An Investigation into Unsafe Behaviors and Traffic Accidents Involving Unlicensed Drivers: A Perspective for Alignment Measurement

Wafa Boulagouas $^{1,2}$, Susana García-Herrero $^2$, Rachid Chaib $^1$, Juan Diego Febres $^3$, Miguel Ángel Mariscal $^2$ and Mëbarek Djebabra $^4$

$^1$ Laboratory of Transportation Engineering and Environment, Department of Transportation Engineering, Faculty of Technology Sciences, University of Mentouri, Constantine 1, Constantine 25017, Algeria; wafa.boulagouas@umc.edu.dz (W.B.); rchaib@umc.edu.dz (R.C.)
$^2$ Escuela Politécnica Superior, University of Burgos, 09006 Burgos, Spain; mariscal@ubu.es
$^3$ Department of Chemistry and Exact Sciences, Universidad Técnica Particular de Loja, Loja 110107, Ecuador; jdfebres@utpl.edu.ec
$^4$ Laboratory of Industrial Prevention Research, Health and Industrial Safety Institute, University of Batna 2, Batna 05078, Algeria; m.djebabra@univ-batna2.dz

* Correspondence: susanagh@ubu.es

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Abstract: Road traffic plays a vital role in countries’ economic growth and future development. However, traffic accidents are considered a major public health issue affecting humankind. Despite efforts by governments to improve traffic safety, the misalignment between the policy efforts and on-ground infringements, distractions and breaches reflect the regulatory failure. This paper uses the Bayesian network method to investigate unsafe behaviors and traffic accidents involving unlicensed drivers as a perspective for the regulatory alignment assessment. The findings suggest that: (1) unlicensed drivers are more likely to have unsafe driving behaviors; (2) the probability of being involved in a severe traffic accident increases when the drivers are unlicensed and decreases in the case of licensed drivers; (3) young drivers are noticeably more likely to engage in unsafe behaviors, usually leading to serious injuries and deaths, when their driving licenses are invalid; (4) women are more likely to engage in right-of-way violations and to have collisions with no serious injuries, contrary to unlicensed men drivers, who are involved in other types of traffic accidents resulting in serious injuries.

Keywords: alignment; regulatory; behaviors; drivers; Bayesian; network; traffic; accidents; unlicensed; unsafe

1. Introduction

Traffic safety has become a major public health concern all around the world [1–3]. The traffic safety problem is multidimensional, and many risk factors, i.e., technical factors (vehicles), environmental factors (the road and infrastructures), human factors (the road users) and their interactions, contribute to causing crashes [4–6]. Generally, two approaches to traffic safety studies have been established so far [7,8]. The first approach focuses on advancing engineering and enhancing traffic infrastructures, and the second approach is interested in the driver’s individual factors and driving behaviors. Indeed, these two approaches are complementary to each other within the systems perspective of Vision Zero [9]. This global vision is conditioned by the efficiency of the abovementioned approaches and involves a mix of initiatives to address safe mobility issues, i.e., vehicle safety, safety of infrastructures and promotion of road users’ behaviors [10,11].
In recent years, governments all around the world have undertaken several initiatives to enhance traffic safety through [12,13]: (1) preventive measures in terms of education and information (i.e., communication campaigns and road safety advertisements); (2) corrective or sanctioning measures (i.e., coactive dissuasion and severe criminal penalties); (3) softer regulations based on economic sanctions (i.e., fines and insurance payments); and (4) license deprivation sanctions (i.e., suspension or withdrawal). Although the fundamental purpose of these regulations is to manipulate the conditions to change drivers’ behaviors and improve the results, the misalignment between policy efforts and breaches and on-ground traffic accidents reflects regulatory failure [14], hence the importance of the regulatory alignment assessment.

Regulatory alignment has firstly been used in the industrial workplace context and refers to the supportive attitudes, alignment and adherence to safety guidelines and policies to maintain an acceptable level of safety at the workplace [15,16]. To assess regulatory alignment, two main approaches have been adopted. The first approach, proactive in nature, investigates the outcomes of the implemented regulations (i.e., the number of accidents and fatalities), and the second approach, which is reactive, considers the assessment of the unsafe behaviors of the drivers, for instance, unlicensed driving, poor driving practices, disregarding the traffic signals and signs, and deliberate deviations from the recommended safe behaviors [17,18]. The first approach has been criticized due to its reactive nature and the fact that it cannot provide early warning information to empower authorities to take action prior to accidents. Thus, there has been a shift towards using leading indicators, such as unsafe behaviors, to more effectively measure the regulatory alignment and secure traffic safety goals [19,20].

Extensive studies have recognized the contribution of unsafe driving behaviors in traffic accidents and emphasized their overrepresentation in crashes, injuries and mortalities [21]. A review conducted to analyze 10 years of data (2005–2014) of fatal road crashes noted that unlicensed drivers were involved in 10% of fatal road crashes [22]. Likewise, an epidemiological study conducted in Japan on risk factors of fatality in traffic accidents found that the risk of fatal traffic accidents was higher among the unlicensed drivers [23]. It is noteworthy that when addressing unsafe driving behaviors, many research studies tended to examine the influence of additional risk factors (e.g., individual factors) as a way to characterize the traffic accidents. For instance, a study analyzing the changes in driving behaviors [24] found a significant relationship between the age and gender of the drivers and unsafe behaviors, i.e., violations, errors and lapses. Further, an analysis study of traffic accidents in China [25] asserted that males are overconfident, risk takers and less likely to respect traffic laws, and concluded that these drivers are at high risk of causing fatigue-related crashes.

Although much valuable knowledge has been obtained from the aforementioned studies, there is still little known about the relationship between unlicensed driving and other aberrant behaviors, on the one hand, and regulatory alignment and traffic accidents, on the other hand. To extend research beyond these trends, this paper conceptualizes the assessment of regulatory alignment of drivers considering the driving performance of unlicensed drivers.

There are good reasons to consider unlicensed driving an isolated risk behavior and to assess its moderating effect on the regulatory alignment. First, unlicensed driving negatively impacts the integrity of the driving management system [26]. That is to say, due to its illegal nature, it is difficult to estimate the driving performance of unlicensed drivers and their qualifications. Second, even though driving without a valid driving license is said to play an indirect causative role in traffic accidents, it is noteworthy that for many countries, it is still a serious problem, and many researchers [27–29] have suggested that there are behavioral differences between the aligned and the misaligned drivers that might be responsible for traffic accidents and their severe consequences. Finally, the purpose of the driving licensing system is identifying, monitoring and enforcing drivers’ behaviors using many programs and technologies (e.g., speed cameras) to facilitate the application of penalties and sanctions to traffic offenders. However, unlicensed driving is outside the licensing system, and it prevents authorities from tracking and managing unsafe behaviors [30].
This study investigates drivers’ unsafe behaviors and violations and the factors concerning traffic accidents considering driving license status and the influence of demographic variables (i.e., gender and age) as a way to better measure the regulatory alignment. Thus, it contributes to the literature in several ways. First, considering the growing concerns related to unlicensed driving and questions about the magnitude of traffic accidents involving unlicensed drivers, the present study examines their severity in depth. Second, whereas previous studies discussed unlicensed driving mainly as part of unsafe driving behaviors, this paper considers it as a separate risk behavior: it investigates the behaviors of the unlicensed drivers and elaborates the mechanism by which their behaviors are influenced by demographic factors so as to proactively measure the regulatory alignment and enable policymakers to set proper corrections. Finally, to overcome the shortcoming of the approaches used in road safety research and allow better estimation of the risk and uncertainties, the present paper uses the Bayesian network methodology to model the interplay between the driving license status and the behaviors of the drivers and therefore assess the impact of the influential factors, i.e., the demographics. For conceptual clarity, in this paper, the term “traffic accident” is used to refer to the road accidents involving motor vehicles and occurring on roads open to public circulation. The traffic accidents are studied based on two factors: the type (i.e., collision, run over and other types), and the severity of the outcomes (none/mild or severe injuries/death).

2. Materials and Methods

2.1. Bayesian Network

Road safety has been approached by many disciplines, for instance, transportation engineering, economics, social sciences, psychology and safety research, and each discipline examines a particular facet. Most studies deploy frequentist approaches, which are ad-hoc and account only for the expected values and do not carry the force of deductive logic [31]. As a response to the limitation of the frequentist methods, and to model the interplay between driving license status and drivers’ behaviors and to assess the impact of influential factors, the present study uses the Bayesian Network to derive posterior distributions from prior knowledge on the considered factors.

The deployment of the Bayesian methodology in recent decades has been developed for various subject areas for learning, modeling, forecasting and decision-making [32,33]. As regards the regulatory alignment and traffic safety research, Bayesian networks have been used to assess the safety impact of red-light cameras on the reduction of traffic signal violations [34], predict road safety hotspots [35], analyze the causation of road accidents [36,37], measure the influence the drivers’ behaviors and psychophysical factors on injury severity and distractions [38], measure the influence of the seat-belt use on the traffic accidents severity [39] and analyze the role of the journey purpose in road traffic injuries [40].

The Bayesian network is a formalism that combines graph and probability theory to provide a compact and natural representation offering effective inference and efficient learning [41]. The directed acyclic graph (DAG) represents the structure of the Bayesian network and qualifies the causal relationship between the variables of interest, while probability theory is responsible for the quantification of the network, that is, the quantification of the probabilistic causal relationships between the variables through the joint probability distribution (Equation (1)) based on the Bayes theorem (Equation (2)) [42]:

\[
P(X_1, \ldots, X_n) = \prod_{i=1}^{n} P(X_i | \text{Parents}(X_i))
\]

\[
P(A|B) = \frac{P(B|A)P(A)}{P(B)}
\]
where \( P(X_1, \ldots, X_n) \) reflects the joint probability distribution, Parents (Xi) are parents of Xi, \( P(A|B) \) is the a posteriori probability, \( P(A) \) is the a priori probability and \( P(B|A) \) is the verisimilitude.

In this way, Bayesian networks consider the direct and conditional statistical dependencies between all of the study variables in one model. This flexibility allows the measurement of the influence of one or more variables on the target variable based on the a priori and a posteriori probabilities.

2.2. Validation Techniques

2.2.1. Cross-Validation

The practicability of the obtained Bayesian network and its accuracy are assessed using the K-fold cross-validation approach, and the Bayes Net Toolbox [43,44] for Matlab [45] is deployed to perform the cross-validation, generate the Bayesian Network and compute the sensitivity analysis.

