"I will just have to keep driving": A Mixed-methods Investigation of Lack of Agency within the Thai Motorcycle Rideshare Driver Community

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CCS Concepts: • **Human-centered computing** → **Empirical studies in HCI**; *Empirical studies in collaborative and social computing*.

Additional Key Words and Phrases: Mixed-Methods Study, Semi-Structured Interview Study, Rideshare

ACM Reference Format:
Nussara Tieanklin*, Joseph Breda*, Tim Althoff, and Kurtis Heimerl. 2024. "I will just have to keep driving": A Mixed-methods Investigation of Lack of Agency within the Thai Motorcycle Rideshare Driver Community. *Proc. ACM Hum.-Comput. Interact.* 8, CSCW1, Article 215 (April 2024), 28 pages. https://doi.org/10.1145/3653706

ABSTRACT

This paper presents a mixed-methods study of app-based motorcycle taxis in Thailand to explore the social dynamics of rideshare drivers and their exercised autonomy both through social pressure and a hostile work environment. As motorcycle taxis are open-air vehicles, drivers can be exposed to prolonged air pollution and other weather events, potentially impacting their health. In an initial quantitative study of server-side rideshare logs, we unexpectedly found that drivers do not exercise the autonomy provided by their rideshare platform to avoid air pollution events. This prompted a follow-on investigation through semi-structured interviews of both drivers and passengers in three provinces to explore why these drivers fail to experience the autonomy promised by gig-work in this context and elucidated further examples this lack of autonomy experienced by drivers. Our study sheds light on the social context that may constrain a driver's agency, including financial pressures, weather conditions, conflicts with local taxi organizations, and a false perception that drivers need to work around the ride assignment algorithm to avoid being blacklisted. We find that when leveraging app-based rideshare opportunities, drivers simultaneously perceive increased flexibility in their work hours and a lack of agency to prioritize their health and safety. We conclude with a discussion on potential interventions aimed at mitigating the forces preventing drivers from exercising their autonomy.

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ACM 2573-0142/2024/4-ART215
https://doi.org/10.1145/3653706

1 INTRODUCTION

Thailand has one of the world's most robust bodies of *motorcycle taxis*, rideshare systems (akin to Uber) where passengers join a driver for a motorcycle ride rather than a traditional protected (and air-filtered) car. The participants in these markets, particularly the often low-income drivers who work in the motorcycle based gig-economy as their primary source of income, spend hours a day outside in dense urban cores. By spending all of this time outside, these drivers are uniquely at risk of the dangers of prolonged pollution exposure in an environment with particularly high localized pollution emission and in countries with endemic air quality harms.

The World Health Organization (WHO) warns that inhalation of air pollutants increases risk of developing a range of diseases including heart disease, stroke, respiratory disease, and lung cancer. Particulate Matter 2.5 (PM2.5) is a commonly measured pollutant that refers to any particles on the scale of 2.5 microns or smaller in diameter, often generated by burning hydrocarbons or plant matter. As of December 2022, WHO estimates around 6.7 million premature deaths globally each year that are associated with the combined effects of ambient (outdoor) and household air pollution [1]. Further, prolonged exposure can lead to increased mortality due to heart disease by 6–13% per 10 $\mu g/m^3$ of PM2.5. The Center for Disease Control (CDC) provides 3 actions to take to protect yourself from PM2.5 exposure during high PM2.5 events, two of which are: "Think about spending more time indoors, where particle pollution levels are usually lower." and "Avoid busy roads and highways where PM is usually worse because of emissions from cars and trucks." [6].

While these suggestions are actionable for many people world-wide, these guidelines fail to protect at-risk populations whose careers require daily exposure to the open outdoor air like those in the transportation industry in Thailand. This is particularly problematic in motorcycle-dominated transportation infrastructure such as Southeast Asia. As an example, as of 2021 there are 21-million motorcycles registered in Thailand [5], making it one of the most popular modes of transportation in the country. This is likely due to a combination of their affordability and flexibility on multi-use roadways. In 2015 Pew Research found that as many as 87% of all households in Thailand own at least one motorcycle [2] making it the highest motorcycle usage in the world. Thailand also frequently ranks among the countries with the worst air quality globally [4]. This poor air quality is due to a combination of wildfires and crop burning in nearby countries, population booms, relaxed restrictions on pollution emitters such as cars and factories, and poor road quality. This sets a large portion of the population at risk for prolonged exposure to PM2.5 given the popularity of open-air transportation - particularly those who drive motorcycles in the transportation industry for a living.

Gig-work, such as motorcycle taxis, provides promises of healthy wages with heightened autonomy for similar pay given its flexible work hours and lack of management hierarchy. However, gig-work has come under scrutiny recently for its repeated failure to deliver on such promises. Researchers have gone as far to label this phenomenon "Fictitious Freedom". Unfortunately, rideshare drivers often come from lower socioeconomic backgrounds and tend to work out-of-necessity [19] and those of lower socioeconomic status are less likely to take action to protect their long term health [35]. This combination of regionally poor air quality, particularly exposed transit workers, and a promise of high autonomy prompted us to ask: "do these uniquely at-risk populations exercise their supposed autonomy to mitigate their personal exposure to extreme air pollution? And if not, why not?" In our exploration, we encountered numerous other risks which drivers take on as part of their work. We uncover how drivers expect a certain amount of flexibility but seemingly see many of these risks and harms as unavoidable, even given their highly flexible role, which we discuss thoroughly in Section 4.

