Case Studies on Transport Policy 10 (2022) 821–830

Contents lists available at ScienceDirect

Case Studies on Transport Policy

journal homepage: www.elsevier.com/locate/cstp

Red-light-running in a Ghanaian metropolis

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ARTICLE INFO

Keywords:
Red-light-running
Theory of planned behaviour
Drivers
Ghana

ABSTRACT

Background: Red-light-running (RLR) is a major cause of road traffic crashes in Ghana. Yet, there is limited scientific research on RLR in Ghana. This study employed the Theory of Planned Behaviour (TPB) and logistic regression models to understand RLR behaviour in the Cape Coast Metropolis, Ghana. An understanding of such behaviour would enable the design of behavioural and technological interventions including change communications and nudges to pro-driver behaviours.

Methods: A naturalistic exploratory road-side observational design of drivers at three (3) signalized intersections in the Cape Coast Metropolis was conducted from 17th-23rdApril, 2021. A structured observational checklist was used to collect data on motorists in two (2) phases (7:00–9:00 am and 3:00–5:00 pm) each day for seven (7) days at the University of Cape Coast (UCC), Pedu Junction and Interbeton Junction traffic light intersections. Data captured included RLR, gender, age group of the driver, type of vehicle, and presence of other passengers. Data was entered and analyzed using STATA IC version 15. Bivariate and Multivariable Logistic regression analysis was done at $p < 0.05$ and 95% confidence interval.

Results: A total of 5,045 motorists were observed at three (3) traffic lights within the seven (7) days with the majority being male (94.4%), aged 25–45 years (77.4%), and on a Friday (18.6%). A low rate of RLR (13.3%) [Pedu Junction traffic lights (15.1%), UCC (12.7%) and Interbeton Junction (10.8%)] in the metropolis. Drivers entering the UCC Gate-Campus were 1.54 times more likely to engage in RLR than were those leaving campus, and vehicles without passengers were 1.27 times more likely to engage in RLR, compared to those with one or more passengers. Motorists were less likely to make an RLR offence on weekdays as compared to Saturday.

Conclusion: The officials of the National Road Safety Authority (NRSA) and Motor Transport and Traffic Department of the Ghana Police Service should educate drivers on the danger associated with RLR and arrest and prosecute errant ones to serve as a deterrent.

1. Introduction

Road traffic crashes (RTCs) are a global public health and development challenge with an estimated cost of 3% of gross domestic product (WHO, 2018). The occurrence and severity of RTCs at an intersection is a global phenomenon (Jiang, Yang, Sun, Wang, & Yang, 2021). The traffic light signal regulates traffic and/or promotes safety at intersections (Li, Chen, Lin, Xu, & Wang, 2018). The presence of a traffic light signal at the intersection is to minimize the incidence of RTCs often resulting from the vehicle characteristics, nature of the road or simply a misunderstanding between or among road users such as drivers, pedestrians, motorcyclists, and cyclists at an intersection. RLR is an occurrence at an intersection with a traffic signal in which a vehicle arrives at the stop line after the onset of the red light and yet proceeds (Zhang, Wang, Zhou, & Zhang, 2012).

Globally, RLR is a common and serious traffic signal violation, contributing significantly to RTCs yearly in China, the United Kingdom (UK), and the United States (US) (Kulanthayan, Phang, & Hayati, 2007; Retting, Williams, & Greene, 1998). Red-light-running by drivers, pedestrians, motorcyclists and cyclists have attracted road safety concerns at intersections (Fraboni, Puchades, De Angelis, Pietrantoni, & Prati, 2018; Olumide & Owoaje, 2017). But the degree of safety hinges on drivers' compliance with the signals (Retting, Ferguson, & Farmer, 2008). For example, 0.14% (China), 11.3% (Jordan) and 12.9% (UK) of

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https://doi.org/10.1016/j.cstp.2022.02.008
Received 6 July 2021; Received in revised form 24 December 2021; Accepted 22 February 2022
Available online 24 February 2022

drivers engage in RLR at signalized intersections (Al-Omari & Al-Masaeid, 2003; Yousif, Alterawi, & Henson, 2014; Yan, Li, Zhang, & Hu, 2016).

RLR is also a major cause of severe injuries at signalized intersections (Wang, Yu, & Zhong, 2016). For example, in the US, almost 260,000 cases of RTCs with about 1000 fatalities are recorded annually at traffic signal intersections (Li et al., 2018; Retting et al., 2008). There were 4200 RTCs caused by RLR with 788 fatalities in 2012 in China (Ministry of Public Security of the People's Republic of China. (2012), 2012). The incidence of drivers not complying with the demands of traffic signals has thus become topical (Retting et al., 2008).

1.1. RLR in Ghana

RLR in Ghana is defined as when a motorist passes through traffic light zones when the traffic light has shown red (Abane, 2004). A driver who waits at the traffic light zones is not counted as RLR. RLR is a source of worry to city authorities including Accra, Cape Coast, Kumasi, Tema, Sekondi-Takoradi and Tamale (Abane, 2004; Ackaah & Aidoo, 2020). Available statistics show that 41% of all RTCs in urban areas occurred at intersections and might be attributed to traffic violations such as RLR in 2018 (Ackaah, Larley, & Larbi, 2020; Ackaah & Aidoo, 2020). To the best of our knowledge, only three studies have assessed the rate of drivers' RLR in Ghana (see Abane, 2004; Ackaah & Aidoo, 2020; Densu, Salifu, & Attafuah, 2014). Abane (2004), pioneered the research on the danger associated with RLR in Accra, the capital city of Ghana drawing on field survey data and secondary data from the Building and Road Research Institute (BRRI). The results revealed that RLR was on the increase in the Accra Metropolitan area, especially at the Kwame Nkrumah, Graphic Road, Obetsebi Lamptey and Liberia Road Intersections.

Ten years later, Densu et al. (2014) employed unobstructed observations to study 42,298 motorists for strict compliance with traffic signal controls at four signalized intersection locations; Barnyard (T1), Kwashieman (T2), Nyamekye junction (T3), and Lapaz (T4)) from 7:00 am-6:00 pm, consistently for one (1) week. This study found that just a few of their sample (0.3%) breached the red traffic signals and of these traffic light infractions, 27% were observed at T2 followed at T1 with 26%, whereas 24% and 23% were recorded at T4 and T3, respectively.

Moreover, Ackaah and Aidoo (2020) in an uninterrupted roadside observational study found a 35% incidence of RLR in Kumasi, the second largest metropolis in Ghana. Using a binary logit model, they showed that age and gender of the driver, presence of a passenger in the vehicle, vehicle type, junction type, cycle length of the signal and queue length had significant relationships with RLR at 10 signalized intersections in the Kumasi Metropolis. Private car drivers were less likely to engage in RLR, compared to commercial car drivers, which they attributed to the nature of their work such as dropping off and picking up passengers.