In this study, a 10-fold cross-validation has been considered. Accordingly, the data were divided into 10 folds, each containing 10% of the sample, and 90% of the sample was used to predict the sample in each of the corresponding folds. This operation was repeated ten times, and the entire sample prediction was obtained by joining the 10 folds. The evaluation of model skills was therefore measured using the area under the receiver operating characteristic (ROC) curve, called AUC. This standard measure for probabilistic and binary classifiers ranges between 0 and 1, where less than 0.5 corresponds to opposite and wrong predictions, 0.5 implies random prediction and non-reliable model and 1 refers to a perfect prediction and denotes that the model is reliable.

2.2.2. Z-Test

To validate the conclusions driven from the sensitivity analysis, the statistical Z-test was used to measure the significance of the differences between the initial and a posteriori probabilities through the following hypotheses [46,47]:

\[
\begin{align*}
H_0 & : P_1 = P_2 \\
H_A & : P_1 \neq P_2
\end{align*}
\]  

where \( P_1 \) is the initial probability and \( P_2 \) is the a posteriori probability.

Under the assumption of binomial distribution, the statistic test, \( Z_0 \), is given by Equation (4):

\[
Z_0 = \frac{P_1 - P_2}{\sqrt{\frac{P_1 (1-P_1)}{n_1} + \frac{P_2 (1-P_2)}{n_2}}}
\]  

where \( n_1 \) and \( n_2 \) are populations of the probabilities \( P_1 \) and \( P_2 \), respectively.

2.3. Data Acquisition

The dataset for the study was prepared from three years of official data (2016, 2017 and 2018) of traffic accidents in Spain. The original data were provided by the Traffic National Department of Spain and are made up of three databases: accidents, drivers and vehicles databases [48]:

- The drivers database contained data about the drivers involved in the accidents, for instance, age, gender and unsafe driving behaviors.
- The accidents database contained data about the type of accidents and the severity of the injuries, zone, etc.
- The vehicles database contained data about the vehicles involved in the accidents, for instance, the type of the vehicle, vehicle inspection and insurance.

In general, the three databases contained a total of 169 statistical elements (variables) collected from the “Form of Traffic Accidents with Victims” and 306,894 registered traffic accidents in which 524,785 drivers and 539,772 vehicles were involved. Each traffic accident has been registered with a unique registration ID; however, one or more driver(s)/vehicle(s) could have been involved in any
registered traffic accident. The traffic accidents involving stationary vehicles, i.e., without drivers, were considered too.

For the purpose of the present study, the dataset used was obtained by filtering the original drivers’ database to consider only car and motorcycle drivers and the study key variables, which were grouped into objective variables, i.e., the driving behaviors of the drivers and the traffic accident factors; the variables affecting the behaviors, i.e., the influential variables; and one evidence variable, i.e., the driving license (Figure 1). In doing so, the final dataset contains only a total of 467,431 drivers.

![Figure 1. The variables of the sub-database used.](image)

### 2.4. Study Variables

In the present study, special attention is paid to the unsafe behaviors of drivers based on the driving license status (Table 1). Unlicensed driving is defined as operating illegally motor vehicles on the road, putting these drivers themselves and other legitimate drivers at great risk [49]. In the context of the present study, the target variable is the driving license, including valid driving license and invalid driving license, which entails not only driving prior to the eligible age for licensing but also those unlicensed due to license expiration, suspension and cancellation, or inappropriate class of the license.

| Driving License | Number of Cases       | Total   | Percentage | Comments                                           |
|-----------------|-----------------------|---------|------------|---------------------------------------------------|
| Valid           | 85,321 84,284 83,701 25,3306 | 54.19%  | Correct driving license                            |
| Invalid         | 2532 2139 2386 7057   | 1.51%   | Inappropriate, expired, canceled, suspended, never had, total loss of points |
| Other           | 67,857 69,562 69,649 207,068 | 44.30%  | The cases in which information about the driving license status are incomplete/not provided in the accident reports |

The objective variables are therefore the unsafe behaviors of drivers and traffic accident factors. In this study, unsafe behaviors were grouped into four main groups: distractive behaviors, speed infringement, other infringements and right-of-way violations (Table 2). As regards the traffic accident factors, two variables were considered, the type of the traffic accident—collision, run over and others—and the severity of the traffic accident, i.e., no-injury or mild injuries and serious injuries or death (Table 3).
Table 2. Frequencies of drivers’ behaviors.

| Unsafe Behaviors                          | Number of Cases | Total    | Percentage | Comments                                                                                           |
|-------------------------------------------|-----------------|----------|------------|---------------------------------------------------------------------------------------------------|
|                                           | 2016 | 2017 | 2018 |                                        |                                                                                                  |
| **Right-of-way violations**                |      |      |      |                                                  |                                                                                                  |
| No                                        | 50,530 | 48,676 | 48,417 | 147,623 | 31.58%                                              | Non-respect of traffic signals, indications of a traffic agent or crosswalk, or similar reckless maneuvers, and others |
| Yes                                       | 32,597 | 33,666 | 34,117 | 100,380 | 21.47%                                              |                                                                                                  |
| Unknown                                   | 72,583 | 73,643 | 73,202 | 219,428 | 46.94%                                              | /                                                                                                  |
| **Speed limit infringement**               |      |      |      |                                                  |                                                                                                  |
| No                                        | 65,579 | 64,692 | 62,393 | 192,664 | 41.22%                                              | /                                                                                                  |
| Yes                                       | 8423  | 7674  | 7880  | 23,977  | 5.13%                                               | Inadequate and excessive speed for road conditions or the established legal speed                   |
| Unknown                                   | 81,708 | 83,619 | 85,463 | 250,790 | 53.65%                                              | /                                                                                                  |
| **Other infringements**                    |      |      |      |                                                  |                                                                                                  |
| No                                        | 59,762 | 60,196 | 60,133 | 180,091 | 38.53%                                              | /                                                                                                  |
| Yes                                       | 578   | 572   | 562   | 1712    | 0.37%                                               | Driving without lights, dazzling, overload in the vehicle, open doors, excess occupants and similar |
| Unknown                                   | 95,370 | 95,217 | 95,041 | 285,628 | 61.11%                                              | /                                                                                                  |
| **Distractions**                           |      |      |      |                                                  |                                                                                                  |
| Technology-based distractions              | 326   | 371   | 354   | 1051    | 0.22%                                               | Use of mobile phone, GPS, hands-free, radio, DVD and similar                                        |
| Other distractions                         | 8767  | 9673  | 10,042 | 28,482  | 6.09%                                               | smoking, interactions with occupants, thoughtful or abstracted, sleepy and similar                  |
| Unknown                                   | 107,813 | 107,057 | 106,483 | 321,353 | 68.75%                                              | /                                                                                                  |
Table 3. Frequencies of traffic accident factors.

| Traffic Accident Factors | Number of Cases | Total | Percentage | Comments |
|--------------------------|-----------------|-------|------------|----------|
|                          | 2016            | 2017  | 2018       |          |
| Traffic accident severity|                 |       |            |          |
| None/mild                | 142,783         | 142,946 | 143,530   | 429,259  | 91.86%   |
| Serious injury/death     | 12,890          | 12,967 | 12,163     | 38,020   | 8.14%    | Serious or fatal traffic accident |
| Total                    | 155,673         | 155,913 | 155,693   | 467,279  | 100%     |
| Traffic accident type    |                 |       |            |          |
| Collision                | 119,137         | 116,680 | 115,177   | 350,994  | 75.11%   | Frontal, side, multiple collision, collision by range or against obstacle |
| Run over                 | 13,169          | 12,576  | 12,302     | 38,047   | 8.14%    | Running over a person or an animal |
| Other                    | 23,367          | 26,657  | 28,214     | 78,238   | 16.74%   | / |
| Total                    | 155,673         | 155,913 | 155,693   | 467,279  | /        | / |
The regulatory alignment in the context of road safety is a multidimensional construct and includes a wide range and multivariate combination of influencing factors, for instance, age, gender, decision-making behavior, personality, visibility, road type, zone, time and weather consideration and vehicle characteristics [50,51]. In the present study, the influential factors were grouped into three categories considering the available data: individual factors, situational factors and vehicle factors. However, the interplay between unlicensed driving and unsafe behaviors was assessed considering only the influence of the first group of factors, i.e., the individual factors, which include two demographic variables: age and gender of the drivers (Table 4).

### Table 4. Frequencies of the individual factors.

| Influential Factors | Number of Cases | Total | Percentage |
|---------------------|-----------------|-------|------------|
|                     | 2016            | 2017  | 2018       |
| **Age**             |                 |       |            |
| <25                 | 21,541          | 20,962| 20,248     | 62,751 | 13.42% |
| 25–40               | 60,012          | 58,462| 57,984     | 176,458 | 37.75% |
| 41–60               | 54,369          | 55,976| 57,696     | 16,8041 | 35.95% |
| >60                 | 16,604          | 17,393| 17,627     | 51,624  | 11.04% |
| Unknown             | 3184            | 3192  | 2181       | 8557    | 1.83%  |
| **Gender**          |                 |       |            |
| Men                 | 110,443         | 111,068| 111,061   | 332,572 | 71.15% |
| Women               | 43,971          | 43,711| 44,128     | 13,1810 | 28.20% |
| Unknown             | 1296            | 1206  | 547        | 3049    | 0.65%  |

### 3. Results

#### 3.1. The Bayesian Network Validation

As explained in the methodology section, the validation of the obtained model was performed with a 10-fold cross-validation method and the results are given in Table 5.

### Table 5. The obtained AUC for the objective variables.

| Objective Variables | Area Under the Curve (AUC) |
|---------------------|-----------------------------|
| Right-of-way violations | No  | Yes | Unknown |
| 0.90 | 0.85 | 0.96 |
| Speed infringement | No  | Yes | Unknown |
| 0.94 | 0.82 | 0.95 |
| Other infringements | No  | Yes | Unknown |
| 0.94 | 0.53 | 0.94 |
| distractions | No  | Technology-based distractions | Other distractions | Unknown |
| 0.91 | 0.69 | 0.85 | 0.91 |
| Traffic accident type | Collision | Run-over | Other |
| 0.69 | 0.75 | 0.77 |
| Traffic accident severity | None/mild | Serious injury/death |
| 0.76 | 0.76 |
All of the AUC scores range between 0.69 and 0.96 (with the exception of the affirmative status of the other infringements variable). These scores reflect the accuracy and high performance of the learned Bayesian network and confirm the practicability of the proposed approaches.

3.2. Z-Test

The differences between the probabilities used in the discussion of the sensitivity analysis results were examined using the statistical Z-test (results are given in Appendix A). The Z-test was conducted considering a confidence interval $\alpha$ of 95% (an admissible error of 5%) in a binomial distribution that proposes as limits +/-1.96 with $Z_{0.02}$. To this end, all differences whose Z values are less than −1.96 or greater than 1.96 are acceptable statistical differences and significant.

