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Drivers' Responses to Countdown Timer at Signalized Intersection

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ABSTRACT: Countdown Timers (CT) have gained significant popularity in recent years not only in many countries but also in Indonesia, particularly in the provinces of Central Java and East Java. CT displays the remaining seconds in numbers clearly before switching the traffic light on or off after a period of time. Three seconds before the light is to be off, drivers prepare to slow down the vehicles. On the contrary, some speed up to hasten the vehicles. The contrast behaviors represent different responses to traffic signals in an intersection. There are contradictions found in a number of previous studies as using a CT has potential advantages and disadvantages. One advantage is the driver is more prepared to continue riding. The disadvantage is the driver manipulates the countdown to speed up by yellow to red signals. To be objective, the data were obtained from the results of questionnaire based on a Likert Scale with eight variables out of 100 respondents of Sragen, 175 of Probolinggo, and 390 of Malang. The data were tabulated and analyses were carried out using Binary Logistic Regression. The results of the research are expected to be able to strengthen the previous findings. It can be concluded that CT is not necessary intall at the signalized intersection which can be the referrence for the further researches.

KEYWORDS: Countdown Timer, Likert Method, responses, signalized intersection

1. INTRODUCTION

The violation of traffic light regulations often occurs on signalized intersections. Private vehicle users were dominant in the violation (Campisi et al., 2020), while cameras were effective in reducing both red light violations and certain types of traffic collisions (Cohn et al., 2020), and the dominant violators were opportunistic drivers speeding up the vehicles to violate the red light in the last seconds (Jantosut et al., 2021). Red Light Running (RLR) violations occurred at a rate of 0.94% of cars/trucks; 2.44% of motorbikes; 1.33% of three-wheeled vehicles (Al-Mistarehi et al., 2021); and 0.94% of motorized vehicles, 2.44% of motorcycles, and 1.33% of three-wheeled vehicles (Amarasingha, 2020). It has been found that in-vehicle warning systems providing audio and/or visual feedback to the driver were the most effective device at reducing RLR violations, referring to studies indicating an 84.3% decline in RLR violations, a 37% decline in collision rate, and a lower probability of RLR. The most probable vehicles to decline RLR rate provided aural and/or visual feedbacks to the driver, at an 84.3% decline in RLR, a 37% decline in collision rate, a higher RLR probability, and a lower crash risk (Elias et al., 2019).

The use of Countdown Timers (CT) providing drivers with the remaining time before the lights are on or off at signalized intersections could be influential to their driving behaviors and safety (Krukowicz et al., 2021), (Nygårdhs, 2021), (Islam et al., 2016). Drivers' responses to CT vary.

2. LITERATURE REVIEWS

2.1 Positive Effect

Positive responses imply that the CT may result in safer driving. For example, slowing down on yellow signal rather than speeding up to violate the red signal, and drivers are likely to stop when stuck in a dilemma zone. In correlation with driver's behavior, CT at signalized intersections makes the drivers aware to make results. The drivers pay more attention to the remaining time before the light is off which may affect their result-making and driving behavior. The results of some case studies indicated that CT devices increased safety at signalized intersections (Kłos et al., 2020), and 29% reduced total pedestrian accidents and 30% fatal pedestrian accidents/injuries (Atta Boateng et al., 2018). Incompetent and irresponsible drivers in complying with traffic regulations resulted in traffic delays, leading to congestion and local pollution. The use of CT resulted in less pollution due to a prepared start (Małecki & Iwan, 2019) and the reduction of start-up time at signalized intersections increasing the efficacy of the signalized intersection (Elias et al., 2019). The use of CT increased 13.10% the average probability of a motorist stopping in a dilemma zone and decreased 1.50ft/s2 the average driver's rate of deceleration. So the CT use contributed to enhancing intersection safety in the United States (Islam et al., 2017) and enhanced the traffic safety and operational efficiency of signalized intersections (Jatoth et al., 2021). Besides, CT use reduced pedestrian and bicycle accidents at intersections (Zhao, 2021). The tendency of the drivers to speed up vehicles in the last seconds of the green light might incline the risk of collisions although CT use improved the intersection capacity (Barbara, 2018). Logistic Regression analysis, which classifies pedestrians based on their behaviors with an accuracy of 97% (Fourkiotis et al., 2022) is a suitable model for determining the effect of using a CT on pedestrians.

