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Analysis Of Drivers Attitude To Variable Speed Limit Systems On Multi-lane Highways

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Abstract

Intelligent Transportation Systems (ITS) such as Variable Speed Limit Systems (VSL) provide new methods and strategies for managing speed limits that also effectively deal with high traffic density and increase road safety. However, the positive effects of VSL are only true when drivers adjust their speed according to VSL indicators, and this compliance is influenced by many factors such as demographics, drivers' knowledge of multi-lane highways, and their driving behaviors such as adhering to their driving lanes and speed limits and avoiding overtaking, aggressive and irresponsible driving behaviors. Thus, in order to obtain more insight into the effectiveness of implementing the VSL system in the Kingdom of Saudi Arabia (KSA) and the extent of Saudi drivers' compliance with it, a quantitative study was conducted through a field survey on a random sample of 400 Saudi drivers to describe their behavior towards VSL in six multilane highways in Jeddah, KSA as well as linking their attitudes toward the frequent use of multi-lane highways, their natural commitment to speed limits, and their natural response to traffic congestion.

Analysis of the data showed that there is an average familiarity of Saudi drivers with the multilane highways, and there is a moderate tendency to lane-changing and exceeding the specified speed. Also, the analysis showed that Saudi drivers' attitude towards VSL is not governed by socio-demographic characteristics where the majority of drivers have similar responses toward VSL systems regardless of their gender, having a driving license, nationality, or educational level. In conclusion, the results showed that there are significant negative impacts of the drivers' familiarity with multilane highways, their response lane changing under traffic congestion, and their lack of commitment to speed on their attitude towards VSL, where drivers' response lane changing under traffic congestion has the strongest effect, followed by drivers' lack of commitment to speed and finally followed by drivers' familiarity with multilane highways with the least effect. The researcher recommends expanding the scope of the research to include other multilane highways in all regions of Saudi Arabia such as Dammam, Riyadh, etc. in a way that adds comprehensiveness and generality to the results of this study.

Keywords: Intelligent Transportation Systems (ITS), Variable Speed Limit Systems (VSL),

Familiarity, Commuters, Lack of Commitment, Drivers' Attitude, Multilane Highways, Lane Changing.

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الملخص

توفر أنظمة النقل الذكية (ITS) مثل أنظمة تحديد السرعة المتغيرة (VSL) طرقًا واستراتيجيات جديدة لإدارة حدود السرعة التي تتعامل أيضًا بشكل فعال مع كثافة حركة المرور العالية وتزيد من السلامة على الطرق. ومع ذلك ، فإن التأثيرات الإيجابية لـ VSL تكون صحيحة فقط عندما يضبط السائقون سرعتهم وفقًا لمؤشرات VSL ، ويتأثر هذا الامتثال بالعديد من العوامل مثل التركيبة السكانية ، ومعرفة السائقين بالطرق السريعة متعددة المسارات ، وسلوكياتهم في القيادة مثل الالتزام حارات القيادة وحدود السرعة وتجنب التجاوز وسلوكيات القيادة العدوانية وغير المسؤولة. ومن أجل الحصول على مزيد من المعلومات حول فاعلية تطبيق نظام VSL في المملكة العربية السعودية ومدى التزام السائقين السعوديين به ، تم إجراء دراسة كمية من خلال مسح ميداني على عينة عشوائية من وصف 400 سائق سعودي سلوكهم تجاه VSL في ستة طرق سريعة متعددة المسارات في جدة ، المملكة العربية السعودية ، بالإضافة إلى ربط مواقفهم تجاه الاستخدام المتكرر للطرق السريعة متعددة المسارات ، والتزامهم الطبيعي بحدود السرعة ، واستجابتهم الطبيعية للازدحام المروري.

أظهر تحليل البيانات أن هناك إلمامًا متوسطًا للسائقين السعوديين بالطرق السريعة متعددة المسارات ، وهناك ميل معتدل لتغيير المسار وتجاوز السرعة المحددة. أظهر التحليل أيضًا أن موقف السائقين السعوديين تجاه VSL لا تحكمه الخصائص الاجتماعية والديموغرافية حيث يكون لدى غالبية السائقين ردود متشابهة تجاه أنظمة VSL بغض النظر عن جنسهم ، أو لديهم رخصة قيادة أو جنسية أو مستوى تعليمي في الختام ، أظهرت النتائج أن هناك آثارًا سلبية كبيرة لإلمام السائقين بالطرق السريعة متعددة المسارات ، وتغير مسار استجابتهم تحت الازدحام المروري ، وعدم التزامهم بالسرعة في موقفهم تجاه VSL ، حيث يتغير مسار استجابة السائقين تحت حركة المرور. يكون للازدحام أقوى تأثير ، يليه عدم التزام السائقين بالسرعة ، ثم يتبعه في النهاية إلمام السائقين بالطرق السريعة متعددة المسارات بأقل تأثير. يوصي الباحث بتوسيع نطاق البحث ليشمل طرقًا سريعة أخرى متعددة المسارات في جميع مناطق المملكة العربية السعودية كالدمام والرياض وغيرها بطريقة تضيف شمولية وعمومية لنتائج هذه الدراسة.

الكلمات المفتاحية : أنظمة النقل الذكية (ITS) ، أنظمة تحديد السرعة المتغيرة (VSL) ، الألفة ، الركاب ، عدم الالتزام ، موقف السائقين ، الطرق السريعة متعددة المسارات ، تغيير المسار.

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Introduction

Globally, the World Health Organization indicated that in 2015 about 1.25 million people die annually due to road accidents, with the largest percentage concentrated on the road transport system in developing countries (Alharbi, 2018). In the latest statistics conducted in 2020, the World Health Organization confirmed that 1.35 million deaths occurred in 2020 from road traffic crashes (World Health Organization (WHO), 2020).

