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Waiting Time Countdown Displays Affect the Idle-Stopping Behavior of Motorcyclists at Signalized Traffic Intersections

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Abstract

Transportation is an important driving force behind the surging global energy demand and a key emission source of air pollutants and greenhouse gases. Turning off vehicle engines while waiting for extended periods at traffic intersections can help reduce transport sector fuel consumption and mitigate air pollution. However, idle-stopping is a personal choice and depends on behavior and awareness among drivers. In this study, we conducted a stated preference survey among motorcyclists in Kathmandu, Nepal, to examine the effect of installing traffic lights with waiting time countdown displays at signalized traffic intersections on idle-stopping behavior and investigated if the display of waiting time countdowns could encourage idle-stopping behavior among motorcyclists. Through logistic regression analysis, we found a significant effect of waiting times on idle-stopping choices ($p < 0.001$). The odds ratio for waiting time was 1.051 (95% CI: 1.046-1.057), suggesting that with a 1-second increase in waiting time, the odds of motorcyclists idle-stopping their motorcycle engines increase by 5.1%. Likewise, the most commonly perceived deterrent to idle-stopping choices was the uncertain waiting time. Therefore, our results suggest that installing waiting time countdown displays at signalized traffic intersections may offer an often overlooked benefit by reducing idling fuel consumption and tailpipe emissions from on-road vehicles. Our findings will provide valuable insights for policymakers in formulating evidence-based policies and city planners in improving transportation infrastructure, especially in cities in developing economies.

Keywords: *Air pollution; ecodriving; logistic regression; road infrastructure; traffic light*

Introduction

Transportation is one of the crucial factors causing a rapid increase in global energy demand and a key emission source of air pollutants and greenhouse gases (GHGs). Globally, it accounts for approximately 25% of energy consumption (Lindstad et al., 2023) and contributes to 20% of CO_2 emissions, with road transportation being a major contributor (Albuquerque et al., 2020). Therefore, the decarbonization of the transport sector is advocated as a requirement to mitigate GHG emissions and global climate change (Lindstad et al., 2023). Moreover, it contributes notably to air pollutant emissions in many countries around the world (Paschalidou et al., 2022; Wu et al., 2023).

Nepal, a developing country in South Asia, has been grappling with degrading air quality (Khokhar et al., 2023). Transportation is the third-largest sector in terms of energy consumption and CO_2 emissions in Nepal (Sadavarte et al., 2019). As such, reducing emissions from this sector can notably contribute to mitigating the country's GHG emissions and reducing air pollution. Over the last two decades, Kathmandu, the capital city of Nepal, has witnessed a significant rise in the number of vehicles, especially motorcycles, with over eightfold increase in its number from 2000 to 2017 (DoTM-GoN, 2017). The city has been facing significant air pollution challenges, with its severity increasing over the past couple of decades (Mahapatra et al., 2019). The city's motorcycle fleet contributes to over 50% of carbon monoxide emissions and 66% of volatile organic compounds (VOC) emissions from road transportation (Shrestha et al., 2013). Motorcycle ownership typically follows a hump-shaped pattern with per capita income (Chu et al., 2020), implying that motorcycle numbers may continue to grow in developing economies. Consequently, controlling emissions from motorcycles may have a substantial impact on air quality in Nepal and its major cities, such as Kathmandu.

Vehicle idling refers to the state in which the engine is running without power transmission to the wheels. On urban roads, idling may constitute approximately 20% of the trip duration (Dhital et al., 2021). However, it can vary across cities and vehicle types. Gasoline vehicles, including motorcycles, emit significant amounts of air pollutants, especially hydrocarbons and VOCs, while idling (Shancita et al., 2014; Tsai et al., 2000). Consequently, idling at signalized traffic intersections incurs significant costs in terms of fuel consumption, emissions, and economic loss (Sharma et al., 2019). Idle-stopping means turning off engines while not running. Idling-Stop-and-Go, a system that automatically shuts off the engine when the vehicle stops, has been found to enhance fuel economy and reduce tailpipe emissions from motorcycles (Yu & Tseng, 2014), making idle-stopping an important aspect of eco-driving.