We divided this high level question into a series of research questions, which we explored in two phases. We first asked:

RQ.1 Do rideshare drivers in these markets consider air pollution and its impacts on their long term personal health when making their decision to drive?

We resolved this by exploring hourly aggregated rides across approximately 250,000 unique locations for approximately 32,000 unique hours amongst the 3 provinces[1]. The data was provided by SEARider, an anonymized regional motorcycle-sharing app service. We unexpectedly found in our analysis that drivers seemingly do not change their driving behavior during periods of high PM2.5 levels.

Given this surprising finding, we followed this study with a series of open-ended semi-structured interviews in 2022 with 25 motorcycle rideshare drivers and 9 passengers that explored the following research questions:

RQ.2 What other factors contribute to a driver's decision to drive?

RQ.3 Do drivers have the agency to act on these considerations when determining how they drive or do these other factors prohibit drivers from exercising there autonomy?

We found that drivers were aware of high pollution events and some of their heath impacts but did not feel they could reasonably diminish their work hours to protect themselves without endangering their income security. Further exploration revealed this stems from a combination of personal work ethics as well as income, and a lack of transparency surrounding ride assignment algorithms. We further uncovered numerous other health risks which drivers similarly lack the agency to avoid for similar reasons. We end by discussing potential mechanisms for improving the safety of motorcycle taxi drivers in high-pollution environments, both with and without application support. This adds to the growing literature around the implications of ridesharing and "gig" work in the Global South, especially within the context of the escalating impacts of climate change.

2 RELATED WORK

In this section we describe the past work exploring rideshare from a variety of angles including: economics, environmental impacts, stakeholder behavior & social dynamics of the systems, and equity across demographics (socio-economic level, gender, race) of both passengers and drivers.

2.1 Rideshare Economy

The economic dynamics of rideshare have been thoroughly studied in recent years both qualitatively and quantitatively [10, 22, 24, 31, 41]. Most notably, researchers have explored the complications of gig-economy and rideshare through the lens of dynamic pricing and the impacts it has on both its patrons and partners. A 2022 study developed a Rideshare Measurement Suite (RMS) to continuously monitor rideshare pricing and availability [24]. Among the results, this study identified a 50% decrease in rideshare availability which lead to both decreased access and increased surge pricing during the COVID-19 pandemic, illustrating one example rideshare economy responding to societal factors. Another 2019 study demonstrates the inequality of income distribution across drivers on the same platform [41]. The authors note the increasingly poor work conditions for drivers and how redistribution of benefits could help alleviate competition.

However, some studies go further and explore factors like *Social Capital* – which refers to the benefits people can draw from their social network – which have been shown to increase upward mobility [32]. In this study, researchers identified that drivers gain social capital through interactions with other drivers, which allows them to adjust their behavior to increase earning

[1]Our dataset included ridership levels for 13-million hourly origin-destination pairs total

potential [22]. Survey responses from a London study of Uber drivers indicate that increased autonomy and flexibility is the primary motivation to drive for rideshare as opposed to other working opportunities [7]. Nevertheless, the same study highlights that Uber drivers are remain situated among the most financially disadvantaged individuals in London. Similarly, a recent study of the Chinese rideshare economy found that those depending on rideshare work for financial stability are more susceptible to working long hours under monetary incentives and customer evaluations [47]. Our study expands these results into motorcycle taxis and similarly finds that the flexibility of rideshare work is often not exercised in practice.

2.2 Equity of Rideshare

Similarly, researchers have explored equity concerns for both passengers and drivers on rideshare platforms. Specifically, transportation scarcity (passengers) in low-resource environments [13, 14] and access to gig-work (drivers) in disadvantaged populations [9, 38]. One such study had researchers pose as passengers hailing rides in both Boston and Seattle and uncovered discrimination both in the form of increased wait times and increased cancellation rates for passengers with African-American sounding names over white counterparts [17].

2.3 Rideshare in Low- and Middle-Income Countries

While there is much past work in the quality and access to rideshare services in North America, there are fewer studies conducted on rideshare services in the Global South and particularly Southeast Asia. One such study conducts a qualitative analysis through interviews in Dhaka, Bangladesh, and highlights the "veneer of objectivity as a potential source of oppression" imposed by the underline algorithms' dictating the distribution of ride requests on the platform [25]. However, another qualitative study identifies an opposing theme that rideshare companies bring structure and organization to an existing informal transportation workforce in India resulting in better best practices [39]. Past work, therefore, demonstrates an array of positive and negative effects of rideshare's proliferation in developing countries.

Furthermore, motorcycle ownership has increased by about 8% since the introduction of motorcycle-based rideshare apps in Dhaka, demonstrating the profound impact rideshare apps have had on the transportation landscape as well as the growing percentage of the population relying on rideshare driving as an avenue for upward mobility [44]. A complementary study found that motorcycle rideshare improved transit accessibility by serving as a feeder mode of transit, supporting the notion that rideshare has had a positive impact on Dhaka's transportation infrastructure [20]. However, another qualitative study in Namibia found that, similar to [22], rideshare communities often leverage peer-to-peer communication and social capital for improving earning potential, indicating that rideshare drivers build their own systems of support to pick up slack left by rideshare platforms [23].

