IATSS Research 44 (2020) 155–161

Contents lists available at ScienceDirect

IATSS Research

Research article

Factors affecting lane change crashes

Mohamed Shawky

Ain Shams University, Cairo, Egypt

ARTICLE INFO

Article history:
Received 2 January 2019
Received in revised form 10 December 2019
Accepted 16 December 2019
Available online 9 January 2020

Keywords:
Lane change
Drivers' behavior questionnaire
Traffic crashes
Logistic regression model
Blind spot

ABSTRACT

This study aims to investigate the contributing factors affecting the occurrence of crashes while lane-changing maneuvers of drivers. Two different data sets were used from the same drivers' population. The first data set was collected from the traffic police crash reports and the second data set was collected through a questionnaire survey that was conducted among 429 drivers. Two different logistic regression models were developed by employing the two sets of the collected data. The results of the crash occurrence model showed that the drivers' factors (gender, nationality and years of experience in driving), location and surrounding condition factors (non-junction locations, light and road surface conditions) and roads feature (road type, number of lanes and speed limit value) are the significant variables that affected the occurrence of lane-change crashes. About 57.2% of the survey responders committed that different sources of distractions were the main reason for their sudden or unsafe lane change including 21.2% was due to mobile usage. The drivers' behavior model results showed that drivers who did sudden lane change are more likely to be involved in traffic crashes with 2.53 times than others. The drivers who look towards the side mirrors and who look out the windows before lane-change intention have less probability to be involved in crashes by 4.61 and 3.85 times than others, respectively. Another interesting finding is that drivers who reported that they received enough training about safe lane change maneuvering during issuing the driving licenses are less likely to be involved in crashes by 2.06 times than other drivers.

1. Introduction

Human error is considered as the lead cause of >90% of traffic crashes around the world [1]. Many studies have attempted to investigate the interrelationship between risky driving behavior and the occurrence of traffic crashes. Most of these studies addressed the speeding, tailgating, alcohol usage, hand-hold mobile usage, failure to follow traffic sign/signal as the most hazardous driving behavior that lead to serious crashes. However, the unsafe lane changing behavior of the drivers has not received the same significant attention from the researchers. In the Emirate of Abu Dhabi (AD), the capital of United Arab Emirate UAE, unsafe lane change is considered as the lead cause of severe crashes (i.e., any crash resulted in at least one injury or fatality). It is worth to mention that the driver's population in AD has a unique composition where >200 different nationalities are living there. This fact puts the road authorities in a big change to deal with different driving norms and road safety culture backgrounds. The crash investigation report defines the lane change related crashes when the crash occurs during the at-fault drivers changing the lane suddenly. In this case, the crash cause is recorded in the crash report as "sudden lane changing".

In general, not much is known about lane-change related crashes especially in the middle east countries where road safety information is not widely published. In the crash reports, it is usually listed that the crash has been occurred due to sudden lane changing behavior of the at-fault drivers (in the crash cause item) without looking for the reasons behind such behavior. Therefore, this study mainly aims to investigate the factors affecting the occurrence of lane-change crashes and to explore the drivers' attitude and perception towards lane change maneuvering. To achieve these objectives, two types of data sets were employed: crash reports data and Driver Behavior Questioner (DBQ) survey data. Each type of these data provides different valuable information regarding the occurrence of the lane change crashes and related drivers' behavior.

Crash data from 2010 to 2017 shows that the sudden lane change caused about 17.0% of total severe crashes, followed by speeding (12.8%) and tailgating (11.2%). Regarding the injury-severity, Table 1 shows a comparison between the frequency of the different injury-severity levels resulted in lane changing and other crash causes. This table indicates that the severity of lane-change related crashes is relatively high compared to other crash causes. Table 2 shows a comparison of three different groups of nationalities. The table also shows that Arabian drivers have higher lane change related crashes compared to other

E-mail address: m_shawky@eng.asu.edu.eg.
Peer review under responsibility of International Association of Traffic and Safety Sciences.

https://doi.org/10.1016/j.iatssr.2019.12.002

Table 1
Statistics of injury-severity levels.

Injury-severity level	Lane change crashes		Other crash types	
	Frequency	Percentage	Frequency	Percentage
Slight	1355	31.7%	6536	41.6%
Medium	2105	49.2%	6536	41.6%
Severe	429	10.0%	1351	8.6%
Fatal	390	9.1%	1286	8.2%

Table 2
Drivers' nationality and lane change crashes.