Traffic lights and the display of waiting time countdowns at signalized intersections inform vehicle drivers and motorcycle riders about anticipated waiting times, enabling them to judge whether or not to turn off their vehicle engines. However, in Kathmandu, very few traffic intersections have traffic lights and waiting time countdown displays. The majority of intersections in the city rely on manual traffic control, creating a chaotic situation, especially during peak traffic hours, where drivers and riders are unable to decide whether or not to idle-stop their vehicle engines. In this study, we conducted a stated preference survey to examine the effect of waiting time countdown displays at signalized traffic intersections on the idle-stopping behavior of motorcyclists in Kathmandu, Nepal. The main objective was to investigate if waiting time countdowns at signalized traffic intersections could encourage idle-stopping behavior among motorcycle riders in Kathmandu.

Materials and methods

Study area, sample size, and data collection tools

This study was conducted in Kathmandu, the capital city of Nepal. In this study, structured interviews were conducted during September–June 2023, among motorcyclists (n = 179), who use motorcycles as the primary mode of transportation for their daily commutes in Kathmandu. The motorcyclists were selected and interviewed from the parking lots located on and inside Ring Road, with surveyed locations including Koteshwor, Lagankhel, Patan Dhoka, Balkhu, and Balaju, distributed across Kathmandu and Lalitpur districts. The interview questions included information about the respondents' motorcycle characteristics, as well as their preferences and opinions regarding idle-stopping motorcycles on Kathmandu's urban roads. Respondents were presented with different waiting scenarios at traffic intersections in Kathmandu through color-printed photographs. These photographs were taken at two intersections in Kathmandu, one representing an intersection with traffic lights and waiting time countdowns and the other representing a manually controlled intersection without traffic lights and waiting time countdowns. The first photograph showed an intersection with waiting time display (time ranging from 10 to 180 seconds) and the second photograph showed an intersection without any display of waiting times. While waiting under each scenario, respondents were asked to express their preference to idle-stop or not to idle-stop their motorcycle engines, as shown in Fig. 1.

Data analysis

The survey data were coded and entered into spreadsheets. The spreadsheet data were checked against the field data for any errors introduced during the data entry. First, the data were analyzed using descriptive statistics. Additionally, in order to test the dependence of idle-stopping behavior on waiting time, a binary logistic regression analysis was employed using the statsmodel Python module (Seabold and Perktold, 2010).