These results indicate that motorcycle rideshare plays an important role in both cheaper and more accessible transportation for riders as well as a income platform with a lower barrier of entry than car-based rideshare for drivers (as motorcycles are inherently less expensive to purchase). However, a small study in Bangkok demonstrated that motorcycle drivers have roughly double the PM2.5 exposure to their car-based counterparts on the same day [21]. So while driving motorcycle rideshare may serve as an accessible platform for upward mobility, it comes at the cost of potentially adverse health impacts. This negative health impact on the population is potentially exacerbated as prior work indicates that people of lower socioeconomic status are less willing or able to prioritize their long term health [15, 28, 35]

2.4 Driver Behavior and Response to Algorithms

Another important concern when discussing rideshare is the automatic process which the platform manages drivers and how this impacts both personal returns and overall equity. The effects of the opaque algorithms present on rideshare platforms have been studied across developed and developing nations [25, 27]. These studies contextualize the aforementioned equity and economic concerns in the reality of third-party control, often limiting drivers earning potential or leading to drivers altering their behavior to side-step the undesirable impacts of algorithmic control. We see similar responses in our interview respondents, despite explicit claims from SEARider that drivers will not be penalized for reducing their driving.

A similar feeling is formalized in a recent study of content moderation appeals which explores users' perceptions of the fairness, accountability, and trustworthiness of algorithmic decisions on the platform[43]. The researchers note that all automated appeal processes reduce users' sense of control.

2.5 Rideshare's Relation to the Environment

Finally, we note that the relationship between rideshare and air quality has been studied to a limited degree in the past. One study takes a quantitative approach to investigate rideshare popularity and its relationship with air quality. They find that ridershare usage was spatially correlated with PM2.5 and PM10 [45]. This study motivates our work by highlighting the increased harmful PM2.5 exposure experienced by rideshare drivers. Further, they note that roughly 5.5% ~10.4% of the total air pollution in Shenzhen can be accounted to rideshare services through exhaust and wheel-to-ground friction. While this demonstrates how rideshare can increase PM2.5 pollution, to our knowledge, the effects of increased pollution on rideshare motorcycle taxi drivers has never been studied.

Another study corroborates these findings, noting that an increase in motorcycle taxi ridership across every socio-econmic class in Jakarta hardly reduced greenhouse gas emissions and increases the city's carbon footprint once considering idle vehicles [40]. Another study looks at the impacts of rainfall on rideshare utilization and finds that it is generally more challenging to hail a ride in rainy conditions [42]. This indicates the importance of disambiguating the effects of air quality from rain in our analyses.

These prior work indicate that many rideshare workers expect increased flexibility but often base their decisions primarily on financial incentives. This is particularly important in low- and middle-income countries where work environments are more hostile with increased PM2.5 levels and where open-air exposed vehicles like motorcycles and tuk-tuks are increasingly popular rideshare platforms. This prompts us to explore the behavior dynamics of rideshare workers in these markets and whether they consider the health impacts of this PM2.5 exposure when exercising their work flexibility.

3 STUDY DESIGN

Our core agenda leverages mixed-methods: we started with a country-scale quantitative investigation to gain high-level insights on drivers' behaviors and then followed-up with on-the-ground qualitative interviews to contextualize the high-level findings. To do this, we first worked with a major regional motorcycle rideshare company to explore how air quality affected driving patterns. We then conducted a series of interviews with SEARider drivers and passengers to ground the quantitative data in their qualitative experiences using the SEARider platform and further explore questions left unanswered by high-level data analysis.

3.1 Ride Data

Our SEARider data is provided by an anonymous major regional motorcycle ride-sharing company operating at scale across Thailand and is anonymized and aggregated at the origin-destination scale (i.e. normalized quantity of trips between two locations per hour). Data was provided in the form of normalized trip counts per-origin-destination-pair every hour in three Thailand provinces[2]. While we were not provided trip level data per passenger or driver to protect privacy, limiting our ability to understand personal decision making as a function of environmental conditions like air quality, we were able to make limited population scale behavioral assessments. The data provided was for the first 6 months of 2018 as well as all 12 months of 2019 with the caveat that Chonburi had no data provided for 2018. This data was selected to remove any potential COVID confounds in more recent datasets.

3.2 Air Quality Data

We joined the ridership data with available air quality data downloaded from *aqicn.org* which is an open-source air quality data hosting site run by the *World Air Quality Project.* The hosted data is pulled from 12,000 different weather stations world-wide. However, air quality monitoring stations are not yet ubiquitous in Thailand. There is often only one air quality sensor per province in much of Thailand. We identified one sensor in Chonburi and Chiang Mai each that had recorded PM2.5 data corresponding to the time of ridership data. Bangkok had four available sensors in this time period, but for consistency across the other two provinces, we selected the central Bangkok sensor for analysis.

3.3 Interviews

We conducted semi-structured interviews of 25 in-person rideshare drivers and 9 online passengers respectively across the three provinces in Thailand in the summer of 2022. We on-boarded new participants on a rolling basis until we reached satisfactory thematic saturation [46]. The goal of the interview study was to capture a broad understanding of participants' decisions to engage with the rideshare platform with a specific focus on driver agency in the context of air quality. The complete list of interview questions is provided in the appendix. The study protocol was approved by our Institutional Review Board (IRB) and we obtained informed consent from all participants.