Ghana's Act (2004) prohibits RLR thus making it a traffic offence.

> "*A person who jaywalks or ignores traffic light signal commits an offence and is liable on summary conviction to a fine not exceeding 25 penalty units or to a term of imprisonment not exceeding one day.* " (According to the Act, 2004; Section 29, Subsection 2).

All three studies provided empirical evidence on RLR in Accra, the capital city (Abane, 2004; Densu et al., 2014) and Kumasi, second largest city (Ackaah, Larley, & Larbi, 2020) but failed to investigate RLR in Cape Coast, the dynamic tourism and educational hub in Ghana. Further, all three studies were conducted on dual carriageways traversing Accra and Kumasi metropolises while the current study considers three different categories of roads-national, regional, and local highways (Table 1; Figs. 3-5). The paper further uses TPB to shed more light on the incidence unlike the previous studies such as Abane (2004) using the three-factor typology understand the phenomenon under investigation.

1.2. TPB's application to traffic rule violations

Driver attitude and behaviour put all road users at risk of RTCs in Ghana (Teye-Kwadjo, Knizek, & Rundmo, 2013; Teye-Kwadjo, 2017, 2019). The Theory of Planned Behaviour (TPB; Ajzen, 1991) comes in handy for gaining insights into traffic violations by drivers. There are three (3) independent but interrelated factors, according to the TPB, that influence a person's intention to commit a traffic violation. These are attitude, perceived behavioural control (PBC) and subjective norm (Ajzen, 1991). Attitude towards committing a violation is the degree to which a driver has a favorable or unfavorable appraisal of such an act. Subjective norm is the perceived pressure to or not to commit a driving or traffic violation. PBC refers to the ease or difficulty associated with committing driving or traffic violations. The TPB has been used extensively in road safety literature to assess and evaluate driving violations (Castanier, Deroche, & Woodman, 2013; Lheureux, Auzoult, Charlois, Hardy-Massard, & Minary, 2016), mobile phone use while driving (Sullman, Hill, & Stephens, 2018), speeding (Conner et al., 2007; Elliott & Armitage, 2009), drunk-driving (Rivis, Abraham, & Snook, 2011), and RLR (Yang et al. (2018).

Specifically, Yang et al. (2018) used a questionnaire based on constructs of the TPB in China and reported that attitude (age, marital status and college degree) and PBC (perceived risk) were significant predictors for RLR. Similarly, Satiennam, et. al., (2018) used a TPB questionnaire to reveal that attitudes and perceived norms influenced the intention to engage in RLR among young motorcyclists in Thailand. In Ghana, TPB was successfully used to predict the commission of driving violations such as non-use of seatbelts (Ojo, 2018; Teye-Kwadjo, Salia, & Mensah Ofori, R, 2020), and thus, shows promise for understanding drivers' RLR behaviour in Ghana.

In the current study, TPB is used as a theoretical framework to understand how attitude (age, gender, vehicle type, location of intersection), subjective norm (Act, 2004) and PBC (presence of a passenger in vehicle or presence of other vehicles) influence the intention to run on red in the Cape Coast Metropolis (see Satiennam et al., 2018; Yang et al., 2018).

Table 1
Characteristics of the three (3) observed intersections.

Signalized intersection	Vice Chancellor's Junction (Fig. 3)	Pedu Junction (Fig. 4)	Interbeton Junction (Fig. 5)
Observed approaches	1. Campus to Gate 2. Gate to Campus	2. Accra to Takoradi3. Takoradi-Accra4. Pedu Junction-Pedu5. Pedu Junction to Town	Abura-Pedu Pedu-Abura Interbeton to Pedu Estate Pedu estate To Interbeton
Road Type	Dual carriageway in a university environment	National highway-dual carriageway	Single carriageway Rd/Regional highway
Crossing approaches	1. CASFORD Rd. 2. V.C's lodge	1. Pedu Rd. 2. Cape Coast Township	3. Cape Coast Teaching Hospital Rd.4. Pedu Estate Rd.
Average Daily Traffic	Low	High	Mo Derate

1.3. Modelling RLR with logistic regression

Few studies such as Ackaah and Aidoo (2020), Wang et al. (2016), Yan et al. (2016) have modelled the incidence of RLR. For example, Wang et al. (2016) used two (2) types of logistic models to compare the RLR and non-RLR groups. An ordinary logistic model was used to identify how variables such as driver characteristics, driving conditions, vehicle types, male gender, having local license plates, and driving a passenger vehicle but without passengers onboard relate to an outcome such as the rate of RLR. A random-effects logistic regression model was considered for the unobserved heterogeneity among different types of intersections. In Ghana, Ackaah and Aidoo (2020) used the binary logit model because the dependent variable (RLR) was binary (coded 1 = RLR and 2 = non-RLR) as reported by Agresti (2007). The results of the study showed that females and drivers wearing a seatbelt were 80% and 70% less likely to engage in RLR respectively. Drivers over 26 years old, were 230% more likely to engage in RLR with a 100% likelihood when the cycle length of the traffic signal was more than sixty seconds. Yan et al. (2016) in China used Poisson regression to examine the significance of the type of day and period on the incidence of RLR among drivers, motorcycle and bicycle riders and pedestrians. The rate of RLR on holidays was 1.89 times more than that on weekdays among drivers.

The present study aims to build on Abane (2004), Densu et al. (2014) and Ackaah and Aidoo (2020)'s works by applying the TPB (see Fig. 1) and a multivariate logistic model to understand RLR behaviour in the Cape Coast Metropolis, Ghana. The following research questions quidded the study:

a. What is the rate of RLR in the Cape Coast Metropolis despite the subjective norm of the Act (2004)?
b. How does the incidence of RLR differ among the three selected signalized intersections in the Cape Coast Metropolis?
c. What attitudinal attributes (gender, age, place of intersection) influence RLR in the Cape Coast Metropolis? and
d. How do the perceived behavioural attributes (presence of other vehicles at the signalized intersections, presence of a passenger in the vehicle) influence RLR in the Cape Coast Metropolis?

An understanding of such behaviour would enable the design of behavioural and technological interventions including change communications and nudges to pro-driver behaviours. This will further add to literature form the context of a metropolis from a middle-income country. The study will provide a policy implication for the officials of the National Road Safety Authority (NSRA) and Motor Transport and Traffic Department (MTTD) of the Ghana Police Service on RLR in the Cape Coast Metropolis.

The study is divided into 6 sections. The next section is on the methodology used in the study, followed by the results. The fourth section addresses the discussion and the next section presents the conclusion and policy implications.