3.3. Sensitivity Analysis

3.3.1. Sensitivity Analysis of the Objective Variables Considering the Driving License Status

The initial probabilities for each of the objective variables considering the driving license status were computed, and results are given in Tables 6 and 7. A confidence interval of 95% was considered to assess the statistical significance of the probabilities change.

**Table 6.** Probabilities of the safe behaviors of the drivers and traffic accident severity considering the driving license status.

| Objective Variables | Valid Driving License | Invalid Driving License |
|---------------------|-----------------------|-------------------------|
| Safe behaviors       |                       |                         |
| No right-of-way violations | 50.84% * | 23.27% * |
| No speed infringement | 67.03% * | 31.80% * |
| No other infringements | 63.09% * | 34.96% * |
| No distractions      | 43.49% * | 18.26% * |
| Traffic accident severity | 90.79% * | 82.88% * |

Values highlighted with an asterisk, *, are statistically significant at a 95% confidence level.

**Table 7.** Probabilities of the unsafe behaviors of the drivers and traffic accident factors considering the driving license status.

| Objective Variables | Valid Driving License | Invalid Driving License |
|---------------------|-----------------------|-------------------------|
| Unsafe behaviors     |                       |                         |
| Right-of-way violations | 35.08% * | 27.79% * |
| Speed infringement   | 8.01% * | 12.38% * |
| Other infringements  | 0.60% * | 0.39%     |
| Distractions         |                       |                         |
| Technology-based distractions | 0.37% * | 0.44% * |
| Other distractions   | 10.42% * | 10.55% * |
| Traffic accident severity |       |                         |
| Serious injury or death | 9.21% * | 17.12% * |
| Traffic accident type |                       |                         |
| Collision            | 77.65% * | 73.56% * |
| Run over             | 8.37% * | 9.11% *  |
| Others               | 13.98% * | 17.33% * |

Values highlighted with an asterisk, *, are statistically significant at a 95% confidence level.
The results in Table 6 show that the probabilities of the licensed drivers having safe driving behaviors are almost two times the probabilities of the unlicensed drivers.

For instance, the probability of committing no right-of-way violations when drivers are licensed is 50.84%, while the probability decreases to 23.27% when the drivers are unlicensed. Similarly, the probability of being involved in a minor traffic accident with no injuries is high at 90.79% when the drivers are licensed, and the probability decreases to 82.88% when the drivers have an invalid driving license.

However, according to Table 7, the probability of speeding is high when drivers are unlicensed, i.e., 12.38%, and decreases to 8.01% when the drivers have a valid driving license. In the case of right-of-way violations, the results show that licensed drivers have the highest probability, i.e., 35.08%, which decreases to 27.79% in the case of unlicensed drivers.

As regards the severity of traffic accidents, the probability of having a serious traffic accident leading to death is 9.21% when drivers are licensed and increases to 17.12% when the drivers have invalid driving licenses (a difference of 7.91%).

As far as the types of traffic accident, results show that the probability of having a collision is high in the case of licensed drivers, i.e., 77.65% and decreases to 73.56% in the case of unlicensed drivers; however, the probabilities of run-overs and other types of traffic accidents are high in the case of unlicensed drivers, i.e., 9.11% and 17.33% respectively.

According to these results, the status of the driving license is likely to have an important impact on the driving behaviors of drivers and the severity of traffic accidents.

3.3.2. Sensitivity Analysis of the Objective Variables Considering the Driving License Status and the Individual Factors

According to the objective of the present paper and considering the learned Bayesian network that includes the joint probability distribution of the study variables, a sensitivity analysis was conducted to measure (1) the influence of individual factors and driving license status on drivers’ behaviors and (2) the influence of individual factors and driving license status on the type and severity of traffic accidents. A confidence interval of 95% has been considered to assess the statistical significance of probability change.

3.3.3. Sensitivity Analysis of the Probabilities of the Drivers’ Behaviors Based on the Driving License Status and the Individual Factors

As regards the influence of individual factors, the sensitivity analysis results of Table 8 show that the probability of engaging in right-of-way violations increases from 27.79% (initial probability) in the case of the young unlicensed drivers (<25 years old) to 28.39% (a difference of 0.6%), and from 27.79% (initial probability) to 29.86% (a difference of 2.07%) in the case of older unlicensed drivers (>60 years old).

The probability of compliance with speed limits increases in the case of drivers older than 40 years old, regardless of the status of their driving licenses. However, the probability decreases when drivers are younger than 25 years old from 67.03% (initial probability) to 60.34% (a difference of 6.69%) in case of valid driving licenses and from 31.80% (initial probability) to 26.98% (a difference of 4.82%) in the case of invalid driving licenses. Similarly, the results show that the probability of committing speed infringement increases in the case of the young licensed drivers by 6.47% and by 9.21% when they are unlicensed. However, in the case of the older drivers (>60 years old), the probability decreases regardless of the status of their driving licenses. The probability of not having other infringements increases in the case of the older licensed drivers (>60 years old) by 2.75% and decreases by 1.87% in the case of young licensed drivers (<25 years old).

For distracted driving behaviors, the sensitivity analysis results show that the probability of having no distracted driving decreases in the case of the young licensed drivers (<25 years old) by 2%. However, the probability increases by about 2% in the case of older licensed drivers (>60 years old).
Table 8. Probabilities for the behaviors of the drivers based on the driving license status and the age of the drivers.

| Objective Variables       | Initial Probabilities | Age | Driving License |
|---------------------------|-----------------------|-----|-----------------|
|                           |                       |     | Valid           | Invalid | Other |
|                           | Valid                 | Invalid |       |       |       |
|                           | <25                   | 50.09% * | 23.31% * | 8.09% * |       |
|                           | 25 ≤ Y ≤ 40           | 50.44% * | 23.35% * | 8.10% * |       |
|                           | 40 < Y ≤ 60           | 51.31% * | 23.73% * | 8.62% * |       |
|                           | Y > 60                | 51.08% * | 25.24% * | 9.08% * |       |
|                           | Unknown               | 59.66% * | 6.02% * | 5.67% * |       |
|                           | Yes                   | 35.08% * | 27.79% * |       |       |
|                           | <25                   | 33.66% * | 28.39% * | 4.45% * |       |
|                           | 25 ≤ Y ≤ 40           | 35.10% * | 28.41% * | 4.61% * |       |
|                           | 40 < Y ≤ 60           | 35.26% * | 27.54% * | 4.73% * |       |
|                           | Y > 60                | 36.47% * | 29.86% * | 5.29% * |       |
|                           | Unknown               | 28.49% * | 8.45% * | 2.31% * |       |
| Right-of-way violations   | No                    | 50.84% * | 23.27% * |       |       |
|                           | Yes                   | 35.08% * | 27.79% * |       |       |
|                           | <25                   | 50.09% * | 23.31% * | 8.09% * |       |
|                           | 25 ≤ Y ≤ 40           | 50.44% * | 23.35% * | 8.10% * |       |
|                           | 40 < Y ≤ 60           | 51.31% * | 23.73% * | 8.62% * |       |
|                           | Y > 60                | 51.08% * | 25.24% * | 9.08% * |       |
|                           | Unknown               | 59.66% * | 6.02% * | 5.67% * |       |
| Speed infringement        | No                    | 67.03% * | 31.80% * |       |       |
|                           | Yes                   | 8.01% * | 12.38% * |       |       |
|                           | <25                   | 60.34% * | 26.98% * | 8.99% * |       |
|                           | 25 ≤ Y ≤ 40           | 65.71% * | 31.16% * | 9.64% * |       |
|                           | 40 < Y ≤ 60           | 69.26% * | 34.02% * | 10.59% |       |
|                           | Y > 60                | 72.01% * | 38.56% * | 11.69% |       |
|                           | Unknown               | 66.50% * | 8.15% * | 5.94% * |       |
|                           | No                    | 63.09% * | 34.96% * |       |       |
|                           | Yes                   | 0.60% * | 0.39% * |       |       |
|                           | <25                   | 41.54% * | 18.04% * | 2.57% * |       |
|                           | 25 ≤ Y ≤ 40           | 43.11% * | 18.36% * | 2.45% * |       |
|                           | 40 < Y ≤ 60           | 43.81% * | 18.49% * | 2.49% * |       |
|                           | Y > 60                | 45.42% * | 20.64% * | 2.84% * |       |
|                           | Unknown               | 39.20% | 7.37% * | 2.35% * |       |
|                           | No                    | 43.49% * | 18.26% * |       |       |
|                           | Yes                   | 0.60% * | 0.39% * |       |       |
|                           | <25                   | 41.54% * | 18.04% * | 2.57% * |       |
|                           | 25 ≤ Y ≤ 40           | 43.11% * | 18.36% * | 2.45% * |       |
|                           | 40 < Y ≤ 60           | 43.81% * | 18.49% * | 2.49% * |       |
|                           | Y > 60                | 45.42% * | 20.64% * | 2.84% * |       |
|                           | Unknown               | 52.71% * | 3.92% * | 0.46% * |       |
| Other infringements       | No                    | 10.42% * | 10.55% * |       |       |
|                           | Yes                   | 0.60% * | 0.39% * |       |       |
|                           | <25                   | 10.40% * | 10.85% * | 0.71% * |       |
|                           | 25 ≤ Y ≤ 40           | 10.41% * | 10.75% * | 0.67% * |       |
|                           | 40 < Y ≤ 60           | 10.34% * | 10.45% * | 0.65% |       |
|                           | Y > 60                | 10.91% * | 11.57% * | 0.72% * |       |
|                           | Unknown               | 6.35% | 2.49% * | 0.15% * |       |

Values highlighted with an asterisk, *, are statistically significant at a 95% confidence level.
Results of the sensitivity analysis of the influence of the gender variable on the behaviors of the drivers, considering the status of the driving license, are given in Table 9. In general, these results propose that the variable gender does not have an important influence on the driving behaviors of the drivers, regardless of the driving license status. However, some slight changes in the probabilities can be noticed. For instance, the probability of not engaging in right-of-way violations in the case of licensed men drivers shows an increase of 0.63%. However, the probability of engaging in these aberrant behaviors increases by about 2% in the case of women drivers regardless of the driving license status. For speed limit infringement, the probability increases by 0.48% in the case of the unlicensed men drivers.