Nationality	Driving licenses percentage	Lane change crashes		Other crash types	
		Frequency	Percentage	Frequency	Percentage
Arabian	40%	1641	61.3%	7221	56.2%
Asian	47%	974	36.4%	5274	41.1%
Others	13%	64	2.4%	346	2.7%

nationalities despite they represent about 40% of the total number of driving licenses. This result can be explained on the basis of differences in driving culture background and the extent to which drivers accept to pay fines for traffic rule violations.

2. Lane changing crashes background

Prior studies that tackled lane-change related crashes are relatively few compared to other crash causes. Chovan, et al. [2] and Eberhard, et al. [3] mentioned that the main factors that may lead to lane change crashes include recognition failure, lack of awareness of a threatening vehicle, and apparent failure to attempt an avoidance maneuver before the crash. Wang and Kniling [4] reported that lane-change crashes in the United States represented about 4% of all crashes and resulted in about 0.5% of total crash fatalities. In addition, about 68% of lane-change crashes were non-junction crashes, 77% occurred during daytime and on roads with a wide range of speed limits. Tijerina et al. [5] investigated eye-glance patters before lane-change intention and they found that specific eye-glance patterns take place before lane-change initiation. In addition, during lane change from right to left, the probability of glancing over the shoulder (blind spot) was 0.08, glancing at the forward's view was 0.41, glancing at the left mirror was 0.22 and glancing at the rearview mirror was 0.21.

Dingus, et al. [6] utilized data of the 100-Car naturalistic driving study to investigate the driver behaviors that lead to lane change crashes and near-crashes. This study examined 241 participants as they drove their personal vehicles during their daily commutes for a period of 12 months. About 135 lane-change events were identified as crashes and the rest were near-crashes. The analysis showed that 85% of the drivers used their turn signals during planned left-lane changes, while 24% used their turn signals when making unplanned left-lane changes to avoid a forward crash threat. About 46% of the drivers looked towards their left mirrors, 50% looked towards their left windows, and 17% looked towards their center mirrors during the 3 s prior to performing planned left-lane changes. Based on the same data set [7], it was found that drivers making planned left-lane changes took an average of 1.5 s to cross into the adjacent left lanes. An average of 2.3 s elapsed before these drivers encountered a lane-change near-crash. These findings suggest that drivers had little time to avoid an event once they started to change lanes. Most of the near-crashes were resolved by drivers braking and steering away from the crash threat.

Erik, et al. [8] presented results of naturalistic lane change distribution, frequency, and duration data collected unobtrusively from 16 commuters using instrumented vehicles. A total of 8667 lane changes (including unsuccessful maneuvers) were investigated. The results showed that >37% of lane changes were due to a slow vehicle ahead. The mean duration for 7192 single lane changes was 6.28 s with a standard deviation of 2.0. In another study, about 539,000 two-vehicle lane-change crashes occurred in the USA in 1999 were investigated [9]. It was found that about 10% of “typical lane-change case” crashes involved large trucks changing lane and light vehicles going straight; about 5% of these crashes involved the reverse combination. The highest involvement of trucks was observed in the “merging” scenario, counting around 42% of these crashes.

Some studies used driving simulation to investigate lane change and risk driving situations [10,11]. Lavallière, et al. [12] investigate the frequency of looking towards the three vehicles' mirrors (right, center and left mirrors) during lane change maneuvering. The simulation results showed differences between young and old drivers. Younger drivers rotate their heads wider than older drivers when inspecting the blind spot. These differences can be partially attributed to the reduced neck mobility in older drivers. Moreover, older drivers inspect their rear-view mirrors and blind spots less frequently than younger drivers: 51 versus 83% for the rear-view mirror and 41 versus 86% for the blind spot. Yun, et al. [13] examined the impacts of in-vehicle navigation information on lane-change behavior. The results showed that the impact of in-vehicle navigation information on lane-changing behavior varies with traffic flow density and timing. The in-vehicle navigation information had a significant positive impact on lane-changing safety under medium and high-density conditions. However, the effect was not significant under light density conditions. In addition, more improvement in operational safety could be gained when in-vehicle navigation information is provided earlier within a range of 2 km upstream of the exit gore.

