JOURNAL OF INNOVATIVE TRANSPORTATION©

YEAR 2024
VOLUME 5
ISSUE 2

JOURNAL OF INNOVATIVE TRANSPORTATION©

e-ISSN: 2717-8889

JOURNAL OF INNOVATIVE© TRANSPORTATION

CONTENTS

Research Articles

Awareness of right-of-way rules at unsignalized intersections: A case study from Isparta, Türkiye
Aydın Kıcı, Mesut Tığdemir 22

Gender-based risk analysis of vehicle control loss due to localized water puddles: An analytical approach
Ekinhan Eriskin 34

The frequency and significance of the primary cause of cost overruns in infrastructure projects
Fares Tarhuni, Rupesh Mahat 40

Journal of Innovative Transportation, 5(2), 22-33

Research Article

JOURNAL OF INNOVATIVE TRANSPORTATION

e-ISSN: 2717-8889

Awareness of right-of-way rules at unsignalized intersections: A case study from Isparta, Türkiye

Aydın KICI[a,*], Mesut TIĞDEMİR[b]

[a]*Department of Civil Engineering, Faculty of Engineering and Natural Sciences, Suleyman Demirel University, Isparta, Türkiye*
[b]*Department of Civil Engineering, Faculty of Engineering and Natural Sciences, Suleyman Demirel University, Isparta, Türkiye*

Highlights

- The level of awareness of right-of-way rules
- Right-of-way rules are crucial for safety at intersections
- The awareness of traffic rules was determined using a questionnaire method
- Average number of correct answers: 13.89 out of 18

Abstract

This study aims to measure the level of awareness of the participants living in Isparta, Türkiye, regarding the right-of-way rules at intersections. A questionnaire was prepared to determine the level of awareness of the right-of-way rules, and a sample of 302 randomly selected participants were invited to respond to the questionnaire. In evaluating the results, participants were categorized into three groups based on their awareness levels: low, moderate, and high. When all questions were considered, it was observed that 24% of the participants had a low level of awareness, 54% had a medium level of awareness, and 22% had a high level of awareness. We established that the least known rules included traffic signs related to yielding and stopping, and right-of-way rules in terms of road priority. According to this, it has been concluded that drivers do not fully understand some fundamental right-of-way rules, and this situation can be a significant factor leading to driver-related accidents at uncontrolled intersections. In this paper, we propose that responsible agencies take measures to reduce accidents caused by violations of right-of-way rules.

Information

Received:
28.10.2024

Received in revised:
01.12.2024

Accepted:
16.12.2024

Keywords: *Traffic safety, right-of-way rules, unsignalized intersections, questionnaire*

1. Introduction

Intersections are connection points where two or more roads merge or intersect, managed by signalization, traffic signs, or basic right-of-way rules. Intersections are critical points where rules must be followed to ensure the safe and continuous movement of vehicles, pedestrians, and cyclists and to enable balanced interactions. As seen in Figure 1, intersections are road connection points where conflicts, such as vehicle-vehicle and vehicle-pedestrian, occur frequently in the forms of crossing, divergence, and merging. Therefore, the accident risk is significantly higher than other parts of the transportation network. The number of conflict points can be reduced by structures with different geometries, such as grade-separated junctions (interchanges) and roundabouts. Additionally, some geometric designs can be used to reduce accidents [1]. Nevertheless, considering the cost of construction and the challenges associated with expropriation, this may not always be feasible. A wide variety of accidents occur at intersections, including head-on, broadside, rear-end, and sideswipe collisions [2].

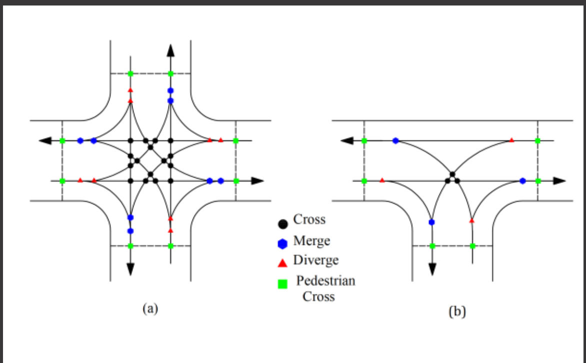

Figure 1. Conflict points at three (a) and four (b) leg intersections [3]

*Corresponding author: aydinkici@sdu.edu.tr (A. Kici), +90 246 211 1222

https://doi.org/10.53635/jit.1575012

The prevailing emphasis in academic research on traffic accidents has been directed towards intersections [4-8]. For this reason, it is crucial to design and manage intersections carefully.

Intersections can be managed using various control methods, which can be evaluated under three main categories [3]: Level 1 involves basic right-of-way rules, Level 2 includes the determination of right-of-way using "Stop" and "Yield" signs, and Level 3 involves the use of signalization.

Choosing the control method for an intersection requires significant engineering knowledge and meticulous evaluation. Traffic control methods for the examined intersection should be determined based on traffic volume, peak-hour factors, and pedestrian and cyclist density. While signalization control is generally considered the most reliable method among traffic control methods, it may not always be the most accurate solution. While signalizations may reduce certain types of accidents and ensure pedestrian safety, they can also lead to increased delays and stop-and-go traffic, potentially causing a higher frequency of specific types of accidents, such as rear-end collisions. The conditions that need to be met to install a signalization system or stop and yield signs for the analysed intersection are specified in the Manual of Uniform Traffic Control Devices (MUTCD) [9]. In cases where these conditions are not met, and the traffic for vehicles and pedestrians is low, the Level 1 traffic control method, based on basic right-of-way rules, is preferred. Uncontrolled intersections include only Level 1 controlled intersections, and in the management of intersections, only basic right-of-way rules are in operation. No traffic signals exist at an uncontrolled intersection, and neither 'Stop' nor 'Yield' signs are present. The presence of location signs and directional arrows does not alter the uncontrolled nature of these intersections.

1.1. Traffic accidents in Türkiye and Isparta

When examining accident statistics, it can be observed that in Türkiye, a total of 281,054 faults were reported in fatal and injury accidents in the year 2023 alone. These faults comprise 249,856 driver-related faults, constituting 86.8% of all faults. As presented in Table 1, the percentages of pedestrian, vehicle, passenger, and road-related faults are 9.02%, 1.12%, 0.62%, and 0.34%, respectively. Approximately 32.5% of driver-related accidents occurred due to non-compliance with right-of-way rules, turning regulations, and traffic sign violations at intersections. In total, 6,548 individuals lost their lives, and 350,855 individuals were injured in accidents, accounting for all fatalities and injuries [10].

When examining the data from the US Department of Transportation, it is observed that during the five years between 2017 and 2021, 192,609 individuals lost their lives due to traffic accidents, with 53,422 of these fatalities occurring at intersections and road connections. 68% of the accidents at intersections and road connections occurred in unsignalized intersections [11].

Table 1. Faults in Fatal and Injurious Accidents Occurred in Türkiye in 2023 [10]

	No. of Faults	Fault Rates
Driver Fault	249 856	88.90%
Pedestrian Faults	25 355	9.02%
Vehicle Faults	3 149	1.12%
Passenger Faults	1 754	0.62%
Roadway Faults	940	0.34%
Total Faults	281 054	100%

A large proportion of accidents at intersections and road connections, as noted by the NHTSA, are caused by human factors. The human factor comprises various characteristics such as age, gender, awareness level, fatigue, stress, socio-cultural background, and many others. Ensuring traffic safety, understanding the human factor, and taking appropriate measures can only be achieved through observations and questionnaires. Using various survey methods, traffic users' awareness of traffic rules and their attitudes toward traffic regulations and safety measures have been examined in many studies [12-21].

To minimize accidents caused by human factors, all road users should learn, know, and understand traffic rules through education, media, or road safety training. In addition, from a holistic perspective, it should be aimed to raise public awareness, internalize the rules by road users, and create a road-safe culture accordingly [12] Especially at un-signalized intersections, drivers are assumed to be aware of traffic signs and right-of-way rules. However, it is not known to what extent this assumption is correct. Therefore, this study aims to determine the awareness of right-of-way rules at uncontrolled intersections using survey method. The study was conducted in the province of Isparta, located in the Mediterranean region of Türkiye as seen in Figure 2. According to the 2023 data, the total population is 449,777, with the city center's population being 271,396 [22]. When considering the number of vehicles per person, the average in Türkiye is approximately 0.31 vehicles per person, whereas in Isparta province, this ratio is approximately 50% higher than the national average, at 0.44 vehicles per person. During the five years between 2018 and 2022, 23,173 traffic accidents occurred in Isparta province. As a result of these traffic accidents, the numbers of fatalities and injuries were determined as 213 and 10,795, respectively [10].

1.2. Right-of-way rules

When considering an at-grade intersection, many factors influence the determination of right-of-way, including the geometry of the intersection, the characteristics of the approach arms, the presence of a police officer or traffic control person at the intersection, and the type of control at the intersection. In the presence of a police officer or traffic control person at the intersection, other signs and signals at the intersection are disregarded, and the instructions of the relevant individual are followed. If the intersection is a roundabout, the right-of-way always belongs to the vehicle inside the roundabout, and vehicles approaching from the entry arms must yield by slowing down to the circulating traffic. Contrary to common practice, in Türkiye, stop signs or signals within roundabouts often confuse road users. If the intersection control is provided by traffic signals or stop and yield signs, drivers follow these signals and signs to determine the right-of-way rules.

Finally, if the intersection is designed as uncontrolled, basic right-of-way rules are followed. In this case, drivers should approach the intersection cautiously and yield to pedestrians and cyclists. At these intersections, vehicles from the undivided approach road must yield to vehicles from the divided approach road. The 'first in, first out principle always applies in uncontrolled intersections. If two or more vehicles approach the intersection simultaneously, turning vehicles must yield to the vehicles going through and those on their right. These rules are explicitly stated in both the Turkish Road Traffic Law and the Turkish Road Traffic Regulations [23,24]. A flowchart illustrating the right-of-way based on the type and condition of intersections is presented in Figure 3.

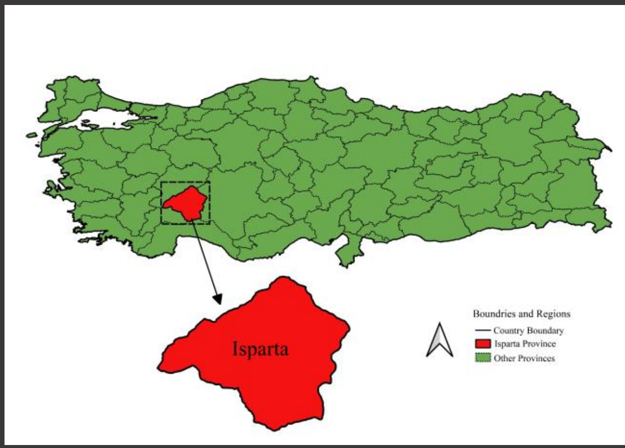

Figure 2. Location of Isparta Province

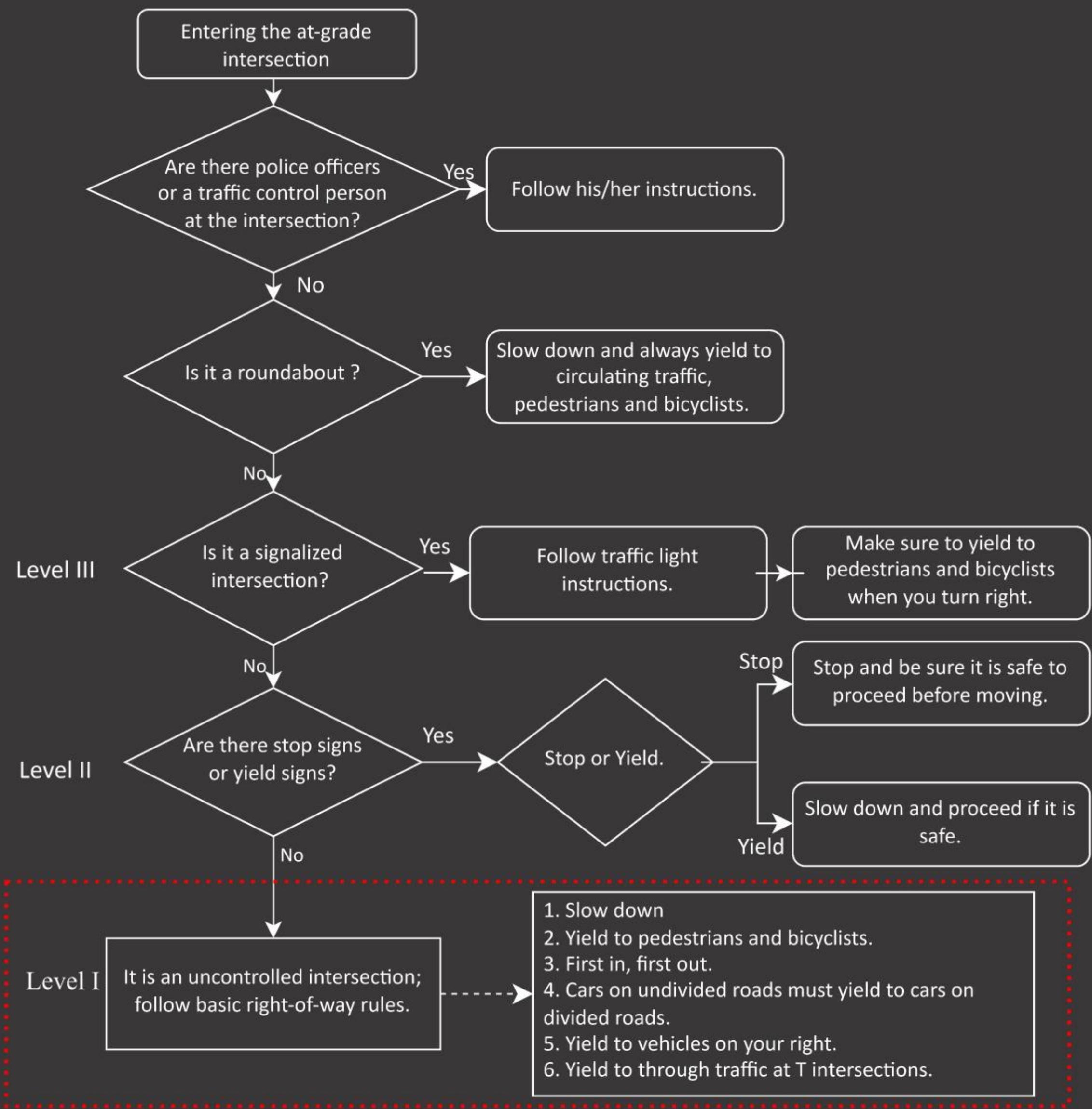

Figure 3. Intersections right-of-way diagram

2. Literature Review

In the study conducted by Bucsuházy et al. [25] the causes of accidents and the effects of human factors on accidents were evaluated concerning experience, attention, mental and physical condition, driving habits, and socio-demographic information. It was emphasized that accidents were more frequent in the young (18-24) and senior (+65) age groups, which was attributed to a lack of experience in young drivers and a decrease in psychomotor functions in senior drivers.