2. Methodology

2.1. Study area

Cape Coast Metropolis is the former capital city, the educational and tourism hub of Ghana. There are seven (7) signalized intersections in the metropolis, out of which, two (2) are on the Accra-Cape Coast-Takoradi highway, (N1, Trans ECOWAS highway) about 150 m apart with a high vehicular volume. The third one is on the Pedu-Abura road which is a part of the Cape Coast-Twifo Praso Highway located towards the Cape Coast Teaching Hospital.

The remaining ones are on the University of Cape Coast (UCC) campus. Three functional traffic signals were thus used in the study; Pedu Junction (near the Regional Police station), Interbeton Junction and UCC Vice-Chancellor's Junction) (see Fig. 2).

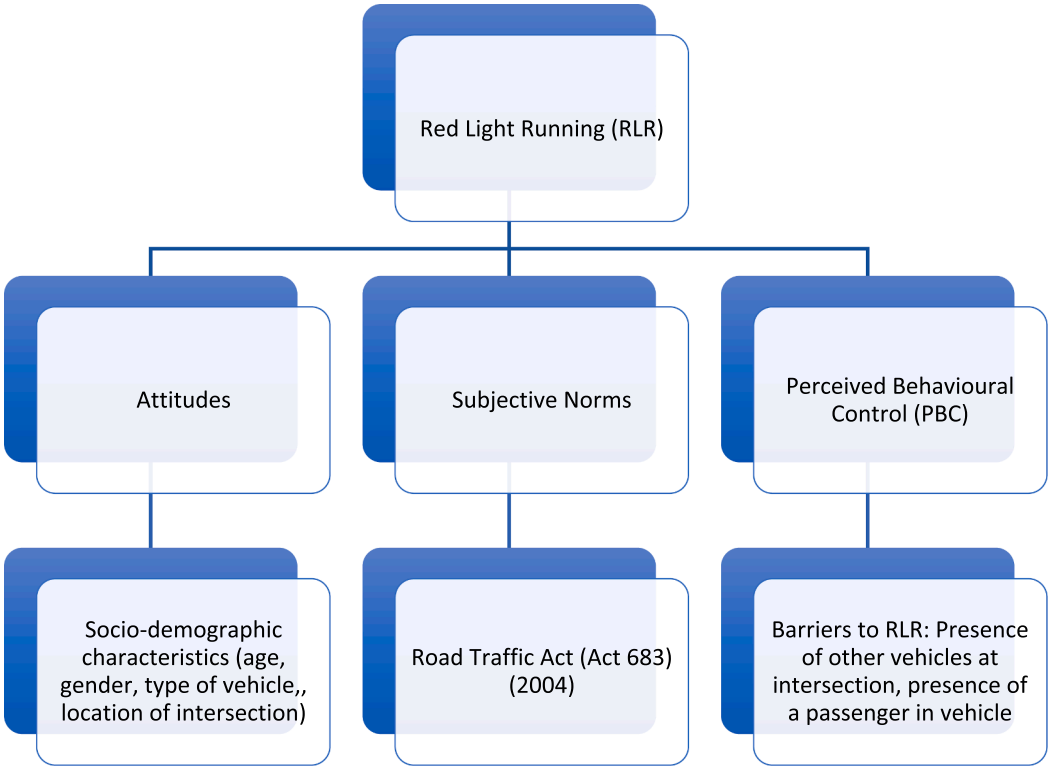

Fig. 1. Incidence of RLR using the Theory of Planned Behaviour.

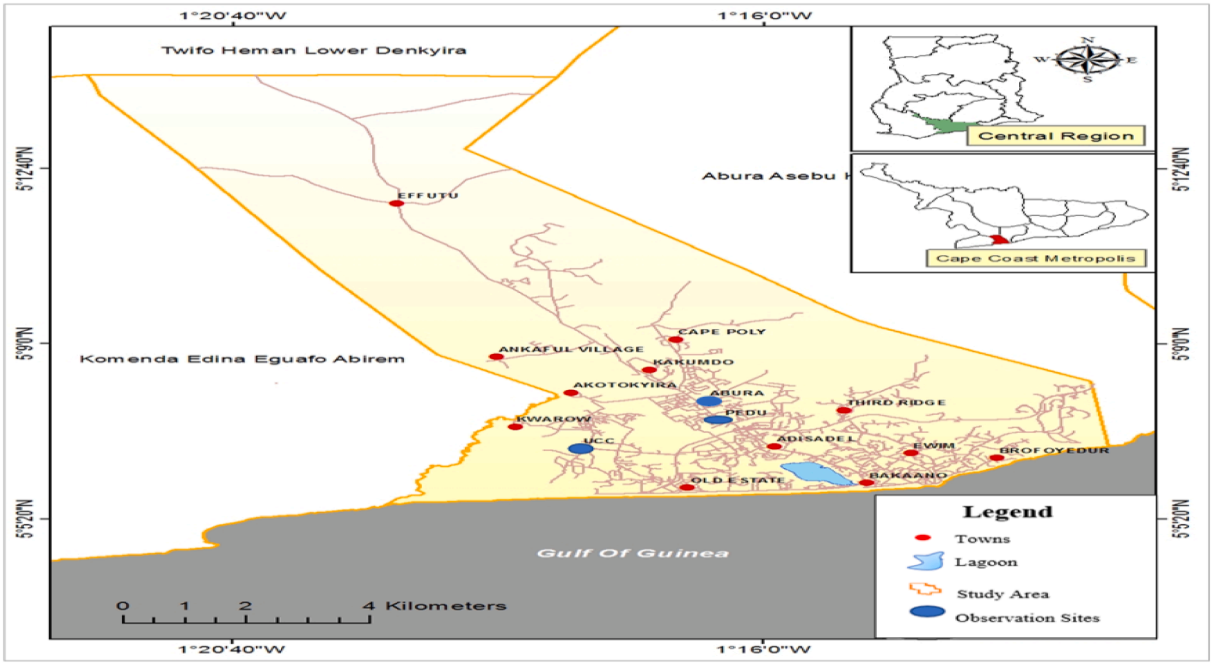

Fig. 2. Location of Signalized Intersections Studied on the Cape Coast Map (marked blue).

3. Research design

A naturalistic exploratory road-side observational design of drivers at three (3) signalized intersections in the Cape Coast Metropolis was adopted. This design was successfully employed by Ackaah and Aidoo (2020).

3.1. Target population and sampling procedure

The target population comprises all vehicle types (private cars, taxis, mini-bus, midi-buses, large buses, tractors/trailers etc.) found at the signalized intersections from 7:00–9:00 am and 3:00–5:00 pm (rush hour periods) (see Ojo, 2018). All vehicles are eligible to be counted but in the case of RLR, only the details of the first vehicle to RLR contrary to what was done in Ackaah and Aidoo (2020).