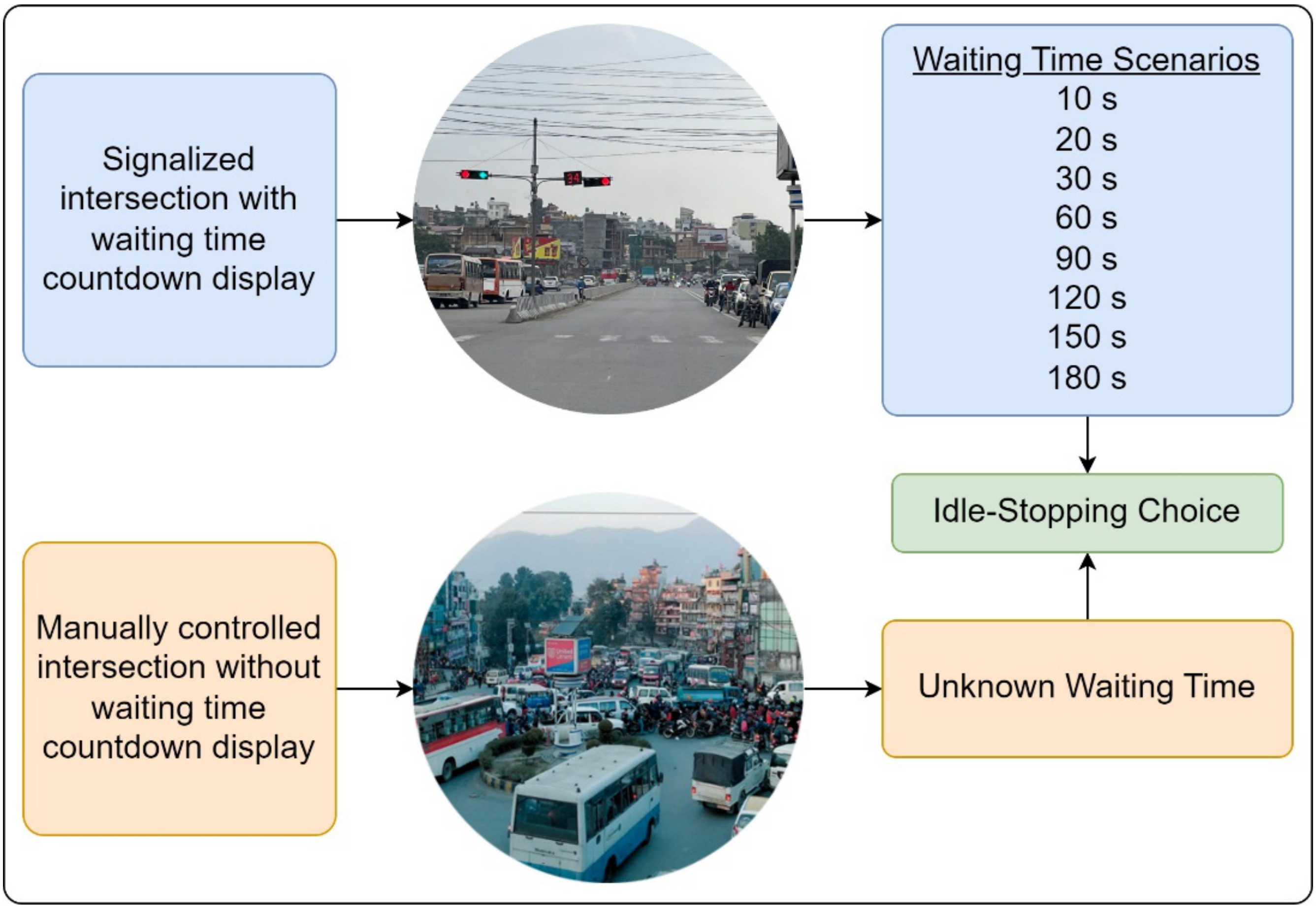

Figure 1: Traffic intersection scenarios presented to respondents

Ethical considerations

In order to protect the privacy of the respondents, no personal or identifying information was collected. Each respondent was provided with an explanation of the purpose of the survey, and their consent was obtained before interviewing them. The respondents were neither compelled to participate in the survey nor provided with any incentives or compensation.

Results and discussion

Motorcycle fleet characteristics

The characteristics of the surveyed motorcycle fleet are illustrated in Fig. 2. The fleet comprised motorcycles of 13 brands, with Honda representing the largest share (32.4%), followed by Bajaj (20.7%), and TVS (11.2%) (Fig. 2a). The remaining brands collectively represented approximately 19% of the surveyed motorcycles. Likewise, Fig. 2b shows the fleet characteristics based on engine displacement volume. It was found that the largest fraction of the motorcycles had engine displacement volume of 101–150 cm^3, representing 72%, while the remaining categories combined accounted for 28% of the fleet. Our results on engine size distribution were consistent with those reported by a prior study (Filippini et al., 2021). The motorcycle age distribution is presented in Fig. 2c. It showed a decreasing population of motorcycles with increasing age. The fleet-average motorcycle age was 4.8 years (range: <1 to 25 years), slightly higher than that of the 2010 fleet (Shrestha et al., 2013). Approximately 50% of the surveyed motorcycles were ≤ 3 years old. Modern motorcycles often have electric start functions, while some are even equipped with automatic idle-stopping functions, which will help avoid idling motorcycle engines for extended periods. The relative dominance of newer motorcycles in this study suggests that they would have such functions, which will be discussed in more detail in the following sections. A study reported that the 2010 motorcycle fleet in the Kathmandu Valley consisted of approximately 60% motorcycles with age ≤ 3 years (Shrestha et al., 2013). Our results showed a decrease in the fraction of new motorcycles (≤ 3 years) compared to the 2010 fleet, indicating a potential increase in older motorcycles over time due to the aging effect. Older motorcycles, due to engine wear and emission control system deactivation, often have reduced performance (Chen et al., 2009), which may increase the fleet-average emission and fuel consumption as idling emissions and fuel consumption are affected by engine age (Shancita et al., 2014).