Mutlu and Yakar [26] conducted a study investigating the awareness of traffic signs. According to this study, the recognition rate of the 'yield' sign in multiple-choice questions was found to be 74.6%, while the awareness of the 'main road' sign was determined to be 34.3%. When demographic data was examined, it was observed that driver experience was the most significant factor in correctly answering the questions. Similarly, in their study measuring the recognition of traffic signs, Umar and Bashir [27] found that the average level of recognition was 79% for all participants and that driver experience was the most crucial factor in correctly answering the questions.

Şehribanoğlu [28] conducted a survey to measure the knowledge levels of individuals about traffic signs living in Van province, Türkiye. It was observed that the participants had very low rates of correct answers. The results obtained from the study indicate that young participants are more successful in recognizing traffic signs. Additionally, the study has found that males have a higher level of knowledge compared to females. Çakıcı and Murat [15] conducted a survey in Denizli province, Türkiye, with the aim of measuring the awareness levels of participants regarding traffic signs, using multiple-choice questions, each consisting of four options. According to the study's results, the awareness level of the yield sign was 51%, while the awareness level of the main road end sign was only 41%. It was determined that out of the 27 traffic signs included in the survey, 37% were awareness at a moderate to low level. Out of the 27 traffic signs included in the survey, 37% were found to have a middle and low level of awareness.

Ningal and Oños [29] analyzed where motorcycle drivers acquire their knowledge about traffic. Accordingly, it has been demonstrated that social media, roads and traffic signs, personal observations and experiences, peer and relatives' instructions, and traffic authorities' examinations play a significant role in shaping drivers' knowledge level about traffic. The study also emphasized the crucial role of public institutions in traffic education. Education levels, along with individuals' decisions and preferences, significantly influence traffic patterns, travel mode choices, and consequently, impact overall safety [30].

Using gamified methods can greatly help to improve people's knowledge of different subjects. İçten [31] provided education on traffic signs and rules in virtual 3D rooms. Through the participants' experiences using VR goggles, the study captured their interest, enthusiasm, and attention, leading to a positive change in the participants' cognitive and perceptual abilities. At the end of the application, a significant amount of positive feedback was received from the participants. In another study, Topkaya [32] demonstrated the potential use of comics in teaching traffic rules. According to the results obtained from this study, comics in traffic education have been shown to create an engaging and enjoyable classroom environment, thereby making traffic education more entertaining.

Cheng et al. [33] examined the utilization of artificial intelligence (AI) and virtual reality-supported (VR) driving simulators and reviewed published articles on this subject. According to the results obtained from the study, artificial intelligence and virtual reality are promising methods that can be utilized in driver education. Backlund et al. [34] and Gounaridou et al. [35] have explored the educational effectiveness of a game-based simulation on traffic rules and traffic safety. Based on the results, it can be concluded that a game-based simulation can be employed to enhance learning in driver education.

In addition to advanced technologies like AI and VR, social media, one of today's essential communication tools, can also be utilized to promote traffic safety awareness and inform individuals. In their study, Özel [36] examined the engagement generated by the Turkish Ministry of Interior's social media posts related to traffic safety. According to the study's findings, it has been emphasized that public institutions are successful in generating significant engagement through social media and that it can be a powerful tool for raising awareness among individuals about traffic safety.

Similarly, Gülada et al. [37] noted that in many countries, public service announcements about the importance of traffic safety are implemented using emotional appeals such as fear and sadness, focusing on themes of death, injury, and family. Another result obtained from the study that there are fewer public service announcements in middle-income countries compared to high-income countries, emphasizing the need for more efforts in this regard in Türkiye as well. Kavsıracı et al. [38] examined the impact of social campaigns, enforcement, and administrative penalties on individuals regarding traffic safety. According to the data obtained from the study, it was demonstrated that in the short term, social campaigns and public service announcements are more effective in creating a long-term traffic culture compared to traffic enforcement and penalties.

3. Method

3.1. Data collection tools and participant

In this study, the survey method was employed to determine the awareness of right-of-way rules at uncontrolled intersections. The survey method is a reliable approach commonly used to measure people's knowledge and awareness levels about various subjects in fields such as economics, politics, health, engineering, and more [39-45]. According to the general trend today, mixed-mode survey methods, which allow different data collection methods to be used simultaneously to increase the low response rate, are preferred in collecting data [46,47]. Therefore, in this study, a mixed-mode survey method has been employed, involving face-to-face and online data collection methods.

As the sample size increases, the approach to actual results will become closer, thus enabling more sensitive estimations [48]. However, having a large sample size does not always guarantee the most accurate results. Therefore, considering specific confidence levels and margin error, a sample size is determined within the framework of criteria such as time, cost, and accuracy.

When considering the selected confidence level, margin of error, and population size, Equation 1 can be used to calculate the sample size [49].

$$n = \frac{n_0}{1+\frac{n_0}{N}}, n_0 = [(t.s)/d]^2 \quad (1)$$

Here, t represents the confidence level, N is the population size, s is the standard deviation, and d is the margin error.

A total population of 271,396 people reside in the city center of Isparta province. When considering road users aged 18 and above, it is estimated that individuals in this age group account for approximately 77% [22]. In this case, the total examined population was obtained as 208,975 individuals. Using Equation 1, the minimum sample size for a 90% confidence level and a 5% margin of error has been determined to be at least 271. Therefore, the questionnaire was conducted with N=302 participants, and as presented in Table 2, four main demographic data were requested from the participants, including gender, age, years as a licensed driver, and education level.

3.2. Data collection tools and participants

In this study, as the aim is to test the awareness of right-of-way rules in Isparta province, the sample population consists of traffic users residing in Isparta province. The sample selection followed the principle of randomness and adhered to the specified sample size. The questionnaire was limited to people who had a driver's license. In addition, the gender distribution of participants was determined based on the ownership rates of driver's licenses among male and female drivers. According to 2022 data, the driver's license ownership rates in Türkiye were 70.6% for men and 29.4% for women [22]. This questionnaire comprises four sections: an introductory information section, a demographic information section, a section containing questions related to fundamental right-of-way rules, and a section containing questions about traffic signs. The first section provides information about the questionnaire's objective, voluntary consent, and the structure of the questions. The second section includes questions about the participants' gender, age, driving status, and education levels. In the third section, visual questions were asked to assess the participants' awareness of right-of-way rules. Finally, questions regarding traffic signs, signalization, and priority of emergency vehicles were asked in the fourth section. The contents of the questions are shown in Table 3.

Table 2. Demographic Characteristics of Questionnaire Participants

Gender	Male (N=205)				Female (N=97)				Total (N=302)
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Years as a licensed driver	0-5 47 (23%)	6-20 87 (42%)	+20 71 (35%)	All 205 (100%)	0-5 23 (24%)	6-20 54 (55%)	+20 20 (21%)	All 97 (100%)	**302 (100%)**
Age				-				-	
18-30 (Young)	47 (100%)	27 (31%)	-	74 (36%)	18 (78%)	20 (37%)	-	38 (39%)	**112 (37%)**
31-45 (Middle)	-	56 (64%)	18 (26%)	74 (36%)	5 (22%)	26 (48%)	2 (10%)	33 (34%)	**107 (35%)**
46-65 (Mid-Old)	-	3 (4%)	40 (56%)	43 (21%)	-	6 (11%)	10 (50%)	16 (17%)	**59 (20%)**
+65 (Old)	-	1 (1%)	13 (18%)	14 (7%)	-	2 (4%)	8 (40%)	10 (10%)	**24 (8%)**
Education Level									
Primary Sc.	-	2 (2%)	15 (21%)	17 (8%)	1 (4%)	3 (6%)	5 (25%)	9 (9%)	**26 (9%)**
Middle Sc.	3 (6%)	7 (8%)	7 (10%)	17 (8%)	-	4 (7%)	7 (35%)	11 (11%)	**28 (9%)**
High Sc.	9 (19%)	18 (21%)	17 (24%)	44 (22%)	7 (30%)	15 (28%)	2 (10%)	24 (25%)	**68 (23%)**
University Deg.	31 (66%)	44 (51%)	23 (32%)	98 (48%)	10 (44%)	14 (26%)	3 (15%)	27 (28%)	**125 (41%)**
Graduate Deg.	4 (9%)	16 (18%)	9 (13%)	29 (14%)	5 (22%)	18 (33%)	3 (15%)	26 (27%)	**55 (18%)**

Table 3. Sections and contents of the questionnaire form

Sections of the Questionnaire Form	
Section I - Information About Questionnaire • Information about the goal of the questionnaire • Consent to voluntary participation • Information about the structure of the questions • Other Information	**Section II - Demographic Information** • Gender • Age • Active driving status • Years as a licensed driver • Level of education
Section III - Questions About Basic Right-of-Way Rules • 6 Questions for testing basic right-of-way rules • 2 Questions for testing traffic signals about yield and stop • 2 Questions for testing pedestrian and bicyclist priority • 4 Questions for testing basic right-of-way rules in terms of road priority	**Section IV - Questions About Traffic Signs and Other Questions** • 1 Question for testing traffic lights • 2 Questions for testing traffic signals about yield and stop • 1 Question for testing emergency car priority

Questions were asked visually in the third and fourth sections to assess participants' awareness levels of right-of-way rules. Participants were presented with visually depicted conflict scenarios for various situations and were asked to indicate the right-of-way for vehicles, bicycles, or pedestrians. Pedestrians, cyclists, and vehicles were designated as entities A and B. To avoid influencing participants' responses, vehicle colors were marked as neutral colors, specifically blue and white. Visuals related to some of the questions asked in the study are presented in Figure 4. In each question, “Which vehicle has the right-of-way?” was asked, and participants' responses were collected. To prevent the prolongation of the questionnaire duration, the questions in the third and fourth sections, which were used to assess awareness of right-of-way, were limited to 18 in total. The average response time for the questionnaire was found to be 190 seconds. This duration is considered ideal for participants to answer all questions without getting bored or distracted.

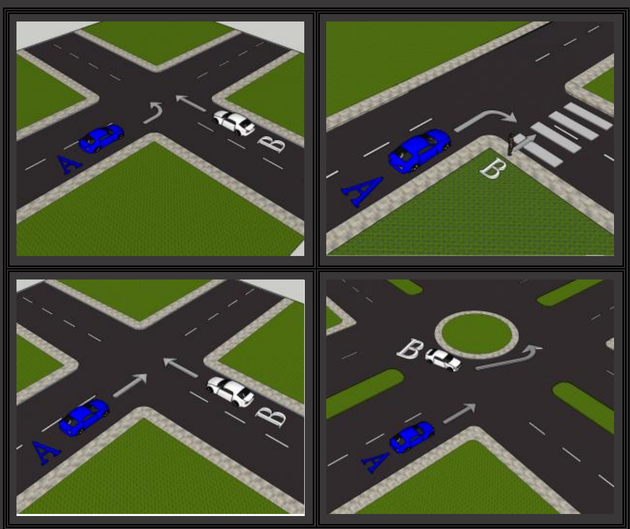

Figure 4. Some of the questionnaire questions

The third and fourth section questions in the questionnaire, which were prepared to assess participants' awareness of right-of-way rules, are generally multiple-choice questions consisting of two options. In two-option questions, since participants have a 50% chance of randomly selecting the correct answer even if they do not know it. The total number of questions participants answered correctly and incorrectly was initially calculated to obtain a meaningful statistical result. Subsequently, based on the number of questions participants answered correctly, they were categorized into three classes of awareness levels: low, moderate, and high. In the questionnaire, a total of 18 questions were asked to measure participants' awareness level regarding right-of-way rules. Similarly, in other studies in the literature, such scaling has been performed to measure the awareness level [15]. Those who answered 12 questions or fewer correctly were categorized as having low awareness, those who answered between 13 and 15 questions correctly were categorized as having medium awareness, and those who answered 16 questions or more correctly were considered to have a good level of awareness about right-of-way rules. Additionally, to determine the questions that participants found easiest and most challenging, the average percentage of correct answers given by all participants to each question was calculated. Questions with a correct answer rate below 70% were classified as low accuracy, those within the range of 71% to 85% were categorized as medium accuracy, and those with a rate exceeding 85% were considered high accuracy.

4. Findings

4.1. Correct answer rates by question

There are 18 questions in this questionnaire to test awareness of the right-of-way rules. 6 of these 18 questions were asked to test basic right-of-way rules, 4 of these asked to test traffic signals about yield and stop, 2 of these asked to test pedestrian and bicyclist priority, 4 of these asked to test basic right-of-way rules in terms of road priority, 1 of these asked to test traffic lights and 1 of these asked to test emergency car priority. The questions have been classified based on the provided correct answer rates. Questions with a correct answer rate below 70% are categorized as Low Accuracy, those falling within the range of 71% to 85% are considered

Table 4. Rate of correct answers to each question

Question Number	Accuracy Rate (%)	The Aim of the Question	Question Number	Accuracy Rate (%)	The Aim of the Question
1	89.7	Basic right-of-way rules	10	58.3	Basic right-of-way rules in terms of road priority
2	71.9	Basic right-of-way rules	11	70.9	Basic right-of-way rules
3	83.8	Basic right-of-way rules	12	87.4	Basic right-of-way rules in terms of road priority
4	88.4	Basic right-of-way rules	13	57.9	Basic right-of-way rules in terms of road priority
5	93	Pedestrian and bicyclist priority	14	73.5	Basic right-of-way rules in terms of road priority
6	96	Pedestrian and bicyclist priority	15	94	Traffic lights
7	86.1	Basic right-of-way rules	16	45.4	Traffic signs about yield and stop
8	56.3	Traffic signals about yield and stop	17	63.2	Traffic signs about yield and stop
9	84.4	Traffic signals about yield and stop	18	88.7	Emergency car priority

Green – High Accuracy Level (16 or more correct), Yellow – Medium Accuracy Level (13-15 correct), Red – Low Accuracy Level (12 or fewer correct)

Medium Accuracy, and questions with a correct answer rate exceeding 85% are classified as High Accuracy questions.