Another methodology for investigating the relationships between driver's behavior and crash involvements was introduced by Reason et al. in 1990 [14]. This methodology used the Driver Behavior Questionnaire DBQ (i.e., self-report questionnaire survey). Winter and Dodou [15] stated that the DBQ has increased tremendously since 1990 and at least 174 studies were published that have used the DBQ up to 2010. Now hundreds of studied used this methodology to measure the aberrant driving behavior and the interaction with crash involvements [16].

3. Lane change crashes analysis

3.1. Descriptive analysis of lane-change crashes

The first set of the employed data has been extracted from the crashes database for eight years (2010–2017). The crash reports include full information about the characteristics of at fault-drivers, casualties, roads, environment and involved vehicles. Out of 15,888 reported severe crashes, about 2705 crashes have occurred as a result of the sudden lane changing behavior. The analysis of this data has been utilized to define and statistically describe the problem of lane-change crashes.

Table 3 shows the frequency and percentage of lane-change crashes and other crash causes in terms of at-fault drivers' characteristics. The table indicates that females, young drivers (18–24 years old) and low driving experience (less than three years of driving) have high percentage involvement in lane-change crashes compared to other crash causes.

Table 4 provides a comparison between the frequency and percentage distribution of lane-change crashes and other crash causes in terms of the characteristics of roads, location, weather conditions, and vehicle types. This table shows that the percentage of crashes that had been occurred due to sudden lanes changing behavior is high on the urban roads, high-speed limit roads, non-junction segments, wet road surface, light vehicles, and rainy weather conditions compared to other crash causes.

3.2. Lane-change crashes modeling

To gain more understanding of the contributing factors that significantly affect the occurrence of lane-change crashes, a binary logistic regression model was developed. The binary logit model is considered as

Table 3
At-fault drivers' characteristics for both lane-change and other causes of crashes.

Variables		Lane change crashes		Other crashes	
		Frequency	Percentage	Frequency	Percentage
Gender	Male	2343	86.9%	11,732	90.6%
	Female	352	13.1%	1211	9.4%
Age	18–24	745	27.6%	3267	25.2%
	25–30	656	24.3%	3177	24.6%
	31–40	712	26.4%	3557	27.5%
	41–50	320	11.9%	1763	13.6%
	50–60	190	7.1%	835	6.5%
	>60	72	2.7%	340	2.6%
years of driving experience	<3	1281	47.4%	5820	44.1%
	3–6	525	19.4%	2726	20.7%
	6–9	323	11.9%	1634	12.4%
	>12	576	21.3%	3003	22.8%
Education level[a]	Low	9474	60.7%	1623	60.2%
	Medium	4881	31.3%	834	31.0%
	High	1253	8.0%	237	8.8%

[a] Low education level who can read and write; medium who has secondary high school certificate and high level who has college and post-graduate certificate.

the best choice for investigating binary variables such as the occurrence of traffic crashes [17]. The dependent variable in the developed model is the lane change crash occurrence (i.e., 1 = lane change crash, 0 = other crash causes). The statistical software SPSS package was used to find the significant model variables. Table 5 shows the output of the model results. The results indicate that drivers' factors (gender, nationality and years of experience in driving), location and surrounding condition factors (crash location regarding junctions, light and road surface conditions) and roads feature (road type, number of lanes and speed limit value) are the significant variables that affected the occurrence of lane-change crashes.

These results reveal that females, local and low number of years in driving drivers are more likely to be involved in lane-change crashes than males, other nationalities and drivers who have high years of experience in driving. Based on the estimated odds ratio, the probability of being involved in lane-change crashes on rural roads is approximately 5.38 times higher than on urban roads and at non-junction segments of roads is 2.89 times higher than at the locations near/at intersections. Moreover, the likelihood of lane change crash occurrence increases on the roads that have poor light conditions, wet road surface conditions, a high number of lanes and high-speed limit values.

4. Lane changing behaviour analysis

4.1. Drivers' behavior data collection

The second set of data was collected through a Drivers' Behavior Questionnaire (DBQ) survey for more understanding of the main reasons behind such unsafe behavior during lane changing. This questionnaire was conducted based on a random sample of the drivers in AD, where some of them have been involved in crashes either sue to sudden lane changing or other crash causes. The questionnaire form included 27 questions and divided into four main sections: I) demographic information of the participants, II) crashes and traffic violation history, III) lane change behavior and perception, IV) background about awareness and education. >1000 questionnaire forms were randomly handed out among drivers in different public areas considering the age and gender distribution of the licensed drivers' population by AD traffic police support and supervision. About 429 completed questionnaire forms were found to be reliable in the analysis process. Table 6 shows the percentage distribution of the drivers' gender and age for both the selected sample and the drivers' population. Based on the result of Chi-Square tests for specified proportions, the sample of the participated drivers in the survey well represents the licensed drivers' population with respect to gender and age.