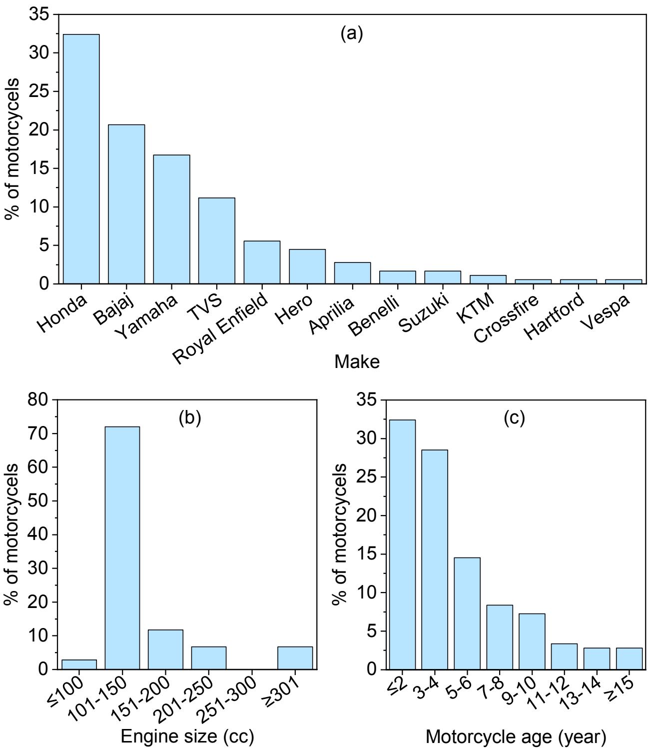

Figure 2: Fleet composition (%, total n = 179) of sampled motorcycles by (a) motorcycle make, (b) engine displacement volume, and (c) motorcycle age

Fig. 3 presents the distribution of accumulated mileage. The accumulated mileage ranged from 30 to 100000 km, with a mean of 29833 km and a standard deviation of 21839 km. Pearson's correlation between age and accumulated mileage was found to be 0.687, which was relatively weaker in the present study than previously reported for motorcycles (Shrestha et al., 2013), suggesting a wide variation in annual vehicle kilometers traveled in the recent motorcycle fleet of Kathmandu.