3.3.1 Recruitment, Consent, and Compensation. We conducted driver interviews in-person at a mutually convenient location by a native Thai speaker in Chiang-Mai and Bangkok and with the assistance of a local translator in Chonburi. Each co-author conducted interviews separately and all interviews in each province were conducted by the same interviewer. The native Thai author conducted passenger interviews remotely over Zoom. We recruited participants through a combination of social media messaging platforms and, in the case of driver recruitment, by also requesting rides on the application ourselves. Recruitment in Chonburi was particularly challenging as we were unable to request a motorcycle taxi through the ridehailing app. We later found through our interviews that Chonburi's rideshare economy suffered substantially during the COVID-19 pandemic as the city is a largely tourism oriented economy. This increased competition between local taxi drivers and SEARider drivers resulting in many (enough that we were unable to hail a single drive during multiple days of recruiting) SEARider drivers switching over to exclusively

[2]Thailand is subdivided into 77 official provinces which is a preferred term over "city". Bangkok province has the largest population and population density of Thailand. Chiang Mai has a much smaller population but is a major metro-area and is one of the northern provinces which experiences significantly higher average PM2.5 levels than the south. Chonburi has the smallest population and is least impacted by pollution (out of the three provinces in our study).

food delivery services. As a result, we conducted all recruitment via word-of-mouth and over social media in Chonburi.

Participants were asked to fill out a brief demographic survey before the interview began. Since SEARider offers multiple work opportunities, ranging from driving passengers to delivery of goods, we validated that each participant has experience driving passengers via motorcycle by presenting their application ride history. However, in Chonburi none of our participants had driven passengers in over 2 years (longer than the history retention period on the app). We were therefore unable to validate that our participants in Chonburi had driven passengers, although each participant did claim to have driven passengers before the COVID-19 pandemic. Passengers were asked to fill out a basic demographic survey. They were then screened on the frequency on which they used SEARider service (i.e. at least twice per week). Similar to drivers, each participant was also validated by showing their ride request history on the app at the start of the interview. We, however, were unable to recruit passengers in Chonburi due to the low SEARider utilization in the area as local markets tend to favor competitor apps.

We collected written consent from drivers and verbal consent from passengers as well as proof of drivers license from drivers. We informed all participants that this work was un-affiliated with SEARider[3], informed drivers that their responses would have no impact on their work, and began the interview. Upon completion, drivers were compensated 500 Baht (approximately $15.06 USD) and 400 Baht (about $12.05 USD) for passengers.

3.3.2 Questions. We structured the interviews into 3 sections: Demographic Questions, Driver/Passenger Perception of Environmental Factors, and Driver/Passenger Personal Preference. The goal of these questions were to better understand (1) how the driver got involved with SEARider or how did the passenger leverage SEARider, (2) how much do the drivers depend on driving for financial stability or passengers depend on SEARider's services, (3) what environmental factors like air quality, weather, current events, and season impact their decision to drive or ride, and (4) whether they held personal biases which could impact these decisions. Beyond this core structure of interview questions, we allowed participants to deviate freely to engage in tangential topics that were important to them. For instance, one participant noted a fear that SEARider was discretely changing the price of rides after completion and others complained about poor road quality that led customers to erroneously associate their driving ability with the bumpy ride. The semi-structured format allowed us to focus on topics most applicable to each participant while maintaining some structure and consistency across all interviews. Our goal with the passenger interviews was two-fold: (1) to disambiguate whether fluctuations in total rides were driven by drivers decision to drive or passengers decision to use the service, and (2) how do passengers use the service (i.e. for regular commutes or one-off trips).

3.3.3 Interview Coding. All interviews were audio recorded and transcribed by native Thai speakers from Thai audio to Thai text. Before coding, each interview was translated to English via Google Translate for the benefit of the non-Thai speaking team members and were reviewed for correctness by a native Thai speaking team member. We conducted the qualitative analysis on interview responses in three cycles [37]. In all three cycles the native Thai speaker had access to both the Thai transcript as well as the English translated transcript and would periodically resolve inconsistencies as they arose in the coding process. This was preferred over reviewing all interviews in English as it removed any potential discrepancies for both transcription and translation artifacts to go unnoticed. In the first cycle, we used structural coding, which is particularly useful to code responses from semi-structured interviews [16, 30, 37]. We derived 3 structural main codes or (e.g. potential themes),

[3]While our partner did share data on the project, the authors are not affiliated with the company.

which were divided into 8 sub-codes (e.g. concrete manifestations of these themes in anecdotes). In a second cycle, the two authors independently analyzed the quotes and sub-themes before coming back together for a third and final cycle of thematic analysis [8]. The same two authors from the team had several hours of coding discussions to collaboratively create the codebook and find the overarching themes. After all the coding disagreements were resolved and the coders agreed on a codebook, which was then applied to all the interview transcripts.

Since the driver interview subsumed the passenger interviews and both interviews shared similar motivations, we coded the passenger interviews using the codebook we constructed in the driver interview study. We used the codebook and themes generated from the driver interviews to analyze the passenger responses. The passenger responses therefore are used primarily to validate findings from the driver interview study.

4 RESULTS

In this section we first present the results of our exploration of SEARider's data. These then motivate our follow-up driver interviews and passengers interviews, and common themes which emerged from the interview responses. We sub-divide each theme into sub-themes which aggregate participant responses.