When the results were examined, it was observed that the accuracy rates of questions 1, 2, 3, 4, 7, and 11, which were asked to test the Basic Right-of-Way Rules, were around an average of 80%. Among these questions, questions 2, 3, and 11 were found to be at the medium accuracy rate, while the others were determined to be at the high accuracy rate. The questions numbered 8, 9, 16, and 17, which were asked to assess awareness of traffic signals about yield and stop, had a significantly lower accuracy rate compared to all other test questions. It was determined that the average accuracy rates of these four questions were around 60%. It has been observed that the awareness of question number 9 is at the medium accuracy level, while the others are at the low accuracy level in this field.

Most participants correctly answered the questions about the priorities of pedestrians and cyclists. Accordingly, it was observed that participants answered questions number 5 and 6 with an average 95% accuracy rate. When examining the responses to questions number 10, 12, 13, and 14, which were asked to test basic right-of-way rules in terms of road priority, it was observed that participants struggled with questions number 10 and 13. Their accuracy rates were below 60%, indicating a low accuracy rate. Question number 11, on the other hand, was answered correctly at the medium accuracy rate. Additionally, it was observed that question number 15, asked to assess the awareness about traffic lights, and question number 18, asked to assess the awareness about emergency car priority, were known at very high accuracy rates. The Accuracy rates for each question are presented in Table 4.

The total number of correct answers given by each of the 302 participants in the questionnaire has been calculated. Subsequently, those who answered 12 or fewer questions correctly were considered to have a low level of awareness (LOA), those who answered 13 to 15 questions correctly were considered to have a medium level of awareness, and those who answered 16 or more questions correctly were considered to have a high level of awareness. According to this, it has been determined that 24% of the participants have a low level of awareness, 54% have a medium level of awareness, and 22% have a high level of awareness. The number of correct answers given by participants is presented in Figure 5. When examining this data, it is observed that 23% of the participants, constituting the largest group, answered 14 questions correctly, while only 1% answered all questions correctly.

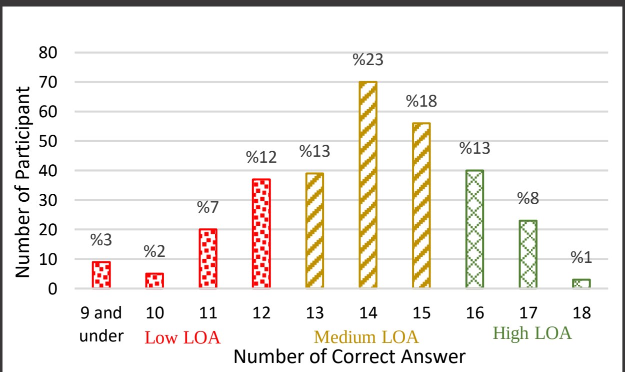

Figure 5. Distribution of participants according to the number of correct answers

4.2. Demographic effect on correct answers

The average number of correct answers for each demographic group has been calculated to examine the relationship between the demographic characteristics of the participants and their correct answers. When considering all 302 participants in the questionnaire, the average number of correct answers is 13.89. Figure 6 provides the average number of correct answers for each demographic group. When considering 18 questions, the overall average correct answer rate was calculated as 77%.

The descriptive statistical data for the participants' scores have been analyzed. According to the analysis results the mean score for correct answers is M=13.89, with a standard deviation of SD=2.09, a variance of var=4.35, and the p-value of the Shapiro-Wilk test is less than p=0.001 were found. As the p-value of Shapiro Wilk Test is below p=0.001 which is less than the %5 level of significance we reject null hypothesis which means that the data is not normally distributed. Non-parametric Kruskal-Wallis and Mann-Whitney U analyses were chosen because the data does not follow a normal distribution. The chosen tests, Mann-Whitney U test is a non-parametric test used to assess differences between two independent groups, while the Kruskal-Wallis test is a non-parametric test used to compare differences among three or more independent groups.

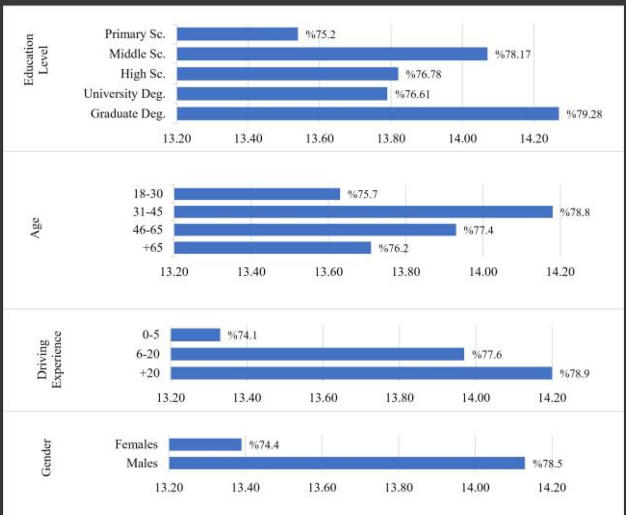

Figure 6. Average number of correct answers and rates by demographic group

Since gender has only two categories (male and female), we used the Mann-Whitney U test. For variables like education level, experience, and age, which have three or more categories, the Kruskal-Wallis test has been preferred. According to the Mann-Whitney U test, a significant difference was observed between female and male groups in terms of scores (p=0.00). The size of the male group is 205, and the size of the female group is 97. The mean and standard deviation values for the male and female groups are found M_{male}=14.2, SD_{male}=1.82 and M_{female}=13.4, SD_{female}=2.35, respectively.

When examining the results of the Kruskal-Wallis test, no significant difference was observed among age groups (p=0.20) and education level groups (p=0.54), while a significant difference was found among experience groups in terms of scores (p=0.02) (Table 5).

Table 5. Kruskal-Wallis test parameters

Scores	Kruskal-Wallis		
	χ^2	df	p
$\text{Experience}_{score}$	7.55	2	0.02
Age_{score}	4.60	3	0.20
Education_{score}	3.09	4	0.54

When examining pairwise comparisons, no significant difference was observed between participants with over 20 years of experience and those with 6-20 years of experience (p=0.89). However, significant differences were found among other groups in terms of scores (p=0.03 and p=0.05) (Table 6).

Examining the participants' education levels it is shown that participants with postgraduate degrees have the highest average with 14.3 correct answers. This group is followed by middle school graduates with an average of 14.07 correct answers. Participants with high school and university degrees were found to have correct answer averages of 13.82 and 13.79, respectively. Thus, participants with middle school education have surpassed those with high school and university degrees in terms of average correct answers. This is mainly because most middle school graduates among the participants fall into the middle-age group of experienced drivers. In Türkiye, in 2012, mandatory education was elevated from middle school to high school level, resulting in a situation where middle school graduates among adults in society are predominantly from middle and older age groups.

Table 6. Pairwise comparisons of experience groups

Experience Group 1	Experience Group 2	W	p
+20 years	6-20 years	-0.66	0.89
+20 years	0-5 years	-3.57	0.03
6-20 years	0-5 years	-3.36	0.05

When examining the number of correct answers by age group, it is observed that the middle-age group (31-45) surpasses other age groups with an average of 14.18 correct answers. The middle age group was followed by the middle-old group, with an average of 13.93. The average number of correct answers for the young and old age groups found 13.63 and 13.71, respectively. Here, it has been demonstrated that experience plays a significant role in answering the questions, but it is also shown that the number of correct answers is inversely proportional to age beyond the middle age group. When these results are examined, it can be said that experience directly influences the awareness of right-of-way rules.

When examining driver experience, those with less than five years of experience scored the lowest at an average of 13.33 correct answers, while the increase in experience corresponded to a higher number of correct answers. It has been observed that drivers with 6-20 years of experience have an average of 13.97 correct answers, while drivers with more than 20 years of experience have an average of 14.20 correct answers. When examining the average number of correct answers for gender groups, it is observed that the average number of correct answers for women is 13.39, whereas for men, it is 14.13.

5. Discussion and recommendations

In this section, the participant awareness levels about right-of-way rules, as measured through conducted survey studies, are discussed. Additionally, recommendations are provided for enhancing individuals' awareness levels.

5.1. Discussion

When considering all participants, the average number of correct answers is 13.89. This result indicates a 77.2%

accuracy rate for all participants. Based on the results the level of awareness level for the right-of-way rules has been found to be insufficient for a safe traffic environment. The analysis of questionnaire responses also revealed patterns in participants' awareness of right-of-way rules. Questions were grouped into three accuracy levels: low, medium, and high. While many questions were answered accurately, some had medium or low accuracy. Participants particularly struggled with recognizing stop and yield traffic signs. These findings emphasize the necessity of taking measures for traffic safety and awareness.

The analysis of participants' responses and demographic data revealed that driver experience was the most significant factor influencing the correct answer scores. As experience increased, scores improved. Those with 6-20 years of experience answered correctly at a slightly higher rate, while drivers with more than 20 years of experience achieved the highest accuracy. These findings emphasize the critical role of experience in driver proficiency and suggest that targeting educational interventions at young and inexperienced drivers could enhance traffic safety by bridging their knowledge gap.

When examining the average correct answers of gender groups, it is observed that women have fewer correct answers compared to me. Regarding age groups, the middle-age group surpasses others with the highest average of correct answers, reflecting the potential impact of experience. Following this group is the middle-old age group, which also performs well. The young and old age groups have similar averages, with both slightly below the middle-old group. This result demonstrates that experience plays a significant role in answering the questions. As a solution, educational and information update programs should be tailored to each age and gender group to help improve level of awareness about right-of-way rules of drivers.

5.2. Recommendations

Bucsuházy et al. [25] link traffic accidents in young individuals to driver experience and associate them with psychomotor functions in elderly drivers. In addition to Bucsuházy et al. [25] findings, when the responses of these young and elderly drivers were examined, it was observed that these age groups had a low level of awareness in our study. Therefore, it is believed that another reason for accidents observed in the young and senior age groups is a low level of awareness.

Studies conducted in the literature to measure people's knowledge levels on traffic safety mostly focus on the awareness of traffic signs [15, 26-28]. In our study, unlike these studies, the awareness of right-of-way rules at intersections has been examined. When examined from the perspective of traffic safety, our results align with the mentioned studies. When examined in conjunction with other studies, drivers have a significantly low awareness of traffic signs and rules. This situation constitutes a threat to traffic safety, increasing the likelihood of accidents. Therefore, it is crucial to educate individuals about traffic safety through various methods, beginning with schools.

The conducted studies demonstrate that drivers can obtain information about traffic from a wide range of sources, such as social media, roads and traffic signs, personal observations and experiences, peer and relatives' instructions, and traffic authorities' examinations [29]. Therefore, all available communication methods should be utilized to raise awareness among individuals regarding traffic safety.

When examined in the literature, it is observed that civil society organizations, public institutions, and schools are making efforts to establish more effective communication with individuals to increase their awareness of traffic safety. This communication can be facilitated through gamified educational methods that emphasize human experience, incorporating technology, virtual 3D rooms [31], and simulations [33-35]. We also believe and recommend that the implementation of virtual rooms and simulations, which allow participants to experience, especially in schools, will increase awareness of traffic safety and reduce traffic accidents.

The evolving communication methods of today have allowed social media to have a substantial impact on people. It is also possible to utilize the communication power of social media for traffic safety [36]. It is believed that public institutions, civil society organizations, and well-recognized politicians, writers, artists, athletes, and celebrities, by using social media, can play a significant role in raising awareness among individuals about traffic safety, which is thought to be crucial in reducing traffic accidents. Furthermore, public service announcements using emotional appeals such as fear and sadness, with a focus on themes of death, injury, and family, can be utilized in raising awareness among individuals [37]. In this regard, it is believed that well-crafted public service announcements, when presented to the right audience, can raise awareness among individuals about traffic safety.

According to the results obtained from the study, participants with medium and low levels of awareness comprise 76% of all participants. To increase the awareness level of individuals in this group, responsible agencies take measures to reduce accidents caused by violations of right-of-way rules. These measures should include tightening the eligibility criteria for obtaining a driver's license, conducting public service campaigns, public service ads, and disseminating information about traffic right-of-way rules. The primary objective of these measures is to enhance public awareness of right-of-way rules. All these outlined measures can be implemented in the province of Isparta and nationwide in Türkiye.

6. Limitations and Future Research

The scope of this study has been limited to the province of Isparta in Türkiye. In future research, the awareness of right-of-way rules can be examined with a larger number of participants from different provinces and regions. This way, the level of awareness regarding right-of-way rules can be more accurately determined for all of Türkiye, and the results obtained for different regions can be compared with each other to identify regional variations.

Due to the challenges of finding participants in the questionnaire method, the participants of this study may not fully represent the demographic groups within the society in equal proportions. In forthcoming studies, increasing the number of participants can lead to a more accurate representation of the demographic groups within the society by the selected participants.

In traffic, driver, pedestrian, and cyclist behaviors can also be influenced by psychological and sociological reasons. Therefore, knowing a rule in traffic does not guarantee compliance with that rule. Knowing them alone does not give them meaning when rules or norms are not followed. In this regard, the behaviors of traffic participants may need to be approached from a more comprehensive perspective. Societies may know or not know the laws, accept or reject them, agree or disagree with the rules, and comply or not comply with them. Therefore, in future studies, participants' levels of awareness about right-of-way rules, their real-life adherence to these rules, and their behaviors can be observed together to determine how well awareness translates into practice.

Declaration of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contribution Statement

A. Kıcı: Formal analysis, Investigation, Resources, Software, Validation, Visualization, Writing – Original draft, Writing – Review & editing; **M. Tığdemir:** Conceptualization, Data curation, Methodology, Project administration, Supervision, Writing – Review & editing.

Acknowledgement

The method and topic of the study were reviewed and approved by the Süleyman Demirel University Ethics Committee, with the approval granted on December 27, 2022 (Decision No: 69/5).

References

[1] Erişkin, E., Karahançer, Ş., Terzi, S., & Saltan, M. (2020). Highway geometric design using Bézier curve approximation. *Journal of Innovative Transportation*, *1*(1), 1104.

[2] Ye, X., Pendyala, R. M., Washington, S. P., Konduri, K., & Oh, J. (2009). A simultaneous equations model of crash frequency by collision type for rural intersections. *Safety Science*, 47(3), 443-452. https://doi.org/10.1016/j.ssci.2008.06.007

[3] Roess, R. P., Prassas, E.S., & McShane, W.R. (2004). Traffic Engineering. Pearson/Prentice Hall.