2.2 Negative Effect

The opposite response to the use of CT implied that the device encouraged risk-takers to cross the intersections at higher speeds in the last seconds of red signal. Therefore, the elimination of CT device (Yan et al., 2022) required further serious studies. It is important to pay attention that CT might be impractical for driven signals whose lights change within 1 - 4 seconds after the result making (Campisi et al., 2020).

Using a CT resulted in 33.3% of drivers stopping before the stop line, 59% of drivers crossing the intersection during the yellow signal, and 7% of drivers committing red signal violations (Al-Mistarehi et al., 2021); a significant increase in red signal violations for bikers to stop less than 40m from the stop line when the signal changes from green to red (Kaths et al., 2019); the violation occurring at a red flash of the signal (Alghafli et al., 2021); 1.3 times more violations of red light (Simeunović et al., 2021); disability to eliminate the red signal violations (Wisetjindawat et al. 2017).

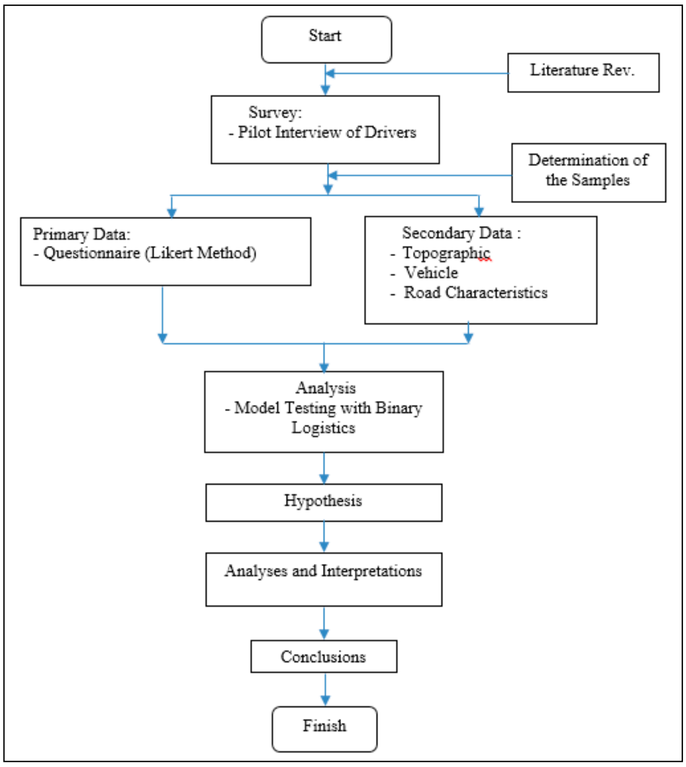
To sum up, the use of CT resulted in both positive and negative effects on drivers' behavior and safety. The effectiveness depends on a number of variables such as the type of intersection, the effect of flashing lights, and the characteristics of the driver. In response to this gap, this research was conducted in Sragen, Probolinggo, and Malang with distinct traffic characteristics. This research aims to identify the factors that influence driver behavior at different types of intersections, as well as the potential negative effects due to a variety of problems, and other factors able to influence a driver's reaction to the CT at signalized intersections.

3. METHODS

3.1 Approach

Graph 1 is a flow chart of the research including interviewing respondents with the Likert Method, the process of tabulating respondent data, Regression testing with the Binary Logistics Test and interpretation of the regression test results.

A Likert scale-based questionnaire was used to collect respondent data through both face-to-face and online methods. Sampling was conducted in three cities: Malang, Probolinggo, and Sragen. In Malang, the sampling took place at licensing offices, on campuses, and at transportation offices. In Probolinggo, interviews were conducted at the licensing office, transportation office, planning office, and Samsat office for extending vehicle fitness permits, as well as at the city sub-district office. In Sragen, the sampling was conducted at the licensing office, planning office, and Samsat office. Additionally, the questionnaire was administered online via Google Forms and distributed through WhatsApp groups. One hundred respondents from Sragen, 175 from Probolinggo, and 390 from Malang completed the questionnaire. Most of the respondents from Malang were university students. The Likert scale parameters listed in Table 1 include five statements as follows (see Table 1).