4.1 Quantitative Results

A priori, we anticipated that air quality would exert a significant influence on driver behavior, as prior research shows that people spend more time indoors during times of extreme pollution [11, 33, 48]. This, coupled with the fact that we were able to obtain a large dataset of air quality measurements, positioned the effects of pollution on driver behavior well for quantitative analysis. So prior to conducting our qualitative study, we sought to answer *do rideshare drivers exercise their autonomy as a self-governed contractor by avoiding work during extreme pollution events?*

We sought to answer this question by identifying population trends in ridership caused by variations in air quality. To isolate these effects, we explored the relationship between ridership and other covariates such as weather conditions, temperature, and season. Figure 1 shows how the three different provinces' ridership per hour changes across different air quality levels as measured through PM2.5 (split into deciles). PM2.5 is measured in $\mu g/m^3$ and is rated by the EPA to be "unhealthy for sensitive groups" between 40-65$\mu g/m^3$, "unhealthy" at 65-150$\mu g/m^3$, "very unhealthy" at 150-250, and "hazardous" above 250$\mu g/m^3$ [3].

Figure 1 shows the average normalized hourly motorcycle rideshare trips across the PM2.5 deciles. While there is no obvious trend in rides across the 3 provinces across PM2.5 levels, Chiang Mai (orange) is the only one to show a consistent downward trend in rides as PM2.5 increases. Figure 4a shows that Chiang Mai has the highest both average PM2.5 annually and maximum PM2.5, which may indicate a more acute sensitivity or awareness to air quality amongst Chiang Mai residents over the other two provinces. In Bangkok, rides only begin to drop after PM2.5 exceeds the EPA definition of "very unhealthy" at 150$\mu g/m^3$. This may indicate a difference in how Bangkok's population decides on "bad" air quality or an increased dependence on rideshare for non-negotiable travel, given its role as a business hub in Thailand. Out the three provinces in our study, Chonburi has the smallest population as well as the lowest average PM2.5 exposure as seen in Figure 4a. The lack of fluctuation in riders may be indicative of a smaller population with less experience with severe air quality. Chonburi is also a large tourist destination meaning driver behavior may be impacted differently than in the other two local provinces. While these patterns themselves do not reveal how drivers or passengers change their behavior during air quality extremes, they do inform the direction and structure of our interview questions.

To test the significance of any trends in ridership across PM2.5 levels while controlling for potential confounds due to variation in hour of day, temperature, rain conditions, month of year (season), we calculate the Average Treatment Effect (ATE) of PM2.5 on SEARider ridership independently for each province using a matching methodology with direct covariate matching (this approach is more conservative than Propensity Score Matching). We estimate the ATE through Equation 1 in which $E(Y|T=1)$ and $E(Y|T=0)$ denote the expected value of the outcome Y (in our case, the quantity of daily rides) in the "treated" ($T=1$ denoting bad air quality) and "untreated" ($T=0$ denoting good air quality) groups respectively for a given strata i. Here the strata are formed by binning each potential confound and directly matching all examples based on similarity within each bin (i.e. examples in the same rain condition bin, month of year, temperature bin, and hour of day are assigned to the same strata). This is done to ensure that the effects of a covariate on the number of total rides observed is isolated from the air quality (i.e. drivers may drive less when it is raining so do not compare examples in heavy rain to examples in clear skies). Treatment is defined as PM2.5 above a predefined threshold τ_i, which we derived from the EPA.

$$ATE = E[Y|T=1] - E[Y|T=0] = \frac{1}{n}\sum_{i=1}^{n} E(Y|T=1)_i - E(Y|T=0)_i \tag{1}$$

We tested multiple thresholds between "good" and "bad" air quality at different levels of PM2.5 as treatment (at the EPA defined thresholds of 40, 65, 150 as well as an extra threshold of 120 corresponding to the sharp drop in rides in Bangkok). To isolate the effects of our treatment from the effects of covariates, we leverage many-to-many direct covariate matching by sub-dividing our dataset into n strata The ATE is calculated across each individual strata of data with similar covariates and then averaged across strata to generate a single ATE metric. In doing this, we only compare data points that are highly similar by their covariates (i.e. deemed comparable) but are assigned to $T=1$ or $T=0$. We follow the common practice to ignore any strata with fewer than 10 treated and untreated samples, which attempts to limit the variance of our matching-based estimator. We evaluated the ATE of each province independently matching only examples from the same city and filtered out 16%, 11%, and 25% of the data for Bangkok, Chiang Mai, and Chonburi provinces respectively using this scheme. In all cases (all thresholds across all provinces) we observe an ATE with confidence intervals including zero in all cases (except Chiang Mai at 40 $\mu g/m^3$) as seen in table 1, indicating that any reduction of ridership at increased levels of PM2.5 is not explained by increasing PM2.5 alone.

This result can be interpreted that any downward trends in ridership during higher PM2.5 levels may be explained by covariates and not by PM2.5 levels alone. What is clear is that there is a pattern in both PM2.5 levels and ridership alike which vary across time throughout the year. Figure 3 shows how PM2.5 levels varied across 2019 and Figure 2 shows a similar plot of ridership varying across 2019. An example of time variant effects other than PM2.5 which may impact ridership over the year is school being in session or tourism seasons (i.e. students calling rides to school or tourists calling rides during tourist season).

While we did expect to find a reduced number of rides in worse air quality, our direct-covariate stratification approach reveals that instead the number of rides appears *independent* of air quality, after controlling for key confounds such as rain condition and time. We further explore the link between PM2.5 and driver behavior as well as alternative influences on driver behavior in Section 4.2. These quantitative findings motivate our interview questions exploring why drivers continue to drive in poor air quality and also what other vectors of harm do drivers tolerate given they do not seem to exercise their autonomy to mitigate the impacts of PM2.5 on their health?