3.2. Sample size

The pilot study conducted at the UCC Vice Chancellor's signalized intersection indicated >150 observations per hour recorded between the hours of 7:00 and 9:00 in the morning peak and 3:00–5:00 in the evening peak daily. This translates to an estimated 4500 observations throughout the study period from Saturday-Friday.

3.3. Data collection procedures

A pilot study was carried out on 15th April 2021 on the University of Cape Coast campus as a part of the training for the research assistants. Eight (8) research assistants were stationed about 5 m to the three signalized intersections to un-obstructively observe the variables for the study during the seven-day exercise (17th-23rdApril, 2021). Data was collected every day of the week to account for seasonal variations that may arise in driver behavior for different days. According to Clark, 2009 only one observation per site randomly distributed per time is sufficient for the naturalistic exploratory roadside observational design. Two research assistants were positioned at the interbeton and Vice Chancellor's signalized intersections. Each research assistant focused on one direction of traffic with the other focusing on the opposite traffic. However, four research assistants were stationed at the Pedu intersection because of the heavy traffic and the nature of the intersection (see Table 1). The traffic directional flow focused on by the research assistants at the Vice-Chancellor's junction were "from" and "to" Campus-Gate representing the major road link. However, observations were made in the traffic flow directions which also indicates the type of movement (see Table 1).

Traffic direction as a variable in this paper indicates the movement typef (left turn, through and right turn). That is through (Campus-Gate; Accra-Takoradi; Gate-Campus; Abura-Pedu; Takoradi-Accra; Pedu-Abura), right turn (Pedu-Cape Coast town), and left turn (Pedu junction-Pedu) (Table 1, Figs. 3-5). Real-time traffic data was collected from the above directions during the morning (7:00 am-9:00 am) and evening (3:00 pm-5:00 pm) peak periods and estimated to a weekly count.

The research assistants used a structured observational checklist containing the following variables- RLR (No or Yes), gender (male or female), age group of the driver (<25, 15–35, 36–45, 46–55, >55), type of vehicle (private, taxi, mini-bus, midi-bus, large bus, truck/trailer), presence of other passengers (Yes or No). No information was collected on the name and license plate number of observed vehicles.

Pictorial presentations of the signalized intersections studied are shown in Figs. 3-5.

3.4. Model specification

Data were entered and cleaned using SPSS version 23 and imported into STATA IC version 15 for analysis. The logistic regression model was then used to predict the relative likelihood of RLR by motorists at traffic points, bivariate and multivariable logistic regression analyses were carried out. The criteria for selecting variables into the multivariable model was based on the Theory of Planned Behaviour (shown in Fig. 1). The goodness of fit of the model was monitored by an increase in the value of the log-likelihood and p-values of the coefficients. The goal of logistic regression is to identify the best fitting model that describes the relationship between a binary dependent variable and a set of independent or explanatory variables. The dependent variable (RLR) in logistic regression analysis is often coded as 0 or 1, where 1 indicates that the driver runs on red and 0 indicates that the driver did not run the red light.

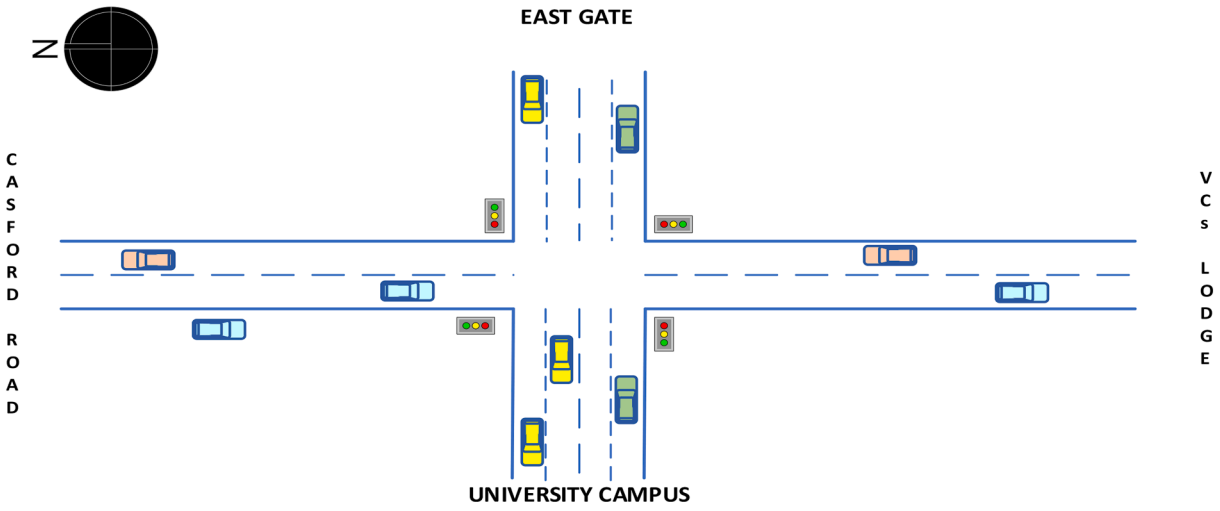

Fig. 3. Vice Chancellor's Junction.

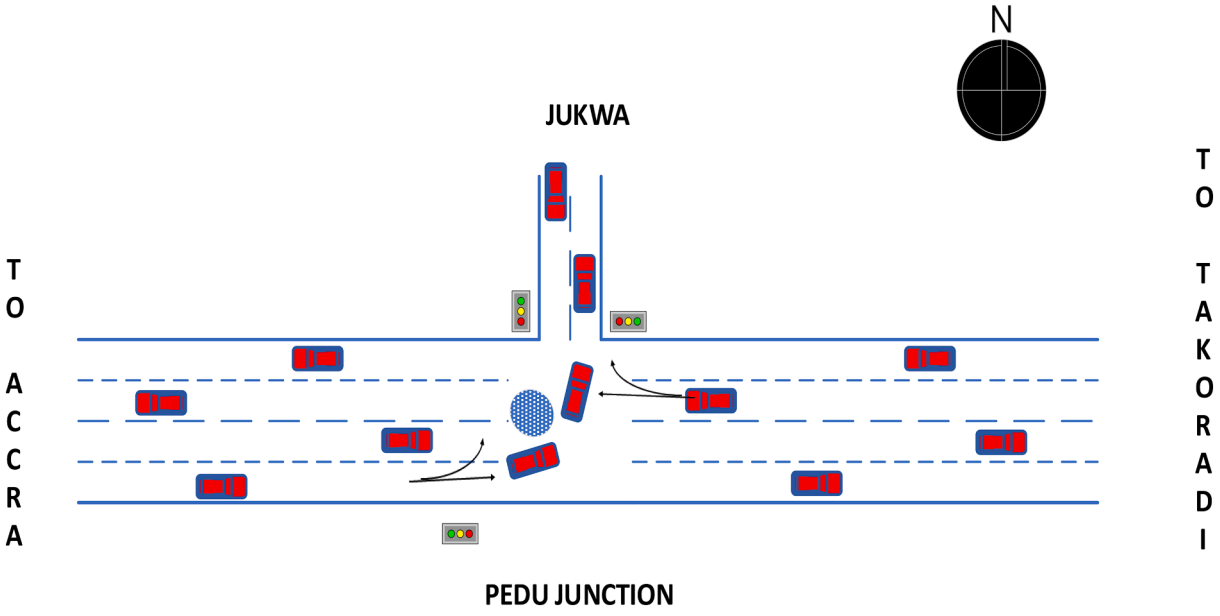

Fig. 4. Pedu Junction.