Graph.1. Research Method

Statement	Positive Score
Strongly Agree/Always	5
Agree/Often	4
Hesitant/Sometimes/Normal	3
Disagree	2
Strongly Disagree	1

Source: Chyung et al. 2017

Table 1. Determining the Value of the Likert Scale

No	Question	Rating Scale				
Y	*Do you agree that a Countdown Timer should be installed at signalized intersections?*	*1. Agree*	*2. Not Agree*			
X_1	All drivers (2 wheeled/4 wheeled) must have a Driving License	1	2	3	4	5
X_2	I prefer an intersection with a yellow before a red-light	1	2	3	4	5
X_3	I prefer the green signal for a long time	1	2	3	4	5
X_4	I will drive even though the signal is not green yet	1	2	3	4	5
X_5	I will drive even though the signal is yellow	1	2	3	4	5
X_6	I will continue riding by red signal.	1	2	3	4	5
X_7	I prefer wide intersections.	1	2	3	4	5
X_8	I prefer passing through 4 approachs to 3 approachs.	1	2	3	4	5

Note:
Y: Consensus on the installation of a Countdown Timer at signalized intersections.
X1: Must to have a Driving License
X2: Response to yellow signal before the red starts
X3: Love to have a long-timed green signal
X4: Will to start riding by red-to-green signal
X5: Will to continue riding by yellow signal
X6: Will to continue riding by red signal
X7: Preference to having wide intersections
X8: Preference to going through three-way intersection (T-junction) or four-way intersection (crossroads).

Table 2. List of Survey Question

The third statement is used to assess people's opinions and means 'neutral'. Researchers continue to debate whether Likert scales are ordinal or interval. The distance separating each point on the scale must be equal for the scale to be considered an interval scale, as shown here: score 1 corresponds to strongly disagree, score 2 corresponds to disagree, score 3 corresponds to normal, score 4 corresponds to agree, and score 5 corresponds to strongly agree (Chyung et al., 2017). There are 8 variables, as shown in Table 2.

These questions were from previous research studies related to countdown timers. Support for taking variables already exists in preliminary research in the dissertation, namely number of approaches, speed, road width, speed at intersections, and intersection width (Al-Atawi, 2014), day (weekday or weekend), camera installation, vehicle type (two-wheeled vehicles or four-wheeled vehicles), traffic light cycle time (long or short) and type of traffic light (with countdown timer or normal) (Kulanthayan et al., 2007), the absence of an adaptive signal to yellow (Lin & Cheng, 2013), Gender (Male or Female) (Hezaveh et al., 2018), Country of origin (Citizenship) (Yoh et al., 2017), length of ownership of a driving license (Timmermans et al., 2019); (Machado et al., 2014); (Machado et al. 2014) and (Peck, 2011); in (Yoh et al., 2017) who concluded that driving safety measures based on driver characteristics in relation to area are effective. Yoh's research is the basis for taking independent variables for 3 regions, namely Sragen (Central Java), Malang (East Java) and Probolinggo (representing Madura), in (Zhao, 2021). The driver's tendency to speed up vehicle in the final phase of the green signal. All of these were written down in the Dissertation manuscript in the preliminary research.