To reduce the rate of accidents safety engineers have developed many technologies to regulate traffic, improve safety conditions, and reduce vehicle speeds (Al-Saleh and Bendak, 2012). Technological progress and the increase of intelligent transportation systems (ITS) contribute to providing new mechanisms for managing speed limits that are commensurate with the increase in traffic movements and deal effectively in situations of fluctuating climatic conditions. Speed management is considered one of the most important measures to ensure road safety, setting a speed limit includes defining the driver to the maximum safe speed under normal roadway conditions.

On the other hand, Papageorgiou et al. (2008) argued that traditional speed limit signs are unable to deal with and adapt to surrounding changes, including traffic congestion, environmental conditions, and others. Hence, there is a need to find a system that can adapt to the current conditions and respond to future needs for highway safety, including the increase in the number of vehicles, which is expected to reach by 2035 about 1.7 billion cars worldwide (Harrington, 2015). This event emphasizes the need to take measures to deal with these changes, including the use of variable speed limit (VSL) systems, which represent digital signals that indicate the speed limit and the changing nature of traffic and weather conditions.

Information provided by speed limit systems presents important information for drivers to reduce accident risk (Yang et al., 2019). VSL systems has proven their effectiveness in dealing with bad weather effects on highways, improving the level of traffic safety, and reducing the number of traffic accidents (Haghani et al. 2013). Hassan et al. (2012) added that VSL signals can reduce traffic congestion and buffering the traffic shock waves and homogenizing speeds. Haghani et al. (2013) found that VSL has a positive effect on traffic flow and traffic safety. Yet, previous studies emphasized a set of factors that limit the effectiveness of VSL systems (Hsssan, 2011; Habtemichael and Santos, 2013; Abojaradeh et al., 2014; Harrington, 2015; Khondaker, 2016; Li et al., 2019), these factors are related mostly to the driver’s personality, such as the level of drivers' commitment to the instructions found on speed signals (Harrington, 2015).

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Khondaker (2016) argued that much of the literature has focused on providing crash prediction algorithms for VSLs, or simulating real-world VSL implementations; however, there is a lack of studies on the driver's level of commitment to VSLs in various circumstances that he/she may encounter suddenly. Moreover, previous studies confirm the importance of maintaining road safety, but they have not succeeded in linking the behavior of the driver with drivers' compliance to VSL. Harrington (2015) argued that there are sufficient studies linking the importance of adherence to traffic signs and traffic safety in developed countries such as Europe. However, the same amount of information and studies cannot be found in Arab countries such as Saudi Arabia. This means that there is a need to understand and evaluate driver behavior toward VSL. According to the latest reports issued by the General Authority for Statistics and the Ministry of Municipal and Rural Affairs; road accidents resulted in the death of 9,031 people in 2016 in Saudi Arabia, with an increase of 2.8% over the year 2015 (Alharbi, 2018). This fact indicates the importance of studying the level of drivers' commitment to safety measures, including VSLs.

This study aims to discuss the attitude of drivers toward VSLs. The study will focus on three factors: the drivers' familiarity with highways, drivers' lane-changing habit under traffic congestion, and the drivers' commitment toward speed limit.

The rest of the paper is organized as follows: Section 1, provides a general introduction to the study and its significance. Section 2; review the research literature the most related to the study. Section 3, describe the adopted methodology. Section 4, analyze the results and state the findings. Finally, section 5, presents our conclusion.

Literature Review

The modern applications that have appeared in intelligent transportation systems (ITS) as a result of the development that has occurred in the technical aspect have provided an important means to improve traffic management systems and control traditional speed limits. These applications have contributed to enhancing the safety of traffic movement and controlling the rates of traffic accidents, which are constantly increasing each year (Knodler, 2015).

Traffic accidents are among the top ten causes of death worldwide after diabetes, and road users are among the most at-risk groups (WHO, 2018). Hassan (2011); Habtemichael and Santos (2013); Abojaradeh et al. (2014) and Harrington (2015) stressed that the main cause of accidents is the driver himself. Generally, drivers are divided into two parts, normal drivers and high-risk drivers. High-risk drivers have more accident rates than regular drivers. Habtemichael and Santos (2013) emphasized that normal drivers are more committed to speed limits than high-risk drivers. They indicated that in many cases the level of violations relates to the drivers' level of knowledge of the road as they usually commit more violations in the roads that they use more. Moreover,, they stress on the importance of restricting the level of freedom for high-risk drivers by limiting their speed and ability to change lanes.

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Variable speed limits are used to enhance drivers 'commitment to the speed limit for each road (Hegyi, 2005). It represents one of the solutions that can be provided for smart traffic systems which contribute to improve the driver's response to weather conditions or to the speed that must be adhered to and not exceeded to avoid traffic accidents. If the driver exposure to sudden weather conditions, the speed limits will be modified through the displays on the roads. Khondaker and Kattan (2015) indicated that there are many uses for variable speed limits, which include enhancing road safety levels by adjusting road speeds and reducing the speed difference between vehicles, and accordingly reduces collision levels and rates. The variable speed limits also contribute to reducing erratic flow levels on the roads, thus reducing jams and bottlenecks. Zegeye et al. (2010) added that variable speed limits contribute to preserving the environment by reducing levels of fuel emissions.

Drivers' attitude is an important factor to determine drivers' behavior toward VSL (Abojaradeh et al., 2014; Li et al., 2019). Li et al. (2019) stressed that one of the most important ways in which road safety can be improved is by improving driver behavior in various surrounding conditions such as weather conditions. The study of Hsssan (2011) has found that there are many factors that affect the behavior of the driver and the level of commitment to follow the instructions of the VSL signs. These factors are gender, age, road type, road use, and the level of the driver's familiarity with VSL signs, in addition to the levels of driving experience (Hsssan, 2011).