For each independent variable x_1,……..,m $x_E = \begin{cases} 1 RLR \\ 0 NotRLR \end{cases}$

If p is the probability that the motorist's RLR is 1, the multiple logistic regression model can be written as

$$p = \frac{\exp(\beta 0 + + \beta 2 x 2 + \cdots \ldots\ldots\ldots\ldots + \beta m x m)}{1 + \exp(\beta 0 + \beta 1 x 1 + \beta 2 x 2 + \cdots \ldots\ldots\ldots\ldots + \beta m x m)}$$

Similarly, the multiple regression equations can be expressed as:

$$\text{logit}(p) = \beta 0 + \beta 1 x 1 + \beta 2 x 2 + \cdots \ldots\ldots\ldots\ldots + \beta m x m$$

where,
p: Probability ranges from 0 to 1
$\beta 0$: constant of regression model
x1: the value of the explanatory variables (1, 2, 3, ……., m)
$\beta 1 x 1$: regression coefficient or the parameter estimates for the independent variables;

Using the model building methods outlined above, four (4) statistical models were developed. The first model (grand model) examined the relationship between RLR and all variables regardless of their p-value; the second model included attributes of attitude (such as age, gender, days of observation, time of observation, and type of vehicle); the third model covered attributes of perceived behavioural control (such as place of a traffic intersection, the direction of traffic, presence of other vehicles at the intersection and presence of passengers in the vehicle); whilst the fourth model (final model) covered only significant variables from model 1,2 and 3. All associations were considered statistically significant at a p-value ≤ 0.05 and 95% confidence interval. The decision to choose a reference level was based on the following reasons:

- Literature confirmed the high risk-taking behaviour among the younger age group and male motorists

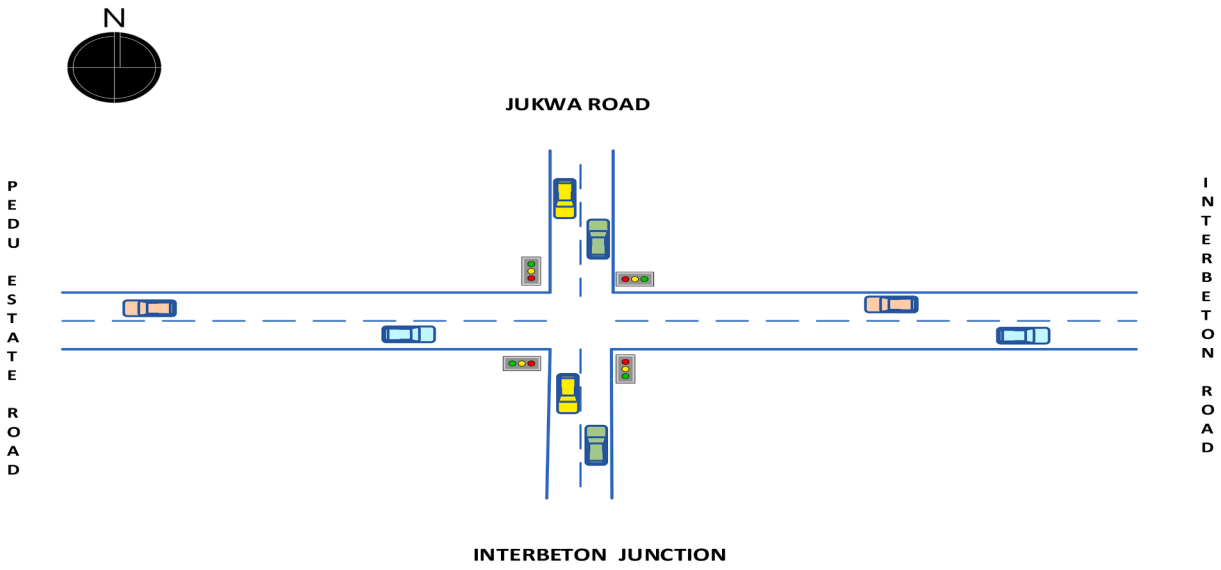

Fig. 5. Interbeton Junction.

- UCC as a signalized intersection location was chosen because it is in a well-organized community with a high-educated population where motorists may not RLR. Most importantly, the presence of security guards may also discourage motorists from RLR.
- Different days and times have been studied but none subjected to regression analysis; the day (Saturday) and time (7 am-9 am) were arbitrarily chosen to explore the model.
- Although the influence of the presence of other vehicles on RLR is yet to be explored, the authors suspect that motorists will not RLR if there is a vehicle at the intersection before his/her arrival. Hence, the relative RLR is assessed for different numbers of vehicles (1, 2, 3, & 4+) present with none (**0**) as a reference point.
- The influence of the presence of passengers in the vehicle on RLR is used as a reference based on the findings of Ackaah and Aidoo (2020). We suspect that motorists are less likely to RLR if passengers are in the vehicle. Hence, we assess the likelihood of RLR for vehicles without a passenger using the presence of a passenger (**yes**) as a reference point.
- The private car was used as a reference. We suspect that most private cars will not commit RLR as compared to taxis and other commercial vehicles who may perform RLR due to competition for passengers.

4. Results

4.1. Overview of the results

In all, 5045 motorists were observed at the signalized intersections with the majority being male (94.4%), aged 25–45 years (77.4%), on the Accra-Takoradi route (17.8%), on a Friday (18.6%), with passengers (59.8%) and no presence of a vehicle on arrival at the intersection (28.7%) and taxis (50.6%) (Table 2).

4.2. Rate of RLR

Of the 13.3% incidence of RLR, the Pedu Junction signalized intersection was the most violated (15.1%) followed by the University of Cape Coast (UCC) (12.7%) and Interbeton Junction (10.8%). (Fig. 6). The rate of RLR was seen in younger drivers aged <25 years (18.6%), males (1%), drivers plying Accra-Takoradi highway (17.9%), and among those observed on Saturday (19.0%). RL violations is also significantly high on right turns. The highest incidence of RLR was observed among drivers who arrived at the intersection when there was no vehicle present (27.6%). Also, a significant proportion of vehicles without passengers (15.6%) and private cars (15.0%) commit RLR (Table 2). Age-group, location of the signalized intersection, traffic direction, day of observation, presence of other vehicles before drivers arrived, presence of a person in the vehicle and type of vehicles were found to be significant concerning RLR (Table 2).