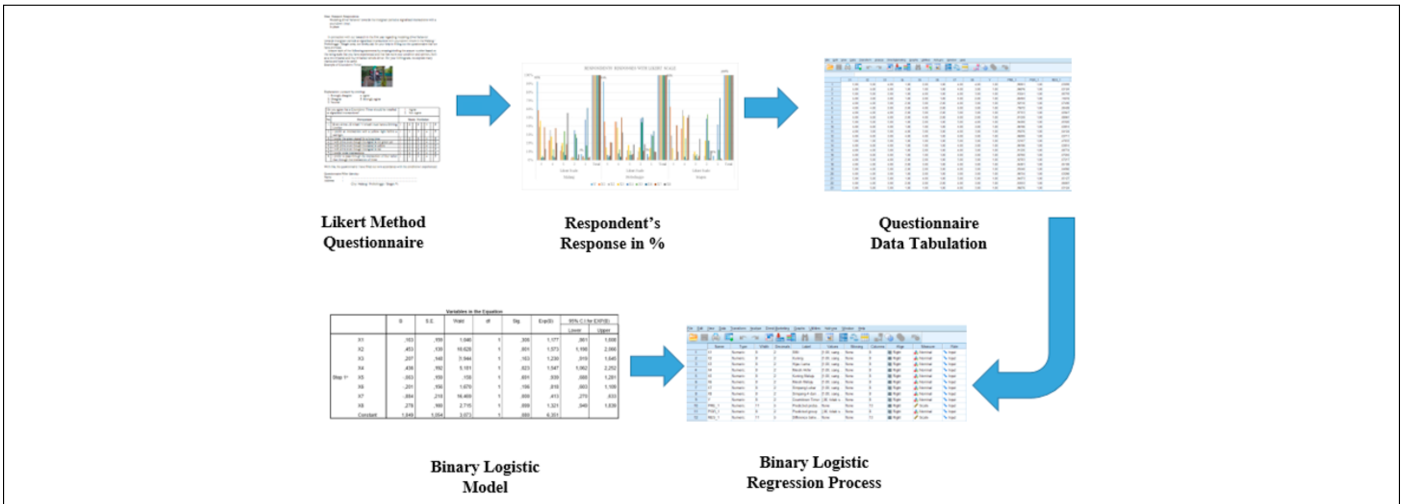
The questionnaire's question selection process was informed by the driver and intersection characteristics observed in three sample cities. In Malang, there were four intersections, with two featuring four-way intersection (crossroads) and the other two having three-way intersection (T-junction). In Probolinggo, three intersections were surveyed, with one featuring four-way intersection (crossroads) and the other two having three-way intersection (T-junction). Similarly, in Sragen, two intersections were examined, with one having four-way intersection (crossroads) and the other three.

3.2 Research Stages

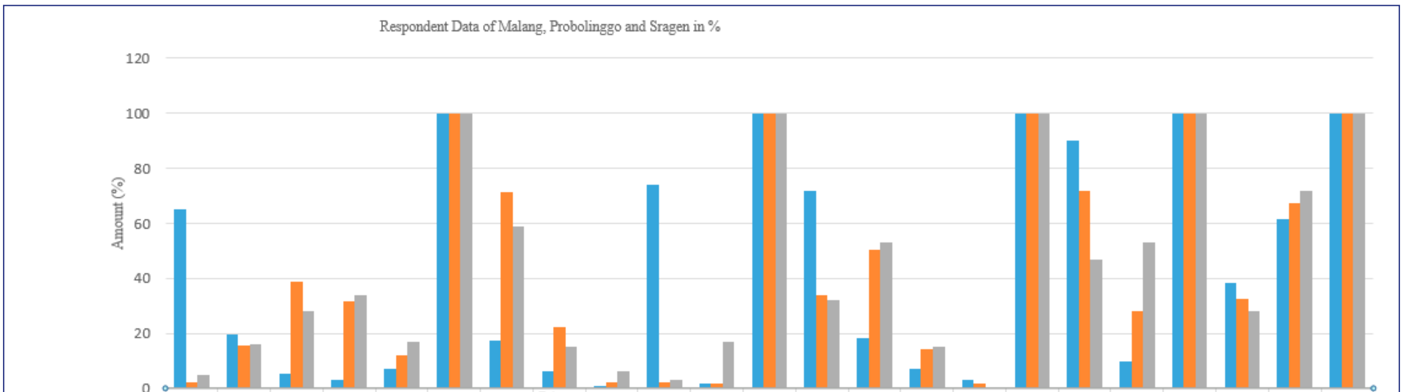
Graph 2 describes the complete stages of the research, starting from distributing questionnaires, tabulating questionnaires, regression analysis, creating a Binary Logistic Regression model followed by field calibration at the intersection of Malang, Probolinggo, and Sragen, and recording using the Time Slice method, Traffic Calculation and Traffic Data Tabulation.