4.2. Drivers' responses analysis

Table 7 summarizes the demographic characteristics of the survey's participants. As shown in this table, approximately 82% of the participants were males while about 18% were females. Regarding the age,

Table 4
Location and surrounding conditions for lane change and other crashes causes.

Variables			Lane-change crashes		Other crashes	
			Frequency	Percentage	Frequency	Percentage
Road and crash location characteristics	Road type	rural	2270	88.7%	6628	57.6%
		urban	290	11.3%	4876	42.4%
	Road speed limit	40	315	12.7%	3245	20.6%
		60	515	20.7%	4381	27.9%
		80	396	15.9%	4872	31.0%
		100	490	19.7%	1659	10.6%
		120	772	31.0%	1561	9.9%
	No. of lanes per direction	2	650	45.7%	2562	35.9%
		3	348	24.5%	2690	37.7%
		4	399	28.0%	1628	22.8%
		5	30	1.9%	299	3.6%
	Intersection-related location	at/near intersection	140	5.7%	2444	21.0%
		roundabout	93	3.8%	939	8.1%
		near U-turn	48	2.0%	300	2.6%
		non-junction	2158	88.5%	7941	68.3%
	Light condition	daytime	1686	62.4%	7560	57.4%
		night with good light	798	29.5%	4599	34.9%
		night without light	219	8.1%	1017	7.7%
	Road surface condition	dry	2413	92.1%	11,999	93.6%
		wet	81	3.1%	216	1.7%
		sand-covered	48	1.8%	153	1.2%
		not paved	78	3.0%	448	3.5%
Weather condition		clear	2576	95.3%	12,662	96.1%
		rainy	79	2.9%	188	1.4%
		fog	21	0.8%	186	1.4%
		stormy	28	1.0%	139	1.1%
Vehicle type		light vehicle	2159	90.8%	10,124	88.5%
		heavy vehicle	219	9.2%	1313	11.5%

Table 5
Output of the binary logit regression model.

Variables	Variable categories	*B*	*S.E.*	*Wald*	*Sig.*	*Odds ratio*
Constant		−4.335	0.249	303.131	0.000*	0.013
Gender	1 = male 0 = female	−0.553	0.093	35.317	0.000*	0.575
Age	continuous variable	0.005	0.003	2.544	0.111	1.005
Nationality	1 = local driver 0 = other nationalities	0.143	0.066	4.700	0.030*	1.154
Education level	continuous variable	0.041	0.104	0.158	0.691	1.042
Year of Experience	continuous variable	−0.041	0.010	17.226	0.000*	0.960
Crash location	1 = at road segment 0 = at/near intersection	1.062	0.111	91.579	0.000*	2.891
Light condition	1 = daytime/good light 0 = night with poor light	−0.240	0.118	4.168	0.041*	0.787
Weather condition	1 = clear 0 = others	0.138	0.144	0.928	0.335	1.148
Road Surface	1 = dry 0 = others	−0.302	0.110	7.553	0.006*	0.740
Road type	1 = rural 0 = urban	1.683	0.084	398.968	0.000*	5.379
No. of lanes	continuous variable	0.282	0.032	78.400	0.000*	1.326
Speed limit	continuous variable	0.009	0.001	57.647	0.000*	1.009
Vehicle type	1 = light vehicle 0 = heavy vehicle	−0.123	0.087	2.013	0.156	0.884

* Significant level of 95%.

about 39.6%, 47.9%, 11.8% and 0.7% of the respondents were 18–30, 31–45, 46–60 and over 60 years old, respectively. In addition, about 23.3% of the participants were local drivers, 39.8% from the Arabian countries, 30.5% Asian and 6.3% other nationalities. The table also shows that nearly 16.1% of the participants were low educated, 25.1% medium and 58.5% high education levels. Furthermore, about 7.2% of the participants were students, 35.7% were government employees, and 57.1% were working in the private sector.