Province	Correlation	τ_1 ATE	τ_2 ATE	τ_3 ATE	τ_4 ATE
Bangkok	0.08	-0.007 ± 0.166	0.002 ± 0.135	0.003 ± 0.113	-0.105 ± 0.998
Chiang Mai	-0.03	-0.318 ± 1.732	0.000 ± 0.014	0.002 ± 0.105	-0.002 ± 0.106
Chonburi	0.16	-0.008 ± 0.082	0.000 ± 0.001	–	–

Table 1. A table of Pearson's correlations and ATE (at 4 thresholds of 40, 65, 120, and 150 $\mu g/m^3$ for "bad air quality" treatment) of quantity of normalized hourly riders with PM2.5 levels in $\mu g/m^3$. Chonburi had the least days with high PM2.5 and too few above 120 to effectively calculate ATE at these thresholds.

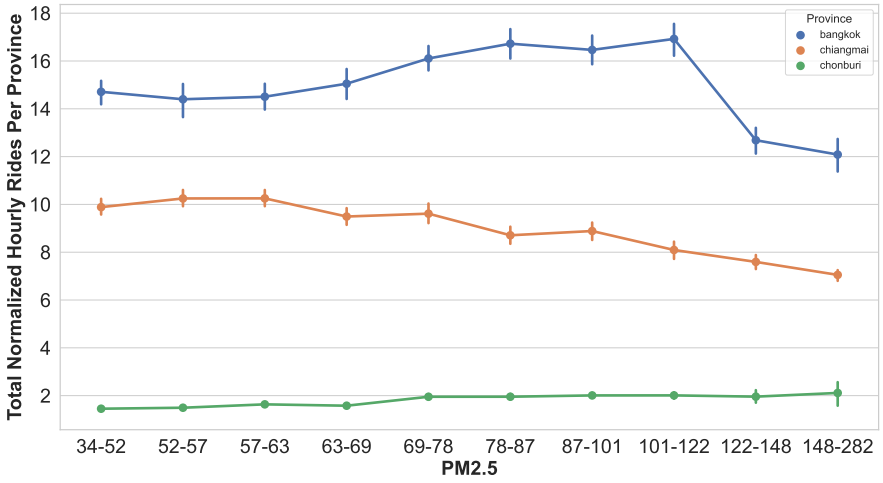


Fig. 1. Motocycle based rideshare rides presented as normalized counts per hour summed across the entire city plotted against PM2.5 10-quantiles for all three cities.

4.2 Qualitative Results: Driver Interviews

With the understanding that drivers do not change their driving behavior during unhealthy levels of pollution, we sought to further explore ways in which drivers may be at risk. We do this through a series of semi-structured interviews to develop a deeper understanding of (1) the factors which prevent them from exercising their autonomy and (2) other vectors of harm that drivers tolerate given that they do not exercise their autonomy to mitigate impacts on their health. We particularly investigate questions such as: Do passengers depend on drivers for non-negotiable travel? Do drivers fully understand the danger of PM2.5? Is PM2.5 the only risk to their health they are willing to tolerate or are there others? and What factors constrain their autonomy in ways that prevent them from making changes to their work, which mitigate its impacts on their health? For a full list of interview questions, refer to Appendix A. Contained in this section are responses from both driver and passenger interviews with references to specific quotes which exemplify emergent themes. Table 2 shows demographic data for the 25 driver participants and 9 passenger participants in this study.

4.2.1 ***Theme 1: Prioritizing Income Over Health.*** The first theme to arose and was most salient throughout the interviews was the notion that all drivers base their decision to drive primarily

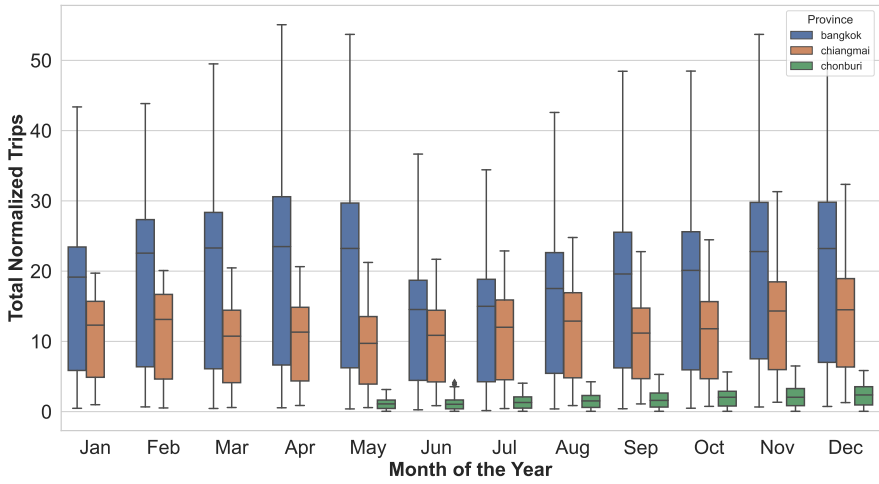


Fig. 2. Sum of daily average rides (rides provided as normalized quantities to preserve anonymity) across all months of 2019. Note that there is significant interseasonal variance.