Moreover, Abojaradeh et al. (2014) indicated that driver behavior could be the best predictor indicating the possibility of traffic violations. Abojaradeh et al. (2014) clarified that individuals have different attitudes and behaviors that depend on the conditions surrounding them and on cultural differences between them. Ismeik et al. (2010) emphasized that the behavior of the driver may be affected by experience and learning.

A simulation-based research study of Hellinga and Mandelzys (2011) revealed that the regulation effects of VSL and the safety benefits of it are very sensitive to driver compliance and that the level of safety is positively related to the level of compliance, and another study by Matowicki and Přibyl (2016) showed that the level of compliance is related to drivers' behavior such as the driver's response under congestion in terms of changing lanes, and the extent of drivers' violation of speed laws and other factors that will be tested in this study, but from the perspective of a special drivers category, mainly Saudi drivers in multi-lane highway.

Drivers' familiarity with highways is another factor that affects the attitude towards VSL. Studies including Huang et al. (2017) suggest that acceptance rates for VSL of drivers who are unfamiliar with the road network (travelers) are higher than familiar drivers (commuters) because familiar drivers may choose a driving route and speed based on experience rather than only indicative information.

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On the other hand, Mannering (2009) indicated that most drivers exceed the speed limit. One of the most important factors associated with speeding is drivers' belief that this simple overtaking will neither endanger their lives nor threaten their safety. Mannering (2009) conducted a study to determine the speed that drivers think they are able to exceed without threatening their safety. The study found that age, gender and race are important factors that influence drivers' perceptions of the permitted speed limit without threatening safety. Such factors relate also the level of commitment and compliance of the driver with instructions of VSL (Li et al., 2019). Studies including Eboli et al. (2017) and Matowicki and Přibyl (2016), indicated that the deviation of vehicle speed from the average speed is positively associated with the increased likelihood of non-adherence to speed guidelines and regulations imposed by VSL, especially for arterial highways and free highways.

Moreover, several studies have examined the effect of VSL on the distribution of lane usage and utilization. Knoop et al. (2010) found that VSL increases the capacity in the underutilized right lane, Also, Duret (2012) found that VSL changed the pattern of lane distribution and the level of homogeneity of lane use, which contributed to increase the capacity of the lane use.

Moreover, VSL contribute to traffic congestion reduction as indicated in Khondaker (2016).

The success of VSL systems is determined to a large extent by the level of the driver’s commitment to the specified speed limit (Khondaker, 2016).

In addition, Khondaker (2016) argued that the increased level of driver's commitment with VSL is related to the level of driver awareness of the importance of adherence to and compliance with traffic regulations. In many states, the level of drivers ’compliance with the speed limit is affected by the level of enforcement of penalties for violating this limit. On the other hand, the low enforcement of penalties will contribute to increasing the drivers' tendency to commit traffic violations as indicated in Khondaker (2016).

Al-Tit et al. (2020) conducted a study to identify the factors that affect traffic safety in the Qassim region. A questionnaire was used to collect data and distributing it to 909 students from Qassim University. The study found that the lack of compliance with VSLs is one of the most common causes of traffic accidents. Excessive speeding, irregular overtakes on roads, lack of preparation for sudden changes on roads, failure to adhere to the safety belt, using a mobile phone while driving, and failure to adhere to traffic lights and VSLs were the most factors that lead to traffic accidents,

From the above, it is clear that most of the previous studies aimed to study the effect of applications of variable speed limits in the real world. Studying the level of driver’ commitment to variable speed limits has not received sufficient attention by researchers despite the importance of its impact on road safety, including factors related to drivers’ behavior. Harrington (2015) argued that the theoretical literature associated with VSL focused specifically on crash prediction algorithms for VSLs and simulation applications,

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while there is a gap in theoretical literature related to the study of the level of driver compliance to adhere to the speed instructions found on VSL.

Moreover, the Saudi environment is one of the environments in which the nature of the relation between the level of commitment to variable speed limits and traffic safety has not been studied, which confirms the existence of a gap in the previous theoretical literature related to this field.

Research Methodology

An inductive approach was adopted in this field study, in which the hypotheses were assumed and then tested for validation. Through this approach, the researcher had studied the phenomenon (drivers' attitude towards VSL) on a convenience representative sample of Saudi participants, and then inductive reasoning was used to move from the specific observations that has been found in this study to broad generalizations, where a theory of how Saudi drivers, in general, behave towards VSL was developed.

It is worth noting that inductive reasoning, also referred to as "cause and effect logic," where it is the act of using specific scenarios and reaching general conclusions from them. Accordingly, this study had investigated the behavior of drivers on multi-lane highways in terms of their frequent usage of multilane-highways (familiarity), their commitment to speed, and in terms of their lane-changing response towards traffic congestion, and how does change lane behavior and committing to speed reflect on attitude toward VSL, through the following methodological steps.

Data Acquisition and Preparation

The target population in this study is all drivers of all ages and genders in the Kingdom of Saudi Arabia. The questionnaire was designed to suit the demographic and socio-cultural nature of the target drivers in the Jeddah city. when choosing the sample size, the six multi-lane highways were chosen in Jeddah in the Kingdom of Saudi Arabia, to be the region of the cross-sectional study. A random convenience sample was selected of drivers who work in companies and offices whose arrival requires them to pass through these multi-lane highways, in addition to another group of random drivers who might drive through those multi-lane highways or not and who delivered the survey electronically. This strategy of sampling was chosen in order to ensure that the study sample consisted of the two required types of drivers, those who are commuters (familiar) with those highways and travel and use them regularly, usually for work, and the travelers who rarely use it, which guaranties the researcher's ability to study the effect of the independent factor represented by drivers' familiarity with highways.