Table 8 shows the response of the participants to section II of the questionnaire survey regarding their history of traffic violations and crash involvements as at-fault drivers. It shows that about 12.8% of drivers claimed that they have not receive traffic violation tickets during the last year. About 9.8% of the questionnaire responders get violation tickets due to sudden lane change behavior. This low percentage of sudden lane change violations does not reflect the real frequency of such behavior due to the difficulties for detecting this type of traffic offends by the traffic police. The table also shows that around half of drivers were involved in traffic crashes during the last three years and about 83.4% of these crashes were property damage only (PDO) crashes and 16.6% were severe crashes. in addition, about 14.3% of participants reported that sudden lane change maneuvering was the main reason for their traffic crashes.

Table 9 shows the participants' responses to the questions about lane changing behavior (section III) and awareness (section IV). This table shows that about 22.8% of the participants did a risky sudden lane change before which led to a near-crash situation. However, about 88.6% reported that they faced a sudden lane change situation from other drivers. Regarding the reason behind the sudden lane change, about 57.2% of the responders committed that driver's distraction was the main reason (36.0% distraction due to talking with a person in the car or other things and 21.2% distraction due to using mobile). Regarding the lane change maneuvering process, 21.0% of the participants committed that they sometimes, rarely or never use the turn signals when they intend to change the lane. In addition, about 6.7% reported that they sometimes, rarely or never look at the mirrors before the intention of lane-change maneuver. Furthermore, about 16.3% of participants do not pay attention to look out to check the vacancy of the adjacent lane (blind spot inspections) before lane changing process.

Regarding the awareness and education of drivers about safe lane change maneuvering, the result showed that about 18.4% of the participants do not know the blind spots, 20.7% do not know how to overcome blind spots problem. About 29.6% of the participants feel that they did not receive enough training about safe lane change maneuvering during issuing driving license. Furthermore, 62.7% of the participants do not know that sudden lane change is the leading cause of crashes in AD. In general, participants' answers for section IV questions reveals that there is a lack of information and awareness about safe lane changing process.

Table 6
Percentage distribution of drivers' gender and age in the sample and drivers' population.

Drivers characteristics		% of drivers in the	
		Sample of participants	Licensed drivers' population
Gender	Male	82.1%	84.5%
	Female	17.9%	15.5%
Age	18–30	39.6%	40.7%
	31–45	47.9%	48.2%
	45–60	11.8%	10.2%
	>60	0.7%	0.9%

Table 7
Participants' demographic information (section I).

Variables (I - Drivers' demographics)		Frequency	Percentage
Gender	Male	352	82.1%
	Female	77	17.9%
Age	18–30	170	39.6%
	31–45	205	47.9%
	46–60	51	11.8%
	>60	3	0.7%
Nationalities	Local	100	23.3%
	Arabian	171	39.8%
	Asian	131	30.5%
	Others	27	6.3%
Education level	Low	69	16.1%
	Medium	109	25.4%
	High	251	58.5%
Occupation	Student	31	7.2%
	Government employee	153	35.7%
	Private	245	57.1%
Income level	Low	135	31.5%
	Medium	169	39.4%
	High	125	29.1%

Table 8
Participants' history of traffic violations and crashes (section II).

Question	Categories	Frequency	Percent
What is the number of traffic violation tickets you got at last year?	0	55	12.8%
	1–2	153	35.7%
	3–5	158	36.8%
	6–10	51	11.9%
	>10	12	2.8%
Did you get a sudden lane change violation ticket before?	Yes	42	9.8%
	No	387	90.2%
If yes, how may sudden lane change violation tickets?	1	28	66.7%
	2	12	28.6%
	>2	2	4.8%
How many times have you involved in a traffic crash during the last three years?	0	212	49.4%
	1	178	41.5%
	2	31	7.2%
	≥3	8	1.9%
If yes, what was the crash type?	PDO crash	181	83.4%
	severe crash	36	16.6%
What was the crash cause?	Sudden lane change	31	14.3%
	Speeding	23	10.6%
	Tailgating	68	31.3%
	Distractions	24	11.1%
	Enter road without checking gap to merge	24	11.1%
	Others	47	21.7%

4.3. Modeling questionnaire responses

To provide a better understanding of the factors related to lane change behavior that significantly affect crash involvement of the drivers, the logistic regression model was developed based on the responses of the survey data. The independent variable in the developed model is the crash involvement of the drivers (1 = driver who was involved in a traffic crash, 0 = others). Table 10 shows the results of the logistic regression model for the factors affecting the involvement in at-fault related crashes. From this table, it can be found that the historical number of violations is a significant variable of crash involvement. Regarding the driver's demographics, nationality is shown as a significant variable where the local drivers seem more likely to be involved in crashes than other nationalities.