[4] Baireddy, R., Pour-Rouholamin, M., Zhou, H., & Qi, Y. (2017). Factors contributing to injury severity of pedestrian crashes at uncontrolled locations in Illinois. *In Transportation Research Board 96th Annual Meeting* (No. 17-03502).

[5] Bhatt, K., & Shah, J. (2022). Driver's Risk Compelling Behavior for Crossing Conflict Area at Three-Legged Uncontrolled Intersection. Paper presented at the Intelligent Infrastructure in Transportation and Management: *Proceedings of i-TRAM 2021.* https://doi.org/10.1007/978-981-16-6936-1_4

[6] Lakshmipriya, C. P. (2018). Development of crash prediction models for uncontrolled intersections. *International journal of engineering technology science and research*, *5*(5), 104-110.

[7] Vajari, M. A., Aghabayk, K., Sadeghian, M., & Shiwakoti, N. (2020). A multinomial logit model of motorcycle crash severity at Australian intersections. *Journal of safety research*, *73*, 17-24. https://doi.org/10.1016/j.jsr.2020.02.008.

[8] Zhang, C., Zhou, B., Chen, G., & Chen, F. (2017). Quantitative analysis of pedestrian safety at uncontrolled multi-lane mid-block crosswalks in China. *Accident Analysis & Prevention,* 108, 19-26. https://doi.org/10.1016/j.aap.2017.08.018.

[9] Federal Highway Administration (FHA). (2009). Manual on uniform traffic control devices for street and highways (MUTCD). Washington, DC: Federal Highway Administrator U.S. Department of Transportation.

[10] Turkish Statistical Institute (TÜİK). (2024). Ulaştırma ve Haberleşme İstatistikleri, Ankara, Hazine ve Maliye Bakanlığı (accessed November 28, 2024, public access data sets available at: https://data.tuik.gov.tr/Kategori/GetKategori?p=Ulastirma-veHaberlesme-112).

[11] National Highway Traffic Safety Administration (NHTSA). (2023). Fatality and Injury Reporting System Tool (FIRST), Washington, DC, Department of Transportation (accessed August 10, 2023, public access data sets available at: https://cdan.dot.gov/query).

[12] Alonso, F., Esteban, C., Montoro, L., & Useche, S. A. (2017). Knowledge, perceived effectiveness and qualification of traffic rules, police supervision, sanctions and justice. *Cogent social sciences*, 3(1), 1393855. https://doi.org/10.1080/23311886.2017.1393855

[13] Björklund, G. M., & Åberg, L. (2005). Driver behaviour in intersections: Formal and informal traffic rules. *Transportation research part F: traffic psychology and behaviour*, 8(3), 239-253. https://doi.org/10.1016/j.trf.2005.04.006

[14] Brandt, R. K., Haustein, S., Hagenzieker, M., & Møller, M. (2022). Cyclists' handheld phone use and traffic rule

knowledge. *Transportation research part F: Traffic Psychology and Behaviour*, 86, 121-130. https://10.1016/j.trf.2022.02.004

[15] Çakıcı, Z., & Murat, Y. Ş. (2017). Trafik işaretlerinin bilinirliği üzerine bir araştırma: Denizli örneği. *Bitlis Eren Üniversitesi Fen Bilimleri Dergisi*, 6(1), 21-30. https://doi.org/10.17798/bitlisfen.305485

[16] Hossain, S., Maggi, E., Vezzulli, A., & Mahmud, K. T. (2021). Determinants of awareness about road accidents and knowledge of traffic rules: Empirical evidence from Khulna City in Bangladesh. *Theoretical Economics Letters*, 11(6), 1247-1272. https://doi.org/10.4236/tel.2021.116079

[17] Islam, M. R., Khan, M. M. A., Hossain, M. M., Mani, K. K., & Min, R. M. (2020). Road traffic accidents in Bangladesh: Why people have poor knowledge and awareness about traffic rules? *International journal of critical illness and injury science*, 10(2), 70. https://doi.org/10.4103/IJCIIS.IJCIIS_65_19

[18] Nagar, K. (2022). Safety Education on Knowledge, Attitude and Practice Towards Road Traffic Signs and Regulations Among College Students At Gujarat. *Journal of Pharmaceutical Negative Results*, 948-958. https://doi.org/10.47750/pnr.2022.13.S04.112

[19] Riaz, I., & Shahid, S. (2018). Knowledge, attitudes, and practice of drivers towards traffic rules and regulations in Multan, Pakistan. *In 7th International RAIS Conference on Social Sciences*. https://doi.org/10.2139/ssrn.3152120

[20] Shaaban, K. (2021). Impact of experience and training on traffic knowledge of young drivers. *The Open Transportation Journal*, 15(1): 61-68. http://dx.doi.org/10.2174/1874447802115010061

[21] Yahia, H. A., & Ismail, A. (2014). Research Article Knowledge of Traffic Laws and Drivers Behavior on the Roads of Tripoli City, Libya. *Research Journal of Applied Sciences, Engineering and Technology*, 7(10), 2040-2045. https://doi.org/10.19026/ajfst.7.497

[22] Turkish Statistical Institute (TÜİK). (2024). Nüfus ve Demografi İstatistikleri, Ankara, Hazine ve Maliye Bakanlığı (accessed November 28, 2024, public access data sets available at: https://data.tuik.gov.tr/Kategori/GetKategori?p=Nufus-ve-Demografi-109)

[23] Presidency of Republic of Türkiye Legislation Information System (1983). Highway Traffic Law (Law No. 2918), Ankara, Presidency of Republic of Türkiye (accessed August 17, 2023, public access legislation available at: https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=2918&MevzuatTur=1&MevzuatTertip=5)

[24] Presidency of Republic of Türkiye Legislation Information System. (1997). Highway Traffic Regulation, Ankara, Presidency of Republic of Türkiye (accessed August 17, 2023, public access legislation available at: https://www.mevzuat.gov.tr/File/GeneratePdf?mevzuatNo=8182&mevzuatTur=KurumVeKurulusYonetmeligi&mevzuatTertip=5)

[25] Bucsuházy, K., Matuchová, E., Zůvala, R., Moravcová, P., Kostíková, M., & Mikulec, R. (2020). Human factors contributing to the road traffic accident occurrence. *Transportation research procedia*, 45, 555-561. https://doi.org/10.1016/j.trpro.2020.03.057

[26] Mutlu, M. A., & Yakar, F. (2022). Effects of driver characteristics, questionnaire type, and sign design on drivers' comprehension of traffic signs. *Journal of the Faculty of Engineering and Architecture of Gazi University*, 37(2), 595-608. https://doi.org/10.17341/gazimmfd.894629

[27] Umar, I. K., & Bashir, S. (2019). Comprehension of road traffic signs by various road users in Kano city. *Cumhuriyet Science Journal*, 40(1), 197-203. https://doi.org/10.17776/csj.403516

[28] Şehribanoğlu, S. (2019). Van ilinde yaşayanların trafik işaretleri bilgisi ve trafik kurallarına bakış açıları üzerine bir araştırma. *Trafik ve Ulaşım Araştırmaları Dergisi*, 2(1), 1-15. https://doi.org/10.38002/tuad.479023

[29] Ningal, J., & Oños, C. (2021). Traffic education, publicity and training in road safety: basis for road safety and accident awareness program. *Social and Crimonol*, 9, 212. https://doi.org/10.24941/ijcr.41750.06.2021

[30] Guzel, D., & Altıntaşı, O. (2023). Exploring the traveler group-based ridership fluctuations before, during and after the COVID-19 pandemic: A case study of rail transit system in Izmir, Türkiye. *Journal of Innovative Transportation*, 4(1), 1-8. https://doi.org/10.53635/jit.1262737

[31] İçten, T. (2021). Trafik güvenliği kurallarının ve işaretlerinin eğitimi için etkileşimli 3B sanal ortam. *Bilişim Teknolojileri Dergisi*, 14(2), 191-206. https://doi.org/10.17671/gazibtd.791458

[32] Topkaya, Y. (2019). Trafik kurallarının öğretilmesine yönelik kullanılan eğitici çizgi romanlara yönelik öğrenci görüşleri (Hatay Mustafa Kemal Üniversitesi örneği). *In International Educational Sciences Congress*.

[33] Cheng, Y.-Q., Mansor, S., Chin, J.-J., & Karim, H. A. (2022). Driving simulator for drivers education with artificial intelligence traffic and virtual reality: a review. *In Proceedings of the 8th International Conference on Computational Science and Technology: ICCST 2021*, Labuan, Malaysia, 28–29 August. https://doi.org/10.1007/978-981-16-8515-6_38

[34] Backlund, P., Engström, H., Johannesson, M., & Lebram, M. (2010). Games for traffic education: An experimental study of a game-based driving simulator. *Simulation & gaming*, 41(2), 145-169. https://doi.org/10.1177/10468781073114

[35] Gounaridou, A., Siamtanidou, E., & Dimoulas, C. (2021). A serious game for mediated education on traffic behavior and safety awareness. *Education Sciences*, 11(3), 127. https://doi.org/10.3390/educsci11030127

[36] Özel, M. (2022). Türkiye'de yürütülen karayolu trafik güvenliği farkındalık kampanyalarının sosyal medya paylaşımları üzerinden incelenmesi. *Türk İdare Dergisi*, 494: 229-266.

[37] Gülada, M. O., Avcı, Ö., & Çakı, C. (2023). Emniyet kemerinin trafik güvenliğindeki rolü: kamu spotlarının nitel analizi. *Trafik ve Ulaşım Araştırmaları Dergisi*, 6(1), 59-79. https://doi.org/10.38002/tuad.1179833

[38] Kavsıracı, O., Demirbaş, M., & Sena, T. (2021). Karayolu trafik güvenliği'ne yönelik gerçekleştirilen sosyal kampanya, denetim, idari cezalar ve bireyler üzerindeki etkileri. *İdeakent*, 12(34), 1285-1309. https://doi.org/10.31198/idealkent.1013602

[39] Esfandiari, Z., Marasi, M. R., Estaki, F., Sanati, V., Panahi, E., Akbari, N., Madani, R. A., & Tanha, J. M. (2019). Influence of education on knowledge, attitude and practices of students of Isfahan University of Medical Sciences to traffic light inserted on food labeling. *Tehran University medical journal*, *77*(1), 54-62.

[40] Mirzaei, R., Hafezi-Nejad, N., Sabagh, M. S., Moghaddam, A. A., Eslami, V., Rakhshani, F., & Rahimi-Movaghar, V. (2014). Dominant role of drivers' attitude in prevention of road traffic crashes: A study on knowledge, attitude, and practice of drivers in Iran. *Accident Analysis & Prevention*, 66, 36-42. https://doi.org/10.1016/j.aap.2014.01.013

[41] Parmenter, K., & Wardle, J. (1999). Development of a general nutrition knowledge questionnaire for adults. *European journal of clinical nutrition*, 53(4), 298-308. https://10.1038/sj.ejcn.1600726

[42] Sun, J., Ren, X., & Anumba, C. J. (2019). Analysis of knowledge-transfer mechanisms in construction project cooperation networks. *Journal of Management in Engineering*, 35(2), 04018061. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000663

[43] Tripathi, S. R., & Tiwari, R. R. (2006). Self-reported hearing quality of traffic policemen: A questionnaire-based study. *Indian Journal of Occupational and Environmental Medicine*, 10(2), 82. https://doi.org/10.4103/0019-5278.27306

[44] Tseng, J.-J., Chai, C. S., Tan, L., & Park, M. (2022). A critical review of research on technological pedagogical and content knowledge (TPACK) in language teaching. *Computer Assisted Language Learning*, 35(4), 948-971. https://doi.org/10.1080/09588221.2020.1868531

[45] Useche, S. A., Alonso, F., Montoro, L., & Tomas, J. M. (2019). When age means safety: Data to assess trends and differences on rule knowledge, risk perception, aberrant and positive road behaviors, and traffic crashes of cyclists. *Data in brief*, 22, 627-634. https://doi.org/10.1016/j.dib.2018.12.066

[46] Baş, T. (2001*). Anket: Anket nasıl hazırlanır? Anket nasıl uygulanır? Anket nasıl değerlendirilir?*. Seçkin Yayıncılık.

[47] Saris, W. E., & Gallhofer, I. N. (2014). *Design, evaluation, and analysis of questionnaires for survey research*. John Wiley & Sons.

[48] Büyüköztürk, Ş. (2005). Anket geliştirme. *Türk Eğitim Bilimleri Dergisi*, 3(2), 133-151.

[49] Cochran, W.G. (1977). *Sampling techniques*. Johan Wiley & Sons Inc.

Journal of Innovative Transportation, 5(2), 34-39

Research Article

JOURNAL OF INNOVATIVE TRANSPORTATION

e-ISSN: 2717-8889

Gender-based risk analysis of vehicle control loss due to localized water puddles: An analytical approach

Ekinhan Eriskin[a],*

[a] *Department of Property Protection and Security, Süleyman Demirel University, Turkey*

Highlights

- Local water puddles in pavements cause risk on steering
- Female and male drivers' risk velocity differs
- 70 km/h velocity and higher cause the same risk for female and male drivers.

Abstract

Adverse weather conditions significantly increase the risk of traffic accidents, yet most studies focus on uniform conditions across all tires. This study investigates the impact of asymmetric drag forces when only one tire encounters a local water puddle, causing potential vehicle control loss. Using analytical methods, we calculate drag forces and their transmission to the steering wheel, accounting for variations in water film thickness, vehicle speed, and driver gender. The results indicate that female drivers face higher risks of control loss, with critical speeds decreasing as water film thickness increases. The study highlights that localized water puddles, especially at low speeds and water depths exceeding 3 cm, pose significant risks. These findings can inform road safety guidelines and vehicle design standards to mitigate accident risks in adverse weather conditions.

Information

Received: 08.10.2024

Received in revised: 04.12.2024

Accepted: 18.12.2024

Keywords: *Control Loss, Drag Force, Traffic Accident, Over-Steering, Asymmetric Resistance*

1. Introduction

According to the World Health Organization's [1] data for 2016, the traffic accidents caused about 1.35×10^6 deaths worldwide. Traffic accidents affect all groups of road users like pedestrians, drivers and passengers. Especially, for peoples, between the ages 15 to 29, the main death cause globally is traffic accidents. Based on the National Highway Traffic Safety Administration's [2] data between 2014 and 2018, 32.4×10^6 crashes occurred and 25.2×10^6 persons are estimated to be involved in injuries while 411.2×10^3 persons died because of fatal crashes. 29.4% of the total crashes have occurred during adverse weather. About 6.8×10^6 (26.9% of total injuries) people are injured by accidents occurred during adverse weather while about 122.5×10^3 (29.8% of total deaths) people died. Hao and Daniel [3], analysed the inclement weather affecting highway-rail grade crossings in the United States between the years 2002 and 2011 and found that 30.7% of the total crashes occurred during adverse weather. Umar and Bashir [4] investigated the truck traffic injuries and found that driver's involvements as statistically significant. Also, Mutlu and Alver [5] in their study put forth that young drivers aged between 18 and 29 are more likely to break red light, using mobile phone during drive and they don't see this behavior as risky.