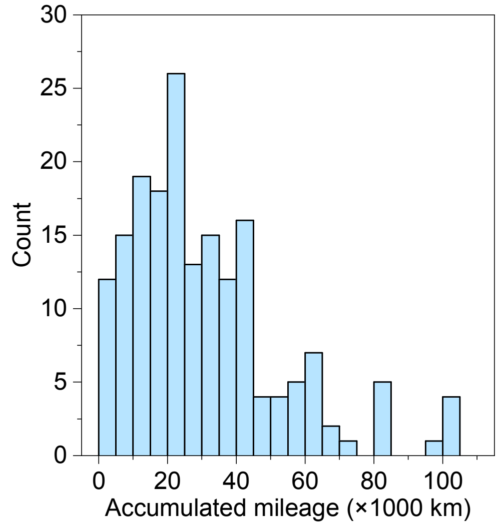

Figure 3: Distribution of accumulated mileage

We analyzed whether the surveyed motorcycles had an electric start function and an engine kill switch in hand (Fig. 4a). It was found that the majority of the motorcycles had the electric start function available (>90%), while for the remaining motorcycles, the electric start function was either absent by design or malfunctioning. Similarly, 56.4% of the surveyed motorcycles had the engine kill switch in hand (Fig. 4b). While driving on busy urban roads, the availability of an electric start function (in addition to kick start) and engine kill switch in hand (in addition to engine kill function with key) may affect riders' preference to idle-stop at traffic intersections. The electric start function and engine kill switch can ease the process of turning off/on motorcycle engines, and hence could positively affect the riders' preference to idle-stop the engine.

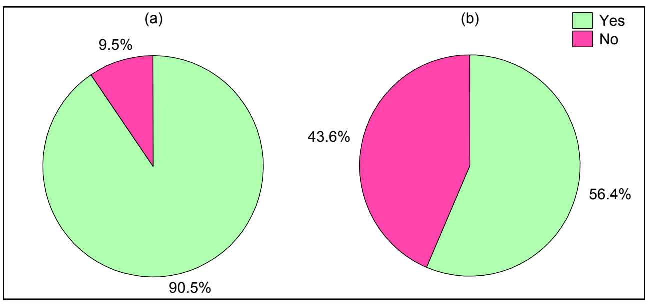

Figure 4: The availability of (a) the electric start function and (b) the engine kill switch in hand in the surveyed motorcycles

Waiting time and idle-stopping preference

We analyzed motorcyclists' stated preference for idle-stopping motorcycles at signalized traffic intersections. Respondents (motorcyclists) were asked if they would prefer to turn off their motorcycle engine while waiting at traffic intersections under different waiting time scenarios in their day-to-day commutes in Kathmandu. The scenarios included waiting times ranging from 10 to 180 seconds, which were displayed to respondents by showing waiting time countdown photographs. The responses (preference) were mutually exclusive.

Fig. 5a shows the percentage of respondents who prefer to idle-stop their motorcycle engines at different waiting times at signalized traffic intersections with the display of traffic light countdown. Interestingly, with the increase in waiting time, more number of motorcyclists preferred to idle-stopping their motorcycles. As Fig. 5a depicts, the proportion of motorcyclists who prefer to turn off engines while waiting increased sharply and consistently from approximately 4% at 10 s waiting time to 82% at 60 s waiting time. Beyond 60 s, the proportion still showed an increasing trend, albeit at a lower rate. At 150 s and beyond, the proportion leveled off at approximately 97%. Likewise, a majority of motorcyclists (>50%) would prefer to turn off the engine when the waiting time is approximately > 42 s. Moreover, the Spearman correlation between waiting time and the percentage of respondents who prefer to turn off the engine was found to be 0.994, which was statistically significant ($p < 0.000$).

We tested the relationship between idle-stopping choices and waiting time using a logistic regression analysis. It was found that the regression coefficient for waiting time was 0.0498 (95% CI: 0.045-0.055), which was statistically significant ($p = 0.000$) (Table 1). The pseudo R^2-value of the regression was 0.4922. Likewise, the odds ratio for waiting time was 1.051 (95% CI: 1.046-1.057), suggesting that with a 1 s increase in waiting time, the odds of motorcyclists idle-stopping their motorcycle engines increase by 5.1%.

Using the logistic regression model, the probabilities of idle-stopping motorcycles at different waiting times at signalized intersections with the display of waiting time countdowns were predicted. The predicted probabilities (Fig. 5b) showed a pattern similar to the actual observed stated preferences (Fig. 5a), with the probability of idle-stopping increasing sharply first, especially between 10 and 100 seconds, and then slowing down. Beyond 140 s, the probabilities were more than 99%, suggesting that almost everyone would turn off the motorcycle engines if they knew that the waiting times were more than 140 s.