Table 9. Probabilities for the behaviors of the drivers based on the driving license status and the gender of the drivers.

| Objective Variables | Initial Probabilities | Gender | Driving License |
|---------------------|-----------------------|--------|----------------|
|                     | Valid | Invalid | Men | Valid | Invalid | Other |
| Right-of-way violations | No    | 50.84%* | 23.27%* | Women | 49.37%* | 23.16%* | 8.27%* |
|                     | Yes    | 35.08%* | 27.79%* | Unknown | 32.44%* | 27.69%* | 4.57%* |
| Speed infringement | No    | 67.03%* | 31.80%* | Men | 67.01%* | 31.93%* | 9.98%* |
|                     | Yes    | 8.01%*  | 12.38%* | Women | 7.91%* | 11.43%* | 1.36%* |
| Other infringements | No    | 63.09%* | 34.96%* | Unknown | 56.15%* | 10.41%* | 4.85%* |
|                     | Yes    | 0.60%*  | 0.39%* | Men | 0.60%* | 0.40% | 0.11%* |
| Distractions | No    | 43.49%* | 18.26%* | Women | 43.59%* | 18.52%* | 2.38%* |
| Technology-based distractions | 0.37%* | 0.44%* | Men | 0.37%* | 0.45%* | 0.03%* |
| Other distractions | 10.42%* | 10.55%* | Women | 10.39%* | 10.56%* | 0.64%* |

Values highlighted with an asterisk, *, are statistically significant at a 95% confidence level.

3.3.4. Sensitivity Analysis of the Probabilities of Traffic Accident Factors Based on Driving License Status and Individual Factors

Results of the sensitivity analysis of the influence of driving license status and individual factors on the traffic accidents are given in Tables 10–13.
Table 10. Probabilities of traffic accident types based on the driving license status and the age of the drivers.

| Traffic Accident Type | Initial Probabilities | Age | Driving License |
|-----------------------|------------------------|-----|-----------------|
|                       | Valid | Invalid | Valid | Invalid | Other |
| Collision             | 77.65% * | 73.56% * | 75.26% | 71.83% | 71.17% * |
|                       | 77.43% * | 73.33% * | 78.01% | 73.87% | 73.01% * |
|                       | 79.90% * | 75.70% | 74.51% * | | |
|                      | 78.83% * | 73.53% | 74.37% * | | |
|                      | 79.90% * | 75.70% | 74.51% * | | |
|                      | 78.83% * | 73.53% | 74.37% * | | |
|                      | 78.83% * | 73.53% | 74.37% * | | |
| Run Over              | 8.37% * | 9.11% * | 7.70% | 8.34% | 6.80% * |
|                      | 8.32% * | 8.97% | 8.58% | 9.31% | 7.76% * |
|                      | 8.57% * | 9.66% | 8.36% | | |
|                      | 10.60% * | 10.78% * | 9.64% * | | |
| Others                | 13.98% * | 17.33% | 17.04% | 19.83% | 22.03% * |
|                      | 14.25% * | 17.70% | 20.21% * | | |
|                      | 13.41% * | 16.82% | 19.23% * | | |
|                      | 15.58% * | 15.68% | 15.99% | | |

Values highlighted with an asterisk, *, are statistically significant at a 95% confidence level.

As regards the influence of the age variable and the driving license status on the type of the traffic accident, results of Table 10 show that the probability of being involved in a collision increases in the case of older drivers (>60 years old) by 2.25% in case of valid driving license and by 2.14% when their driving licenses are invalid. However, the probability of the younger drivers being involved in other types of traffic accidents increases by 3.06% when their driving licenses are valid and by 2.5% in the case of invalid driving licenses. As regards the severity of the traffic accidents, results in Table 11 show

Table 11. Probabilities for the traffic accident severity based on the driving license status and the age of the drivers.

| Traffic Accident Severity | Initial Probabilities | Age | Driving License |
|---------------------------|------------------------|-----|-----------------|
|                           | Valid | Invalid | Valid | Invalid | Other |
| None/mild                 | 90.79% * | 82.88% * | 90.03% | 80.89% | 92.96% * |
|                           | 90.75% | 82.49% | 90.90% | 83.23% | 93.52% * |
|                           | 91.28% | 83.47% | 93.57% * | | |
|                           | 93.28% | 93.62% | 97.40% * | | |
| Serious injury/death      | 9.21% * | 17.12% * | 9.97% * | 19.11% | 7.04% * |
|                           | 9.25% * | 17.51% | 9.10% | 16.77% | 6.48% * |
|                           | 8.72% * | 16.53% | 4.3% * | | |
|                           | 6.72% | 6.38% | 2.60% | | |

Values highlighted with an asterisk, *, are statistically significant at a 95% confidence level.
that in the case of older drivers (>60 years old), the probability of having a traffic accident with mild or no injuries increases regardless of the status of their driving licenses and it decreases in the case of serious traffic accidents.

Table 12. Probabilities of the traffic accident types based on the driving license status and the gender of drivers.

| Traffic Accident Type | Initial Probabilities | Gender | Driving License |
|-----------------------|-----------------------|--------|-----------------|
|                       | Valid | Invalid | Valid | Invalid | Other |
| Collision             | 77.65% * | 73.56% * | Men  | 76.88% * | 73.05% * | 72.30% * |
|                       |       |         | Women | 79.43% * | 75.20% * | 73.88% * |
|                       |       |         | Unknown | 78.00% | 74.11% | 74.10% |
| Run over              | 8.37% * | 9.11% * | Men  | 8.20% * | 9.01% * | 7.47% * |
|                       |       |         | Women | 8.78% * | 9.33% | 7.93% |
|                       |       |         | Unknown | 8.42% | 10.41% | 9.40% * |
| Others                | 13.98% * | 17.33% | Men  | 11.79% * | 15.47% | 18.19% * |
|                       |       |         | Unknown | 13.58% | 15.48% | 16.49% |

Values highlighted with an asterisk, *, are statistically significant at a 95% confidence level.

Table 13. Probabilities of traffic accident severity based on the driving license status and the gender of the drivers.

| Traffic Accident Severity | Initial Probabilities | Gender | Driving License |
|---------------------------|-----------------------|--------|-----------------|
|                           | Valid | Invalid | Valid | Invalid | Other |
| None or mild              | 90.79% * | 82.88% * | Men  | 89.57% * | 80.50% * | 92.86% * |
|                           |       |         | Women | 93.58% * | 89.80% * | 95.17% * |
|                           |       |         | Unknown | 96.33% | 95.45% | 96.03% * |
| Serious injury or death   | 9.21% * | 17.12% * | Men  | 10.43% * | 19.50% * | 7.14% * |
|                           |       |         | Women | 6.42% * | 10.20% | 4.83% * |
|                           |       |         | Unknown | 3.67% | 4.55% | 3.97% |

Values highlighted with an asterisk, *, are statistically significant at a 95% confidence level.

However, with younger drivers (<25 years old), the probability of having a severe traffic accident increases, and does so more importantly when they are driving unlicensed, by 2%.

Results of the influence of drivers’ gender and driving license status on the probabilities of traffic accident types are summarized in Table 12.

These results reveal that the probability of having a collision increases by about 2% in the case of women drivers regardless of their driving licenses, while in the case of unlicensed men drivers, the probability increases in the case of other types of traffic accidents.

As regards the severity of the traffic accidents, results in Table 13 show that the probability of having a mild traffic accident with no injuries decreases in the case of men drivers regardless of their driving licenses; however, it increases in the case of women drivers by 2.79% when they have a valid driving license and, more importantly, when they hold an invalid driving license by about 7%. The same results show that the probability of having a serious traffic accident decreases in the case of women drivers regardless of their driving licenses. However, in the case of men drivers, the probability
of having a serious traffic accident increases and, more importantly, when their driving licenses are invalid (an increase of 2.38%).

4. Discussion

Despite the improvements in the legislation and enforcement of laws targeting many traffic risk factors [52] and the fact that the drivers are aware of the adverse outcomes of engaging in unsafe driving behaviors, regulatory breaches continue to be witnessed and severe injuries, disabilities and deaths caused by traffic accidents continue to be recorded. Research studies have either shown the relationships between unsafe behaviors and traffic accidents or explained the contribution of unlicensed drivers to the frequency of traffic accidents. However, the relationship between these has not been investigated.

To assess the regulatory alignment, this study investigated the unsafe behaviors of unlicensed drivers. Such a focus first sheds light on the illegal driving of unlicensed drivers that escapes, in one way or another, follow-up strategies and road safety improvement projects. Second, such a focus proposes a proactive perspective for the assessment and monitoring of regulatory alignment, which is better than doing so reactively depending on traffic accident data, to help policymakers detect real deficiencies and make efficient and effective countermeasures.

In doing so, three years (2016, 2017 and 2018) of data were obtained from the Spanish National Traffic Department, and a Bayesian network has been deployed to provide predictions of changes in the probabilities and estimate how individual factors, i.e., demographic variables, impact the objective variables considering the statistical dependency relationships in the Bayesian network model.

This study demonstrated that licensed drivers are more likely to engage in safe driving behaviors such as respecting speed limits and less likely to be involved in run-over traffic accidents. In contrast, unlicensed drivers were found to engage in more unsafe behaviors like speeding and to have severe traffic accidents. This finding supports previous research studies [29, 53] that have reported similar observations on risky driving behaviors of unlicensed drivers such as speeding and non-use of seatbelts, showing that unlicensed drivers form an important part of the profile of regulatory misalignment and that better traffic safety results could be achieved if policymakers and road safety authorities tackle unlicensed driving. As regards the severity of traffic accidents, results of the present study show that the probability of being involved in a minor traffic accident with no injuries is high when the drivers are licensed. In contrast, the probability of having a serious traffic accident leading to death increases when drivers have invalid driving licenses. This finding is in line with conclusions of many scholars [54, 55], confirming that unlicensed drivers are more likely to be involved in fatal traffic accidents than licensed drivers, and the severity of such accidents is therefore high.

However, the present study marked some exceptions and found that the probability of licensed drivers engaging in right-of-way violations is higher than that of unlicensed drivers. In our opinion, the explanation lies in the complexity of the phenomenon of driving behavior, which, in such a particular case, is not exclusively influenced by the status of the driving license. The high probability of licensed drivers engaging in right-of-way violations could be explained by the fact that unlicensed drivers become “prudent drivers” in the streets because, in many countries, if the driver is cited for driving without a valid driving license, they may be fined, barred from obtaining a valid driving license for a period of time or incarcerated. Indeed, as reported by [56, 57], drivers on roads or highways are more likely to be unlicensed than drivers on streets because on rural roads and highways, less public transport and taxi services are available and, considering the long distances, the likelihood of the unlicensed driver encountering the police is slim.

Another finding of notable interest is that both elder and younger drivers have unsafe driving behaviors. However, the results showed that each age group is likely to engage in some unsafe behavior more than others. For instance, young drivers are more likely to commit speed infringement, especially when their driving licenses are invalid. In contrast, older drivers (>60 years old) are more likely to engage in right-of-way violations. This finding supports the results of [57–59], confirming
that young unlicensed drivers are the least committed to traffic instructions and violate traffic lights and use mobile phones the most. Adolescence is a critical developmental period that brings many important cognitive, social and emotional changes, affecting these young drivers’ ways of dealing with hazard and their proneness to engage in unsafe driving behaviors. Furthermore, as in many studies [60,61], the present study found that young drivers, and particularly young unlicensed drivers, are overrepresented in traffic accidents resulting in most of the serious injuries and deaths.