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The "Raosoft" calculator was used to determine the required sufficient sample size for this study, taking into account a margin error of 5%, a 95% confidence level, and an expected 50% response rate. Hence, the calculated sample size was 396. Therefore, the researcher conducted an electronically survey on a random sample of 400 drivers, who agreed to participate in the study after the researcher indicated to them that voluntary nature of participation, and that the information provided by them will be dealt with in confidence and will not be used except in the context of scientific research. The researcher delivered the survey form to the respondents electronically via google drive forms and their answers were documented directly.

Table 1: Participants demographic information and their vehicle characteristic

Categorical Variables	Category	N=396	%
Gender	Male (1)	301	76.0
	Female (2)	95	24.0
Nationality	Saudi (1)	346	87.4
	Non-Saudi (2)	50	12.6
Educational level	Undergraduate (1)	56	14.1
	Graduate (2)	212	53.5
	Higher degree (3)	128	32.3
Driving License	No (0)	60	15.2
	Yes (1)	336	84.8
Vehicle size	Small car (1)	278	70.2
	Big car (2)	118	29.8
Vehicle type	Sport car (1)	26	6.6
	Sedan (2)	257	64.9
	Family car (3)	113	28.5

Continues Variables	Minimum	Maximum	Mean	SD
Age	18.00	67.00	32.81	10.49
Driving years	0.00	55.00	12.65	11.43
Traffic violations have been caused by speed in the past two years	0.00	50.00	2.69	4.71
Times have you been involved in a traffic accident	0.00	31.00	1.63	2.28

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Hypotheses and Modeling

In the context of the nature of the current study and according to its objectives of describing the behavior of Saudi drivers towards VSL; the quantitative cross-sectional survey has been used and exploited in this study to create a good understanding of the research topic in addition to the theoretical literature that contributed to enhancing the level of this understanding. This cross-sectional survey will help in obtaining sufficient empirical evidence that enriches and supports the relationship between the different variables.

It should be noted that cross-sectional surveys are observational surveys that are conducted in situations in which the researcher intends to collect data from a sample of the target population at a certain point in time, which justifies the appropriate adoption of it in describing and investigating the patterns of Saudi driver's response to VSL and its relevance to their driving behavior under normal circumstances or traffic congestions.

The quantitative cross-sectional method can uncover patterns in research, which could formulate facts using measurable data; therefore, primary data will be collected with the mean of a survey. This approach is helpful and very common as it helps the researchers to get quantitative insights into the practices that are being applied and adopted by the Saudi drivers in natural conditions without the need to implement any external interventions on these practices and responses.

The study approach was based on developing the research model based on the study's hypotheses and questions, then collect data using quantitative data collection techniques, and then get results by conducting statistical analysis for the collected data. The research model as represented in Figure 1 indicates the assumed three relationships among the study variables.

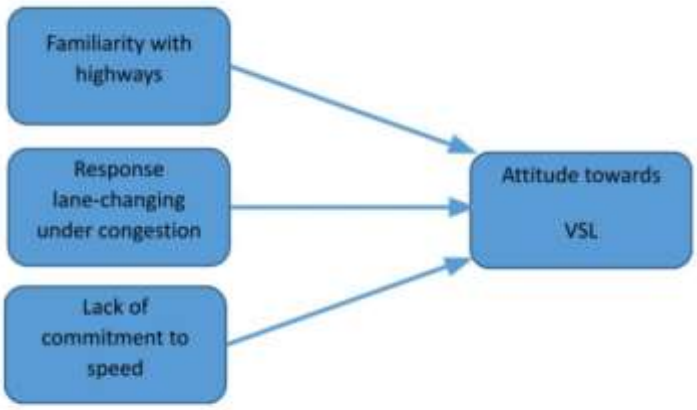

Figure 1. Research Model

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Research Variables and Hypotheses:

According to the previous model, it can be noticed that the model is consisted from three independent variables and another dependent variable, which are as shown below:

- Drivers' attitude towards VSL: It means the driver's reaction towards VSL, which is the extent of the driver's commitment and compliance to the specified speed that appears on the screen of VSL systems.

- Drivers' familiarity with highways: This means the extent of the driver's usage of multi-lane highways , i.e., whether uses regularly, usually , or rarely uses it.

- Drivers' response lane changing under congestion: It means the driving action that drivers take under the specific condition due to traffic congestion, and the response can be measured by driver's lane changing characteristics.

- Lack of drivers' commitment to speed: which refers to deliberate violations of driving rules and the pursuit of high speed and racing, as driving at excessive speeds is often a decisive factor in determining drivers' ability to comply with traffic instructions.

Accordingly, the following hypotheses were assumed to be tested in this study: **H_1:** There is a significant relationship between drivers' familiarity with highways and their attitude towards VSL.

H_2: There is a significant relationship between drivers' response lane changing under congestion and their attitude towards VSL.

H_3: There is a significant relationship between drivers' lack of commitment to speed and their attitude towards VSL.

Data Evaluation, Interpretation and Deployment

A self-administered structured survey was designed in Arabic based on previous valid studies' survey forms including (Hassan et al., 2012; Matowicki & Přibyl (2016), Hellinga & Mandelzys, 2011). The survey form consisted of six different sections and a set of closed-ended questions (statements) directed to drivers and inquiring personal and study related information. The first two parts of the survey inquired about the driver's personal information, and the information related to his/her vehicle. The other four sections inquire about the study main variables including the drivers' familiarity with highways, drivers' responses to lane-changing under traffic congestion, and the drivers' lack of commitment to speed as well as their attitudes towards VSL.