3.3 Data Collections

The results of the questionnaire are as follows (see Graph 3).



Graph.2. Research Stages



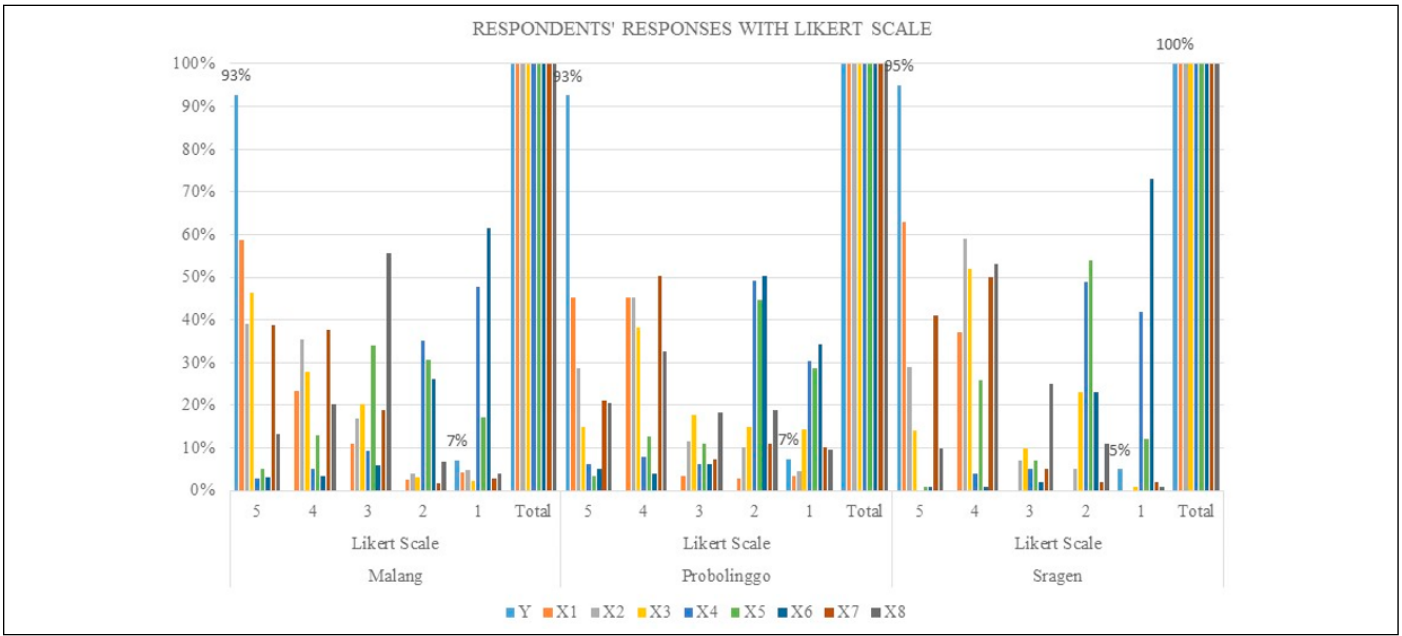
	Age						Work						Income					Vehicle			Gender		
	< 20 Year	20 – 30 Year	30 - 40 Year	40 - 50 Year	> 50 Year	Total (%)	civil servants /soldiers	Private sector employee	Self-employed	Student	Other	Total (%)	< IDR 2 million	> IDR 2 – 5 million	> IDR 5 – 10 million	> IDR 10 million	Total (%)	Motorcycle	Car	Total (%)	Female	Male	Total (%)
Malang (N = 390)	64,88	19,74	5,12	3,08	7,18	100	17,18	6,4	1,03	73,85	1,54	100	71,79	18,21	6,92	3,08	100	90,26	9,74	100	38,27	61,73	100
Probolinggo (N=175)	2,29	15,43	38,86	31,42	12	100	71,42	22,29	2,29	2,29	1,71	100	33,71	50,29	14,29	1,71	100	72	28	100	32,6	67,4	100
Sragen (N = 100)	5	16	28	34	17	100	59	15	6	3	17	100	32	53	15	0	100	47	53	100	28	72	100

Graph 3. Questionnaire Results in Percentage

Graph 3 shows: 73.3% of 390 respondents from Malang—student town— were students under 20 years old with less than IDR 2,000,000 pocket money riding motorbikes; 71.4% of 175 respondents from Probolinggo were civil servants/soldiers at the age of 30 – 40 years with IDR 2,000,000 - 5,000,000 income riding motorbikes; and 59% of 100 respondents from Sragen were civil servants aged 40 – 50 years with IDR 2,000,000 – 5,000,000 income riding motorbikes. Sragen and Probolinggo have similar characteristics.

