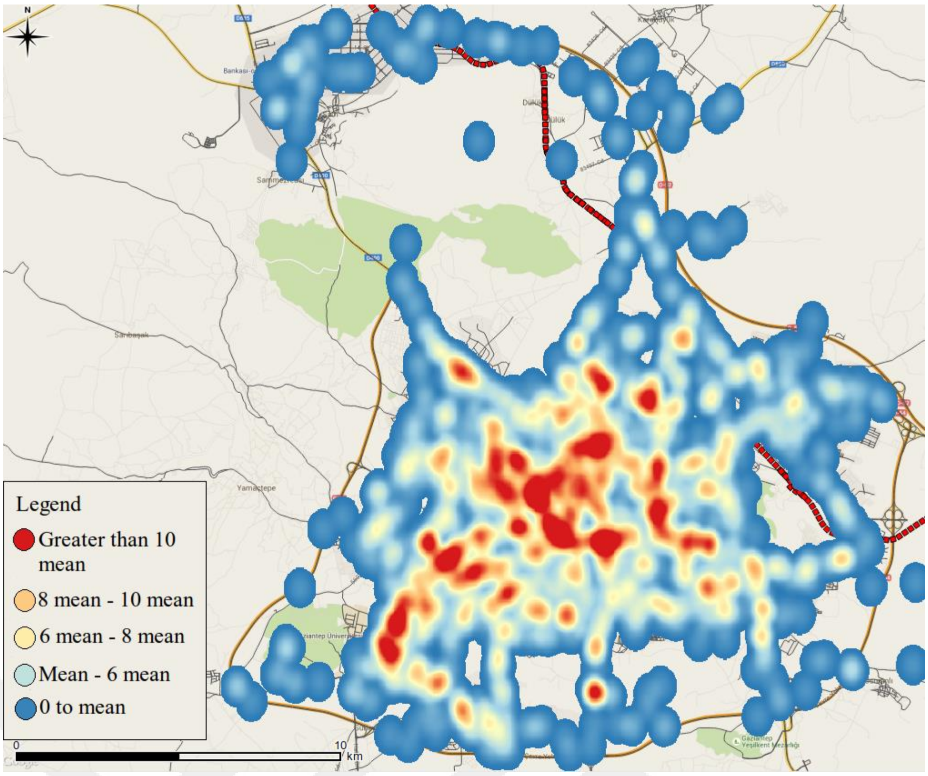


Figure 4.35 Kernel density map by the number of accident repetition with 500 m bandwidth.

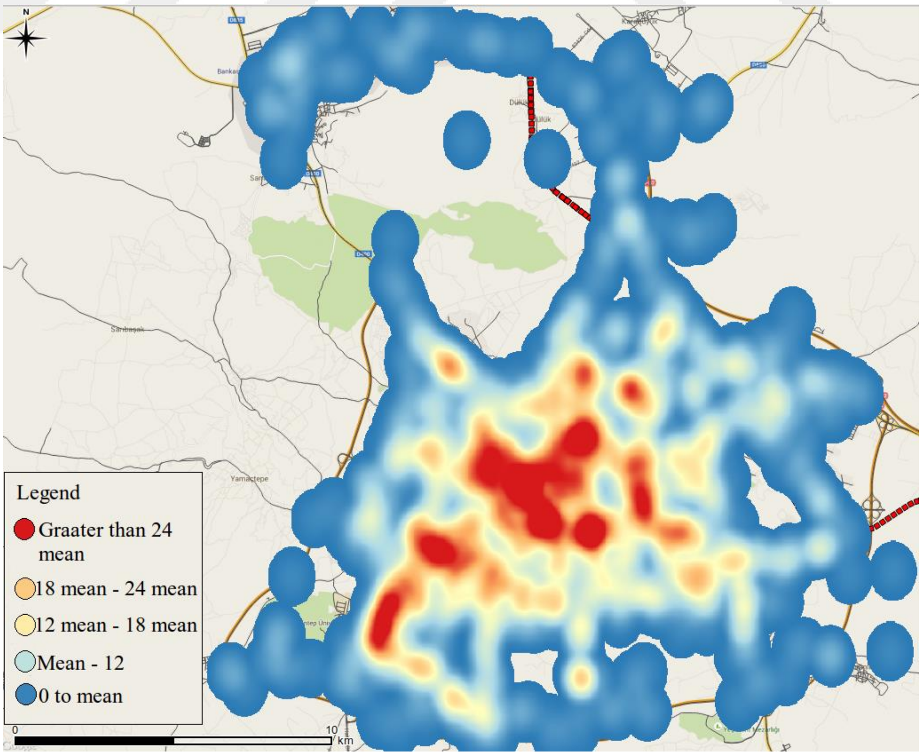


Figure 4.36 Kernel density map by the number of accident repetition with 750 m bandwidth.