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The survey's statements were scaled using the fourth-point Likert scale, where the respondents were asked to rank their possible responses and actions regarding lane changing encountered under congestion, their lack of commitment to speed as well as their familiarity with the multi-lane highways and their attitudes towards VSL by four response options ranged in value from 0 to 3 ("always" = 3, "seldom" = 2, "sometimes" = 1, "never" = 0) for a positive affirmative statement that reflects the driver's commitment to speed, his lack of lane changing response and his commitment to the VSL's instructions, while this scale was given inverse weights ("always" = 0, "seldom" = 1, "sometimes" = 2, "never" =3) for negative statements that express violations regarding speed limits or lane changing responses as well as his/her commitment to the VSL.

The scale-based method was used to evaluate the main variables of the study, which required determining the weighted average of the participants' responses to statements measuring each variable. Thus, descriptive statistics including mean and standard deviations were computed for each statement as well as the variable to describe the general trends and behaviors of drivers, by identifying the extent of their commitment or violation of traffic rules in terms of speed and lane adherence, their commitment, and acceptance of the VSL, and their familiarity with multi-lane highways. Moreover, the main variables' variations according to the participant's demographic characteristic were assessed by T-test for parametric descriptive and Mann-Whitney test for none- parametric demographic variables with two independent groups such as gender, while one-way ANOVA was used for parametric descriptive statistics where means are compared among three or more independent groups, see Table (4).

Finally, the structural study model and its main hypotheses were analyzed through the person correlation test to examine the validity of acceptance or rejection for the hypotheses of the study and whether there is a relation between the independent variables (drivers' familiarity with highways, drivers' responses lane-changing under traffic congestion and the drivers' lack of commitment to speed) and the dependent variable (drivers' attitudes towards VSL) see Table (5). Also, a multiple linear regression test was used to study the overall fit of the hypothesized model, and to find the rate of factor effects on the dependent variable.

Data analyses were carried through the Statistical Package for Social Science (SPSS) program (Version 22.0). However, before evaluating the hypotheses, it is necessary to verify the reliability and validity of the measurement model. In this study, the survey was validated by presenting the survey to a group of specialists and adjusting it according to their feedback and comments. Moreover, the reliability was verified by conducting a pilot study on a sample of 30 drivers other than the members of the original sample. The reliability of the tool and its components was determined by SPSS' Alpha Cronbach test before distributing the tool to the study sample members and conducting the real study. Table 2 shows the Cronbach alpha values for the overall survey and its different variables.

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Table 2: Reliability by Cronbach Alpha Coefficient for N=30

Construct	Cronbach Alpha	Internal consistency	Items
Familiarity with highways	0.76	Acceptable	7
Response lane changing under congestion	0.72	Acceptable	10
Lack of commitment to speed	0.82	Good	12
Attitude towards VSL	0.77	Acceptable	6
Overall	0.761	Acceptable	35

Table 2 shows that the internal consistency coefficients for each of the four variables and their subscales that were assessed using Cronbach's alpha test. The Cronbach' alpha value was determined to be (0.76) for the first independent factor's items

(Familiarity with highways), (0.72) for the second independent factor's items (Response lane changing under congestion), (0.82) for the third independent factor's items (Lack of commitment to speed), and (0.77) for the dependent factor' items (Attitude towards VSL). Moreover, it was (0.761) for the overall 35 statements, meaning that the tool's reliability is acceptable as long as Cronbach's Alpha values are higher than (0.7) for all of its individual parts as well as the overall part. These results indicate that all of the statements are correlated to its section and the overall sections' statements are related to the survey form and no need for revising or discarding any item. This results also indicate that the measure would generate the same result from one occasion to another, by re-test the test of reliability on overall participants. Thus, the scales used for this study were considered reliable and valid overall (Graham, 2006).

Results and Optimizations

Descriptive statistics

Results in Table 3 showed that there is an average familiarity of drivers with the six multilane highways in the Kingdom of Saudi Arabia (M=1.96, SD=0.55) and that there is a moderate tendency of drivers to change lanes under traffic congestion (M=1.7, SD=0.30) and to exceed the specified speeds (M=1.89, SD= 0.50). This gives the impression that some drivers are familiar with multilane highways, and some are not, and that there is a good percentage of drivers who do not adhere to traffic regulations and who tend to change their lanes and violate speeds, which may in turn affect their behavior and compliance response towards VSL.

However, the mean of attitude towards VSL was high (M=2.49) which gives the impression that drivers always adhere and comply with VSL. This can be related to the presence of a group of respondents who are not familiar with the highways, committed to speed limits, and rarely engage in risky behavior while driving, such as lane changing, which altogether represent motivating behavioral factors for the drivers' commitment to VSL.

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Table 3: Descriptive statistics of the main variables

Variable	Evaluation	Mean	SD
Familiarity with highways	Sometimes	1.96	0.55
Response lane changing under congestion	Sometimes	1.7	0.30
Lack of commitment to speed	Sometimes	1.89	0.50
Attitude towards VSL	Always	2.49	0.63

The impact of socio-demographic variables on drivers' attitude towards VSL

The impact of socio-demographic variables on drivers' attitude towards VSL The drivers' attitude towards VSL may have contrasted by groups according to the participants' demographic characteristics. So, in order to find the difference of drivers' attitudes towards VSL according to socio-demographic variables with two independent groups; such as gender, nationality, and having a driving license, T-test as a parametric test and Mann Whitney as a non-parametric test have been utilized. However, one-way ANOVA was used for comparing means among three or more independent groups of a variable, such as educational level as it showed in Table 4. This analysis gives an indication of the effect of demographic variables on drivers' attitudes towards VSL, and the extent of the differences in the sample individuals in adhering to traffic rules and regulations according to gender, education and nationality.