Graph 4 shows 93% of respondents strongly agree with the use of CT in Malang, 93% in Probolinggo and 95% in Sragen. The highest X1 on a scale of 5 was 63% in Sragen.The highest X2 on scale 4 was 59% in Sragen. The highest X3 on scale 4 was 52% in Sragen. The highest X4 on scale 2 was 49% in Probolinggo and Sragen. The highest X5 on scale 2 was 54% in Sragen. The highest X6 on scale 1 was 73% in Sragen. The highest X7 on scale 1 is 50% in Sragen. And the highest X8 on scale 3 was 56% in Sragen.

The initial inquiry in the questionnaire requires respondents to indicate their consent regarding the installation of a Countdown Timer (CT) at signalized intersections. This query serves as the dependent variable (Y). Subsequently, respondents are prompted to answer questions X1 through X8, which represent independent variables.



Graph 4. Respondent's Response in %

4. RESULT

The Results of the Questionnaire Data Analysis

Iteration		-2 Log likelihood	Coefficients								
			Constant	X1	X2	X3	X4	X5	X6	X7	X8
Step 1	1	370,385	1,272	,030	,135	,049	,102	-,008	-,049	-,190	,076
	2	315,868	1,495	,081	,304	,118	,252	-,024	-,121	-,480	,176
	3	306,833	1,675	,139	,424	,183	,392	-,049	-,184	-,769	,256
	4	306,282	1,827	,161	,452	,205	,433	-,062	-,200	-,875	,277
	5	306,278	1,848	,163	,453	,207	,436	-,063	-,201	-,884	,278
	6	306,278	1,849	,163	,453	,207	,436	-,063	-,201	-,884	,278

a. Method: Enter
b. Constant is included in the model.
c. Initial -2 Log Likelihood: 340,829
d. Estimation terminated at iteration number 6 because parameter estimates changed by less than 0.001.

Table 3. Iteration History[a,b,c,d]

Value -2 log likelihood: 340,829
Table Value 665-1 = 664
$\chi^2_{0,05(664)}$ = **725,057**
Value -2 Log Likelihood (340,829) < $\chi^2_{0,05(664)}$ table (725,057) so that it accepts Ho, then it shows that the model by including the independent.

Table 4 model summary: Cox & Snell R Square and Nagelkerke R Square values are used to find out the ability of the independent variables and the dependent variable. These values are also called Pseudo R-Square known as R-Square in linear regression (OLS). The combination of Malang, Probolinggo, and Sragen resulted in 0.126 Nagelkerke R Square value representing 12.06% the ability of the independent variable to clarify the dependent variable. The remaining is influenced by variables outside the model.

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	306,278[a]	0,050	0,126

a. Estimation terminated at iteration number 6 because parameter estimates changed by less than, 001.

Table 4. Model Summary

Step	Chi-square	df	Sig.
1	7,307	8	0,504

Table 5. Test Hosmer and Lemeshow

This test is employed to measure the feasibility of the logistics model.
Ho: The model is sufficiently capable of clarifying the data/in accordance with it.
H1: The model is not sufficiently able to clarify the data.
Reject Ho if the sig value is < 0.05
The combination obtained 0.504 sig value. Result: approved Ho.

Conclusion: The combination of Malang, Probolinggo, and Sragen resulted in a 5% significant level. It can be concluded that the used logistic regression model has been able to clarify the data/in accordance with it.