If the density map with 250 m. band width is grouped by their threshold degrees, Figure 4.37 is obtained.

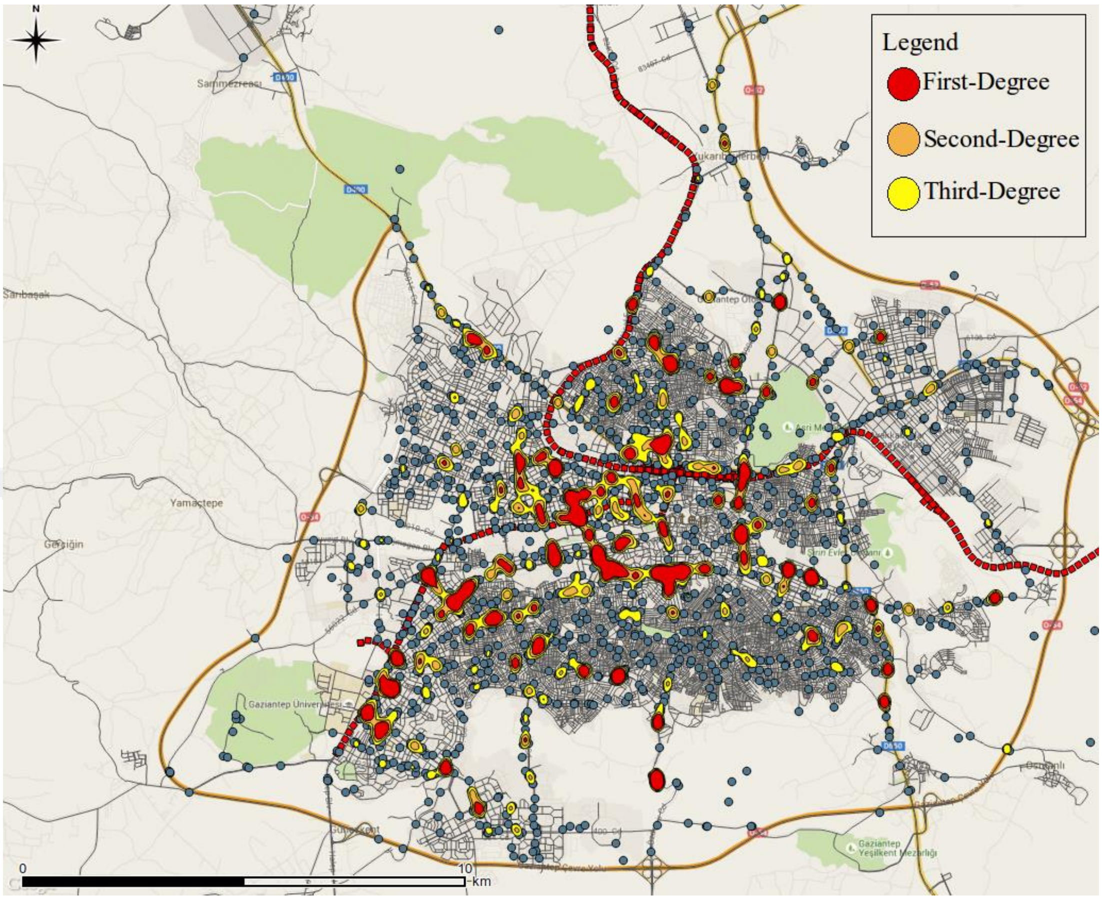


Figure 4.37 Map of accidents that occurred in the center of the province of Gaziantep in 2013.

The accidents that occurred at 2351 locations in the city center in 2013 are evaluated in themselves, it is indicated that they cause occurrence of 68 hot spots in the first degree. The accident locations and numbers that create hot spots are seen on Table 4.2.

Table 4.2 The hot spots located as a result of the accidents that occurred in the center of the province of Gaziantep in 2013.