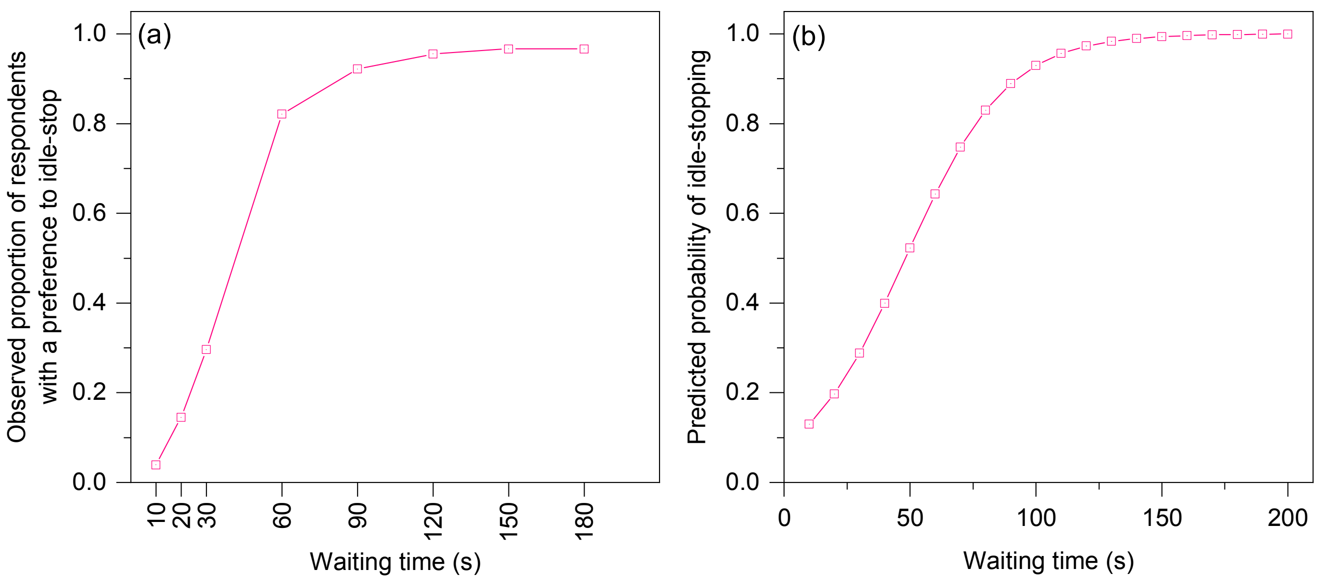

Figure 5: Observed and predicted idle-stopping behaviors of motorcyclists at signalized traffic intersections: (a) stated preference of idle-stopping motorcycles under different waiting time scenarios at traffic intersections with the display of waiting time countdowns, (b) predicted idle-stopping probabilities at different waiting times at traffic intersections with the display of waiting time countdowns

Table 1: Binary logistic regression between idle-stopping behavior and waiting time

Parameters	Constant	Waiting time (s)
Coefficient	-2.3996	0.0498
Standard error	0.145	0.003
z	-16.564	18.582
p-value	0.000	0.000
2.5^{th} percentile	-2.684	0.045
97.5^{th} percentile	-2.116	0.055
Odds ratio (95% CI)	0.091 (0.068– 0.121)	1.051 (1.046– 1.057)
Pseudo R^2	0.4922	

Signalized traffic intersections are generally hotspots of air pollution, mainly due to the acceleration of a large number of vehicles after idling, especially during rush hour traffic congestions (Goel and Kumar, 2015). Implementing idle-stopping policies may help reduce unwanted idling fuel losses and emissions at such intersections (Pai et al., 2016; Sharma et al., 2019), which will help mitigate air pollution, as well as protect commuters' health from the harmful effects of air pollution. Many countries around the world have policies recommending turning off engines beyond specified idling time thresholds at intersections (NRC, 2016; Pai et al., 2016). In the present study, a majority (> 50%) of the respondents expressed a preference to turning off the engine, instead of extended idling (beyond 42 s), if they knew the waiting times. Therefore, the installation of waiting time countdown displays will help people determine the waiting time, which will assist them in making decisions about idle-stopping engines.