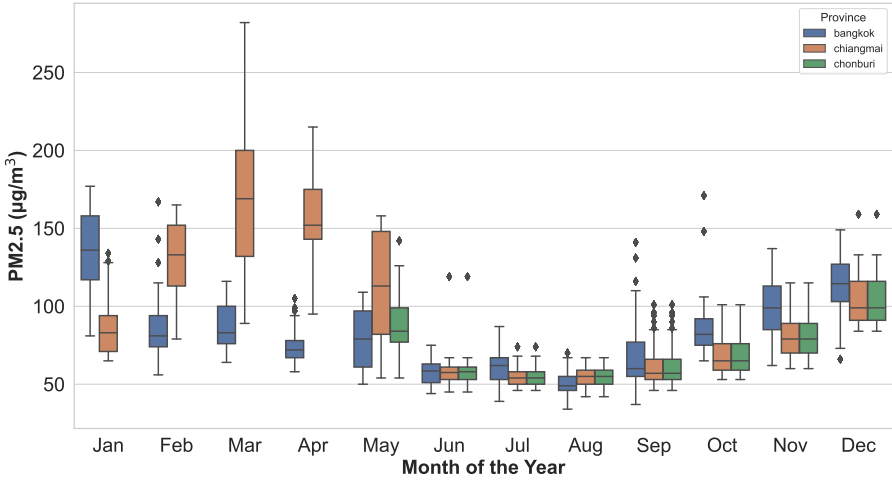
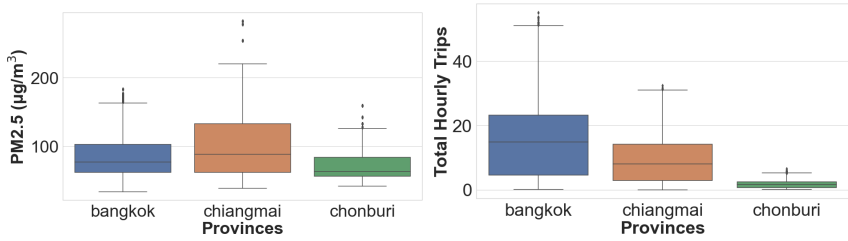


Fig. 3. Average PM2.5 in $\mu g/m^3$ across all months of 2019. Anything over 65 is considered unhealthy.

on whether they have made sufficient income (i.e. reached a self-defined daily income target) or not. Similar themes have been identified in qualitative studies in other low- and middle-income countries [23]. We found that most drivers do understand the dangers of air pollution to some degree. However, all drivers agreed choosing not to drive in unhealthy air quality conditions was not justifiable given the lose of potential income. In some cases, drivers even cited that they could



(a) Average hourly PM2.5 levels in each city. (b) Average hourly trips in each city.

Fig. 4. Box-plots showing average houghly PM2.5 (a) and rideshare trips (b) in each of the 3 cities representing the variation in both rideshare behavior and air quality amongst the 3.

ID	Primary Source of Income	Daily Income	ID	Primary Source of Income	Daily Income
bkk-1	SEARider	1000-1300	chon-1	SEARider	600-700
bkk-2	SEARider	1000	chon-2	SEARider	800-1000
bkk-3	SEARider	1000	chon-3	SEARider	700-1000
bkk-4	SEARider	1000	chon-4	Owns a restuarant	200-1200
bkk-5	SEARider	1000-1300	chon-5	SEARider	1500
bkk-6	SEARider	500-1000	chon-6	SEARider	300-1000
bkk-7	SEARider	1000	chon-7	SEARider	1000
bkk-8	Chauffeur	200-500	chon-8	SEARider	800
bkk-9	SEARider	500-600	bkkp-1	Recruiter	700-1000
cnx-1	SEARider	1000	bkkp-2	Project Manager	850-950
cnx-2	SEARider	1000	bkkp-3	Investment Officer	1200
cnx-3	Online Shop Owner	800	bkkp-4	N/A (student)	0
cnx-4	Construction	200	bkkp-5	Analyst	1300
cnx-5	SEARider	1000	bkkp-6	Human Resources	670
cnx-6	SEARider	1200	bkkp-7	N/A (student)	0
cnx-7	SEARider	1000	bkkp-8	N/A (student)	0
cnx-8	SEARider	600	cnxp-1	Research Assistant	500-800

Table 2. Table of participants' primary source of income and the self-estimated daily income in Baht (approximately 33 Baht corresponds to $1 USD). The *ID* contains an abbreviation for each province where the interview was conducted (bkk for Bangkok, cnx for Chiang Mai, and chon for Chonburi) as well as a 'p' if the interview was with a passenger.

just see a doctor to fix their health problems. This suggests that they viewed increasing their income as something currently open to negotiation, whereas healthcare concerns were perceived as a future issue. This pattern was consistent among all interviewees. None of the drivers were willing to let PM2.5 levels influence their decision not to drive. With the exception of two drivers, cnx-2 and cnx-6, were only willing to accept alternate routes if they were shorter and resulted in higher estimated income. Some went as far as to say even slight detours (2-3 minutes) to avoid particularly polluted roadways was too much to ask. The *time is money* theme also materialized in drivers working long hours (as much as 36 consecutive hours) in already poor working conditions.