Regarding the lane change behavior variables, the findings showed that sudden lane change violations mirrors usage and paying attention by looking around before lane-change intention are the significant variables that affected crash involvements of drivers. Drivers who committed that they did risky lane change before are more likely to being involved in crashes (2.525 times) compared to others. Drivers who always look at the mirrors before lane change have 78.3% (=1–0.217) are less likely to be involved in crashes compared to drivers who rarely or never do that. In other words, the likelihood that drivers who rarely or never use the mirrors to be involved in traffic crashes is about 4.61 times (=1/0.217) higher than drivers who look at mirrors before lane-change intention. The same conclusion can be figured out for the drivers who do not pay attention by look over the shoulder (blind spot inspection)) before lane change is more likely to be involved in crashes with 3.85 times (=1/0.260) more than others. An interesting finding shows that drivers who reported that they received enough training about safe lane change during issuing the driving licenses are less likely to be involved in crashes by 2.06 times (=1/0.486) than other drivers.

The results also showed that the drivers characteristics such as gender, education level and income are significantly affected lane-change related crashes. Male drivers are more likely to be involved in lane-change crashes by 1.835 times compared to female. In addition, drivers who use the Flashlight turn indictor during lane change maneuvering are less likely to be involved in lane-change related crashes compared to drivers who do not use the turn light indicators.

5. Conclusion

This study provided a deep analysis of the traffic crashes that occurred as a result of the unsafe lane change of at-fault drivers. Two sources of data were employed: crash reports and drivers' behavior questionnaires. The analysis of the crash data showed that the percentage of lane-change crashes is high on the rural roads, high-speed limit, non-junctions, wet road surface, rainy weather, light vehicles compared to other crashes causes. The first model was developed based on crash data and showed that drivers' factors (gender, nationality and years of experience in driving), location and surrounding condition factors (crash location regarding intersections, light and road surface conditions) and roads feature (road type, number of lanes and speed limit value) are the significant variables that affected the occurrence of lane-change crashes.

Table 9
Participants' behavior and awareness regarding lane change process.

Question	Categories	Frequency	Percent
Section III - Lane change behavior			
have you done a risky sudden lane change before that led you to a near-crash situation?	yes	98	22.8%
	no	331	77.2%
If yes, what was the reason that led you to do such sudden lane changing?	distraction due to talking with beside person or other things	37	36.0%
	distraction due to using mobile phone	22	21.2%
	trying to avoid sudden obstruct on the road	9	8.7%
	trying to catch a near road exit	19	18.3%
	trying to overtake a slow front car	11	10.6%
	trying to avoid sudden lane changing from another near car	4	3.8%
	fatigue or sleepiness while driving	2	1.9%
Do you use a vehicle turn signals before lane-change intention?	always	207	48.3%
	often	132	30.8%
	sometime	69	16.1%
	rarely	17	4.0%
	never	4	0.9%
Do you look at the mirror before lane-change intention?	always	257	59.9%
	often	143	33.3%
	sometime	24	5.6%
	rarely	4	0.9%
	never	1	0.2%
Do you pay attention to lookout (for visual inspection the blind spot) before lane-change intention?	yes	359	83.7%
	no	70	16.3%
Have you ever faced a sudden lane change while driving from another driver?	yes	380	88.6%
	No	49	11.4%
Section IV - Lane change awareness and education			
Do you know the blind spot?	yes	350	81.6%
	no	79	18.4%
Do you know how to avoid the blind spot problem while lane change maneuvering?	yes	340	79.3%
	no	89	20.7%
Do you know that sudden lane change is considered as the main cause of traffic crashes in AD?	yes	160	37.3%
	no	269	62.7%
Did you receive enough training when issuing a driving license about safety lane change?	yes	302	70.4%
	no	127	29.6%
Have you received information or awareness concerning how to do a safe change lane?	yes	167	38.9%
	no	262	61.1%

Table 10
Results of the regression model of lane-change behavior and crash involvement.