Table 3 shows the results of logistic regression models. In the final model (model 4), the direction of traffic flow (such as Accra to Takoradi [aOR = 2.08, 95%CI: 1.51–2.87], Gate to Campus [aOR = 1.54, 95%CI: 1.08–2.20], Pedu to Cape coast town [aOR = 1.51, 95%CI:1.06–2.17], and Abura-Pedu [aOR = 1.43, 95%CI: 1.01–2.06]) remained significant with an increased odd of RLR. Motorists were less likely to RLR on weekdays as compared to Saturday. Similarly, significant, but lower odds of RLR were observed among motorists who arrived in the presence of another vehicle (aOR = 0.24, 95%CI: 0.19–0.31) and for those who were taxis drivers (aOR = 0.82, 95%CI: 0.68–0.99).

On the other hand, motorists of vehicles without passengers were 1.27 times more likely to flout red light signals compared to those with one or more passengers (aOR = 1.27, 95%CI: 1.07–1.52).

The test of collinearity was performed on the variables (a passenger in vehicle and vehicle type) and no collinearity was found. Three tests were performed: correlation analysis, tolerance/variance inflation factor (VIF), and the condition index (CI). The correlation coefficient was low indicating that no collinearity is suspected. The VIF was 1.006 confirming that no collinearity is suspected, and the condition indices were <10, thus no collinearity exists between the suspected variables.

5. Discussion

An un-obstructive roadside survey of RLR was carried out at three (3) signalized intersections in the Cape Coast Metropolis. The three (3) constructs of the TPB framework were tested to determine the incidence of RLR with the logistics regression model. The incidence of RLR was observed to be low in the study area despite the subjective norm of the Act (2004) and Road Traffic Regulation (2012). It is noted that attitudinal ("day of observation" and "type of vehicle") and PBC attributes ("presence of other vehicles") influence the incidence of RLR. The day of observation, the UCC Gate-Campus route, presence of other vehicles before motorist arrived, presence of a passenger in the vehicle, and taxis as a type of vehicle remained statistically significant in all the models. Thus, it may be more effective to enforce RLR sanctions on Fridays and Saturdays and the UCC Gate-Campus route since RL violations are more significant as expected of weekend travel behaviour.

The use of ordinary logistics regression was able to measure the

Table 2
Characteristics of Motorists RLR in Cape Coast.

Characteristics	Number of Motorists (N = 5045)	RLR (n = 669)	Not RLR (n = 4376)	Pearson Chi^2 test
	n (%)	n (%)	n (%)	
Age group (years)				0.017*
<25	220(4.4)	41 (18.6)	179 (81.4)	
25–45	3907(77.4)	502 (12.8)	3405 (87.2)	
46–55	871(17.3)	124 (14.2)	747 (85.8)	
>55	47(0.9)	2 (4.3)	45(95.7)	
Gender				0.616
Male	4760(94.4)	634 (13.3)	4126 (86.7)	
Female	285(5.6)	35 (12.3)	250 (87.7)	
Place of intersection				0.001*
UCC	1332(26.4)	169 (25.3)	1163 (26.6)	
Pedu	2313(45.8)	349 (52.2)	1964 (44.9)	
Interbeton	1400(27.8)	151 (22.5)	1249 (28.5)	
Traffic Direction				<0.001**
Campus to Gate	791(15.7)	78(9.9)	713 (90.1)	
Accra to Takoradi	899(17.8)	161 (17.9)	738 (82.1)	
Gate to Campus	541(10.7)	91 (16.8)	450 (83.2)	
Pedu to Cape coast town	614(12.2)	103 (16.8)	511 (83.2)	
Abura-Pedu	651(12.9)	78 (12.0)	573 (88.0)	
Takoradi-Accra	520(10.3)	50(9.6)	470 (90.4)	
Pedu to Abura	749(14.8)	73(9.7)	676 (90.3)	
Pedu Junction to Pedu	280(5.6)	35 (12.5)	245 (87.5)	
Day of observation				<0.001**
Saturday	464(9.2)	88 (19.0)	376 (81.0)	
Sunday	786(15.6)	133 (16.9)	653 (83.1)	
Monday	646(12.8)	96 (14.9)	550 (85.1)	
Tuesday	713(14.1)	92 (12.9)	621 (87.1)	
Wednesday	714(14.2)	97 (13.6)	617 (86.4)	
Thursday	786(15.6)	66(8.4)	720 (91.6)	
Friday	936(18.6)	97 (10.4)	839 (89.6)	
Time (From)				0.816
7–9 am	2573(51.0)	344 (13.4)	2229 (86.6)	
3–5 pm	2472(49.0)	325 (13.1)	2147 (86.9)	
Presence of other vehicles before motorist arrived				<0.001**
0	1450(28.7)	400 (27.6)	1050 (72.4)	
1	1081(21.4)	94(8.7)	987 (91.3)	
2	896(17.8)	72(8.0)	824 (92.0)	
3	642(12.7)	37(5.8)	605 (94.2)	
4+	976(19.3)	66(6.8)	910 (93.2)	
A passenger in the vehicle				<0.001**
Yes	3017(59.8)	352 (11.7)	2665 (88.3)	
No	2028(40.2)	317 (15.6)	1711 (84.4)	
Type of vehicles				0.006*
Private cars	1961(38.9)	294 (15.0)	1667 (85.0)	
Taxis	2555(50.6)	295 (11.5)	2260 (88.5)	
Mini-buses	296(5.9)	41 (13.0)	255 (86.1)	
Midi-buses	77(1.5)	10 (13.0)	67(87.0)	
Large buses	24(0.5)	3(12.5)	21(87.5)	
Trucks	132(2.6)	26 (19.7)	106 (80.3)	

* ≤ 0.05.
** ≤ 0.001.

phenomenon under investigation because this study was not interested in the unobserved heterogeneity among the different types of intersections as conducted in China (Wang et al., 2016). Hence there was no need to use the random effects logistics regression model.

RLR is a global phenomenon and a precursor to the occurrence of RTC at signalized intersections in China, Jordan, Malaysia, the UK, and the US (Li et al., 2018; Wang et al., 2016; Yan et al., 2016; Yousif et al., 2014). However, its rate is noted to be high in Jordan and the UK. As evident in the current study, the rate of RLR is low like that of China and it is even lower than what was observed in Kumasi Metropolis, Ghana (Lin, Xu & Wang, 2018; Ackaah & Aidoo, 2020).