As regards the influence of the gender variable, the sensitivity results showed that women are more likely to engage in right-of-way violations and to have collisions. It was also found that the probability of having mild traffic accidents increases in the case of women unlicensed drivers. For men drivers, the results suggested that they are more likely to be involved in other types of traffic accidents and that the probability of having a serious traffic accident generally increases when their driving licenses are invalid. In general, these results are significantly consistent with many previous studies [62,63] that have agreed that women take fewer risks than men do when driving and are less involved in fatal traffic accidents.

To this end, it is clear that unlicensed driving is more than an unsafe behavior and that unlicensed driving motivates other disqualified driving performances. Thus, this study provides the most direct means for proactively estimating regulatory alignment and allows policymakers to better implement effective and efficient actions that might, first, buffer the impact of unlicensed driving unlicensed; second, reduce the likelihood of committing other unsafe behaviors; and finally, reduce the severity of traffic law violations and improve the alignment.

5. Conclusions

It is widely accepted that many people all around the world are killed or suffer disabilities due to traffic accidents. As a result, immense efforts are being made by road safety authorities all over the world to develop alternative ways to improve the behaviors of drivers at the wheel and therefore reduce the heavy costs of traffic accidents.

Relatively little previous research has investigated the mechanisms by which unlicensed driving affects driving performance and drivers’ regulatory alignment. In this paper, the interrelations between the alignment and compliance with traffic enforcement regulations, unlicensed driving, unsafe behaviors and traffic accidents were investigated.

As expected, findings of the present study confirmed that unlicensed driving exerts a significant negative impact on drivers’ behaviors and consequently their alignment with traffic regulations. Consequently, these findings provide evidence for promoting and improving traffic safety enforcements by targeting unlicensed driving in various safety education and enforcement programs.

5.1. Practical Implications

The present study provides a useful conceptualization of the regulatory alignment and the unsafe behaviors of unlicensed drivers that negatively affect traffic safety records. Accordingly, policymakers and practitioners could consider these results as the basis and empirical framework for interventions aimed at addressing unsafe behaviors and improving driving performance by paying more attention to the unlicensed driving problem. The interventions could fundamentally involve two important points: (i) the sanctions for the unlicensed driving should be reviewed, the laws tightened and special attention paid to unlicensed driving in prevention campaigns; and, (ii) since unlicensed driving is illegal and therefore goes underreported, moving towards using electronic driver licenses to deter unlicensed drivers from operating vehicles has become a necessity.

This study has also considered the use of big data techniques allowing, based on prior probabilities, the calculation of posterior probabilities, which is important to approach such public health problems and traffic safety studies.
5.2. Limitations and Future Research

The main limitation of the present study lies in the fact that the study variables were limited to those extracted from the database; however, there are many other unsafe driving behaviors and influential factors that could be of interest.

As regards the methodology, the machine-learning technique requires large amounts of data to train the data’s behavior; consequently, the concept of unlicensed drivers, in this paper, has grouped all of the categories. Thus, it is recommended that future research considers the influence of each category separately. This is because not all unlicensed drivers are similar. For example, a driver whose license was suspended or canceled due to a past driving offense is not the same as a driver whose license was expired. In considering each category separately, the interventions targeting unlicensed driving could be more specified and the focus could be directed to the disqualified drivers only. Moreover, this study has investigated only the influence of individual factors, and follow-up studies could investigate the influence of other factors.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

| Table A1. Z-Test for safe behaviors and severity of traffic accidents considering driving license status. |
|---------------------------------------------------------------|
| **Safe behaviors of the drivers**                           | **P<sub>1</sub>** | **P<sub>2</sub>** | **ΔP** | **Z**  |
| No right-of-way violations                                  | 0.508           | 0.233           | −0.276 | 161.826 ** |
| No speed infringement                                       | 0.670           | 0.318           | −0.352 | 233.689 ** |
| No other infringements                                       | 0.631           | 0.305           | −0.281 | 175.963 ** |
| No distractions                                              | 0.435           | 0.183           | −0.252 | 137.042 ** |
| **Traffic accident severity**                                | None/mild       | 0.908           | 0.829  | −0.079  | 109.133 ** |

Z-Values highlighted with asterisks, **, are statistically significant differences at a 95% confidence level.
### Table A2. Z-Test for unsafe behaviors and type and severity of traffic accidents considering driving license status.

| Objective Variables | P₁ | P₂ | ΔP   | Z    |
|---------------------|----|----|------|------|
| **Unsafe behaviors of drivers** |     |     |      |      |
| Right-of-way violations | 0.351 | 0.278 | −0.073 | 35.287 ** |
| Speed infringement | 0.081 | 0.124 | 0.043 | −15.496 ** |
| Other infringements | 0.006 | 0.004 | −0.002 | 0.876 |
| Technology-based distractions | 0.004 | 0.004 | 0.001 | −0.253 |
| Other distractions | 0.104 | 0.106 | 0.001 | −0.506 |
| **Traffic accident severity** |     |     |      |      |
| Serious injuries or death | 0.092 | 0.171 | 0.079 | −32.479 ** |
| **Traffic accident type** |     |     |      |      |
| Collision | 0.777 | 0.736 | −0.041 | 39.942 ** |
| Run over | 0.084 | 0.091 | 0.007 | −3.614 ** |
| Others | 0.140 | 0.173 | 0.034 | −18.253 ** |

Z-Values highlighted with asterisks, **, are statistically significant differences at a 95% confidence level.

### Table A3. Z-Test for unsafe behaviors and type and severity of traffic accidents considering age and invalid driving license.

| Objective Variables | Age | P₁ | P₂ | ΔP   | Z    |
|---------------------|-----|----|----|------|------|
| **Unsafe behaviors of drivers** |     |     |     |      |      |
| Right-of-way violations | <25 | 0.278 | 0.284 | 0.006 | −3.132 ** |
| 25 ≤ Y ≤ 40 | 0.278 | 0.284 | 0.006 | −4.929 ** |
| 40 < Y ≤ 60 | 0.278 | 0.275 | −0.003 | 1.966 ** |
| Y > 60 | 0.278 | 0.299 | 0.021 | −9.773 ** |
| Unknown | 0.278 | 0.085 | −0.193 | 62.847 ** |
| Speed infringement | <25 | 0.124 | 0.216 | 0.092 | −53.807 ** |
| 25 ≤ Y ≤ 40 | 0.124 | 0.134 | 0.011 | −11.124 ** |
| 40 < Y ≤ 60 | 0.124 | 0.094 | −0.030 | 34.413 ** |
| Y > 60 | 0.124 | 0.078 | −0.046 | 35.831 ** |
| Unknown | 0.124 | 0.035 | −0.088 | 43.019 ** |
| Other infringements | <25 | 0.004 | 0.004 | 0.000 | −0.569 |
| 25 ≤ Y ≤ 40 | 0.004 | 0.004 | 0.000 | 0.536 |
| 40 < Y ≤ 60 | 0.004 | 0.004 | 0.000 | 0.0 |
| Y > 60 | 0.004 | 0.004 | 0.000 | 0.536 |
| Unknown | 0.004 | 0.002 | −0.002 | 4.840 ** |
| Technology-based distractions | <25 | 0.004 | 0.005 | 0.001 | −2.015 ** |
| 25 ≤ Y ≤ 40 | 0.004 | 0.005 | 0.000 | −0.536 |
| 40 < Y ≤ 60 | 0.004 | 0.004 | 0.000 | 0.536 |
| Y > 60 | 0.004 | 0.005 | 0.000 | −0.949 |
| Unknown | 0.004 | 0.001 | −0.003 | 9.574 ** |
| Other distractions | <25 | 0.106 | 0.109 | 0.003 | −2.272 ** |
| 25 ≤ Y ≤ 40 | 0.106 | 0.108 | 0.002 | −2.316 ** |
| 40 < Y ≤ 60 | 0.106 | 0.105 | −0.001 | 1.148 |
| Y > 60 | 0.106 | 0.116 | 0.010 | −6.902 ** |
| Unknown | 0.106 | 0.025 | −0.081 | 46.232 ** |
| Traffic accident severity | Serious injuries or death | <25 | 0.171 | 0.191 | 0.020 | −11.963 ** |
| 25 ≤ Y ≤ 40 | 0.171 | 0.175 | 0.004 | −3.682 ** |
| 40 < Y ≤ 60 | 0.171 | 0.168 | −0.004 | 3.286 ** |
| Y > 60 | 0.171 | 0.165 | −0.006 | 3.420 ** |
| Unknown | 0.171 | 0.064 | −0.107 | 39.795 ** |
### Table A3. Cont.

| Objective Variables | Age | P₁ | P₂ | ΔP | Z       |
|---------------------|-----|----|----|-----|---------|
| **Collision**       |     |    |    |     |         |
| <25                 | 0.736 | 0.718 | -0.018 | 9.224 ** |
| 25 ≤ Y ≤ 40         | 0.736 | 0.733 | -0.003 | 2.106 ** |
| 40 < Y ≤ 60         | 0.736 | 0.739 | 0.003  | -2.230 **|
| Y > 60              | 0.736 | 0.757 | 0.021  | -10.578 **|
| Unknown             | 0.736 | 0.735 | -0.001 | 0.125   |
| **Run over**        |     |    |    |     |         |
| <25                 | 0.091 | 0.083 | 0.008  | 6.519 ** |
| 25 ≤ Y ≤ 40         | 0.091 | 0.090 | -0.001 | 1.750    |
| 40 < Y ≤ 60         | 0.091 | 0.093 | 0.002  | -2.426 **|
| Y > 60              | 0.091 | 0.097 | 0.006  | -4.025 **|
| Unknown             | 0.091 | 0.108 | 0.017  | -4.942 **|

Z-Values highlighted with asterisks, **, are statistically significant differences at a 95% confidence level.