When the five-year-long period for the United States is examined, almost one-third of the accidents occur during adverse weather. Pitaksringkarn et al. [6] studied the correlation between skid resistance and wet pavement related accidents in Thailand. They found that there is an inverse proportion between them. Lee et al. [7] investigated the city of Seoul for nine years between 2007 and 2015 and found that accident severity is correlated with rain and water film thickness on the pavement. Mondal et al. [8], point that rainy weather and wet pavement conditions are one of the significant weather-related parameters which increase the probability of occurrence of an accident. Saplioglu et al. [9] investigated the skid resistance at accident occurred urban intersections. They found a relation between the texture depth and the accident occurrence probability which is also an inverse proportion. When the texture depth decreases, the probability of accident occurrence

Corresponding author: ekinhaneriskin@sdu.edu.tr (E, Eriskin), +90 246 211 4649

https://doi.org/10.53635/jit.1563541

increases. Kassu and Anderson [10] analysed the effect of wet pavement surface condition to non-severe crashes on two and four-lane highways. They found that the effective parameters which influence the crash are the segment length, traffic volume and speed limit. Liu et al. [11], evaluated the braking performance on wet pavement using integrated tire and vehicle approach. They build a 3D tire, water and pavement model on ABAQUS and simulate the hydroplaning effect. They simulate the water film thickness between 0.5-10 mm and used a 170/70R15 tire size. Besides these, there are many aquaplaning/hydroplaning studies [12-15].

Moreover, there are many studies about; vehicle control loss is the role of environmental factors, such as water accumulation on roadways [16], the integration of advanced technologies in vehicle systems has been explored in the context of improving safety [17], in the realm of artificial intelligence and decision-making frameworks [18]. Furthermore, the research by Yoo et al. [19] on risk-conditioned reinforcement learning provides a foundation for developing adaptive systems that can respond to varying risk measures in real-time. The impact of urbanization on traffic safety and vehicle control is also a pertinent topic [20].

When these studies are examined, the effect of low skid resistance and wet pavement are all well studied. However, all these studies focus on the situation where both tires drive on the same circumstances and pavement-tire contact. But it is not always true that all the tires encounter the same conditions while driving, and therefore a resistance force difference occurs. When there are pavement deteriorations like rutting, corrugations or shoving occurs, only one of the front wheels may drive into water puddle while the other one drive-through dry or drained through macro-texture/slope of the pavement. When such a case has occurred, there would be a tremendous difference between the resistance faced by the front wheels. In such a situation, the difference in the resistance of the wheels would affect the vehicle in a way where the vehicle changes its direction. Here, the driver should react on time with a corresponding force on the wheel to keep the vehicle in its way. Since the vehicle's velocity decreases overtime during an ordinary drive in the fluid, the resistance force is maximum when the vehicle contacts the fluid puddle. Therefore, the calculated forces are subject to the contact time in this study.

Localized water puddles can cause asymmetric drag forces, which may lead to loss of vehicle control. This study addresses this gap by investigating the effects of these forces on vehicle steering dynamics. The analysis will focus on how driver gender, speed, and water film thickness influence the risk of vehicle control loss. By analyzing these parameters, we aim to highlight the importance of localized water hazards and their impact on different driver demographics.

There are few studies about such a case which could lead to over- or under-steering the vehicle and losing control. A sample could be given with the technical paper of Hight et al. [21]. Ivan et al. [22], investigated accidents in Connecticut and listed four major factors for fatal and injury crashes. Drivers losing control is the second and third major factor for fatal and an injury resulted in crashes, respectively. Penmetsa et al. [23] found that over-steering results most likely with fatality or injury to the driver. They also suggest researching the factors associated with over-steering to reduce the frequency and severity of the crashes. This study aims to highlight that asymmetric wheel resistance because of fluid on the pavement could also lose control of steering.

The primary goals of the study could be listed as; (i) analyzing the resistance forces for different water film thicknesses on the pavement, (ii) associate the resistance forces with the driver gender, and at last (iii) getting the speed limits for the vehicle which leads to likely control loss (defined as critical speed), and probably accident occurrence (defined as accident speed).

In this study, the gap in the literature is aimed to be filled by using an analytical approach. Therefore, a 205/55R17 sized tire (Figure 1) is used as the object tire. The resistance force on the tires' contact area has been calculated. Next, the force needed to control the steering wheel because of the resistance force has been got and compared with drivers control force based on gender, age and speed. As a result, the critical speed of the vehicles based on water film thickness is got. First, the drag force applying on the tire is explained as the next section. After, the force transmitted to the steering wheel is calculated.

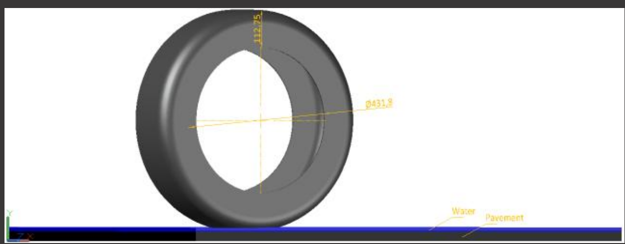

Figure 1. 205/55R17 size tire on a water layer

2. Methodology

This study models the effect of asymmetric resistance forces caused by localized water puddles. A 205/55R17 tire was used as the test case, and the drag force has been calculated. Drag force is a force which acts opposite to the motion of the object moving through the liquid or gas. This force could be between fluid and solid surface as well as fluid and fluid surfaces. The force is the dynamic pressure applied on a surface with a coefficient of the shape of the object moving through the fluid. The formula of the drag force because of the fluid (liquid or gas) is given in Equation (1).

$$F_d=\frac{1}{2}\rho V^2 C_D A \quad (1)$$

where, F_d is the drag force (N), ρ is the density of the corresponding fluid (kg/m^3), V is the velocity of the object (m/s), C_D is the complex coefficient for the shape of the object, and A is the cross-sectional area of the object faced with the fluid (m^2). The cross-sectional area is calculated using the water film thickness on the pavement.

As seen from Equation (1), the force depends on the velocity, area, density and coefficient. In our study, the most important part is the density because the rest of the parameters affect both tires as the same. However, there is a tremendous difference between the water ($1000\,kg/m^3$) and air ($1.225\,kg/m^3$). Because water's density is almost 815 times higher than the density of air, a huge drag force difference occurs between the tires which are transmitted to the steering wheel. When the driver cannot react on time with enough force for exactly the needed duration, it is possible to lose control of the vehicle. Velocity is the speed of the vehicle. The area is the cross-sectional area of the tire placed in the water paddle. The coefficient is the most complex parameter of the equation. The coefficient is determined experimentally. In this study, the coefficient is taken as 0.33 which is used by Keogh et al. [24]. Here, it should be noted that the coefficient is determined based on the shape of the wheel and does not affected from the environment.

Once the drag force is calculated, the force needed to control the steering wheel will be calculated. To do it first, the force on the wheel should be determined. For a steady-state vehicle, the force would be the mass multiplied with the friction coefficient, also the friction force. But in this paper, drag force will be taken into consideration since the vehicle is not in a steady-state and because friction force affects both tires the same, it is neglected. We focus only on forces affecting one tire. Once the force on the wheel is got, the torque on the wheel should be calculated (Equation 2).

$$\tau_{drag}=F_d \times r_{scrub} \quad (2)$$

where, τ_{drag} is the torque because of drag force (Nm) and r_{scrub} is the scrub radius (m). Scrub radius can be explained by the distance between the kingpin axis's theoretical extension to the road and the centre of the contact area of the wheel to the road. Scrub radius is taken as 0.1 m in this study. Next, the force on the tie rod should be calculated (Equation 3).

$$F_{tierod}=\frac{\tau_{hf}}{d} \quad (3)$$

where, F_{tierod} is the force on the tie rod (N), τ_{hf} is the torque for horizontal force from the tie rod (Nm) and d is the perpendicular distance between the kingpin axis to the end of the outer tie rod. The distance is taken as 0.0945 m in this study. The calculated torque because of drag force would be equal to the torque because of horizontal force from the tie rod. So, the force on the rack would be the difference between the force on tie rod from the two tires where one drives through water puddle and the other on the regular surface, through the air in this paper. Once the force on the tie rod is calculated, the force needed to control the steering wheel can be finally determined (Equation 4).

$$F_{driver}=\frac{F_{rack}\times r_{pinion}}{r_{SW}} \quad (4)$$

where, F_{driver} is the force applied by the driver to the steering wheel to control (N), F_{rack} is the total force on rack calculated as the difference on tie rod from two tires as mentioned above (N), r_{pinion} is the radius of the pinion (m) and r_{SW} is the radius of the steering wheel (m). Pinion radius is taken as 0.028 m while the steering wheel radius is 0.2 m.

3. Results and Discussion

As explained above, calculating the force needed to control the steering wheel depends on the radius of the steering wheel, pinion and scrub, total force on the rack, and force on the wheel. Since all parameters are the same but the force on the wheel, force on the wheel will be simulated and the needed force to control the steering wheel will be determined. Calculated forces on the steering wheel will be analysed to determine whether the forces are applicable. Eksioglu and Kizilaslan [25] analysed the applied forces on the steering wheel by 13 participants where 8 of them are males aged between 22 – 43, while 5 are females aged between 24 – 30. Eksioglu and Kizilaslan [25] take measurements of forces to control the vehicle while the drivers drive through a test area with speeds of 72 and 105 km.h-1 where the pavement type includes smooth and rough areas. As a result, they found that only the gender of the drivers is statistically significant. The maximum grip force values are 223.7 N and 135.1 N for males and females, respectively. An average grip force value while driving is reported as 66.3 N and 42.7 N for males and females, respectively. Based on the study of Eksioglu and Kizilaslan [25], when the force needed to control the steering wheel exceeds the maximum grip forces reported, the vehicle is most likely to get out of the way resulting with an accident. When the force needed is between the average and maximum grip force values, then the vehicle is at critical speed and the outcome would be up to the driver's mental and physical condition. Here, the idea behind using the grip forces of the drivers is that the difference of the resistance on the wheels would try to turn the steering wheel and the drivers should keep it stationary.

Using Equations (1-4) the needed force to control the steering wheel is calculated for a speed ranged between

30 – 150 km.h-1 and water film thickness ranged between 0.001 – 0.3 m. Calculated force values are visualized and given in Figure 2.

As seen in Figure 2, the needed force to control the steering wheel increases polynomial. While the needed force is very low to control during low speeds, even high-water film thickness, with the increase of the velocity value the needed control force increases quickly. In Table 1, the critical speeds (CS) and probably accident speeds (AS) are given for male and female drivers. The terms CS and AS are when force incurred at the steering wheel exceeds the average grip strength and when force incurred at the steering wheel exceeds maximum grip strength, respectively.

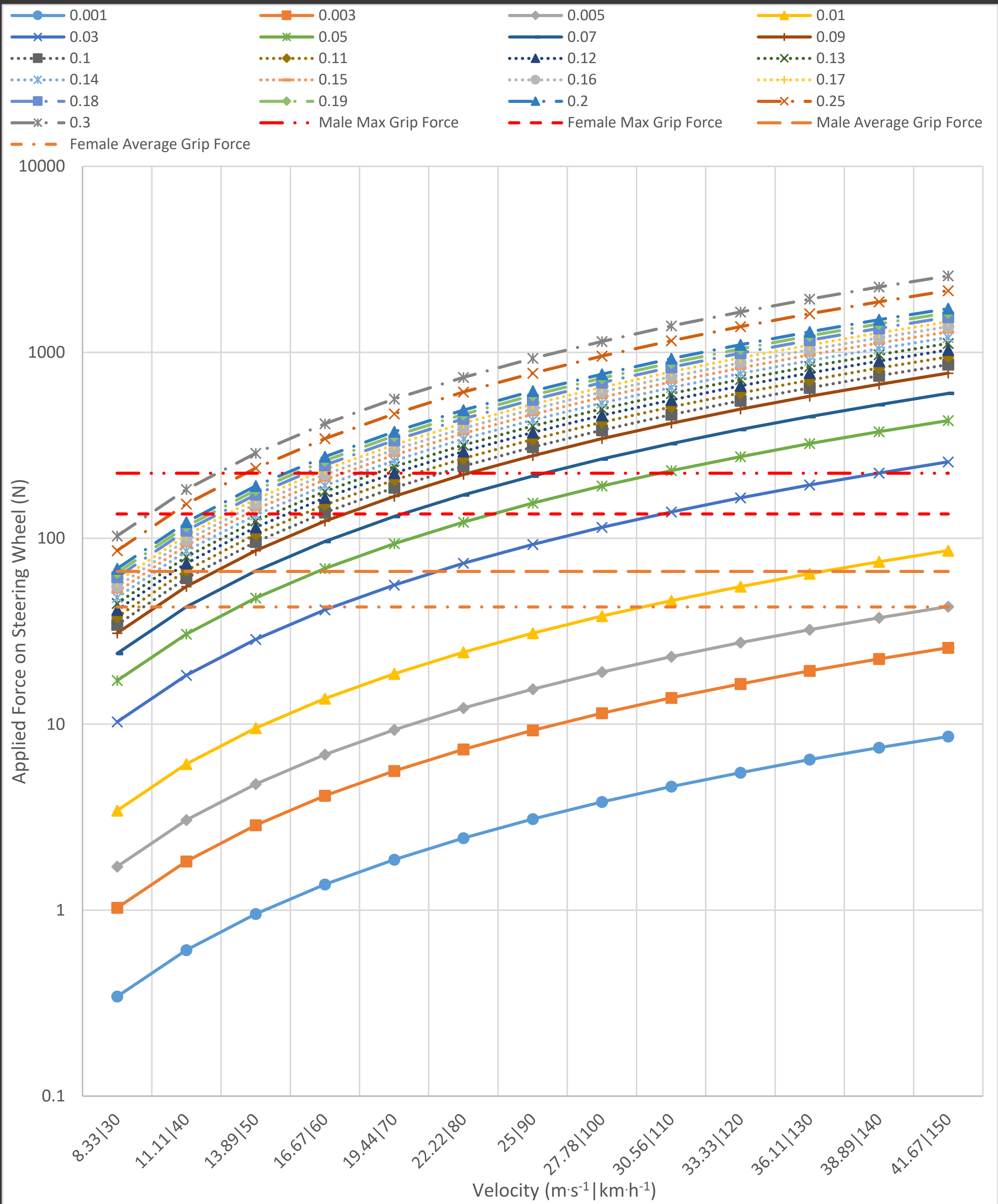

Figure 2: The calculated force needed on the steering wheel to control based on velocity and water film thickness.