Variables	Category	B	S.E.	Wald	Sig.	Odds ratio
Constant		1.567	0.821	3.645	0.056	4.794
Nationality	1 = local 0 = other	0.733	0.323	5.131	0.024*	2.081
Gender	1 = male 0 = female	0.607	0.311	3.808	0.051**	1.835
Age	1 = young (<35) 0 = others	0.258	0.238	1.181	0.277	1.295
Education	Categorical in 3 levels	0.353	0.184	3.659	0.056**	1.423
Income	Categorical in 3 levels	−0.423	0.220	3.697	0.055**	0.655
No. of Violations	Continuous	0.121	0.052	5.377	0.020*	1.129
Lane change violations	1 = get sudden lane change violation before 0 = others	1.854	0.772	5.772	0.016*	6.386
No. of Lane change Violations	Continuous	−0.161	0.538	0.090	0.764	0.851
Risky lane change	1 = did risky lane change before 0 = others	0.926	0.349	7.030	0.008*	2.525
Flashlight turn indictor usage	1 = use falser 0 = others	−0.678	0.331	4.186	0.061**	0.970
Mirror usage	1 = look at mirror before lane change 0 = others	−1.526	0.582	6.890	0.009*	0.217
Look around	1 = look at side before lane change 0 = others	−1.346	0.433	9.687	0.002*	0.260
Crash cause	1 = if the crash du to driver distraction 0 = others	−0.175	0.424	0.170	0.680	0.840
Knowledge about crash causes in AD	1 = know that lane change is the top of crash causes 0 = other	−0.442	0.255	2.995	0.084**	0.643
Training when get driving license	1 = get enough training 0 = do not	−0.721	0.271	7.075	0.008*	0.486
Knowledge about Blindspot	1 = know 0 = don't	−0.039	0.441	0.008	0.929	0.962
Know how to deal with Blindspot	1 = know 0 = don't	−0.190	0.423	0.202	0.653	0.827
Receiving awareness	1 = received awareness before 0 = do not	−0.096	0.243	0.157	0.692	0.908

* Significant at a significant level of 95%.
** Significant at a significant level of 90%.

Based on the drivers' behavior survey, the analysis of 429 questionnaire forms showed that about 22.8% of the responders did a risky sudden lane change before. About 57.2% of the participants committed that the main reason behind their sudden lane change was driver's distraction (36.0% distraction due to talking with a person in the car or other things and 21.2% distraction due to mobile users). In addition, about 21.0% of the participants reported that they sometimes, rarely or never use the turn signals and about 6.7% sometimes, rarely or never look at the mirrors before lane change intention. Furthermore, about 16.3% of participants do not pay attention to look out to check the blind spots. The analysis also showed a lack of information and awareness about safe lane change maneuvers where about 18.4% of the participants do not know the blind spots and 20.7% do not know how to overcome blind spots problem. The second model was developed by using questionnaire data. The findings of this model confirmed the results of the first model regarding the driver's characteristics variables (i.e., gender and nationalities). The driving experience has also been confirmed as a significant variable in lane-change crash involvements in terms of the driver's usage of vehicle mirrors and turn light indicators during lane-change maneuver. The model results showed that the drivers who look towards the mirrors and who look out the windows (for blind spot inspection) have less probability to be involved in crashes by 4.61 and 3.85 times than others, respectively. In addition, the drivers who did sudden lane change before are more likely to be involved in crashes with 2.525 times than others. Another interesting finding showed that drivers who committed that they received enough training about safe lane change during issuing the driving licenses are less likely to be involved in crashes by 2.06 times than other drivers.

The findings of this research proved the importance of the awareness and education of drivers in improving the unsafe lane change behavior and its positive impact on road safety. These findings can be utilized not only in the case study city but could be extended to other countries. The awareness campaigns and training efforts should focus on the proper usage of side and mid-mirrors, turn signal indicators, avoiding districted devices during driving and how to check blind spots before changing lanes. The findings also reveal that advanced systems that help drivers in perceiving adjacent vehicles, prevent drivers' distraction and recognizing crash threats while concurrently monitoring the forward [1–17] roadway may mitigate these human factors dilemmas.

Acknowledgments

The author would like to thank the Department of Traffic Engineering and Road Safety, Traffic and Patrols Directorate in the Emirate of Abu Dhabi for providing the required data and for their help for conducting the questionnaire survey.