### Table A4. Z-Test for unsafe behaviors and type and severity of traffic accidents considering gender and invalid driving license.

| Objective Variables | Gender | P₁ | P₂ | ΔP | Z       |
|---------------------|--------|----|----|-----|---------|
| **Right-of-way violations** |       |    |    |     |         |
| Men                 | 0.2779 | 0.2769 | -0.001 | 0.985   |
| Women               | 0.2779 | 0.2958 | 0.018  | -12.627 **|
| Unknown             | 0.2779 | 0.1063 | -0.172 | 30.532 **|

| **Speed infringement** |       |    |    |     |         |
| Men                 | 0.1238 | 0.1286 | 0.005  | -6.363 **|
| Women               | 0.1238 | 0.1143 | -0.009 | 9.500 ** |
| Unknown             | 0.1238 | 0.0458 | -0.078 | 20.438 **|

| **Other infringements** |       |    |    |     |         |
| Men                 | 0.0039 | 0.0040 | 0.000  | -0.702   |
| Women               | 0.0039 | 0.0039 | 0.000  | 0.000    |
| Unknown             | 0.0039 | 0.0018 | -0.002 | 2.717 ** |

| **Technology-based distractions** |       |    |    |     |         |
| Men                 | 0.0044 | 0.0045 | 0.000  | -0.662   |
| Women               | 0.0044 | 0.0046 | 0.000  | -0.952   |
| Unknown             | 0.0044 | 0.0014 | -0.003 | 4.386 ** |

| **Other distractions** |       |    |    |     |         |
| Men                 | 0.1055 | 0.1073 | 0.002  | -2.572 **|
| Women               | 0.1055 | 0.1056 | 0.000  | -0.104   |
| Unknown             | 0.1055 | 0.0329 | -0.073 | 22.260 **|

| **Serious injury or death** |       |    |    |     |         |
| Men                 | 0.1712 | 0.1950 | 0.024  | -27.025 **|
| Women               | 0.1712 | 0.1020 | -0.069 | 69.253 **|
| Unknown             | 0.1712 | 0.0455 | -0.126 | 32.957 **|

| **Collision**       |     |    |    |     |         |
| Men                 | 0.7359 | 0.7305 | -0.005 | 5.379 ** |
| Women               | 0.7359 | 0.7520 | 0.016  | -11.899 **|
| Unknown             | 0.7359 | 0.7411 | 0.005  | -0.653   |

| **Run over**        |     |    |    |     |         |
| Men                 | 0.0911 | 0.0901 | -0.001 | 1.536    |
| Women               | 0.0911 | 0.0933 | 0.002  | -2.431 **|
| Unknown             | 0.0911 | 0.1041 | 0.013  | -2.344 **|

| **Others**          |     |    |    |     |         |
| Men                 | 0.1733 | 0.1793 | 0.006  | -6.933 **|
| Women               | 0.1733 | 0.1547 | -0.019 | 16.322 **|
| Unknown             | 0.1733 | 0.1548 | -0.019 | 2.814 ** |

Z-Values highlighted with asterisks, **, are statistically significant differences at a 95% confidence level.
Table A5. Z-Test for unsafe behaviors and type and severity of traffic accidents considering age and valid driving license.

| Objective Variables | Age | P₁ | P₂ | ΔP | Z  |
|---------------------|-----|----|----|----|----|
| **Right-of-way violations** |     |    |    |    |    |
| <25                 | 0.351 | 0.337 | 0.014 | 7.060 ** |
| 25 ≤ Y ≤ 40         | 0.351 | 0.351 | 0.000 | −0.150 |
| 40 < Y ≤ 60         | 0.351 | 0.353 | 0.002 | −1.325 |
| Y > 60              | 0.351 | 0.365 | 0.014 | −6.232 ** |
| Unknown             | 0.351 | 0.285 | −0.066 | 13.370 ** |
| **Speed infringement** |     |    |    |    |    |
| <25                 | 0.081 | 0.145 | 0.064 | −43.688 ** |
| 25 ≤ Y ≤ 40         | 0.081 | 0.087 | 0.006 | −7.561 ** |
| 40 < Y ≤ 60         | 0.081 | 0.060 | −0.021 | 30.010 ** |
| Y > 60              | 0.081 | 0.048 | −0.033 | 32.166 ** |
| Unknown             | 0.081 | 0.048 | −0.033 | 13.848 ** |
| **Unsafe behaviors of drivers** |     |    |    |    |    |
| **Other infringements** |     |    |    |    |    |
| <25                 | 0.006 | 0.006 | 0.000 | 0.392 |
| 25 ≤ Y ≤ 40         | 0.006 | 0.006 | 0.000 | 0.000 |
| 40 < Y ≤ 60         | 0.006 | 0.006 | 0.000 | 0.000 |
| Y > 60              | 0.006 | 0.006 | 0.000 | 0.567 |
| Unknown             | 0.006 | 0.005 | −0.001 | 1.588 |
| **Technology-based distractions** |     |    |    |    |    |
| <25                 | 0.104 | 0.104 | 0.000 | 0.154 |
| 25 ≤ Y ≤ 40         | 0.104 | 0.104 | 0.000 | 0.117 |
| 40 < Y ≤ 60         | 0.104 | 0.103 | −0.001 | 0.923 |
| Y > 60              | 0.104 | 0.109 | 0.005 | −3.396 ** |
| Unknown             | 0.104 | 0.064 | −0.041 | 15.222 ** |
| **Other distractions** |     |    |    |    |    |
| <25                 | 0.092 | 0.100 | 0.008 | −5.991 ** |
| 25 ≤ Y ≤ 40         | 0.092 | 0.093 | 0.000 | −0.494 |
| 40 < Y ≤ 60         | 0.092 | 0.091 | −0.001 | 1.343 |
| Y > 60              | 0.092 | 0.087 | −0.005 | 3.735 ** |
| Unknown             | 0.092 | 0.067 | −0.025 | 9.090 ** |
| **Traffic accident severity** |     |    |    |    |    |
| Serious injury or death |     |    |    |    |    |
| <25                 | 0.774 | 0.753 | −0.022 | 11.872 ** |
| 25 ≤ Y ≤ 40         | 0.777 | 0.774 | −0.002 | 1.885 |
| 40 < Y ≤ 60         | 0.777 | 0.780 | 0.004 | −3.051 ** |
| Y > 60              | 0.777 | 0.799 | 0.023 | −12.057 ** |
| Unknown             | 0.777 | 0.788 | 0.012 | −2.647 ** |
| **Collision** |     |    |    |    |    |
| <25                 | 0.084 | 0.077 | 0.007 | 5.884 ** |
| 25 ≤ Y ≤ 40         | 0.084 | 0.083 | −0.001 | 0.647 |
| 40 < Y ≤ 60         | 0.084 | 0.086 | 0.002 | −2.644 ** |
| Y > 60              | 0.084 | 0.086 | 0.002 | −1.542 |
| Unknown             | 0.084 | 0.106 | 0.022 | −6.652 ** |
| **Run over** |     |    |    |    |    |
| <25                 | 0.140 | 0.170 | 0.031 | −19.314 ** |
| 25 ≤ Y ≤ 40         | 0.140 | 0.143 | 0.003 | −2.771 ** |
| 40 < Y ≤ 60         | 0.140 | 0.134 | −0.006 | 5.853 ** |
| Y > 60              | 0.140 | 0.115 | −0.025 | 16.395 ** |
| Unknown             | 0.140 | 0.106 | −0.034 | 10.108 ** |
| **Others** |     |    |    |    |    |

Z-Values highlighted with asterisks, **, are statistically significant differences at a 95% confidence level.
Table A6. Z-Test for unsafe behaviors and type and severity of traffic accidents considering gender and valid driving license.

| Objective Variables | Gender   | P₁     | P₂     | ΔP      | Z       |
|---------------------|----------|--------|--------|---------|---------|
| **Unsafe behaviors of drivers** |          |        |        |         |         |
| Right-of-way violations | Men      | 0.351  | 0.342  | −0.008  | 7.785 **|
|                      | Women    | 0.351  | 0.370  | 0.020   | −12.982 **|
|                      | Unknown  | 0.351  | 0.325  | −0.026  | 3.043 **|
| Speed infringement   | Men      | 0.081  | 0.081  | −0.001  | 0.809   |
|                      | Women    | 0.081  | 0.079  | −0.002  | 2.252 **|
|                      | Unknown  | 0.081  | 0.065  | −0.016  | 3.644 **|
| Other infringements  | Men      | 0.006  | 0.006  | 0.000   | 0.000   |
|                      | Women    | 0.006  | 0.006  | 0.000   | 0.841   |
|                      | Unknown  | 0.006  | 0.006  | 0.000   | 0.219   |
| Technology-based distractions | Men    | 0.004  | 0.004  | 0.000   | 0.000   |
|                      | Women    | 0.004  | 0.004  | 0.000   | −0.523  |
|                      | Unknown  | 0.004  | 0.003  | 0.000   | 0.384   |
| Other distractions   | Men      | 0.104  | 0.104  | 0.000   | −0.144  |
|                      | Women    | 0.104  | 0.104  | 0.000   | 0.315   |
|                      | Unknown  | 0.104  | 0.089  | −0.016  | 2.999 **|
| **Traffic accident severity** |          |        |        |         |         |
| Serious injury or death | Men    | 0.092  | 0.104  | 0.012   | −17.992 **|
|                       | Women    | 0.092  | 0.064  | −0.028  | 35.021 **|
|                       | Unknown  | 0.092  | 0.037  | −0.055  | 16.145  |
| Collision            | Men      | 0.774  | 0.769  | −0.005  | 5.771 **|
|                       | Women    | 0.777  | 0.794  | 0.018   | −14.025 **|
|                       | Unknown  | 0.777  | 0.780  | 0.004   | −0.465  |
| Run over             | Men      | 0.084  | 0.082  | −0.002  | 2.721 **|
|                       | Women    | 0.084  | 0.088  | 0.004   | −4.667 **|
|                       | Unknown  | 0.084  | 0.084  | 0.001   | −0.099  |
| Others               | Men      | 0.140  | 0.149  | 0.009   | −11.760 **|
|                       | Women    | 0.140  | 0.118  | −0.022  | 21.410 **|
|                       | Unknown  | 0.140  | 0.136  | −0.004  | 0.643   |

Z-Values highlighted with asterisks, **, are statistically significant differences at a 95% confidence level.
Table A7. Z-Test for safe behaviors and severity of traffic accidents considering age and invalid driving license.

| Objective Variables | Age          | P₁   | P₂   | ∆P  | Z    |
|---------------------|--------------|------|------|-----|------|
|                     | < 25         | 0.233| 0.232| −0.001| 0.334 |
| No right-of-way     | 25 ≤ Y ≤ 40  | 0.233| 0.234| 0.001| −0.677 |
| violations          | 40 < Y ≤ 60  | 0.233| 0.237| 0.005| −3.808 ** |
|                     | Y > 60       | 0.233| 0.252| 0.020| −9.805 ** |
|                     | Unknown      | 0.233| 0.060| −0.173| 65.229 ** |
| Safe behaviors      | < 25         | 0.233| 0.270| −0.048| 25.391 ** |
| of drivers          | 25 ≤ Y ≤ 40  | 0.318| 0.312| −0.006| 4.938 ** |
|                     | 40 < Y ≤ 60  | 0.318| 0.340| 0.022| −16.548 ** |
|                     | Y > 60       | 0.318| 0.386| 0.068| −30.072 ** |
|                     | Unknown      | 0.318| 0.082| −0.237| 77.920 ** |
| No speed            | < 25         | 0.350| 0.353| 0.004| −1.870 |
| infringement        | 25 ≤ Y ≤ 40  | 0.350| 0.351| 0.001| −0.900 |
|                     | 40 < Y ≤ 60  | 0.350| 0.354| 0.005| −3.458 ** |
|                     | Y > 60       | 0.350| 0.386| 0.036| −15.979 ** |
|                     | Unknown      | 0.350| 0.074| −0.276| 94.831 ** |
| No other            | < 25         | 0.183| 0.180| −0.002| 1.345 |
| infringements       | 25 ≤ Y ≤ 40  | 0.183| 0.184| 0.001| −0.925 |
|                     | 40 < Y ≤ 60  | 0.183| 0.206| 0.024| −12.736 ** |
|                     | Y > 60       | 0.183| 0.039| −0.143| 66.000 ** |
|                     | Unknown      | 0.183| 0.039| −0.276| 94.831 ** |
| Traffic accident    | < 25         | 0.829| 0.809| −0.020| 11.963 ** |
| severity            | 25 ≤ Y ≤ 40  | 0.829| 0.825| −0.004| 3.682 ** |
| None/mild           | 40 < Y ≤ 60  | 0.829| 0.832| 0.004| −3.286 ** |
|                     | Y > 60       | 0.829| 0.835| 0.006| −3.420 ** |
|                     | Unknown      | 0.829| 0.936| 0.107| −39.795 ** |

Z-Values highlighted with asterisks, **, are statistically significant differences at a 95% confidence level.