Table 1: The lower limit of critical (CS) and probably involving into accident speed (AS) matrix obtained from Figure 2

Water film thickness, m	The limit velocity of vehicle for different conditions, km.h-1			
	♀-CS	♂-CS	♀-AS	♂-AS
0.30	>30	>30	34	45
0.25	>30	>30	37	48
0.20	>30	>30	42	54
0.19	>30	30	43	55
0.18	>30	31	44	56
0.17	>30	32	45	58
0.16	>30	33	47	61
0.15	>30	34	48	63
0.14	>30	35	50	65
0.13	>30	36	52	68
0.12	30	38	54	70
0.11	32	40	57	73
0.10	33	42	60	77
0.09	35	44	63	81
0.07	40	50	71	92
0.05	52	59	84	108
0.03	61	71	109	140
0.01	106	132	>150	>150
0.005	150	>150	>150	>150
0.003	>150	>150	>150	>150
0.001	>150	>150	>150	>150

As seen in Table 1, up to 5 mm height water film thickness could be able to be tolerated because the needed force is very low. For a high-speed road section, 1 cm height water film thickness causes serious safety issues for female drivers. For urban areas where the speed limit is 70 km.h-1 or higher, 3 cm high water film thickness is dangerous for male and female drivers. For low-speed roads, there is a tremendous difference for male and female drivers between the critical and probably involving into accident water film thicknesses. When the drivers drive less or are equal to 30 km.h-1, they only need to pay attention and the force they face is lower than their maximum grip force. When Table 1 is investigated, 12 cm height water film thickness is critical because it is possible that this height would occur on the pavement because of rutting heavy traffic, especially in the developing countries, and the speed values for probably involving into accident speeds are very easily accessible and posted design speeds for urban areas.

4. Conclusion

In this study, the gap in the literature as the lack of speeds and water film thicknesses leading to an accident for male and female drivers when only encounter on one wheel. An analytical approach is used to model the case for different speeds and water film thicknesses. A 205/55R17 sized tire is considered, but the texture is neglected. Based on the results of the study, the following conclusions could be drawn.

Male and female drivers have a significant difference in the grip of the steering wheel. This leads female drivers to probably involving into an accident at lower water film thicknesses for lower speeds than male drivers. The ratio for probably involving into accident thicknesses is about 1.8 times higher for males when Table 1 is examined and decreases with the increase of the speed. From up to 140 km.h-1, 3 cm height water film thickness is dangerous for both male and female drivers. The ratio for the critical area is lower than the ratio of probably involving into accident thicknesses. Here is the ratio 1.6 for the speed of 30 km.h-1 while almost the same for higher speeds.

Drivers would face up with higher force on the steering wheel than their average force applied at speeds 70 km.h-1 and higher while driving through 3 cm depth water puddles. If the driver is not fatigue or give correct reactions on the correct time, the vehicle would pass experiencing no adverse situation. But, since 3 cm is very low, the drivers should be warned when there is water puddles locally distributed on the pavement.

This study puts forth, though not a normative paper, the importance of the relationship between gender of drivers, water puddle depths and speeds of vehicles. This result may lead the way for further studies about the water film thickness and one-wheel contact. Type of vehicles, the effect of the mass of the vehicles, tire type, size and texture could be investigated for future works. Also, the mechanical characteristics of steering for autonomous vehicles could be investigated.

Declaration of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] World Health Organization. (2019). *Global status report on road safety 2018*. World Health Organization.

[2] National Highway Traffic Safety Administration. (2020). Fatality and injury reporting system tool (FIRST). *National Highway Traffic Safety Administration*.

[3] Hao, W., & Daniel, J. (2016). Driver injury severity related to inclement weather at highway–rail grade crossings in the United States. *Traffic injury prevention*, *17*(1), 31-38. https://doi.org/10.1080/15389588.2015.1034274

[4] Umar, I. K., & Bashır, S. (2020). Investigation of the factors contributing to truck driver's involvement in an injury accident. *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, *26*(3), 402-408. https://doi.org/10.5505/pajes.2019.65391

[5] Mutlu, M. M., & Alver, Y. (2014). Genç sürücülerin trafik kural ihlalleri ve sosyo-ekonomik yapıları arasındaki ilişkiler: Aydın ve Malatya örnekleri. *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, *20*(9), 344-350. https://doi.org/10.5505/pajes.2014.19970

[6] Pitaksringkarn, J., Tanwanichkul, L., & Yamthale, K. (2018). A correlation between pavement skid resistance and wet-pavement related accidents in Thailand. In *MATEC Web of Conferences*. 192. 02049. https://doi.org/10.1051/matecconf/201819202049

[7] Lee, J., Chae, J., Yoon, T., & Yang, H. (2018). Traffic accident severity analysis with rain-related factors using structural equation modeling–A case study of Seoul City. *Accident Analysis & Prevention*, *112*, 1-10. https://doi.org/10.1016/j.aap.2017.12.013

[8] Mondal, P. (2011). Are road accidents affected by rainfall? A case study from a large Indian metropolitan city. *Current Journal of Applied Science and Technology*, *1*(2), 16-26. https://doi.org/10.9734/BJAST/2011/106

[9] Saplioglu, M., Yuzer, E., Aktas, B., & Eriskin, E. (2013). Investigation of the skid resistance at accident occurred at urban intersections. *Journal of Traffic and Transportation Engineering*, *1*(12), 2328-2142.

[10] Kassu, A., & Anderson, M. (2018). Analysis of Nonsevere Crashes on Two-and Four-Lane Urban and Rural Highways: Effects of Wet Pavement Surface Condition. *Journal of Advanced Transportation*, *2018*(1), 2871451. https://doi.org/10.1155/2018/2871451

[11] Liu, X., Cao, Q., Wang, H., Chen, J., & Huang, X. (2019). Evaluation of vehicle braking performance on wet pavement surface using an integrated tire-vehicle modeling approach. *Transportation research record*, *2673*(3), 295-307. https://doi.org/10.1177/0361198119832886

[12] Zhilin, Y. D., Kharaldin, N. A., Cvetkov, P. S., Stepanov, A. V., Aleshin, M. V., & Borovkov, A. I. (2020). Tire tread optimization method to improve to push aside the water from the road contact patch. In *IOP Conference Series: Materials Science and Engineering*. 986(1), 012037). https://doi.org/10.1088/1757-899X/986/1/012037

[13] Zhu, X., Pang, Y., Yang, J., & Zhao, H. (2022). Numerical analysis of hydroplaning behaviour by using a tire–water-film–runway model. *International Journal of Pavement Engineering*, *23*(3), 784-800. https://doi.org/10.1080/10298436.2020.1774587

[14] Das, S., Dutta, A., Dey, K., Jalayer, M., & Mudgal, A. (2020). Vehicle involvements in hydroplaning crashes: Applying interpretable machine learning. *Transportation research interdisciplinary perspectives*, *6*, 100176. https://doi.org/10.1016/j.trip.2020.100176

[15] Spitzhüttl, F., Goizet, F., Unger, T., & Biesse, F. (2020). The real impact of full hydroplaning on driving safety. *Accident Analysis & Prevention*, *138*, 105458. https://doi.org/10.1016/j.aap.2020.105458

[16] Wang, B., Zhang, C., Zhang, M., Liu, C., Xie, Z., & Zhang, H. (2022). Digital twin analysis for driving risks based on virtual physical simulation technology. *IEEE Journal of Radio Frequency Identification*, *6*, 938-942. https://doi.org/10.1109/JRFID.2022.3203694

[17] Şimşek, N., & Kirisci, M. (2023). A new risk assessment method for autonomous vehicle driving systems: Fermatean fuzzy AHP approach. *İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi*, *22*(44), 292-309. https://doi.org/10.55071/ticaretfbd.1300893

[18] Ayala-Romero, J. A., Garcia-Saavedra, A., & Costa-Perez, X. (2024, March). Risk-Aware Continuous Control with Neural Contextual Bandits. In *Proceedings of the AAAI Conference on Artificial Intelligence* 38(19), 20930-20938. https://doi.org/10.1609/aaai.v38i19.30083

[19] Yoo, G., Park, J., & Woo, H. (2024). Risk-Conditioned Reinforcement Learning: A Generalized Approach for Adapting to Varying Risk Measures. In *Proceedings of the AAAI Conference on Artificial Intelligence* 38(15), 16513-16521. https://doi.org/10.1609/aaai.v38i15.29589

[20] Zhang, X., Huang, H., Yang, J., & Jiang, S. (2024). Research on Deep Learning-Based Vehicle and Pedestrian Object Detection Algorithms. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *48*, 213-220. https://doi.org/10.5194/isprs-archives-XLVIII-4-W10-2024-213-2024

[21] Hight, P. V., Wheeler, J. B., Reust, T. J., & Birch, N. (1990). *The effects of right-side water drag on vehicle dynamics and accident causation* (No. 900105). SAE Technical Paper.

[22] Ivan, J. N., Ravishanker, N., Jackson, E., Aronov, B., & Guo, S. (2012). A statistical analysis of the effect of wet-pavement friction on highway traffic safety. *Journal of Transportation Safety & Security*, *4*(2), 116-136. https://doi.org/10.1080/19439962.2011.620218

[23] Penmetsa, P., Pulugurtha, S. S., & Duddu, V. R. (2018). Factors associated with crashes due to overcorrection or oversteering of vehicles. *IATSS research*, *42*(1), 24-29. https://doi.org/10.1016/j.iatssr.2017.06.001

[24] Keogh, J., Doig, G., & Diasinos, S. (2014). Flow compressibility effects around an open-wheel racing car. *The Aeronautical Journal*, *118*(1210), 1409-1431. https://doi.org/10.1017/S0001924000010125

[25] Eksioglu, M., & Kızılaslan, K. (2008). Steering-wheel grip force characteristics of drivers as a function of gender, speed, and road condition. *International journal of industrial ergonomics*, *38*(3-4), 354-361. https://doi.org/10.1016/j.ergon.2008.01.004

Journal of Innovative Transportation, 5(2), 40-46

Research Article

JOURNAL OF INNOVATIVE TRANSPORTATION

e-ISSN: 2717-8889

The frequency and significance of the primary cause of cost overruns in infrastructure projects

Fares Tarhuni[a,C*], Rupesh Mahat[b]

[a]*Department of Civil Engineering, Faculty of Engineering and Computer Science, Arkansas State University, Arkansas , USA*
[b]*Department of Civil Engineering, Faculty of Engineering and Computer Science, Arkansas State University, Arkansas , USA*
[C]*Department of Engineering, The High Institute for Engineering Professions-Almajurie, Benghazi, Libya.*

Highlights

- Managing the delay and cost overrun.
- Identify the causes of road project delays and cost overruns.
- Minimizing the effects of project overrun in developing nations.

Abstract

Many road construction projects often go over budget. Take longer than expected. This research focuses on pinpointing the reasons, for delays and cost increases in road construction ventures in Libya. A survey was conducted with owners, consultants and contractors involved in road projects in Libya resulting in 163 completed questionnaires being analyzed. The study examined 55 factors identified through literature review. Improper planning emerged as the factor leading to project delays and cost overruns in road projects. Respondents ranked factors based on their impact with the top five issues being lack of experience with contracts, political instability, unrealistic contract durations and insufficient details and specifications. The insights gained from this study can aid all parties involved in construction projects to better handle delays and cost overruns. Researchers focusing on delay causes and cost escalations, in developing countries within the realm of road construction can also benefit from these findings.

Information

Received: 16.03.2024

Received in revised: 15.12.2024

Accepted: 20.12.2024

Keywords: *Infrastructure cost overrun, road construction project, risk management*

1. Introduction

Most construction projects exceed their budgets due to communication issues among the various parties involved. Clients and project owners frequently receive estimates at the outset leading to cost overruns. This trend is observed in both developing countries with a number of projects facing such challenges globally. Research spanning 20 countries and five continents revealed that 90% of sampled companies encountered cost overruns in their projects [1]. The construction sectors susceptibility to budget deviations is well known with costs varying widely across projects and regions [2]. The construction industry plays a role in the economy [3]. Olawale's research given its employment rates and resource consumption compared to sectors it significantly influences GDP growth and job creation in many nations. Consequently, it is considered a driver of progress [4]. Addressing concerns about cost overruns requires examination and analysis to streamline project timelines and manage discrepancies, for future endeavors. The consequences of exceeding the budget can sometimes have implications and amount, to as much as 100% of the initial project estimate in certain affluent countries [5]. The construction industry plays a role in supporting and providing the components for a nation's economic advancement. Hence it is widely believed that the construction sector is closely linked to and significantly contributes to the growth or rejuvenation of all countries.

Given the scale and intricate nature of the projects being executed a significant number of both international companies in Libya along with various developing nations have faced challenges in fulfilling their commitments. This has resulted in project delays. Exceeding the designated budget over the three decades [6]. The industry management often receives criticism due, to projects failing to meet their deadlines, budgets and quality standards [7]. The Libyan Construction Industry (LCI) has struggled with managing delays and cost overruns since the 1970s. Research conducted by the Public has highlighted the prevalence of schedule and cost overruns

Corresponding author: fares.s.tarhuni@gmail.com (F, Tarhuni), +14059687087

https://doi.org/10.53635/jit.1293629

in Libya [8]. The Public Committee, for Project Monitoring and Follow up conducted a study in Libya in 2004 uncovering a problem of delays and exceeding budgets in construction projects. In Libya the government frequently serves as the client, for building endeavors with legal matters involving both project owners and contractors as indicated by the Directorate of Projects and Contract Management [8]. Currently the sector is grappling with a challenge of escalating cost overruns that are adversely affecting the economy at large.

2. Literature Review

Since 2011 ongoing unrest, in Libya has led to pauses in projects. Security issues notably play a role in this situation. Particularly affected are projects in areas where security conditions worsen. The political turmoil in Libya has had an impact on multinational projects across the country leading to challenges such as payment delays, cash flow problems and weakened determination [9]. Many of these projects have been left unfinished due to constraints [10]. Construction project setbacks, including delays and cost overruns are issues faced globally in developing countries. Libya is no exception, to this trend as highlighted by studies [11-13]. A similar scenario can be observed in Saudi Arabia well [14, 15].