Table 4: Mean Scores Variations for by Demographic Characteristics

Variable	Demographic characteristic	Statistics		Test Value(P value)
Attitude towards VSL	**Gender**	**Mean**	**SD**	**t (394)= -0.925, P= 0.355(NS)**
	Male (n=301)	2.48	.63	
	Female (n=95)	2.55	.62	
	Nationality	**Mean**	**SD**	**t (394)= 0.929, P= 0.354 (NS)**
	Saudi(n=346)	2.50	.62	
	Non-Saudi(n=50)	2.42	.65	
	Driving License	**Mean**	**SD**	**Mann-Whitney =9423.00, P= 0.411 (NS)**
	No(n=60)	2.39	187.55	
	Yes(n=336)	2.51	200.46	
	Educational level	**Mean**	**SD**	**F (2)= 0.737 , P= 0.479 (NS)**
	High school or less (n=56)	2.40	.64	
	BS (n=212)	2.50	.63	
	High degree (n=128)	2.52	.62	

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According to Table 4 results, it can be noticed that there are no significant differences in means for the attitude towards VSL among study sample due to gender (P=0.35> 0.05), driving license (P= 0.411> 0.05), nationality (P= 0.354> 0.05) or educational level (P=0.479 > 0.05). These results show that Saudi drivers' reaction to VSL is not governed by gender, educational level, or nationality of the driver, as it indicates that drivers of different gender, male or female, and of different levels of education from high school to postgraduate studies, and regardless of their nationality and whether they have a license or not, have a similar response to VSL. Therefore, the difference in the response of Saudi drivers towards VSL may be attributed to other behavioral reasons rather than demographic ones, such as their tendency to violate speed, or the extent of their changing lane response while driving, as well as their familiarity with the road they are driving in, which will be verified below by examining the relationships between these variables and drivers' attitude towards VSL.

Testing Relations between Study Variables

The correlations between the independent variables (the drivers' familiarity with highways, their responses lane-changing under traffic congestion, and lack of commitment to speed) and the dependent variable (drivers' attitude towards VSL) were tested through a bivariate Pearson correlation test in SPSS, in order to verify the possibility of accepting or rejecting the three main hypotheses. The results are as shown in the following Table 5:

Table 5: Pearson Correlations matrix between Variables

	Variable	1	2	3	4
1.	Familiarity with highways	--	--	--	--
2.	Response lane changing under congestion	-0.041	--	--	--
3.	Lack of commitment to speed	0.139**	-0.129*	--	--
4.	Attitude towards VSL	-0.147**	-0.155**	-0.246**	--

* Correlation is significant at the 0.05 level (1 tailed)

** Correlation is significant at the 0.01 level (2 tailed)

The results shown in the previous Table 5 indicate that there is a significant weak negative relationship between the drivers' familiarity with multilane highways and their attitude towards VSL ((p-value=0.003 < 0.01), r = -0.147**), which means that that the attitude and response of drivers who are familiar with multilane highways are negative towards the VSL, indicating that the more the drivers' familiarity and their usage of the road (commuters), the more they will be less responsive to the VSL signs, unlike drivers who are not familiar with the multilane highway network (travelers). This can be justified in a way that familiar drivers may choose a driving route and speed based on experience rather than only indicative information, hence the first hypothesis was accepted.

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Also, the results indicate that there is a significant weak negative relationship between the drivers' response lane changing under traffic congestion in multilane highways and their attitude towards VSL ((p-value= 0.002< 0.01), r = -0.155**), which means that the driver's response under specific physiological conditions due to traffic congestion, which can be measured by changing the driver's lane, may affect their response to the VSL, as high-risk drivers who tend to change lanes frequently in traffic congestion would be less responsive to VSL, compared to other careful and patient drivers. It can be said that drivers who change lanes frequently are less guided and more likely to violate VSLs, due to their risk-taking, irresponsible and aggressive behavior, hence the second hypothesis was accepted.

Furthermore, the results in Table 5 indicate that there is a significant weak negative relationship between the drivers' lack of commitment to speed and their attitude towards VSL ((p-value=0.000< 0.01), r = -0.246**), which means that the reckless and careless manner of drivers and their lack of commitment to speed and their pursuit of high speed and racing in driving negatively affect drivers' ability to comply with VSL, that is, the driver's tendency towards speed and the deviation of his driving style and speed from the average speed is positively related to an increase in the possibility of non-compliance with speed instructions and regulations imposed by VSL, hence the third hypothesis was accepted. For a summary of the results of tested hypotheses, see table 6.

Table 6: Results of tested hypotheses

Hypothesis	Conclusion
H1: **Familiarity with highways** **Attitude towards VSL (-)**	H1: Accepted
H2: **Response lane changing under congestion** **Attitude towards VSL (-)**	H2: Accepted
H3: **Lack of commitment to speed** **Attitude towards VSL (-)**	H3: Accepted

Furthermore, the overall fit of the research hypothesized model is shown in Figure 1 was tested using Multiple Linear Regression which attempts to model the relationship between two or more explanatory variables and a response variable by fitting a linear equation to observed data, Accordingly, the rate of the impact of the independent variables (the drivers' familiarity with highways, drivers' responses lane-changing under traffic congestion and drivers' lack of commitment to speed) on the dependent variable (drivers' attitude towards VSL) was examined through multiple linear regression as well as the direction of this impact. The results were as shown in Table7.