No	Accident Location	Number of Accidents
1	133394. Avenue - 400. Avenue Juncture	5
2	14002. Avenue - Sakin Street Intersection	5
3	216. Avenue - 102237. Street Juncture	5
4	216. Avenue - 72. Avenue Juncture	8
5	On 37100. Avenue	8
6	On 7. Avenue	6
7	77. Avenue - 87160 Avenue Juncture	9
8	On 77. Avenue	7
9	8026. Avenue - 8015. Avenue Juncture	6
10	86061. Street - 85204. Street Juncture	6
11	Abdulkadir Aksu Boulevard - 56003. Street Juncture	11
12	Abdulkadir Aksu Boulevard - Muhsin Yazıcıoğlu Juncture	5
13	Abdulkadir Konukoğlu Boulevard - 25082. Street Intersection	5
14	Ahmet Turan Ertuğ Avenue - 14. Avenue Juncture	5
15	Ali Fuat Cebesoy Blvd. In front of Çetinkaya Hypermarket	6
16	Asfalt Şantiye Avenue - 30082. Street Juncture	5
17	Atatürk Blvd. - Gazi Muhtar Paşa Blvd. Juncture	10
18	Bahaddin Nakipoğlu Avenue - Hafız Tevfik Avenue Juncture	7
19	Bahaddin Nakipoğlu Avenue-Terminal Juncture	10
20	Cemil Cahit Güzelbey Avenue - Ali Nadi Ünler Blvd. Juncture	7
21	Cemil Cahit Güzelbey Avenue - Külekçi Ali Street	5
22	Durdu Yetkin Şekerci Avenue - 3010. Street Juncture	6
23	Gazi Muhtar Paşa Blvd. - Mithat Enç Avenue Juncture	6
24	Hafız Tevfik Avenue - 40010. Avenue Juncture	8
25	Hafız Tevfik Avenue - 64047. Avenue Intersection	6
26	On Hafız Tevfik Avenue, in front of Miraç Pastry Shop	5
27	Hamdi kutlar Avenue - Maaşkuyu Avenue Intersection	6
28	Hasip Dürri Avenue - 97016. Avenue Juncture	5
29	Havaalanıyolu Avenue - 37074. Avenue Juncture	6
30	Havaalanıyolu Avenue. - 99082. Avenue Juncture	7
31	Hoşgör Avenue - Şht. Mahmut Street Intersection	5
32	Hürriyet Avenue - Kemal Köker Street Juncture	6
33	İbrahim Tevfik Kutlar Avenue - 33014. Avenue Juncture	11
34	İbrahim Tevfik Kutlar Avenue - 33044. Avenue Juncture	9
35	İbrahim Tevfik Kutlar Avenue - Tüfekçi Yusuf Blvd. Juncture	6
36	İnönü Avenue - Mahmut Söylemez Avenue Intersection	6
37	İnönü Avenue. - Meçhul Asker Street Intersection	5
38	İnönü Avenue - Ordu Avenue Juncture	11
39	İnönü Avenue - Samancı Pazarı Street Intersection	5
40	İpek Road - 29026. Avenue Juncture	8

41	İstasyon Avenue- in front of Hasan Ali Yücel High School	5
42	Kavaklık Avenue - in front of Bar Association Club	5
43	Kıbrıs Avenue - Nail Bilen Avenue Juncture	5
44	Kilis-Gaziantep Road	8
45	On Korutürk Avenue – in front of Karşıyaka Security Chief Office	11
46	Mareşal Fevzi Çakmak Blvd. - Milli Egemenlik Avenue Juncture	12
47	Mareşal Fevzi Çakmak Blvd. - Ömer Asım Aksoy Avenue Juncture	7
48	Mareşal Fevzi Çakmak Blvd. - Zübeyde Hanım Blvd. Juncture	17
49	On Mareşal Fevzi Çakmak Blvd. – 1,2 kilometers before 38025. Avenue Juncture	7
50	On Mareşal Fevzi Çakmak Blvd. üzeri in front of Sanko Park	7
51	Mehmet Erdemoğlu Avenue - 49022. Avenue Juncture	5
52	Milli Egemenlik Avenue - Üniversite Blvd. Juncture	6
53	Mithat Enç Avenue - İmam Hüseyin İncioğlu Avenue Juncture	6
54	Ordu Avenue - Kavaklık Avenue Juncture	7
55	Özdemirbey Avenue- 77. Avenue Juncture	10
56	Özdemirbey Avenue – in front of Genç Aslanlıbel Roadhouse	16
57	Özdemirbey Avenue - inönü Avenue Intersection	25
58	Sani Konukoğlu Blvd. - Bahaddin Nakıboğlu Blvd. Juncture	8
59	Sani Konukoğlu Blvd. - Kıbrıs Avenue Köprülü Juncture	8
60	Tüfekçi Yusuf Blvd. - Nizip Avenue Juncture	5
61	Tüfekçi Yusuf Blvd- 14002. Avenue Juncture	7
62	Tüfekçi Yusuf Blvd - Hamdi Kutlar Avenue Juncture	11
63	Üniversite Blvd - 216. Avenue Juncture	8
64	Üniversite Blvd - 56060. Avenue Juncture	10
65	Üniversite Blvd - Şht. Emre Bakırcı Avenue Juncture	5
66	Üniversite Blvd – in front of Ziraat Bank	10
67	On Yavuz Selim Avenue - 82053. Street Intersection	6
68	On Yavuz Selim Avenue – in front of Mosque of M.Ekrem Özdil	11

CHAPTER 5

CONCLUSIONS

Traffic has become a significant problem of Gaziantep due to the increasing number of immigrants and vehicles. Traffic congestion and infrastructure deficiency are the main problems of traffic. The leading factor increasing traffic congestion is the use of private vehicles in large numbers. However, decrease in private vehicle use cannot be expected as long as public transportation is not made attractive. As public transportation is inadequate in proportion to the population in Gaziantep, it gets extremely crowded and private vehicle owners do not prefer to use it. Another factor that increases traffic congestion is the wrong use of signalization. Signalization has been increased to enhance access on any road to roads, but the possibility of queues has been ignored and it fails to comply with developing signalization techniques. For instance, applications such as green waves reduce time losses of vehicles at traffic lights substantially.