Idle-stopping preference at intersections without waiting time countdown

In addition to the waiting time scenarios, respondents were also presented with a scenario (by showing an actual photograph) when they were waiting at a manually-controlled traffic intersection without the display of waiting time countdowns, and the results are presented in Fig. 6. It was found that only 16.2% of respondents preferred to turn off their motorcycle engine when they have to wait at such intersections. In contrast, 30.7% of the respondents preferred not to turn off the engines. Interestingly, a majority of the respondents (53.1%) could not decide whether or not they would turn off their motorcycle engines when they have to wait at intersections without waiting time countdown displays. These findings suggest that the display of the waiting time countdown is crucial for motorcycle riders to make decisions about whether or not to idle-stop their motorcycle engines.

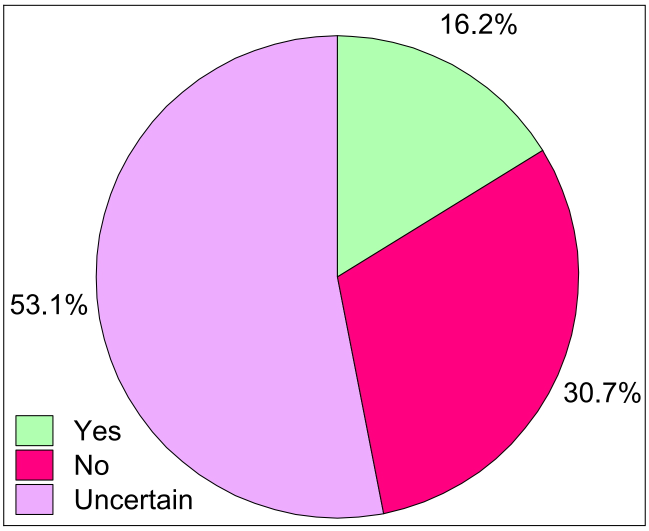

Figure 6: Motorcyclists' preference to idle-stopping engines while waiting at manually-controlled traffic intersections without traffic lights and waiting time countdowns

Perceived motivators and deterrents of idle-stopping

In order to understand the pulling and pushing factors of idle-stopping, we asked respondents about the benefits and deterrents of idle-stopping. The responses were categorized, and the results are presented in Fig. 7. Among the different perceived benefits, potential fuel saving by idle-stopping was the most important pulling factor with 88.2% of the respondents stating that it was a reason for idle-stopping (Fig. 7a). Additionally, 22.2% respondents stated that idle-stopping will help reduce air pollutant emissions, 36.8% stated that it will reduce noise, and 5.6% respondents stated other benefits (e.g., engine durability, reduced maintenance cost).

Several factors were reported as deterrents to idle-stopping behaviors. Among such factors were inconvenient to frequently turn on/off the motorcycle engine (31.4%), malfunctioning electric start function (11.4%), and uncertain waiting times (57.1%), no significant perceived benefits (8.6%) and others (8.6%) (Fig. 7b). It is worth noting that uncertain waiting time was the major deterrent, as stated by a majority of respondents, suggesting that motorcyclists tend to turn off their motorcycle engines while waiting at traffic intersections if they know the waiting time. Therefore, traffic lights and waiting time count-down at traffic intersections can be crucial road infrastructure to reduce idling fuel consumption and tailpipe emissions.

Limitations

We focused on stated preference for idle-stopping motorcycle engines while waiting at signalized traffic intersections, while we did not measure actual fuel consumption and emissions during idling. Since tailpipe emissions can be significantly higher during the engine startup process than during idling, they can outweigh idling emissions if the idling periods are brief. Therefore, it is crucial to determine the breakeven time for idle-stopping emissions, which can be an important subject for future research.