References

[1] M. Karacasu, A. Er, An analysis on distribution of traffic faults in accidents based on driver's age and gender: Eskisehir case, Proc. Soc. Behav. Sci. 20 (2011) 776–785.
[2] J.D. Chovan, L. Tijerina, G. Alexander, D.L. Hendricks, Examination of Lane Change Crashes and Potential IVHS Countermeasures (DOT HS 808 071), National Highway Traffic Safety Administration, Washington, DC, 1994.
[3] C.D. Eberhard, K.M. Luebkemann, P.J. Moffa, S.K. Young, R.W. Allen, E.A. Harwin, J. Keating, R. Mason, Development of Performance Specifications for Collision Avoidance Systems for Lane Change, Merging and Backing. Task 1 Interim Report. Crash problem Analysis (DOT HS 808 431), National Highway Traffic Safety Administration, Washington, D. C, 1994.
[4] J. Wang, R. Knipling, IVHS/Crash Avoidance Countermeasure Target, 1993.
[5] L. Tijerina, R.W. Garrott, M. Glecker, D. Stoltzfus, E. Parmer, Van and Passenger Car Driver Eye Glance Behavior During Lane Change Decision Phase. (Revised Draft: Interim Report), Transportation Research Center, Inc. and National Highway Traffic Safety Administration, Vehicle Research and Test Center, 1997.

[6] T.A. Dingus, N. Klauer, et al., The 100-Car Naturalistic Driving Study: Phase II – Results of the 100-Car Field Experiment, Contract No. DTNH22-00-C-07007 (Task Order 6) National Highway Traffic Safety Administration, Washington, D.C, 2006.
[7] G.M. Fitch, S.E. Lee, S. Klauer, J. Hankey, J. Sudweeks, T. Dingus, Analysis of Lane-Change Crashes and Near-Crashes, Department of Transportation, National Highway Traffic Safety Administration, Report No. DOT HS 811 147, 2009.
[8] E.C.B. Olsen, S.E. Lee, W.W. Wierwille, Analysis of distribution, frequency, and duration of naturalistic lane changes, Proceeding of the Human Factors and Ergonomics Society. the 46th Annual Meeting, 2002.
[9] B. Sen, J.D. Smith, W.G. Najm, Analysis of Lane Change Crashes, Department of Transportation, National Highway Traffic Safety Administration, Report No. DOT HS 809 571, 2003.
[10] John D. Chovan, Louis Tijerina, Graham Alexander, L. Donald, Examination of Lane Change Crashes and Potential IVHS Countermeasures, National Highway Traffic Safety Administration, Report No. DOT-VNTSC-NHTSA-93-2, 1994.
[11] K. Kurokawa, W.W. Wierwille, Validation of a driving simulation facility for instrument panel task performance, Proceedings of the Human Factors Society 34th Annual Meeting 1990, pp. 1299–1303.
[12] M. Lavallière, D. Laurendeau, M. Simoneau, N. Teasdale, Changing lanes in a simulator: effects of aging on the control of the vehicle and visual inspection of mirrors and blind spot, Traffic Injury Prevent. 12 (2011) 191–200.
[13] M. Yun, J. Zhao, J. Zhao, X. Weng, Impact of in-vehicle navigation information on lane-change behavior in urban expressway diverge segments, Accid. Anal. Prev. 106 (2017) 53–66.
[14] J. Reason, A. Manstead, S. Stradling, J. Baxter, K. Campbell, Errors and violations on the roads: a real distinction? Ergonomics 33 (10–11) (1990).
[15] J. Winter, D. Dodou, The driver behavior questionnaire as a predictor of accident: a meta-analysis, J. Saf. Res. 41 (2010) 463–470.
[16] M. Sucha, L. Sramova, R. Risser, The Manchester driver behavior questionnaire: self-reports of aberrant behavior among Czech drivers, Eur. Transp. Res. Rev. 6 (2014) 493–502.
[17] A. Agresti, Categorical data analysis, Crash Problem Size Assessment and Statistical Description: Lane Change/Merge Crashes: Problem Size Assessment and Statistical Description (DRAFT), 2nd ed.NHTSA Office of Crash Avoidance Research (OCAR), Washington, DC, 2002 , Hoboken, New Jersey.