Traffic accidents are caused by problems in traffic and drivers. Uncontrolled pedestrian crossing, public transportation vehicles’ stopping at places other than bus stops, narrow sidewalks, parking vehicles in impact area of intersections, considering the compatibility of intersections with the existing structuring instead of their geometrical functionality while designing, lack of parking space which narrows down the roads due to parking on roads, and using asphalt of poor quality are among the causes of traffic accidents.

When traffic accidents that occurred in Gaziantep are analyzed in general, it is observed that accidents increase as the weather gets hotter and accidents occur mostly in summer. As for months, accidents occur most in October and August. If analyzed by days of the week, accidents occur most on Mondays and Saturdays and accidents involving death occur mostly on Saturday and during day time. In terms of hours, generally accidents are observed to occur mostly between 17:00 and 18:00.

The greatest handicap on preparing data set is that information on reports are not consistent and most of the sections on reports are left blank though for analyses all sections of reports must be filled out conscientiously. The reason for inconsistency is that on most reports latitude and longitude values are confused with each other and errors caused by GPS device's accuracy. Therefore, reports should be kept not only by GPS devices but also with a system that is integrated with GIS and in addition if needed traffic polices should be educated as well.

In this study, necessary information was collected and analyzed with GIS by setting up a model with data base. Reason for GIS to be preferred is that GIS can process large amounts of geographical data, display it on a map and can also perform many analyses with analyses methods within. These functions make GIS ideal for traffic accident analyses.

Density maps were formed using accident repetition numbers with kernel density method and hot spots were determined according to average magnitude values. As a result, it is determined that hot spots were formed on 68 spots and most risky first 10 regions among these spots are respectively as follows;

- Özdemirbey Avenue-İnönü Avenue Intersection
- Mareşal Fevzi Çakmak Blvd. – Zübeyde Hanım Blvd. Intersection
- Özdemirbey Avenue – In front of Genç Aslanlıbel Stopover
- Mareşal Fevzi Çakmak Blvd. – Milli Egemenlik Ave. Intersection
- Abdulkadir Aksu Blvd. – 56003^{rd} Ave. Intersection
- İbrahim Tevfik Kutlar Ave. – 33014^{th} Ave. and 33044^{th} Ave. Intersection
- İnönü Ave. – Ordu Ave. Intersection
- On Korutürk Ave. – In front of the Karşıyaka General Commandership of Police
- On Yavuz Selim Ave. – In front of m.ekrem özdil mosque
- On Mareşal Fevzi Çakmak Blvd. – 1.2 kilometers before 38025th Ave. Intersection

After determination of hot spot locations, conditions of accidents on these spots are also investigated and solutions were offered for 10 most risky regions;

Figure 5.1 Özdemirbey Avenue-İnönü Avenue Intersection

Özdemirbey Avenue – İnönü Avenue Intersection: Where most of the accidents occurred in 2013 in the city center of Gaziantep province. Because this intersection is located exactly in the city center, traffic flow is excessive and also because of the narrowness of roads and workplaces and public hospitals that fall into position, the traffic is usually not flowing. When accidents occurred at this intersection are analyzed, pedestrian collision ranks first among accident occurrence reasons. This is because the region draws excessive numbers of vehicles and pedestrians and lack of signalization application and rejecting use of overpass by pedestrians. In order to enhance pedestrian overpass usage, available but inactive escalators can be put into function, elevators can be added to overpasses or signalization application can be activated at intersections. Also as radical solution vehicle traffic can be provided through undercrossing and the square can be totally closed to traffic.

Figure 5.2 Mareşal Fevzi Çakmak Blvd. – Zübeyde Hanım Blvd. Intersection

Mareşal Fevzi Çakmak Blvd. – Zübeyde Hanım Blvd. Intersection: This road is the main arterial which goes all the way along the city center. This boulevard grants access to three shopping centers of the city. On this boulevard used intensively by pedestrians, public transportation and private vehicles in addition there is also a tram route. When accidents that occurred at intersections are analyzed it is seen that number one reason of accidents are lateral collision, the reason for this is sudden signalization changes to prioritize tram route which causes confusion in drivers' mind. As a solution, priority of tram route which causes sudden changes on signalization should be removed and in order the prevent traffic rule violations traffic polices should constantly perform.