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Table 7: Coefficients of the equation model

Model		Unstandardized Coefficients		Standardized Coefficients	t	Pvalue	R	R Square
		B	Std. Error	Beta				
1	(Constant)	0.934	0.240		3.885	0.000		
	Familiarity with highways	-0.136	0.055	-0.120	2.487	0.013		
	Response lane changing under congestion	-0.405	0.101	-0.193	4.018	0.000	-0.332[a]	0.110
	Lack of commitment to speed	-0.317	0.060	-0.254	5.248	0.000		

The results from Table 7 indicated the coefficients that contribute to the formation of the linear equation that shows the extent to which the independent variables influence the dependent variable (drivers' attitude towards VSL); the linear equation is expressed as follows;

Y= B+ a X1 + bX2+ cX3

Where:

Y= Dependent variable: drivers' attitude towards VSL

B= intercept constant

X1= First independent variable: drivers' familiarity with highways,

X2= Second independent variable: drivers' responses lane-changing under traffic congestion

X3= Third independent variable: drivers' lack of commitment to speed a, b, c= slope coefficients for each of the independent variables

Therefore, the linear equation for the study investigated model would be:

Drivers' attitude towards VSL = 0.934- 0.136* Familiarity with highways - 0.405*Lane changing response -0.317*Lack of speed commitment

From the above Table (7), the multiple correlation coefficient is (R = -0.332) indicating that there is a negative correlation between the integration of Saudi drivers' familiarity with multilane highways, their response of lane changing under traffic congestion and their lack of commitment to speed with their attitudes towards VSL and this correlation is statistically significant ($p=0.000 <0.05$).

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This means that the independent variables (the drivers' familiarity with highways, drivers' responses lane-changing under traffic congestion, and drivers' lack of commitment to speed) and the dependent variable (drivers' attitude towards VSL) change in a different direction, meaning that the increment in drivers' familiarity with highways, their violation of speed limit and driving lane would lead to a decrement response and a negative attitude of drivers towards VSL.

Moreover, the goodness of fit value of (R^2=0.110) indicates that the integration of the three dependent variables: drivers' familiarity with multilane highways, their response of lane changing under traffic congestion and their lack of commitment to speed can explain (11%) of the variation and change in Saudi drivers' attitude towards VSL.

However, in order to identify which of the independent variables have the most influential effect on Saudi drivers' attitude towards VSL, Unstandardized (Beta) coefficients (β) and (α) significance levels in the multiple linear regression were used to test that effect. Table (7) shows that the β coefficients were statistically significant at the significance level ($p < 0.05$) for all of the independent variables. In terms of the strongest effect of the independent variables on Saudi drivers' attitude towards VSL, the level of effect of these independent variables depends on the (β) value, the higher (β) value the higher effect on the dependent variable. Accordingly, the drivers' response lane changing under traffic congestion (β=-0.405) has the strongest effect, followed by drivers' lack of commitment to speed (β= -0.317) and finally followed by drivers' familiarity with multilane highways (β= -0.136) with the least effect.

In other words, the previously calculated degree of impact (β) for each of the dependent variables, indicated that a one-step increase in the drivers' familiarity with multi-lane highways would result in a decrement of drivers' compliance towards VSL by (0.136). In the same manner, the one-step increment in drivers' response lane changing under traffic congestion and drivers' lack of commitment to speed would result in a decrement of drivers' compliance towards VSL by (0.405) and (0.317) respectively. Figure 3 shows the statistical model.

This proved that drivers' driving behavior (lane changing and speed) as well as their familiarity with multilane highways affect their attitudes and compliance towards VSL. Figure 2 shows the summary of the obtained results related to the study statistical model.

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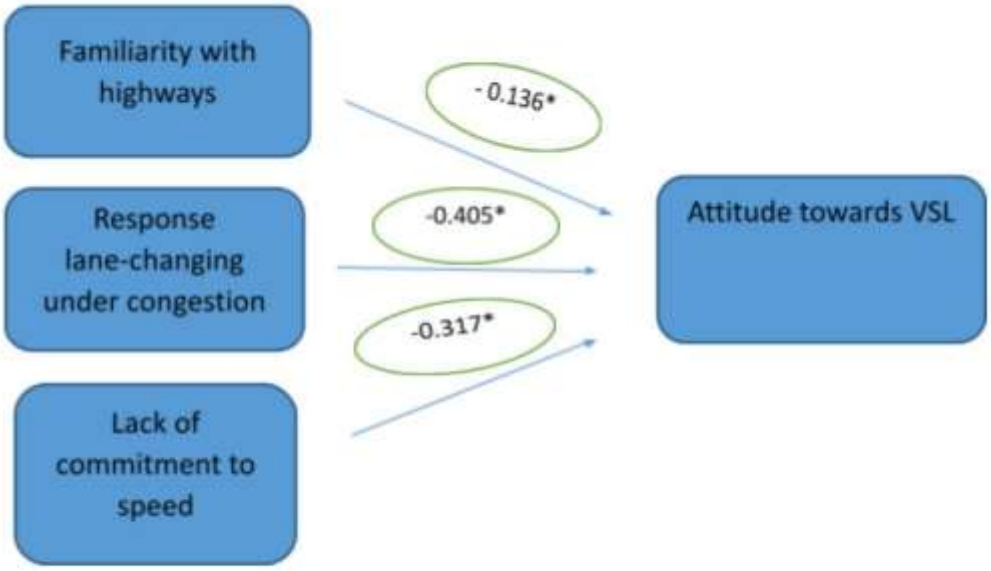

Figure 3: Statistical Model results

Discussion and Conclusions

Nowadays, highway management systems and modern applications in Intelligent Transportation Systems (ITS) provide new mechanisms for managing speed limits which also effectively deal with high traffic volumes and increase road safety. These systems interact in real-time with different traffic situations in order to improve traffic flow characteristics. To achieve this goal, various management strategies are used, such as coordinating speed through variable speed limit (VSL) systems, ramp metering, informing drivers, lane management, and more. In this paper, it was focused on investigating the effectiveness of applying the VSL system in multilane highways of Saudi Arabia, as it is an essential part of most highway management systems in developed countries, and because it has proven effective in improving road safety and managing traffic congestions, yet it has not received much attention in developing countries such as the Kingdom of Saudi Arabia.