Table A8. Z-Test for safe behaviors and severity of traffic accidents considering gender and invalid driving license.

| Objective Variables | Gender | P₁   | P₂   | ∆P  | Z    |
|---------------------|--------|------|------|-----|------|
| No right-of-way     | Men    | 0.233| 0.237| 0.004| −4.469 ** |
| violations          | Women  | 0.233| 0.232| 0.001| 0.836 |
|                     | Unknown| 0.233| 0.077| −0.155| 31.832 ** |
| Safe behaviors      | Men    | 0.318| 0.319| 0.001| −1.230 |
| of drivers          | Women  | 0.318| 0.332| 0.014| −9.285 ** |
|                     | Unknown| 0.318| 0.105| −0.213| 38.014 ** |
| No speed            | Men    | 0.350| 0.353| 0.003| −2.953 ** |
| infringement        | Women  | 0.350| 0.360| 0.010| −6.625 ** |
|                     | Unknown| 0.350| 0.104| −0.246| 44.040 ** |
| No other            | Men    | 0.183| 0.185| 0.002| −2.844 ** |
| infringements       | Women  | 0.183| 0.185| 0.003| −2.149 ** |
|                     | Unknown| 0.183| 0.053| −0.129| 31.533 ** |
| No distractions     | Men    | 0.829| 0.805| −0.024| 27.025 ** |
| Traffic accident    | Women  | 0.829| 0.898| 0.069| −69.253 ** |
| severity            | Unknown| 0.829| 0.955| 0.126| −32.957 ** |

Z-Values highlighted with asterisks, **, are statistically significant differences at a 95% confidence level.
Table A9. Z-Test for safe behaviors and severity of traffic accidents considering age and valid driving license.

| Objective Variables | Age          | P1     | P2     | ∆P     | Z       |
|---------------------|--------------|--------|--------|--------|---------|
| No right-of-way violations | <25         | 0.508  | 0.501  | −0.007 | 3.528 **|
|                      | 25 ≤ Y ≤ 40  | 0.508  | 0.504  | −0.004 | 2.863 **|
|                      | 40 < Y ≤ 60  | 0.508  | 0.513  | 0.005  | −3.306 **|
|                      | Y > 60       | 0.508  | 0.511  | 0.002  | −1.035  |
| Unknown              | 0.508        | 0.597  | 0.088  | −16.475 **|
| No speed infringement | <25         | 0.670  | 0.603  | −0.067 | 32.313 **|
|                      | 25 ≤ Y ≤ 40  | 0.670  | 0.657  | −0.013 | 9.979 **|
|                      | 40 < Y ≤ 60  | 0.670  | 0.693  | 0.022  | −16.907 **|
|                      | Y > 60       | 0.670  | 0.720  | 0.050  | −23.803 **|
| Unknown              | 0.670        | 0.665  | 0.005  | 1.029  |
| Safe behaviors of the drivers | Unknown     | 0.670  | 0.665  | −0.005 | 1.029  |
| No other infringements | <25         | 0.631  | 0.612  | −0.019 | 9.037 **|
|                      | 25 ≤ Y ≤ 40  | 0.631  | 0.626  | −0.005 | 3.923 **|
|                      | 40 < Y ≤ 60  | 0.631  | 0.638  | 0.007  | −5.482 **|
|                      | Y > 60       | 0.631  | 0.658  | 0.028  | −12.481 **|
| Unknown              | 0.631        | 0.392  | −0.239 | 44.868 **|
| No distractions | <25         | 0.435  | 0.415  | −0.020 | 9.301 **|
|                      | 25 ≤ Y ≤ 40  | 0.435  | 0.431  | −0.004 | 2.746 **|
|                      | 40 < Y ≤ 60  | 0.435  | 0.438  | 0.003  | −2.268 **|
|                      | Y > 60       | 0.435  | 0.454  | 0.019  | −8.361 **|
| Unknown              | 0.435        | 0.527  | 0.092  | −16.931 **|
| Traffic accident severity | None/mild   | 0.908  | 0.900  | −0.008 | 5.991 **|
|                      | 25 ≤ Y ≤ 40  | 0.908  | 0.908  | 0.000  | 0.494  |
|                      | 40 < Y ≤ 60  | 0.908  | 0.909  | 0.001  | −1.343  |
|                      | Y > 60       | 0.908  | 0.913  | 0.005  | −3.735 **|
| Unknown              | 0.908        | 0.933  | 0.025  | −9.090 **|

Z-Values highlighted with asterisks, **, are statistically significant differences at a 95% confidence level.

Table A10. Z-Test for safe behaviors and severity of traffic accidents considering gender and valid driving license.

| Objective Variables | Gender      | P1     | P2     | ∆P     | Z       |
|---------------------|-------------|--------|--------|--------|---------|
| No right-of-way violations | Men        | 0.508  | 0.515  | 0.006  | −5.556 **|
|                      | Women       | 0.508  | 0.494  | −0.015 | 9.428 **|
|                      | Unknown     | 0.508  | 0.542  | 0.034  | −3.756 **|
| No speed infringement | Men        | 0.670  | 0.670  | 0.000  | 0.188  |
|                      | Women       | 0.670  | 0.671  | 0.000  | −0.273  |
|                      | Unknown     | 0.670  | 0.676  | 0.006  | −0.670  |
| No other infringements | Men        | 0.631  | 0.630  | −0.001 | 0.822  |
|                      | Women       | 0.631  | 0.633  | 0.002  | −1.397  |
|                      | Unknown     | 0.631  | 0.562  | −0.069 | 7.699 **|
| No distractions | Men        | 0.435  | 0.434  | −0.001 | 0.445  |
|                      | Women       | 0.435  | 0.436  | 0.001  | −0.647  |
|                      | Unknown     | 0.435  | 0.462  | 0.027  | −3.003 **|
| Traffic accident severity | Men        | 0.908  | 0.896  | −0.012 | 17.992 **|
|                      | Women       | 0.908  | 0.936  | 0.028  | −35.021 **|
|                      | Unknown     | 0.908  | 0.963  | 0.055  | −16.145 **|

Z-Values highlighted with asterisks, **, are statistically significant differences at a 95% confidence level.
1. Alghuson, M.; Abdelghany, K.; Hassan, A. Toward an integrated traffic law enforcement and network management in connected vehicle environment: Conceptual model and survey study of public acceptance. Accid. Anal. Prev. 2019, 133, 105300. [CrossRef] [PubMed]
2. Uzondu, C.; Jamson, S.; Lai, F. Investigating unsafe behaviours in traffic conflict situations: An observational study in Nigeria. J. Traffic Transp. Eng. 2019, 6, 482–492. [CrossRef]
3. Useche, S.; Montoro, L.; Alonso, F.; Oviedo-Trespalacios, O. Infrastructural and Human Factors Affecting Safety Outcomes of Cyclists. Sustainability 2018, 10, 299. [CrossRef]
4. Oviedo-Trespalacios, O.; Scott-Parker, B. The sex disparity in risky driving: A survey of Colombian young drivers. Traffi c Inj. Prev. 2018, 19, 9–17. [CrossRef] [PubMed]
5. Luo, Q.; Chen, X.; Yuan, J.; Zang, X.; Yang, J.; Chen, J. Study and Simulation Analysis of Vehicle Rear-End Collision Model considering Driver Types. J. Adv. Transp. 2020, 1, 1–11. [CrossRef]
6. Hong, Z.; Chen, Y.; Wu, Y. A driver behavior assessment and recommendation system for connected vehicles to produce safer driving environments through a “follow the leader” approach. Accid. Anal. Prev. 2020, 139, 105460. [CrossRef]
7. Šeibokaítė, L.; Endriulaitienė, A.; Žardeckaitė-Matulaitienė, K.; Oviedo-Trespalacios, O.; Watson-Brown, N.; Scott-Parker, B. The self-reported driving behaviour of young drivers in Lithuania: An application of the behaviour of young novice drivers scale–Lithuania (BYNDS-Li). Transp. Res. Part F 2020, 69, 311–323. [CrossRef]
8. Kim, E.; Muennig, P.; Rosen, Z. Vision zero: A toolkit for road safety in the modern era. Inj. Epidemiol. 2017, 4. [CrossRef]
9. Tingvall, C.; Haworth, N. Vision Zero-An Ethical Approach to Safety and Mobility. In Proceedings of the 6th ITE International Conference Road Safety & Traffic Enforcement: Beyond 2000, Melbourne, Australia, 6–7 September 1999; p. 5.
10. Safarpour, H.; Khorasani-Zavareh, D.; Mohammadi, R. The common road safety approaches: A scoring review and thematic analysis. Chin. J. Traumatol. 2020, 23, 113–121. [CrossRef]
11. Castillo-Manzano, J.I.; Castro-Nuño, M. Driving licenses based on points systems: Efficient road safety strategy or latest fashion in global transport policy? A worldwide meta-analysis. Transp. Policy 2012, 21, 191–201. [CrossRef]
12. Tong, R.; Yang, X.; Parker, T.; Zhang, B.; Wang, Q. Exploration of relationships between safety performance and unsafe behavior in the Chinese oil industry. J. Loss Prev. Process Ind. 2020, 66, 104167. [CrossRef]
13. Barjonet, P.-E. Traffic Psychology Today; Springer US: Boston, MA, USA, 2001; ISBN 978-1-4757-6867-1.
14. Elliott, M.R.; Ginsburg, K.R.; Winston, F.K. Unlicensed Teenaged Drivers: Who Are They, and How Do They Behave When They Are Behind the Wheel? Pediatrics 2008, 122, e994–e1000. [CrossRef]
15. Sagberg, F. Characteristics of fatal road crashes involving unlicensed drivers or riders: Implications for countermeasures. Accid. Anal. Prev. 2018, 117, 270–275. [CrossRef]
23. Shibata, A.; Fukuda, K. Risk factors of fatality in motor vehicle traffic accidents. *Accid. Anal. Prev.* 1994, 26, 391–397. [CrossRef] [PubMed]

24. Soliman, A.; Alhajyaseen, W.; Alfar, R.; Alkaabi, I. Changes in Driving Behavior Across Age Cohorts in an Arab Culture: The Case of State of Qatar. *Procedia Comput. Sci.* 2018, 130, 652–659. [CrossRef]

25. Zhang, G.; Yau, K.K.W.; Zhang, X.; Li, Y. Traffic accidents involving fatigue driving and their extent of casualties. *Accid. Anal. Prev.* 2016, 87, 34–42. [CrossRef] [PubMed]

26. Watson, B.C. The crash involvement of unlicensed drivers in Queensland. In Proceedings of the Road Safety Research and Enforcement Conference, Hobart, Australia, 9–12 November 1997.