Table 6. displays the coefficient of each independent variable, as well as the results of a test to determine if the independent factors have an effect on the dependent variable or not. This test is analogous to the t-test used in regression analysis.
Conducting partial tests for each variable.
Ho: β_1=0 (variable Xi does not have a significant effect on Y)
H1: β_1≠0 (variable Xi has a significant effect on Y)
Reject Ho if sig < 0.05
Result: Ho is rejected

Conclusions are drawn using a significance level of 5%, that the factors X2 and X4 indeed have a substantial effect on the outcome Y. Of Variable X2 and X4, each has a smaller than 0.050 Wald test significance value indicating that each has a positive and statistically significant effect on Variable Y if the coefficient is positive. The incline of the variable score toward category 1 (totally) of variable Y indicates that the coefficient is positive.
Ho: β_1=0 (variable Xi does not have a significant effect on Y)
H1: β_1≠0 (variable Xi has a significant effect on Y)
Reject Ho if sig < 0.05
Result: Ho is approved
Conclusion: at a real level of 5% it can be concluded that variables X1, X3 and X8 do not have a significant effect on Y. Using a significance level of 5%, conclusion can be drawn that variable X7 has a significant effect on Variable Y.

In accordance with the results of each Wald test, Variable X7 has a substantial and detrimental influence on Variable Y, with significance values greater than 0.050. The higher the score of the variable the closer to the category Y 0 (not) not yet definite, as indicated by the negative coefficient.
Ho: β_1=0 (variable Xi does not have a significant effect on Y)
H1: β_1≠0 (variable Xi has a significant effect on Y)
Reject Ho if sig < 0.05
Result: Ho is approved
Conclusion: at a real level of 5% it can be concluded that variables X1, X3 and X8 do not have a significant effect on Y.

It is plausible to draw the conclusion, using the 5% significance threshold, that Factors X1, X3, and X8 do not have a significant impact on Variable Y.
Variables X1, X3, and X8 each has a significance value for the Wald test that is greater than 0.050, indicating that they have a positive and insignificant effect on Variable Y. When the coefficient is positive, an incline in the score of the variable toward category 1 (totally) of variable Y indicates that the coefficient is positive.
Ho : β1=0 (The effect that Xi has on Y is not particularly substantial.)
Y is significantly influenced by Variable Xi (H1: β1=0; this relationship exists).
If the sig is greater than 0.05, Ho should be rejected.
Result: Ho is rejected.

It is plausible to draw the conclusion, using a significance threshold of 5%, in which Variables X5 and X6 have no effect on Variable Y. Of Variables X5 and X6, each has significance values from the Wald test greater than 0.050, indicating that they contribute a negative but insignificant influence to the overall value of Variable Y. The higher score of the variable the closer to the category Y=0 (not) not yet definite, as indicated by the negative coefficient.

The sort of influence having a substantial effect on the variables is indicated in the Exp (B) column of Table 6. If the value is greater than 1, the greater the possibility of negative outcomes for Y. As the exp value (X2) is 1.573, every single change in Value X4 will result in a change in Y that is 1.573 persons. Therefore, if more persons agree that the yellow light comes on before the red light, possibly someone agreeing that there is a CT of 1.573 persons will incline. This, however, is not the case if the results of the Wald test are insignificant and the independent variable does not have any effect on the dependent variable.

5. DISCUSSION

The data collected from the three cities has characteristics that are specific to each city. As a student city, Malang has the highest number of student respondents with 73.9% riding a motorbike. Probolinggo has the highest number of respondents who are civil/military employees with 71.4%. Sragen has similar characteristics to Probolinggo, with the highest number of respondents being civil servants and soldiers at 59%.

After analysing CT usage at signalised intersections, three important variables were found: drivers who drove through the intersection at yellow lights (X2), drivers who drove

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	X1	,163	,159	1,046	1	,306	1,177	,861	1,608
	X2	,453	,139	10,628	1	,001	1,573	1,198	2,066
	X3	,207	,148	1,944	1	,163	1,230	,919	1,645
	X4	,436	,192	5,181	1	,023	1,547	1,062	2,252
	X5	-,063	,159	,158	1	,691	,939	,688	1,281
	X6	-,201	,156	1,670	1	,196	,818	,603	1,109
	X7	-,884	,218	16,469	1	,000	,413	,270	,633
	X8	,278	,169	2,715	1	,099	1,321	,949	1,839
	Constant	1,849	1,054	3,073	1	,080	6,351		

a. Variable(s) entered on step 1: X1, X2, X3, X4, X5, X6, X7, X8.