It is worth noting that the aforementioned positive effects of VSL are true only when drivers adjust their speed according to VSL system indicators, and this discipline and compliance is influenced by many factors such as demographics, their familiarity with multilane highways, and drivers' driving behaviors such as adhering to their driving lanes, avoiding changing lanes and overtaking, their commitment to speed limits and their avoidance of aggressive and irresponsible driving behaviors.

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Based on the above and in order to obtain more insight into the effectiveness of implementing the VSL system in the Kingdom of Saudi Arabia and the extent of Saudi drivers' compliance with it, this cross-sectional quantitative study was conducted through a field survey on a random sample of 400 Saudi drivers to describe their behavior towards VSL in six multilane highways in Jeddah in the Kingdom of Saudi Arabia as well as linking their attitudes towards it with their frequent use of multi-lane highways, their natural commitment to speed limits, and in terms of their natural response to traffic congestion by changing lanes or remaining in the same lane.

Results showed that there is an average familiarity of Saudi drivers with the six multilane highways, and that there is a moderate tendency of drivers to change lanes under traffic congestion and exceed the specified speeds. This gave an impression that some Saudi drivers are familiar with multilane highways, and some are not, and that there is a good percentage of drivers who do not adhere to traffic regulations and who tend to change their lanes and violate speeds, which may, in turn, affect their behavior and compliance response towards VSL. These results are in line with (Shen et al., 2018) who consider drivers' behavior factors, namely the Positive Driver Behavior Scale (PDBS), that incorporates drivers' compliance with speed limits and their careful driving style and response to lane changing as a motivating factor for the compliance and attitude of drivers towards VSL guidance.

Moreover, Saudi drivers' attitudes towards VSL may be assumed to be contrasted according to their demographic characteristics. According to the survey's results, no significant differences in means for the drivers' attitude towards VSL among study sample have been found due to gender, driving license, nationality, or educational level.

This result shows that Saudi drivers' reaction to VSL is not governed by sociodemographic characteristics where the majority of drivers has a similar response to VSL. This result was contrary to the findings of previous studies such as (Hsssan, 2011; Habtemichael and Santos, 2013; Abojaradeh et al., 2014; Harrington, 2015; Khondaker, 2016; Li et al., 2019; Naghawi & Bannoura 2019) who stated that the level of effectiveness of VSL systems and the level of drivers' compliance to them are mostly related to the personality of the drivers, such as their general and socio-demographic characteristics including age, gender, driving age and educational level.

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Therefore, it can be said that the difference in the response of Saudi drivers towards VSL may be attributed to other behavioral reasons rather than demographic ones, such as their tendency to violate speed, or the extent of their changing lane response while driving, as well as their familiarity with the road they are driving in. The study developed a research model, where three different correlations are hypothesized between the independent variables (the drivers' familiarity with highways, drivers' responses lane-changing under traffic congestion and drivers' lack of commitment to speed) and the dependent variable (drivers' attitude towards VSL). These relations were tested empirically and the results proved the existence of the three hypothesized relationships at the significant level ($p<0.05$).

The first tested hypothesis result indicated that there is a significant negative relationship between the drivers' familiarity with multilane highways and their attitude towards VSL. This was consistent with (Huang et al., 2017) who affirmed that drivers' attitude towards VSL is influenced by their familiarity and frequent usage of multilane highways, where the acceptance rates for VSL of drivers who are unfamiliar with the road network (travelers) are higher than familiar drivers (commuters) because familiar drivers may choose a driving route and speed based on experience rather than only indicative information. However, Roos and Kazemi (2018) found that drivers' attitude towards VSL was unrelated to drivers' overall road network usage and to their familiarity with it, which contradicts the obtained results of this study.

Regarding the second result for the tested hypotheses, it was shown that there is a significant negative relationship between the drivers' response lane changing under traffic congestion and their attitude towards VSL. This was also consistent with (Habtemichael & Santos, 2013; Qi et al.2013) who stated that in many cases, the level of violations towards VSL committed by high risky drivers, who tend to change lanes frequently under traffic congestion situation and tend to overtake other vehicles, are more than other careful and patient drivers. It can be said that frequent lane-changing drivers are less guided and more susceptible to violate VSL indications.

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Finally, the result of the last tested third hypothesis showed that there is a significant negative relationship between the drivers' lack of commitment to speed and their attitude towards VSL. This was affirmed and emphasized by Studies including (Eboli et al., 2017; Matowicki & Přibyl, 2016) who indicated that reckless and careless style, which refers to deliberate violations of driving rules and the pursuit of high speed and racing, like driving at excessive speeds is often a decisive factor in determining drivers' ability to comply with traffic instructions and VSL system. It was indicated by previous studies including (Khondaker, 2016; Hellinga et al., 2010) that the deviation of vehicle speed from the average speed is positively associated with the increased likelihood of non-adherence to speed guidelines and regulations imposed by VSL, especially for arterial highways and free highways.

In conclusion, the study revealed that the behavior of Saudi drivers on multi-lane highways in terms of their frequent usage of multilane-highways (familiarity), their commitment to speed, and in terms of their lane-changing response towards traffic congestion have a significant effect on their attitudes towards VSL. This finding would be helpful for traffic engineers and traffic safety authorities in Saudi Arabia and other countries to focus on significant drivers' behavior criteria to solve road issues and developing systems that help in managing traffic congestion in cities and optimizing traffic safety and efficiency in multilane highways networks. Moreover, **the study recommends** expanding the scope of the research to include other multilane highways in all region of Saudi Arabia such as Dammam, Riyadh, etc. in a way that adds comprehensiveness and generality to the results of this study.

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