Earlier research [16, 17] has shown a link, between delays in schedules and exceeding project budgets. Nevertheless, of the socioeconomic position of the country concerned [18], delays have a negative impact on the production planning and control component of operations [19], especiallt in construction projects [20]. Regardless of the situation of a country delays can have impacts on the planning and control aspects of operations especially in construction projects. These delays can lead to issues such as disagreements, over contracts increased construction costs decreased productivity and even contract terminations [21-23]. Alsuliman [15] highlights that contractors who overlook opportunity costs may experience reduced profitability and productivity. Studies have indicated that in Nigeria delays frequently result in exceeding costs and schedules [24]. In South Africa schedule delays can lead to time extensions, cost overruns, profit loss, disputes and lower quality work due, to rushing to projects [25]. The pressure of scheduling could adversely impact the quality and efficiency of work by causing tasks to be completed out of sequence resorting to cost saving measures and reducing staff involvement [26, 27].

Over the five years Larsen et al. [28] Highlighted how issues related to consultants have significantly impacted project scheduling, in Denmark. They demonstrated that delays not affect project quality but lead to increased costs. A study in Vietnam conducted by Nguyen and Chileshe [29] identified planning and staff incompetence as the reasons for project failures. Similarly research carried out in Burkina Faso [30] revealed that contractor incompetence, lack of expertise and funding shortages were the obstacles to completing projects on time. In Egypt delays in road construction projects are primarily caused by constraints, inadequate resources, incompetent contractors and material shortages [11]. In the United Arab Emirates delays can be attributed to strategies inherited from parties [13]. Bajjou and Chafi noted that Moroccos challenges stemmed from waste management plans, lack of training and competence among project staff and delayed payment processes [31]. Delays in China are commonly due to variations in project requirements slow progress payments, competition during bidding processes, subcontractor underperformance and breakdowns, in communication channels [32]. Zidane and Andersen [33] found 10 factors that caused delays, in Norway in the year. The primary reasons for delays included planning and scheduling design changes during construction and delayed payments to contractors.

The literature review aimed to identify and evaluate the factors contributing to cost overruns requiring consideration, for understanding and resolution. A detailed examination of 55 variables linked to cost overruns was conducted for this study. These variables were classified into six categories; construction material related factors, labor related factors project finance related factors, project management related factors, external influence related factors and political factors. Existing literature guided the selection of these variables.

3. Methodology

In the construction industry a study found that there are 55 factors contributing to delays and increased costs, in projects. These factors were compiled into a questionnaire after research and interviews with figures. The questionnaire consists of two parts; Part I includes details about the organization and the individual being surveyed while Part II lists the known reasons for cost overruns and schedule delays in road construction projects. The goal of the questionnaire is to assess how much these identified causes are impacting project delays using a five point rating system ranging from high to little. Each category is rated on a scale from 5 to 1. An average index of components was calculated using Formula (1) to analyze the collected data helping project stakeholders rank these causes based on their perceived impact levels, on schedule delays and cost overruns. Each response, in this scenario is given a weight represented by the ai," which ranges from 1 (indicating importance) to 5 (reflecting significant importance).

$$\text{Average index} = \frac{\sum_{i=0}^{n}(ai \times xi)}{\sum(xi)} \quad (1)$$

The variable "x_i" signifies the weight assigned to each response and its frequency. The significance indices of all factors were. The average values within each group were used to determine the group index. An ordinal scale was utilized to measure the extent of each of the 55 identified attributes with a sample of 95 contractors completing the questionnaire. A total of 79 contractors responded to the survey. For surveys an email invitation was sent to remaining respondents in the database encouraging them to participate in a survey. Table 1 shows that out of 227 questionnaires sent 163 (72%) were completed and returned. These included responses, from 36 owners/clients, 48 project management consultants and 79 contractors.

Table 1. Distribution of questionair

Description	Percentage (%)
Owner/Clients	22.0
PM consultants	29.5
Contractors	48.5

4. Results and discussion

For the purpose of to determine the components' relevance, the respondents (owners/clients, contractors, and project management) evaluated the components' respective degrees of significance during the questionnaire survey phase.

4.1. Effect of construction material

The materials category in Figure 1 encompasses several aspects. Participants assessed their level of agreement using a 10-point scale. The graphic illustrates that the inflation rate and currency rate volatility had the greatest levels, namely 3.31 and 2.99, respectively.

4.2. Effect of workforce

Infrastructure projects rely heavily on both manpower and machinery. Employee involvement, in the procurement process plays a role. According to the findings illustrated in Figure 2 individuals involved in infrastructure projects attribute cost overruns to factors related to the workforce the increased expenses linked to having a skilled and knowledgeable labor force. This conclusion is supported by research conducted by authors [34,35] indicating that one of the contributors to project cost overruns is the scarcity of qualified individuals and their associated high costs. It is deemed reasonable as the high cost of labor helps mitigate issues such as rework, time and cost delays well as non performance from suppliers and subcontractors. Within the realm of workforce considerations these factors were identified as being second, in importance.

4.3. Effect of finance

In Figure 3 it's evident that longer and expensive contracts are the concerns. This is mainly due, to how market conditions influence construction expenses. The next factor discussed pertains to government regulations suggesting that implementing policies could help reduce financial challenges causing cost overruns in road construction ventures in Libya. Addressing issues effectively such, as financial planning and management can also prevent cost overruns.

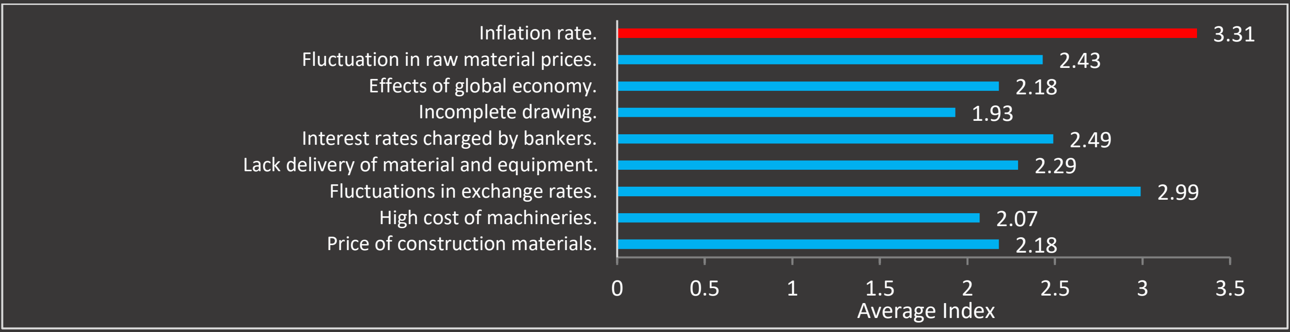

Figure 1. The effects of construction material on projects cost overrun.

Figure 2. The effect of the workforce on project coost overrun.

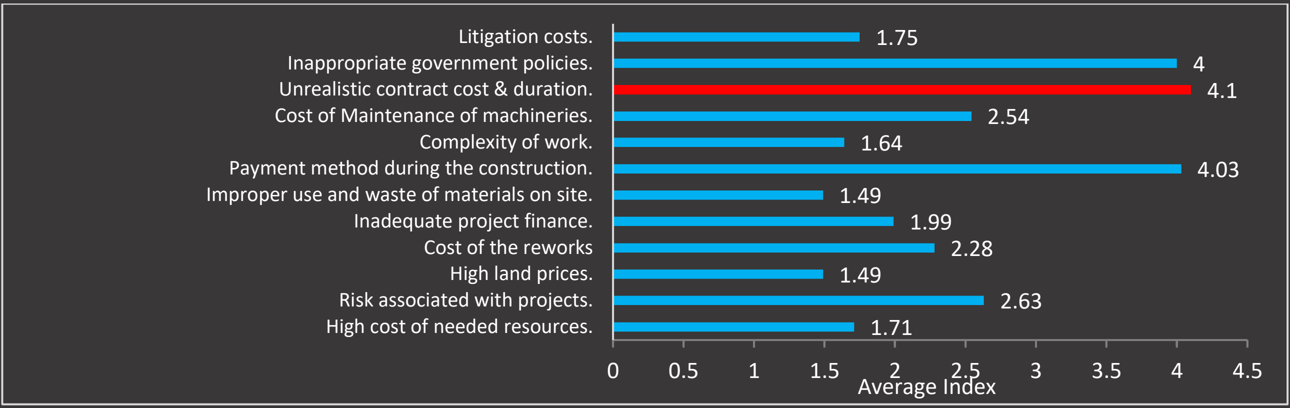

Figure 3. The effects of finance on projects cost overrun.

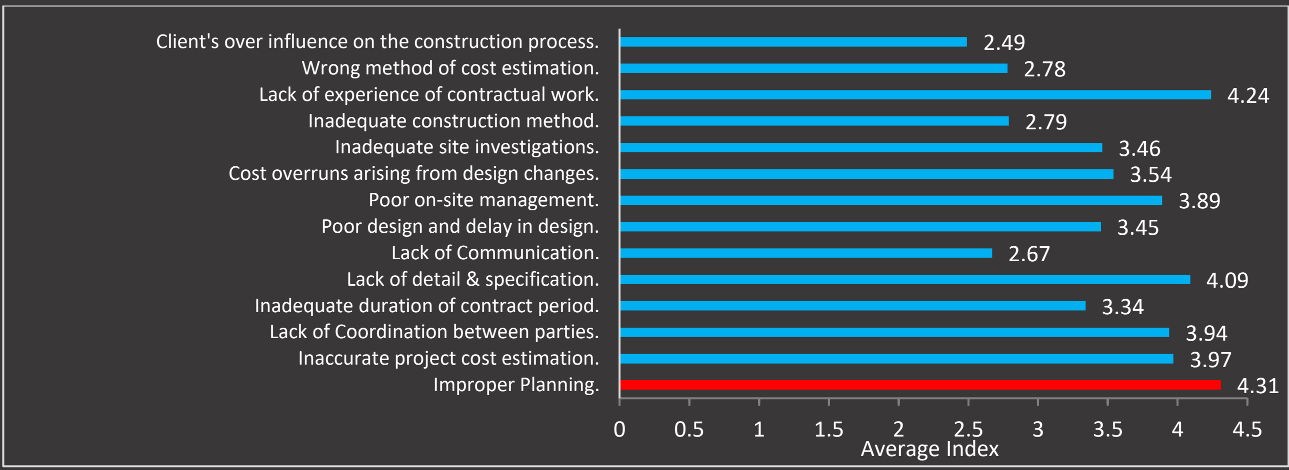

Figure 4. The effects of management on project cost overrun.

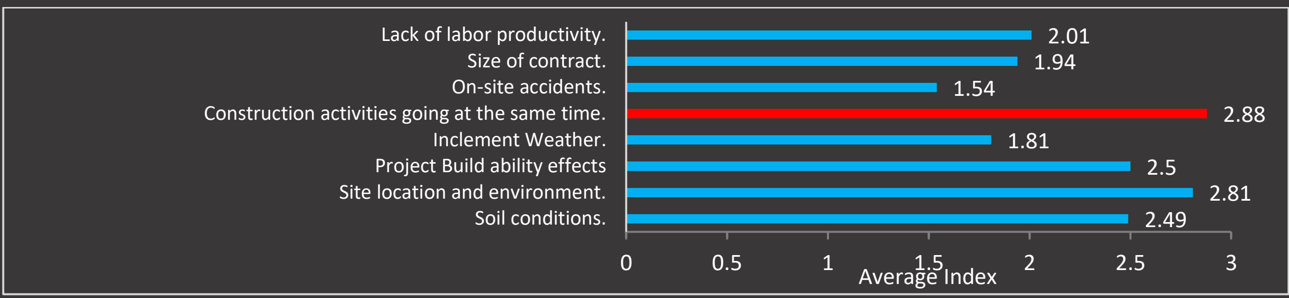

Figure 5. The effects of external factors on projects cost overrun.

4.4. Effect of management

Figure 4 examines how aspects, within the project management category impact road projects in Libya. Among the 55 sub factors studied it was found that inadequate planning emerged as the factor leading to cost overruns. This finding is consistent with studies highlighting the effects of poor planning on construction costs. The importance of cost construction planning in achieving project goals is emphasized as a key justification for this outcome. Additionally specifications and lack of specificity were identified as the influential factors contributing to cost overruns in road projects. Proper cost analysis, during the construction phase is crucial to avoid exceeding project budgets considering various cost factors involved in estimating processes to mitigate potential overruns.

4.5. Effect of external factor

The different elements, within the category that contribute to exceeding costs are displayed in Figure 5. Concurrent construction activities emerged as the element. Following in the external variables ranking, site location and environment stand out as significant factors leading to cost overruns in projects in Libya. Several researchers [36,37] delved into the effects of weather, on project expenses. Found it to be notably influential. Nevertheless according to Figure 5 adverse weather conditions were positioned sixth in terms of impact.

4.6. Effect of political

Politicians, in emerging countries such as Africa significantly impact contract costs as shown in the data from Figure 6 where the political climate is identified as the factor. Following closely is the control over resources and suppliers which plays a role in causing budget overruns in projects within Libya. Other challenges mentioned involve obstacles related to importing materials and equipment highlighting the need, for enhanced infrastructure to streamline imports. Consequently escalating supplier rates contribute to project cost escalations.

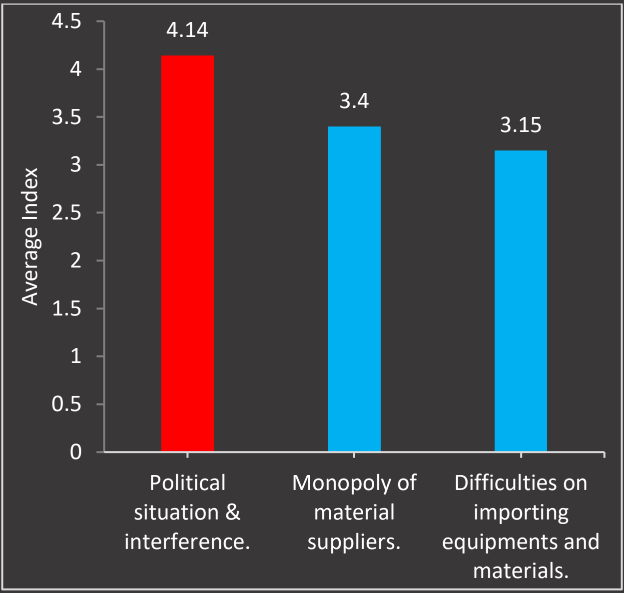

Figure 6. The effects of political on project cost overrun.