Figure 5.3 Özdemirbey Avenue – In front of Genç Aslanlıbel Stopover

Özdemir Avenue – In front of Genç Aslanlıbel Stopover: When accident occurrence types on this road are reviewed, it is determined that these accidents consist of collision with barrier objects, turnover, skidding, tumbling and running off the road and the reasons are improper curve radius, narrowness of the road and drivers entering the curve speedy. This road should be expanded and its geometry should be redesigned, and as a priority precaution retarders should be placed.

Figure 5.4 Mareşal Fevzi Çakmak Blvd. – Milli Egemenlik Ave. Intersection

Mareşal Fevzi Çakmak Blvd. – Milli Egemenlik Ave. Intersection: At this intersection it is discovered that there are lack of traffic lights because when we look at accident occurrence reasons, number one reason is lateral collision. In order to prevent vehicles violating traffic lights, traffic polices should constantly perform.

Figure 5.5 Abdulkadir Aksu Blvd. – 56003rd Ave. Intersection

Abdulkadir Aksu Blvd. – 56003rd Ave. Intersection: There are two different problems at this intersection. First one is sudden changes of traffic lights because of the priority of the tram route which is located on the intersection; whereas the second one is caused by confusion because of angle differences between intersection ways which results these reciprocal ways to mismatch with each other. Therefore side to side collision accidents are considered as number one accident occurrence reason among the accidents that occur at intersections. To avoid this, intersections should be redesigned.

Figure 5.6 İbrahim Tevfik Kutlar Ave. – 33014^{th} Avenue Intersection

Figure 5.7 İbrahim Tevfik Kutlar Ave. – 33044^{th} Avenue Intersection

İbrahim Tevfik Kutlar Ave.–33014th Ave. and İbrahim Tevfik Kurtlar Ave.-33044th Ave. Intersections: For these intersections traffic lights must be installed because 90% of accidents occur as side to side collision and this reveals the need of traffic lights.

Figure 5.8 İnönü Avenue – Ordu Avenue Intersection

İnönü Ave. – Ordu Ave. Intersection: Traffic lights should be redesigned in a way that will prevent accidents and also with the help of electronic inspection systems that can be inserted into traffic lights; traffic light violation can be reduced.

Figure 5.9 Korutürk Avenue – In front of the Karşıyaka General Commandership of Police

On Korutürk Ave.– In front of the Karşıyaka General Commandership of Police: On this road there are many connections from streets and since there are three schools in the area excessive numbers of vehicles and pedestrians come there. When accident reasons are inspected it is seen that pedestrian accidents are number one and 4 out of 7 injured pedestrian are under 7 years. Therefore raising traffic awareness of parents and children should be put on the agenda. Accidents occurred in front of Karşıyaka General Commandership of Police. Inserting retarders before and after the police chief office building is a must and also signalization application should be done at Fedai Mehmet Ave. and Koruturk Ave. intersection.

Figure 5.10 On Yavuz Selim Ave. – In front of m.ekrem özdil mosque

On Yavuz Selim Ave. – In front of M. Ekrem Özdil Mosque: 11 accidents occurred in one year at the beginning of a 250 meters diameter wide area that begins after the M. Ekrem Özdil Mosque on this road. Many streets and passages are connected to this road however; there no traffic lights and accidents occur because of this reason. There must be a traffic light application.

Figure 5.11 On Mareşal Fevzi Çakmak Blvd. 1.2 kilometers before 38025^{th} Ave. intersection

On Mareşal Fevzi Çakmak Blvd. 1.2 kilometers before 38025^{th} Ave. intersection: Mareşal Fevzi Çakmak Boulevard is straight and convenient for speeding however; the viaduct which is located in continuation of this road is comprised of a united curve with a insufficient radius. This curve challenges drivers' decision making mechanism because of their speed. It causes confusion and making a mistake especially for those drivers who uses the road for the first time. In fact, number of accidents that occurred on the viaduct can be understood by only looking at the conditions of shoulders. Regardless of existing speed reducing warnings and retarders, there were not a decrease on accident numbers. Therefore redesign of the geometry is needed for this curve.

Though this research makes progress in order to study car accidents that took place in Gaziantep and to determine accident road spots, it has the characteristics of offering an insight to future studies. In this study, risky areas are determined only according to density of accident but, for a further study, traffic volumes should be measured, characteristic features of roads and environment conditions should be evaluated and a mathematical model should be developed according to these. This way, a neat answer can be given about why some areas are riskier than others. Apart from this, there is also a need for a test method in order to measure statistical significance of hardcopies of kernel density estimation analysis method because this way the probability of anticipating the areas of future accidents rises and interpretation of maps for thematic threshold value becomes easier. Also, necessary steps should be taken in order to increase the accuracy of accident reports and so as to reach to statistical accuracy, not only those who die at the moment of accident, but also those who die in certain periods of time following an accident should be recorded on reports.