Table 6. Variables in Equations

through the intersection at red lights (X4), and drivers who preferred to drive on wider roads (X7). These findings support research (Nygårdhs 2021) that the use of CTs at signalised intersections reduces safety, in line with another study which found that 33.3% of drivers stopped at stop lines, 59% of drivers crossed intersections with yellow lights, and 7% of drivers committed red light violations (Alghafli et al., 2011). Another study found a significant trend of red signal violation by motorcyclists less than 40 m from the stop line when the signal changed from green to red (Simeunović et al., 2021), which is also in line with the studies of (Yan et al., 2022), and (Wisetjindawat et al., 2017), which stated that violations start from the beginning of the red signal. On the other hand, this finding is contradictory/inconsistent with studies stating that the use of CT improves safety at signalised intersections (Kłos et al., 2020); improves traffic safety and operational efficiency at signalised intersections (Jatoth et al., 2021). Moreover, these findings contradict the results of another study (Fourkiotis et al. 2022), which showed that the duration of CTs makes intersections safer.

Driving on red and yellow signals is quite risky in terms of road safety. When the red signal is flashing, the driver has to stop the vehicle completely because there are vehicles coming from the opposite direction or from the other arm. It can be concluded that the use of CTs at signalised intersections should be based on some more careful considerations.

6. CONCLUSIONS

This research consists of 8 variables. X1 (All drivers (2 wheeled/4 wheeled) must have a Driving License), X2 (I prefer an intersection with a yellow before a red-light), X3 (I prefer the green signal for a long time), X4 (I will drive even though the signal is not green yet), X5 (I will drive even though the signal is yellow), X6 (I will continue riding by red signal), X7 (I prefer wide intersections), X8 (Preference to going through three-way intersection (T-junction) or four-way intersection (crossroads), Y (Consensus on the installation of a Countdown Timer at signalized intersections).

This research examines the use of CT (Countdown Timer) at signalized intersections. The research results show that 93% of respondents in both Malang and Probolinggo strongly support the use of CT at signalized intersections, as do 95% of respondents in Sragen. In Sragen, the highest percentage of agreement (X1) on scale 5 was 63%, while the highest percentage for X2, X3, X5, X6, and X7 ranged from 49% to 73%. From the answers to 8 questions regarding licensing, preferences, and driving intentions, Binary Logistic Regression analysis shows that X2, X4, and X7 are significant. The change in units of X2 (1,573) is equal to the change of 1,573 individuals who consented (Y) to the installation of the Countdown Timer. This means that for every 1 person who agrees to install the Countdown Timer, there are 1,573 people who drive when the yellow light is on. Likewise, X4 (1.547) and X7 (0.413) are related to driver behavior towards red lights and wide intersection choices. Higher values of X2 and X4 correlate with increased offending. Because the more drivers agree with the installation of a countdown timer, the more drivers are driving yellow lights and red lights (this is included in traffic violations).

These findings highlight important considerations for authorities and policy makers regarding the development of public transport systems. The actions of some respondents, such as ignoring yellow and red signals, highlight areas of concern. It is important for policymakers in Indonesia and other developing countries to commit to a global agenda that focuses on creating safe, accessible, reliable, affordable and sustainable transport systems. In addition, further research into the effect of installing countdown timers at more complex signalized intersections is needed for further research.

The limitation of this study is that questions X1 to X8 have not yet specifically mentioned whether they relate to intersections with or without a countdown timer, making the drivers' perceptions of the questionnaire unclear regarding their perception of the countdown timer. Additionally, the question in the questionnaire asking how many times someone passes through a signalized intersection with a countdown timer in a week is too vague because it only mentions the day without clarifying how many times per day. As a result, the total frequency for the week is unclear. For future research, it is necessary to specify whether each variable (question) pertains to an intersection with or without a countdown timer and also to indicate how many times it is passed through each day.

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