The low rate in the current study may be attributed in part to the lower traffic flows in the Cape Coast Metropolis as compared to Accra and Kumasi Metropolis. A similar study on traffic violations in the Cape Coast Metropolis also showed low driver violation of seatbelt and child restraint use as compared to other metropolitan areas such as Accra and Kumasi in Ghana (Afukaar, Damsere-Derry, & Ackaah, 2010; Densu et al., 2014; Ojo, 2018). Notably, no RLR offender was arrested during the data collection as observed in Kumasi, Ghana (Ackaah & Aidoo, 2020).

The TPB is being applied to understand the commission of RLR by drivers in the Cape Coast Metropolis. The first construct *attitude* as used in the study relates to the gender and age of drivers, time and day of observation and the location of the signalized intersection. Studies have revealed that females are less likely to commit RLR and this is confirmed by the current study (Zhang & Wu, 2013). Female drivers are mostly risk-averse, have less risky driving attitudes and behaviours and would not want to commit RLR (Harré, Brandt, & Dawe, 2000). Younger drivers are generally more likely to engage in risky behaviour such as RLR, non-use of the seatbelt, using a mobile phone while driving, speeding and drunk-driving (Ackaah et al., 2020; Ojo, 2018).

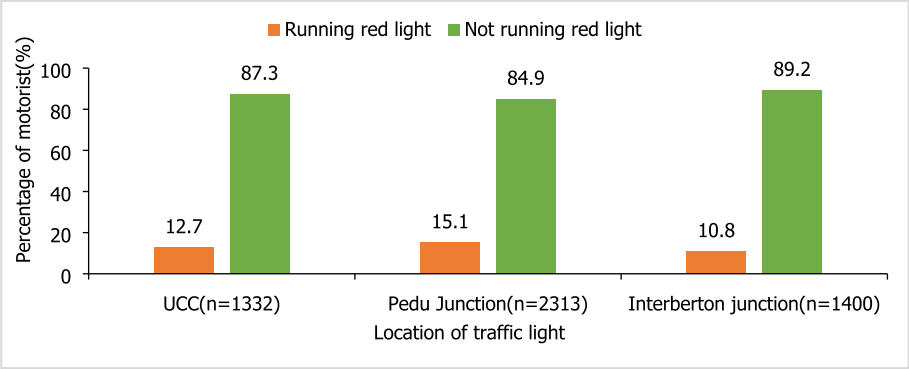

Fig. 6. Incidence of RLR in Cape Coast Metropolis.

We found the days of the observation to be a significant factor of RLR. There is always heavy vehicular traffic mostly on weekends attributable to several social functions such as weddings and funerals that happen in the Metropolis. Alcoholic drinks are shared during these social gatherings which might affect the incidence of RLR. Another reason may be the presence of travellers on the Accra-Takoradi highway who may be travelling home or returning to work during the weekend. They may be in a haste and as such contribute to the incidence of RLR in the Metropolis. Unexpectedly long queues and delays experienced by motorists and travellers on these national highways may also contribute to the RLR incidence.

It is noted in the study that more than half of the incidence of RLR occurred at the Pedu intersection. This intersection connects travelers to Accra to the east and Sekondi-Takoradi to the west and as such forms a part of the Trans-ECOWAS corridor. This above scenario indicates that there will be heavy vehicular movement. Despite the danger posed by this heavy vehicular traffic in the form of RTCs, the incidence of RLR is comparatively higher.

The Vice-Chancellor's Junction was significant in all the models with drivers from UCC campus-Gate more likely to commit RLR. The signalized intersection located within a university campus should not have had these characteristics but it is consistent with a similar study on seatbelt use on the same campus and other cities in Ghana (Afukaar et al., 2010; Ogunleye-Adetona, Ojo, & Afukaar, 2018). This is despite higher educational and socio-economic characteristics known on university campuses. However, it should be noted that university campuses are small cities or towns on their own and thus will exhibit the characteristics of the general populace. The possible explanation may be that because the campus environment is perceived to be a confined one with familiar drivers, they may tend to be relaxed in their compliance with traffic rules and regulations as offenders may not necessarily suffer the supposed penalties.

The second construct *subjective norm* relates to what should be the prevailing behaviour in a particular society. This is largely a product of law and order. The Road Traffic Act 683 (2004) and Road Traffic Regulations 2180 (2012) enjoin drivers to obey traffic signals. However, there is serious laxity with compliance and enforcement (Ackaah et al., 2020), although the incidence of RLR is observed to be low as compared to that of Kumasi in the current study. The presence of officials of MTTD of the Ghana Police Service could have averted the rate of RLR. In other jurisdictions such as Hong Kong and some cities in the US, there is a reduction in RLR because of legislation and enforcement (Retting et al., 2008; Wong et al., 2008). As noted, there are no automatic red-light surveillance cameras in Ghana. The presence of these cameras has been adopted successfully in reducing the rate of RLR in Qatar and Turkey (Aydın, Köfteci, Akgöl, & Yıldırım, 2017, 2018). However, this strategy can be supplemented with the presence of officials of MTTD of the Ghana Police Service for enforcement.

The third construct relates to PBC. Two variables such as the type of vehicles and the presence of passengers were identified as the PBC in the current study. Private car drivers are noted to be law-abiding as evident in the Metropolis and as such tend to commit a traffic violation against taxi or commercial drivers (Ojo, 2018). Private car drivers are thought to be more educated than taxi drivers. Drivers with passengers are always careful and as such less likely to commit RLR (Wang et al., 2016). These drivers are afraid of a possible rebuke by passengers and are forced to adhere to the traffic signal. Taxi drivers are more likely to commit traffic violations such as non-use of seatbelts, speeding and RLR because of the nature of their work (Ojo, 2018; Sam, 2015). They hurriedly want to pick up and drop off passengers to rake in more money for the day. The findings in this study differ from that of Kulanthayan et al. (2007) and Ackaah, Larley, and Larbi, (2020) that revealed a higher aberration from private cars in Malaysia and Ghana respectively.

6. Conclusion and policy implication

The incidence of RLR is noted to be low in the Metropolis but the subjective norm in the form of enforcing the Act (2004) and Road Traffic Regulation (2012) can reduce this incidence drastically. Attributes of *attitudes* (such as days of observation and type of vehicle), and PBC (such as the presence of other vehicles at the intersection and presence of passengers in the vehicle) have a significant influence on the intention to commit RLR. This incidence portends danger for the drivers and other road users. The officials of the National Road Safety Authority (NRSA), Motor Transport and Traffic Directorate (MTTD) of the Ghana Police Service (GPS) should increase the tempo of road safety education to eradicate the incidence of RLR as a precursor to reducing RTCs at signalized intersections in the Metropolis.