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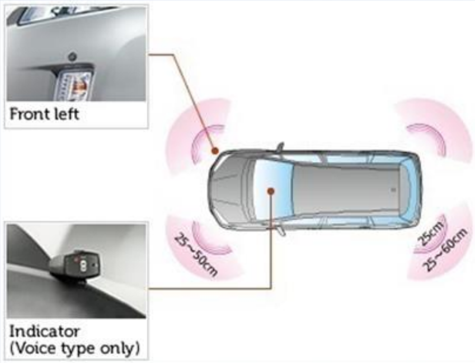
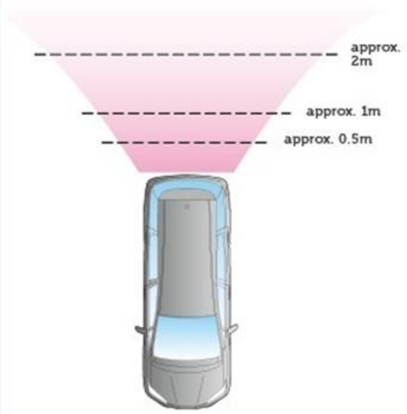
APPENDIX

Optimal Safety Technology - Parking

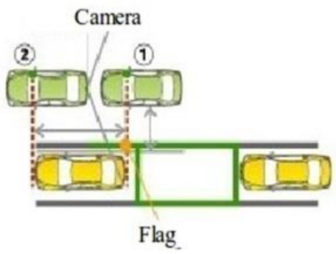


1) Intelligent Clearance Sonar (ICS): The ultrasonic wave sensor is built into the corners of the bumper. It detects the distance to objects and notifies the driver with sound and display lamp alerts.

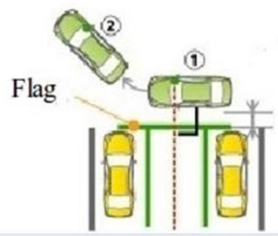


2) Back Guide Monitor: The camera installed on the rear side of the vehicle displays the view when backing into a garage. A guidance line appears according to how the steering wheel is operated.