4.7. Identifying the "Root Causes" of a project's cost variation

Root cause analysis also known as RCA is a method, for comprehending and resolving issues. One recognized process that assists individuals in addressing the core reasons behind a problem is called Root Cause Analysis (RCA). The objective is to pinpoint the factor contributing to an issue through the application of defined techniques and relevant tools to uncover the root cause of the problem. Root cause analysis (RCA) serves as a management tool that can be easily adopted by both supervisors and frontline personnel. These strategies offer value providing insights and a holistic view. They enable the assessment of systems, identification of measures monitoring trends and detecting patterns. Managers can ascertain the frequency of errors compared to prevailing trends. This analysis may prove beneficial than its predecessor. The approach extends beyond engineering applications, into academic domains [38]. It represents a problem solving methodology focused on identifying the cause of deviations or issues. Its purpose is to address or mitigate these root causes to prevent recurrence of problems [39]. "Root cause analysis often referred to as RCA involves following established protocols, in an detailed manner to identify and solve issues. It is an structured process integrated into quality management practices, not a term used randomly." [40].

In root cause analysis methods a range of techniques are employed to boost the thinking process. These methods include Fishbone diagrams, Mind mapping, Pareto analysis, causal tree analysis, brainstorming, nominal group technique, metaphorical thinking and 5 Why analysis. The focus of the study will primarily be, on Fishbone diagrams, Pareto diagrams and the 5 Why method. The fishbone diagram was created by Professor Kaoru Ishikawa in the 1960s as part of quality management practices. The concept was further elaborated in a paper titled "Introduction to Quality Control" in 1990. Known as Ishikawa diagrams or cause and effect analysis charts due to their resemblance to a fishs structure [41] these tools aid in sparking ideas through discussions similar to collaborative brainstorming sessions but with a more impartial approach [42]. The cause and effect diagram provides a way to identify factors contributing to a specific problem. It helps organize problem solving efforts by categorizing factors that could be linked to challenges systematically. This method is commonly applied following Pareto or brainstorming sessions, for arrangement of ideas [42]. This chart shows an analysis of all factors that could play a role in a problem. Utilizing a fishbone diagram to capture and illustrate details can help in pinpointing solutions [39]. Figure 7 offers a representation of this approach.

The reasons, behind exceeding project budgets in Libya are depicted in Figure 7. They stem from project planning, limited understanding of contractual arrangements, political conditions, extended contract durations, lack of clear specifications inadequate construction payment methods, inappropriate government policies, inaccurate cost estimations, lack of coordination, among stakeholders and ineffective site management.

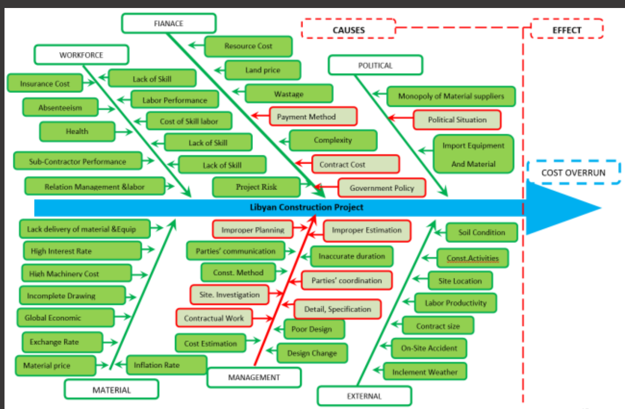

Figure 7. Fishbone diagram.

4.8. Ranking group' effect on the project

The factors that have the impact, on exceeding project budgets are indicated in Table 2. Management plays a role in steering efforts affecting decision makers and potentially leading to project delays and increased costs. With a rating of 4.31 it's clear that the management had an impact on the projects advancement. The political and finance teams also wields influence with average index 4.1 each. Then followed by workforce, material and external with average index 3.47, 3,31 and 2,88, respectively.

Table 2. Ranking group' effect on the project

Groups	Average Index	Rank
Management	4.31	1
Political	4.10	2
Finance	4.10	2
Workforce	3.47	3
Material	3.31	4
External	2.88	5

5. Conclusions

The success of a project depends on its timely and economical execution. To accomplish this goal, a variety of strategies and techniques are used. Road construction encounters obstacles such limitations and project delays on a global scale. To identify the main causes of delays and cost overruns in road construction projects in Libya, a survey of professionals in the field was carried out. After investigation, a total of fifty-five factors were found. Industry professionals participated in a study that identified 55 common and important criteria. Clients, consultants, and contractors with prior building industry expertise were given the questionnaire. The results of the study show that a number of factors regularly affect road construction in Libya. A number of important variables have been highlighted, including unrealistic contract durations and conditions, bad site management, a lack of specifications, payment methods during construction phases, weak government rules, inaccurate project cost projections, and poor coordination among stakeholders. Three significant categories management, politics and finance are highlighted in the ranking findings. It has been determined that the other groups workplace, material, and external are less impact on the cost overrun in construction projects.

Declaration of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contribution Statement

F. Tarhuni: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – Original draft; **R. Mahat:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – Review & editing

References

[1] Flyvbjerg, B., Skamris Holm, M. K., & Buhl, S. L. (2003). How common and how large are cost overruns in transport infrastructure projects?. *Transport reviews*, *23*(1), 71-88. https://doi.org/10.1080/01441640309904

[2] Wa'el, A., Mohd, R. A., Kadir, A. S., & Ernawati, D. (2007). The significant factors causing delay of building construction projects in Malaysia. *Engineering, Construction and Architectural Management*, *14*(2), 192-206.

[3] Takim, R. (2005). *A framework for successful construction project performance* (Doctoral dissertation). Glasgow Caledonian University.

[4] Yakubu, O. A. (2010). *Cost and time control practice of construction projects in the UK: The pursuit of effective management control* (Doctoral dissertation). University of the West of England, Bristol.

[5] Reina, P., & Angelo, W. J. (2002). Megaprojects need more study up front to avoid cost overruns. *ENR*, *249*(3), 11-11.

[6] Krima, N. (2001). *Supervision and delay in implementing construction project: The role of owner's supervisor* (Unpublished master's thesis). Department of Engineering Management, El-Fateh University, Tripoli, Libya.

[7] Smith, N. J., Merna, T., & Jobling, P. (2014). *Managing risk in construction projects*. John Wiley & Sons.

[8] The Public Committee of Project Monitoring and Follow-up. (2004). *The annual reports of projects following-up*. Tripoli, Libya.

[9] Ismail, A., Alfakhri, A. Y., Khoiry, M. A., Abdelsalam, H. M., & Elhub, B. (2018). Investigating delays in Libyan road construction projects using structural equation modelling (SEM). *International Journal of Engineering & Technology*, *7*(2.29), 858-864.

[10] Kusakcı, A. O., Ayvaz, B., & Bejtagic, E. (2017). An analysis of causes and effects of delays in construction projects in Libyan oil industry. *Karaelmas Fen ve Mühendislik Dergisi*, *7*(1), 274-282.

[11] Aziz, R. F., & Abdel-Hakam, A. A. (2016). Exploring delay causes of road construction projects in Egypt. *Alexandria Engineering Journal*, *55*(2), 1515-1539. https://doi.org/10.1016/j.aej.2016.03.006

[12] Mahdi, I., & Soliman, E. (2021). Significant and top ranked delay factors in Arabic Gulf countries. *International Journal of Construction Management*, *21*(2), 167-180. https://doi.org/10.1080/15623599.2018.1512029

[13] Mpofu, B., Ochieng, E. G., Moobela, C., & Pretorius, A. (2017). Profiling causative factors leading to construction project delays in the United Arab Emirates. *Engineering, Construction and Architectural Management*, *24*(2), 346-376.

[14] Higham, A. P., & Troug, M. A. (2018). Exploration of time delay and cost overrun in Libyan public housing projects. *In ARCOM Conferences Archive of Working Papers.* 2018, 350-359. Belfast, UK.

[15] Alsuliman, J. A. (2019). Causes of delay in Saudi public construction projects. *Alexandria Engineering Journal*, *58*(2), 801-808. https://doi.org/10.1016/j.aej.2019.07.002

[16] Olawale, Y. A., & Sun, M. (2010). Cost and time control of construction projects: inhibiting factors and mitigating

measures in practice. *Construction management and economics*, *28*(5), 509-526. https://doi.org/10.1080/01446191003674519

[17] Yap, J. B. H., & Skitmore, M. (2018). Investigating design changes in Malaysian building projects. *Architectural Engineering and Design Management*, *14*(3), 218-238. https://doi.org/10.1080/17452007.2017.1384714

[18] Durdyev, S., & Hosseini, M. R. (2020). Causes of delays on construction projects: a comprehensive list. *International journal of managing projects in business*, *13*(1), 20-46. https://doi.org/10.1108/IJMPB-09-2018-0178

[19] Zarei, B., Sharifi, H., & Chaghouee, Y. (2018). Delay causes analysis in complex construction projects: A semantic network analysis approach. *Production Planning & Control*, *29*(1), 29-40. https://doi.org/10.1080/09537287.2017.1376257

[20] Shahsavand, P., Marefat, A., & Parchamijalal, M. (2018). Causes of delays in construction industry and comparative delay analysis techniques with SCL protocol. *Engineering, Construction and Architectural Management*, *25*(4), 497-533. https://doi.org/10.1108/ECAM-10-2016-0220

[21] Amoatey, C. T., Ameyaw, Y. A., Adaku, E., & Famiyeh, S. (2015). Analysing delay causes and effects in Ghanaian state housing construction projects. *International Journal of Managing Projects in Business*, *8*(1), 198-214. https://doi.org/10.1108/IJMPB-04-2014-0035

[22] Gbahabo, P., & Samuel, A. O. (2017). Effects of infrastructure project cost overruns and schedule delays in sub-saharan Africa. In *11th International Conference on Social Sciences Helsinki*. 20-21.

[23] Sambasivan, M., Deepak, T. J., Salim, A. N., & Ponniah, V. (2017). Analysis of delays in Tanzanian construction industry: Transaction cost economics (TCE) and structural equation modeling (SEM) approach. *Engineering, Construction and Architectural Management*, *24*(2), 308-325. https://doi.org/10.1108/ECAM-09-2015-0145

[24] Aibinu, A. A., & Jagboro, G. O. (2002). The effects of construction delays on project delivery in Nigerian construction industry. *International journal of project management*, *20*(8), 593-599. https://doi.org/10.1016/S0263-7863(02)00028-5

[25] Mukuka, M., Aigbavboa, C., & Thwala, W. (2015). Effects of construction projects schedule overruns: A case of the Gauteng Province, South Africa. *Procedia Manufacturing*, *3*, 1690-1695. https://doi.org/10.1016/j.promfg.2015.07.989

[26] Nepal, M. P., Park, M., & Son, B. (2006). Effects of schedule pressure on construction performance. *Journal of Construction Engineering and Management*, *132*(2), 182-188. https://doi.org/10.1061/(ASCE)0733-9364(2006)132:2(182)

[27] Yap, J. B. H., Rou Chong, J., Skitmore, M., & Lee, W. P. (2020). Rework causation that undermines safety performance during production in construction. *Journal of construction engineering and management*, *146*(9), 04020106. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001902

[28] Larsen, J. K., Shen, G. Q., Lindhard, S. M., & Brunoe, T. D. (2016). Factors affecting schedule delay, cost overrun, and quality level in public construction projects. *Journal of management in engineering*, *32*(1), 04015032. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000391

[29] Nguyen, T. P., & Chileshe, N. (2015). Revisiting the construction project failure factors in Vietnam. *Built Environment Project and Asset Management*, *5*(4), 398-416. https://doi.org/10.1108/BEPAM-10-2013-0042

[30] Bagaya, O., & Song, J. (2016). Empirical study of factors influencing schedule delays of public construction projects in Burkina Faso. *Journal of management in engineering*, *32*(5), 05016014. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000443

[31] Bajjou, M. S., & Chafi, A. (2020). Empirical study of schedule delay in Moroccan construction projects. *International Journal of Construction Management*, *20*(7), 783-800. https://doi.org/10.1080/15623599.2018.1484859

[32] Wang, T. K., Ford, D. N., Chong, H. Y., & Zhang, W. (2018). Causes of delays in the construction phase of Chinese building projects. *Engineering, Construction and Architectural Management*, *25*(11), 1534-1551. https://doi.org/10.1108/ECAM-10-2016-0227

[33] Zidane, Y. J. T., & Andersen, B. (2018). The top 10 universal delay factors in construction projects. *International Journal of Managing Projects in Business*, *11*(3), 650-672. https://doi.org/10.1108/IJMPB-05-2017-0052

[34] Memon, A. H., Rahman, I. A., Abdullah, M. R., & Azis, A. A. A. (2010). Factors affecting construction cost in Mara large construction project: perspective of project management consultant. *International Journal of Sustainable Construction Engineering and Technology*, *1*(2), 41-54.

[35] Azhar, N., Farooqui, R. U., & Ahmed, S. M. (2008, August). Cost overrun factors in construction industry of Pakistan. In *First International Conference on Construction in Developing Countries (ICCIDC–I), Advancing and Integrating Construction Education, Research & Practice*. 499-508.

[36] Ameh, O. J., Soyingbe, A. A., & Odusami, K. T. (2010). Significant factors causing cost overruns in telecommunication projects in Nigeria. *Journal of Construction in Developing Countries*, 15(2): 49-67.

[37] Williams, P. M. (2001, April). Techniques for root cause analysis. In *Baylor University Medical Center Proceedings* 14(2), 154-157. https://doi.org/10.1080/08998280.2001.11927753

[38] Geoff, V. (2008). Mini Guide to Root Cause Analysis. *Quality Management and Training (publications) Ltd, Guildford Surrey United Kingdom GU2 7FN.*

[39] Rosenfeld, Y. (2014). Root-cause analysis of construction-cost overruns. *Journal of construction engineering and management*, *140*(1), 04013039. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000789

[40] Mahto, D., & Kumar, A. (2008). Application of root cause analysis in improvement of product quality and productivity. *Journal of Industrial Engineering and management*, *1*(2), 16-53. https://doi.org/10.3926/jiem..v1n2.p16-53

[41] Nyrén, G. (2007). *Product development according to six sigma and the DAMIC improvement cycle* (Master's thesis). Department of Business Administration and Social Sciences, Industrial Business Administration, Luleå University of Technology, Sweden.

[42] Stevenson, W. J. (2005). *Operations management* (8th ed.). McGraw-Hill/Irwin.