City authorities in the Cape Coast Metropolis can also post city guards to assist officials of MTTD of the GPS to arrest and prosecute offenders to serve as a deterrent to others. Interviewing drivers in the Cape Coast Metropolis on the incidence of RLR could have given readers an idea of what motivates drivers to RLR and any possible involvement in RTCs. It is thus recommended that further studies should look into that. It is recommended that further research should collectively look into the incidence of RLR by all motorists comprising drivers, motorcyclists and tricyclists in the Metropolis.

What is already known on the subject?

- There is an increasing rate of red-light running in Ghanaian metropolises such as Accra and Kumasi, and Tamale.

What this study adds

- The use of the Theory of Planned Behaviour to understand the incidence of red-light running in a Ghanaian Metropolis.
- Modelling the incidence of red-light running in the Cape Coast Metropolis.

Table 3
Logistic regression modelling of predictors of drivers' RLR.

Characteristics	Crude	Model 1	Model 2	Model 3	Model 4
	cOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)
Age group (years)					
<25	1	1	1	–	1
25–45	0.64(0.45–0.92)*	0.89(0.60–1.31)	0.75(0.52–1.07)	–	0.88(0.60–1.30)
46–55	0.72(0.49–1.07)	0.96(0.63–1.47)	0.82(0.55–1.22)	–	0.96(0.63–1.47)
>55	0.19(0.05–0.83)*	0.22(0.05–0.98)*	0.21(0.05–0.88)*	–	0.23(0.05–0.98)
Gender					
Male	1	1	1	–	[b]
Female	0.91(0.63–1.31)	0.83(0.56–1.23)	0.77(0.53–1.12)	–	[b]
Location of traffic light					
UCC	1	1	–	1	
Pedu Junction	1.22(1.00–1.49)*	1.49(0.95–2.38)	–	1.39(0.89–2.16)	[b]
Interbeton Junction	0.83(0.66–1.05)	1.15(0.79–1.68)	–	1.19(0.84–1.69)	[b]
Traffic Direction					
Campus to Gate	1	1	–	1	1
Accra to Takoradi	1.99(1.49–2.66)**	1.41(0.92–2.16)	–	1.59(1.06–2.39)*	2.08(1.51–2.87)**
Gate to Campus	1.85(1.34–2.56)**	1.54(1.08–2.19)*	–	1.68(1.19–2.35)*	1.54(1.08–2.20)*
Pedu to Cape coast town	1.84(1.34–2.53)**	1.03(0.65–1.65)	–	1.37(0.89–2.11)	1.51(1.06–2.17)*
Abura-Pedu	1.24(0.89–1.74)	1.27(0.86–1.87)	–	1.31(0.92–1.85)	1.43(1.01–2.06)*
Takoradi-Accra	0.97(0.67–1.41)	0.77(0.47–1.29)	–	0.66(0.41–1.06)	1.14(0.75–1.71)
Pedu to Abura	0.99(0.71–1.38)	[a]	–	[a]	1.13(0.77–1.64)
Pedu Junction to Pedu	1.31(0.85–1.99)	[a]	–	[a]	1.47(0.93–2.31)
Day of observation					
Saturday	1	1	1	–	1
Sunday	0.87(0.65–1.17)	0.78(0.56–1.10)	0.85(0.63–1.15)	–	0.79(0.57–1.10)
Monday	0.75(0.54–1.02)	0.64(0.45–0.92)*	0.76(0.55–1.04)	–	0.65(0.46–0.93)*
Tuesday	0.75(0.46–0.87)*	0.45(0.32–0.65)**	0.62(0.45–0.86)*	–	0.46(0.33–0.66)**
Wednesday	0.67(0.49–0.92)*	0.53(0.37–0.75)**	0.65(0.48–0.90)*	–	0.53(0.37–0.76)*
Thursday	0.39(0.28–0.55)**	0.36(0.24–0.54)**	0.39(0.28–0.56)**	–	0.37(0.25–0.55)**
Friday	0.49(0.36–0.68)**	0.40(0.28–0.57)**	0.50(0.37–0.69)**	–	0.40(0.28–0.57)**
Time (From)					
7–9 am	1	1	1	–	[b]
3–5 pm	0.98(0.83–1.15)	1.05(0.87–1.26)	0.98(0.83–1.15)	–	[b]
The presence of other vehicles before the driver arrived					
0	1	1	–	1	1
1	0.25(0.19–0.32)**	0.24(0.19–0.31)**	–	0.25(0.19–0.32)**	0.24(0.19–0.31)**
2	0.23(0.11–0.29)**	0.22(0.16–0.28)**	–	0.23(0.17–0.30)**	0.22(0.16–0.28)**
3	0.16(0.11–0.23)**	0.15(0.11–0.22)**	–	0.16(0.11–0.23)**	0.15(0.11–0.22)**
4+	0.19(0.14–0.25)**	0.18(0.14–0.24)**	–	0.19(0.14–0.25)**	0.18(0.14–0.24)**
A passenger in the vehicle					
Yes	1	1	–	1	1
No	1.40(1.19–1.65)**	1.27(1.06–1.52)*	–	1.25(1.05–1.49)*	1.27(1.07–1.52)*
Type of vehicles					
Private cars	1	1	1	–	1
Taxis	0.74(0.62–0.88)**	0.81(0.67–0.98)*	0.73(0.61–0.87)**	–	0.82(0.68–0.99)*
Mini-buses	0.91(0.64–1.29)	0.79(0.54–1.15)	0.82(0.57–1.17)	–	0.80(0.55–1.16)
Midi-buses	0.85(0.43–1.66)	0.64(0.31–1.31)	0.81(0.41–1.61)	–	0.66(0.32–1.33)
Large buses	0.81(0.24–2.73)	0.63(0.17–2.28)	0.66(0.19–2.24)	–	0.63(0.18–2.28)
Trucks	1.39(0.89–2.17)	0.99(0.61–1.63)	1.27(0.81–1.99)	–	1.02(0.63–1.66)
R^2		0.115	0.018	0.099	0.114

[a] Removed from the model due to Multiple Collinearity.
[b] Non-significant (p-value > 0.05) in model 1, 2, & 3.
* ≤ 0.05.
** ≤ 0.001.

- Advocating for the blend of police surveillance and surveillance cameras to arrest the incidence of red-light running
- The subjective norm in the form of Road Traffic Act 683 (2004) and Road Traffic Regulations 2180 (2012) should be enforced by the officials Motor Transport and Traffic Department of the Ghana Police Service.

CRediT authorship contribution statement

Thomas Kolawole Ojo: Conceptualization, Writing – original draft, Project administration. **Enoch Teye-Kwadjo:** Methodology, Formal analysis, Data curation. **Abena Obiri-Yeboah:** Writing – review & editing. **Anthony Baffour Appiah:** Validation, Formal analysis, Investigation.

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