Parallel Parking

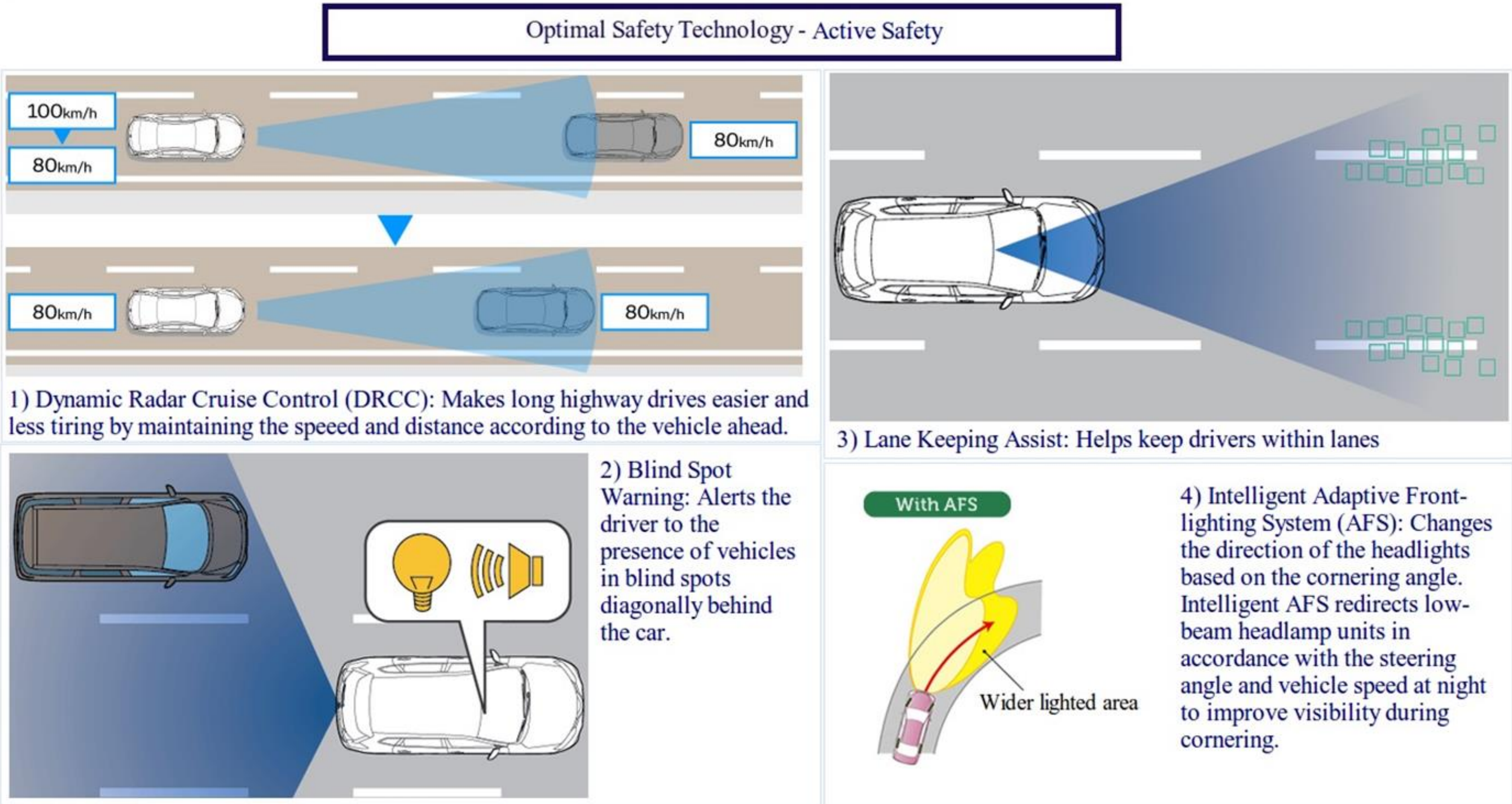


Garage Parking

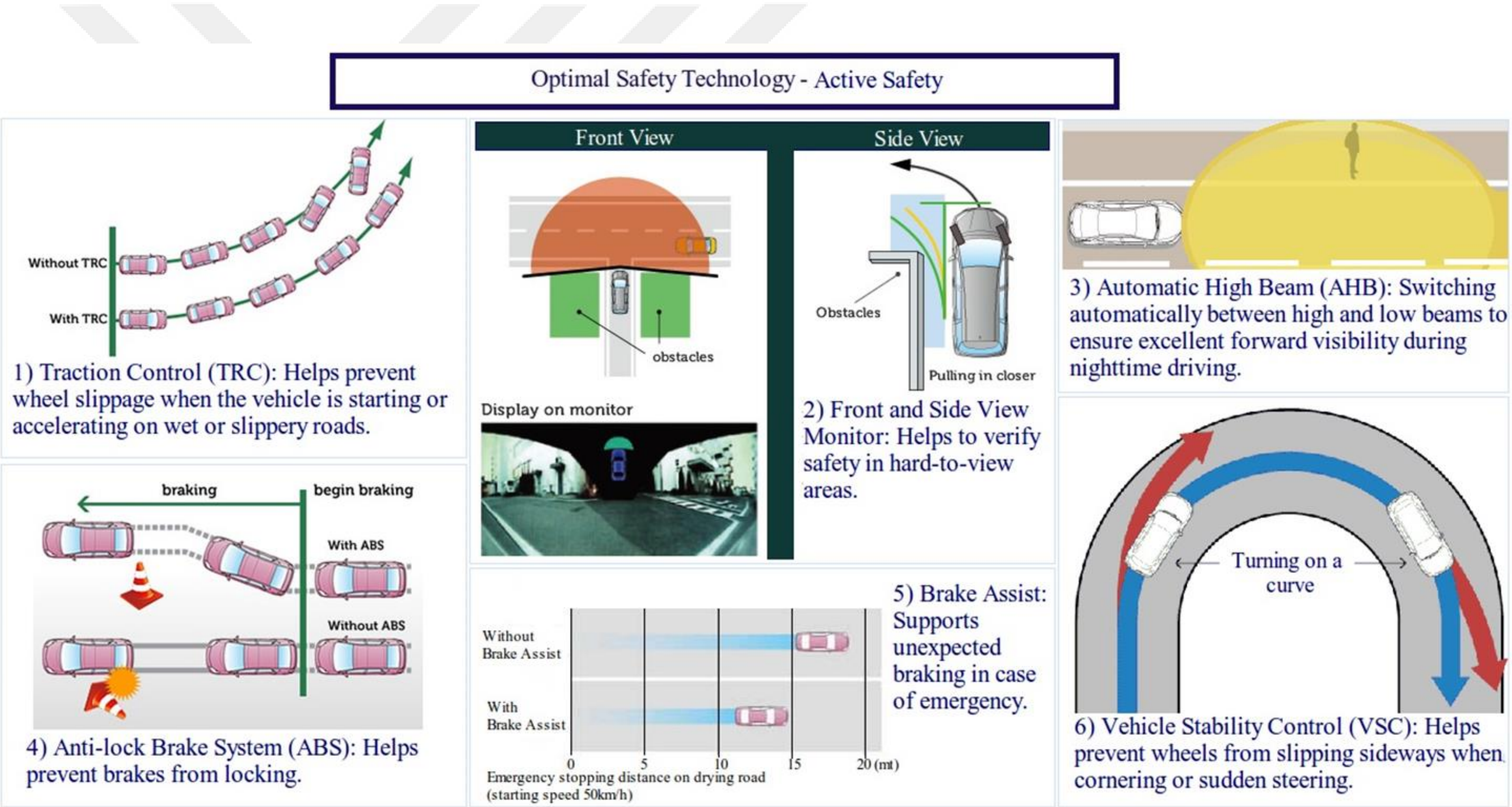


3) Intelligent Parking Assist (IPA): This system assists with the steering wheel operation while parallel parking or parking in garages.When the driver sets the designed parking position on the monitor, the system assists the steering wheel operation. Even if the driver is not good at parking, they will be able to park their car more smoothly.