27. Watson, B.C.; Armstrong, K.; Watson, A.; Wilson, A.; Livingstone, K. A Roadside Survey of Unlicensed Driving in Queensland. In *Proceedings of the 2011 Australasian Road Safety Research, Policing and Education Conference*; Hellyer, S., Ed.; Insurance Commission of Western Australia: Perth, Australia, 2011; pp. 1–11.

28. Farris, C.; Spaite, D.W.; Criss, E.A.; Valenzuela, T.D.; Meislin, H.W. Observational Evaluation of Compliance with Traffic Regulations Among Helmeted and Nonhelmeted Bicyclists. *Ann. Emerg. Med.* 1997, 29, 625–629. [CrossRef] [PubMed]

29. Hanna, C.L.; Laffamme, L.; Elling, B.; Möller, J. Unlicensed driving and other related health risk behaviors: A study of Montana high school students. *Accid. Anal. Prev.* 2013, 54, 26–31. [CrossRef]

30. Watson, B. A Survey of Unlicensed Driving Offenders. In Proceedings of the Road Safety Research, Policing and Education Conference, Adelaide, Australia, 4–5 November 2002; pp. 181–190.

31. Smid, S.C.; McNEish, D.; Miočević, M.; van de Schoot, R. Bayesian Versus Frequentist Estimation for Structural Equation Models in Small Sample Contexts: A Systematic Review. *Struct. Equ. Modeling* 2020, 27, 131–161. [CrossRef]

32. García-Herrero, S.; Mariscal-Saldaña, M.Á.; López-Perea, E.M.; Quiroz-Flores, M.F. Influence of demand, control and social support on job stress. *Analysis by employment status from the V European working conditions survey*. *Dyna* 2016, 83, 52–60. [CrossRef]

33. Novikova, G.M.; Azofeifa, E.J. Current Perspectives on the Application of Bayesian Networks in Different Domains. In *Databases and Information Systems*; Lupeikiene, A., Vasilecas, O., Dzemyda, G., Eds.; Springer International Publishing: Cham, Switzerland, 2018; Volume 838, pp. 376–390. ISBN 978-3-319-97570-2.

34. Lee, S.H.; Lee, Y.D.; Do, M. Analysis on safety impact of red light cameras using the Empirical Bayesian approach. *Transp. Lett.* 2016, 8, 241–249. [CrossRef]

35. Fawcett, L.; Thorpe, N.; Matthews, J.; Kremer, K. A novel Bayesian hierarchical model for road safety hotspot prediction. *Accid. Anal. Prev.* 2017, 99, 262–271. [CrossRef]

36. Zou, X.; Yue, W.L. A Bayesian Network Approach to Causation Analysis of Road Accidents Using Netica. *Int. J. Adv. Transp.* 2017, 3, 1–18. [CrossRef]

37. Cantillo, V.; García, P.; Márquez, L. Factors influencing the occurrence of traffic accidents in urban roads: A combined GIS-Empirical Bayesian approach. *Dyna* 2016, 83, 21–28. [CrossRef]

38. García-Herrero, S.; Gutiérrez, J.M.; Herrera, S.; Azimian, A.; Mariscal, M.A. Sensitivity analysis of driver’s behavior and psychophysical conditions. *Saf. Sci.* 2020, 125, 104586. [CrossRef]

39. Febres, J.D.; García-Herrero, S.; Herrera, S.; Gutiérrez, J.M.; López-García, J.R.; Mariscal, M.A. Influence of seat-belt use on the severity of injury in traffic accidents. *Eur. Transp. Res. Rev.* 2020, 12. [CrossRef]

40. Febres, J.D.; Mohamadi, F.; Mariscal, M.A.; Herrera, S.; García-Herrero, S. The Role of Journey Purpose in Road Traffic Injuries: A Bayesian Network Approach. *J. Adv. Transp.* 2019, 1, 1–10. [CrossRef]

41. Friedman, N. *Learning Belief Networks in the Presence of Missing Values and Hidden Variables*; Morgan Kaufmann Publishers Inc.: San Francisco, CA, USA, 1997; pp. 125–133.

42. Arnaldo Valdés, R.; Gomez Comendedor, V.F.; Perez Castan, J.A.; Rodriguez Sanz, A.; Perez Sanz, L.; Saiz Nieto, F.J.; Sanchez Aira, E. Bayesian inference in Safety Compliance Assessment under conditions of uncertainty for ANS providers. *Saf. Sci.* 2019, 116, 183–195. [CrossRef]

43. Murphy, K. The bayes net toolbox for matlab. *Comput. Sci. Stat.* 2001, 2, 1024–1034.

44. Toolbox, F.M. Available online: [https://github.com/bayesnet/bnt](https://github.com/bayesnet/bnt) (accessed on 10 August 2020).

45. Matlab. *MATLAB para Inteligencia Artificial*. Available online: [https://es.mathworks.com](https://es.mathworks.com) (accessed on 10 August 2020).

46. Guo, J.; Drasgow, F. Identifying Cheating on Unproctored Internet Tests: The Z-test and the likelihood ratio test: Identifying Cheating on UIT. *Int. J. Sel. Assess.* 2010, 18, 351–364. [CrossRef]
47. Gutiérrez Pulido, H.; De La Vara Salazar, R. Analisis y Diseno de Experimentos, 2nd ed.; Mc Graw Hill: Ciudad de México, Mexico, 2008; ISBN 978-970-10-4017-1.

48. Formulario de Accidentes de Tráfico. Available online: https://www.boe.es/eli/es/a/2014/10/27/int2223/con (accessed on 13 August 2020).

49. Demmel, S.; Freeman, J.; Larue, G.S.; Rakotonirainy, A. Evaluation of in-vehicle technologies to prevent unlicensed driving in Queensland and Victoria. Accid. Anal. Prev. 2019, 127, 210–222. [CrossRef]

50. Joewono, T.B.; Susilo, Y.O. Traffic violations by young motorcyclists on Indonesian urban roads. J. Transp. Saf. Secur. 2017, 9, 236–261. [CrossRef]

51. Shangguan, Q.; Fu, T.; Liu, S. Investigating rear-end collision avoidance behavior under varied foggy weather conditions: A study using advanced driving simulator and survival analysis. Accid. Anal. Prev. 2020, 139, 105499. [CrossRef]

52. Notrica, D.M.; Sayrs, L.W.; Krishna, N.; Rowe, D.; Jaroszewski, D.E.; McMahon, L.E. The impact of state laws on motor vehicle fatality rates, 1999–2015. J. Trauma Acute Care Surg. 2020, 88, 760–769. [CrossRef] [PubMed]

53. Blows, S.; Ivers, R.Q.; Connor, J.; Ameratunga, S.; Woodward, M.; Norton, R. Unlicensed Drivers and Car Crash Injury. Traffic Inj. Prev. 2005, 6, 230–234. [CrossRef] [PubMed]

54. Heck, K.; Sousa, C.; Hanna, C.; Nathaniel, K. Unlicensed Driving Among California High School Seniors. Al/Calif. J. Health Promot. 2008, 6, 36–48. [CrossRef]

55. Hanna, C.L.; Hasselberg, M.; Laflamme, L.; Möller, J. Road traffic crash circumstances and consequences among young unlicensed drivers: A Swedish cohort study on socioeconomic disparities. BMC Public Health 2010, 10. [CrossRef]

56. McDowell, A.; Begg, D.; Connor, J.; Broughton, J. Unlicensed Driving Among Urban and Rural Māori Drivers: New Zealand Drivers Study. Traffic Inj. Prev. 2009, 10, 538–545. [CrossRef]

57. Yahia, H.A.M.; Ismail, A. Knowledge of Traffic Laws and Drivers Behavior on the Roads of Tripoli City, Libya. Res. J. Appl. Sci. Eng. Technol. 2014, 7, 2040–2045. [CrossRef]

58. Parlangeli, O.; Bracci, M.; Guidi, S.; Marchigiani, E.; Duguid, A.M. Risk perception and emotions regulation strategies in driving behaviour: An analysis of the self-reported data of adolescents and young adults. Int. J. Hum. Factors Ergon. 2018, 5, 166. [CrossRef]

59. Shaaban, K.; Hassan, H.M. Underage driving and seat-belt use of high school teenagers in Qatar. J. Transp. Saf. Secur. 2017, 9, 115–129. [CrossRef]

60. Scott-Parker, B.; Watson, B.; King, M.J.; Hyde, M.K. Young and Unlicensed: Risky Driving Before Entering the Licensing System. Traffic Inj. Prev. 2012, 13, 213–218. [CrossRef]

61. Romano, E.; Kelley-Baker, T.; Voas, R.B. Female involvement in fatal crashes: Increasingly riskier or increasingly exposed? Accid. Anal. Prev. 2008, 40, 1781–1788. [CrossRef]

62. Cordellieri, P.; Baralla, F.; Ferlazzo, F.; Sgalla, R.; Piccardi, L.; Giannini, A.M. Gender Effects in Young Road Users on Road Safety Attitudes, Behaviors and Risk Perception. Front. Psychol. 2016, 7. [CrossRef]

63. Korn, L.; Weiss, Y.; Rosenbloom, T. Driving violations and health promotion behaviors among undergraduate students: Self-report of on-road behavior. Traffic Inj. Prev. 2017, 18, 813–819. [CrossRef] [PubMed]

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