Conclusion

In this study, we used a stated preference survey to investigate the effect of waiting time countdown displays on idle-stopping choices of motorcyclists at signalized traffic intersections in Kathmandu, Nepal. We performed a logistic regression analysis between idle-stopping choices and waiting time, and the result revealed that the idle-stopping choices of motorcyclists were significantly affected by waiting times ($p < 0.001$). The odds ratio for waiting time was 1.051 (95% CI: 1.046–1.057), suggesting that with increasing waiting time, motorcyclists tend to have more probability of idle-stopping the engine. Moreover, the most commonly perceived benefit of idle-stopping motorcycles was fuel saving, followed by reducing noise and emissions. Likewise, the most commonly perceived barrier of idle-stopping engines at traffic intersections was found to be the uncertain waiting time. Overall, our results suggested that installing traffic lights

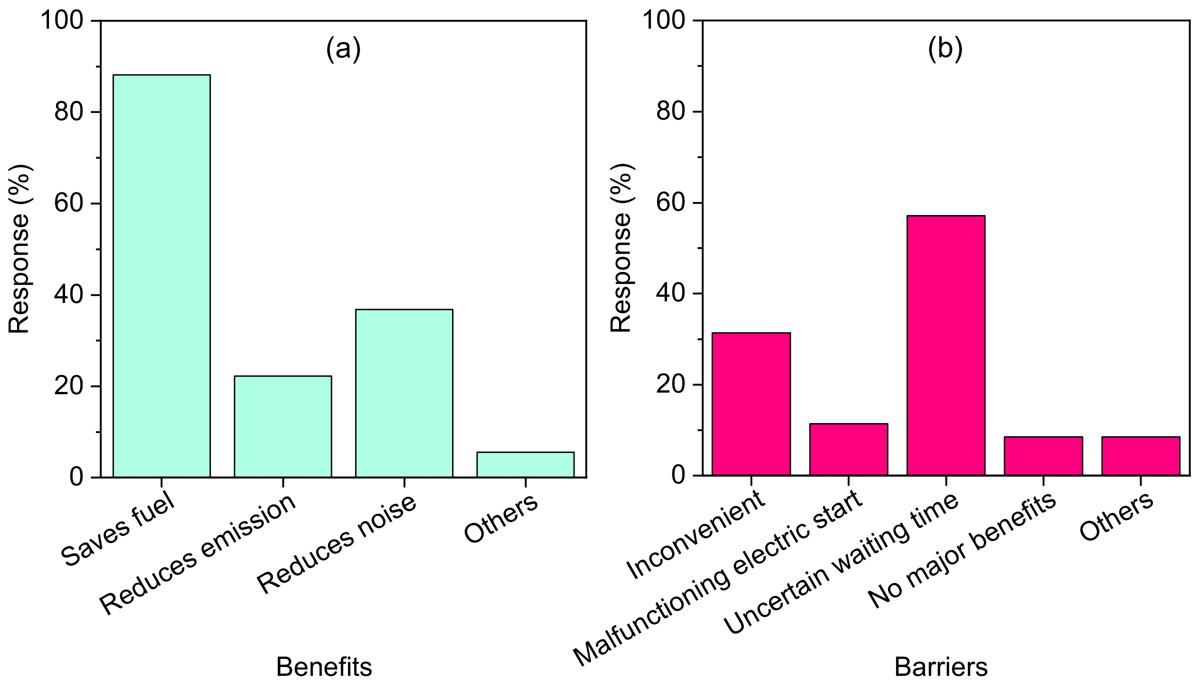

Figure 7: Perceived benefits and barriers of idle-stopping: (a) percentage of respondents stating different benefits of idle-stopping, (b) percentage of respondents stating different barriers of idle-stopping. The responses are not mutually exclusive

and waiting time countdown displays at signalized traffic intersections might offer an often overlooked benefit by reducing idling fuel consumption and tailpipe emissions from on-road vehicles, providing important insights for policymakers and city planners for building sustainable cities.

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