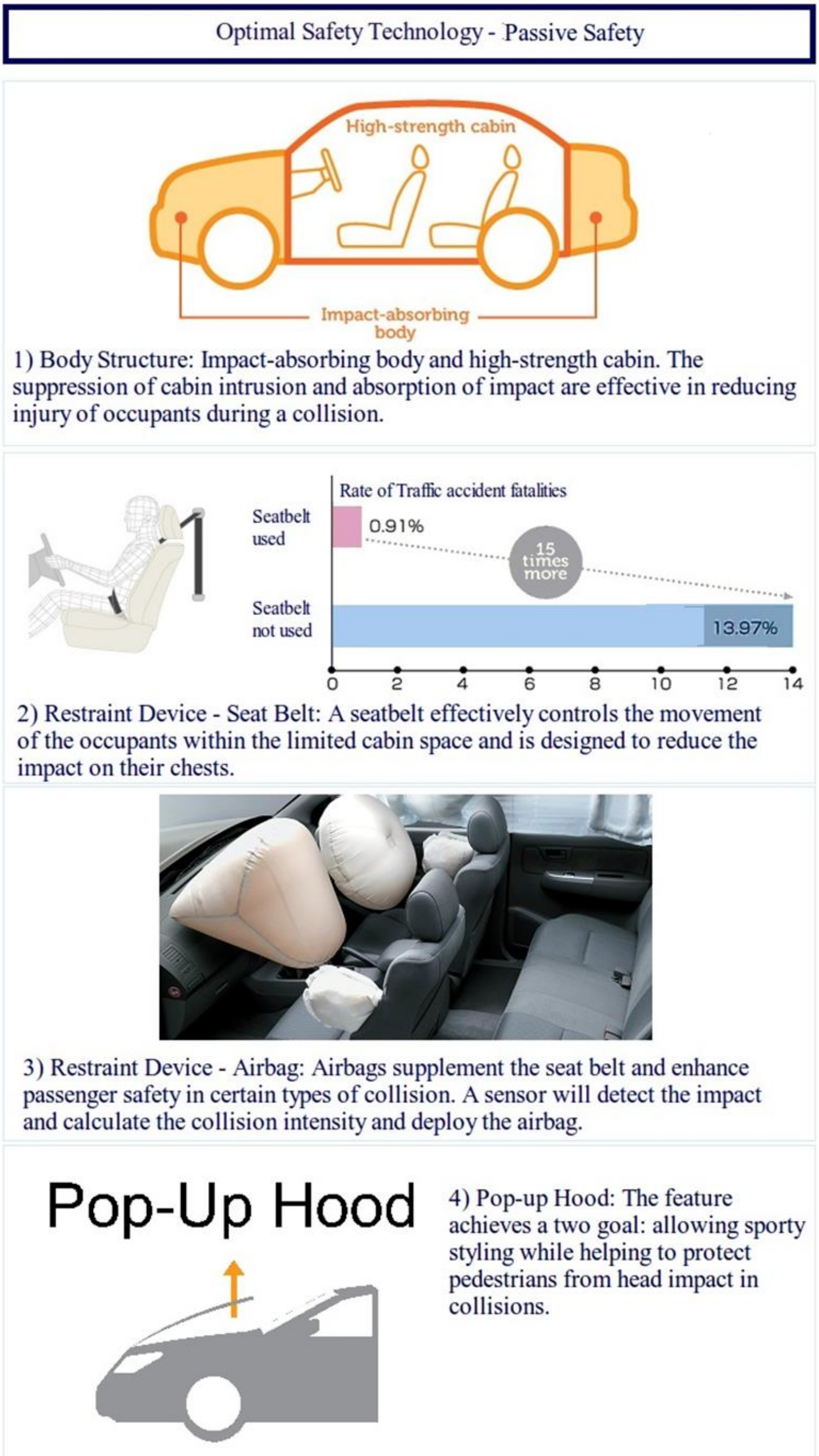
Appendix 1 - Vehicle Safety Technologies [91].



Appendix 2 - Vehicle Safety Technologies [91].



Appendix 3 - Vehicle Safety Technologies [91].



Appendix 4 - Vehicle Safety Technologies [91].