One driver mentions these long hours when they say, *"I usually drive every day. But when I'm actually in need of money, I will drive even more." (bkk-1).*

Drivers also indicated that they base their decision to drive primarily on their current savings. Multiple drivers noted that they drive slightly less immediately after pay-day and will drive more when they are short on cash. This opposes the findings from prior work which suggest that rideshare platforms can bring structure and organization to workers' schedules [39]. The interview results indicate that drivers schedules are largely defined by their income alone. In fact, many participants either explicitly stated or implicitly revealed a feeling of lack of agency when choosing whether to drive or not as they are constrained by the need to make money. One Bangkok driver who has been driving for SEARider for the past 5 years revealed that he has never felt fully compensated for all the risks associated with driving. But he notes that this still does not justify seeking alternative work,

> "Even if there is no customer, I'd still drive. I will keep driving every day as long as my body is still up for it." (bkk-1)

Driver's even cited prioritizing work over sleep. A Chiang Mai participant, *cnx2* , has driven 36 hours straight, taking naps at restaurants between each order/ride request. This is something explicitly noted as violating code of conduct by SEARider.

Drivers recognize the effects of driving in pollution through itchy eyes and skin, sneezing, runny nose, coughing, and nosebleeds and take actions such as periodically washing their face, eyes, nose, and mouth during their workday to compensate. However, the extent to which the drivers understand the health risks varies between participants. Although most participants understood PM2.5 to be unhealthy, few participants understood its effects beyond the short-term symptoms they mentioned. Some participants felt health effects from PM2.5 exposure can be ignored and dealt with in the future: *"We can always go see a doctor if it actually gets severe." (cnx-8)*, which is not the case for many of the common ailments associated with high air pollution (e.g., asthma, heart disease). Drivers consciously disregard these health effects in favor of seeking stability in their income. As participant *bkk-6* summarizes,

> "Most of us are rarely afraid of negative health impacts because we scare of being short in cash more." (bkk-6)

These findings indicate that participants understand some, but not all, of the health risks associated with driving in pollution. Drivers still perceive the risks of losing money to be more severe than the risks of PM2.5 exposure. Drivers also see this as an explicit trade-off in which they must choose to take on the risks of PM2.5 exposure as a consequence of the job. No participants indicated an understanding or concern for the reverse problem in which adverse health effects of PM2.5 could come at an economic cost or inhibit future work.

4.2.2 ***Theme 2: Perception of Flexibility vs Practical Lack of Agency.*** In the last section, we identified how drivers are primarily concerned with income and do not choose to reduce their earning potential to avoid pollution, despite some understanding and experiencing the danger of PM2.5 exposure to some degree.

The theme which emerged that best addresses this was the juxtaposition of drivers' perception of flexibility and their experienced lack of agency through different constraints (either self-imposed, or put on them by the rideshare platform or social dynamics with other transportation services). Many drivers changed careers from traditional office jobs or chose to drive for SEARider due to the supposed flexibility of work hours and freedom to be their own boss. Drivers cited freedom to spend more time with family, agency to take breaks and vacations without asking a boss, and control over when they drove each day as reasons they continue to drive for SEARider. However, the practical

reality often contradicts these assertions, as the same participants highlighted numerous instances where they lacked agency, contrasting this supposed freedom (mentioned in the previous section and the following sections to come). Participants specifically cited driving long hours (averaging 12-16 hours), an inability to take breaks to avoid being de-prioritized by the ride assignment algorithm or simply due to financial constraints that compelled them to continue driving. This highlights a potential ethical concern in which drivers are marketed an increased flexibility upfront but often do not develop the confidence or security to act on it due to the unpredictability of rideshare income.

These anecdotes serve to contextualize drivers' inability to stop driving during extreme pollution in a broader theme of general lack of agency.

Lack of Agency Due to Algorithms. In many cases, participants referenced more constraints than freedoms in their work as a rideshare driver. A majority of those constraints they reported were imposed on them by "AI" or "The Algorithm"; a topic that has been discussed thoroughly in past automatically moderated platform research [25, 27, 43].

Although SEARider indicated in a follow up conversation that they do not penalize drivers from taking breaks from driving (see 5.4), most participants believe time away from the app could de-prioritize them in the ride assignment algorithm:

> "Assuming that I took 5 days off, once I get back driving again, I would get significantly fewer requests. [...] SEARider drivers may be looked at as hard workers, but no. The truth is there are so many tricks and competitions that we just have to play the game." (bkk-6)

Another participant noted a similar experience but directly called out SEARider's algorithms, demonstrating how drivers feel constrained by the platform and forced to work potentially longer hours in conditions they may have otherwise avoided. This invokes connections to the "oppression" of these control algorithms cited by past researchers [25].

> "*author*: Is that true that you don't like to take a long break from driving because you are afraid that SEARider may stop assigning you requests?
> *bkk-7*: Yes, that is quite true. It's like AI does not recognize me. It stops feeding me requests as if it already gave to other drivers instead of me, even it's in the areas that I usually drive. So I have to wait (for it to assign to me again). Most of time, if the a passenger has taken a ride with me before, it will reassign again as if AI remembers me. " (bkk-7)

Drivers are also concerned with their customer rating and fear that lower customer ratings may impact their likelihood of receiving future customers. This constrains their behavior to actions they think will benefit their ratings (which may be misaligned with decisions that benefit their personal health). This is shown in one female participant from Bangkok noting her experience in speaking up about inappropriate behaviors by customers: *"If I ever get a complaint, SEARider won't listen to me but will listen to the customer first. Then they will ban me for a week" (bkk-9).*

Another lack of agency is shown in drivers' inability to choose passengers. None of our participants felt comfortable canceling a ride, citing a need to maximize riders per day and therefore income. SEARider drivers did mention preferences in passengers, despite their inability to control which passengers they were assigned. One participant mentioned that, as a smaller individual themselves, it is physically challenging to control their motorcycle with significantly heavier passengers. They noted that, *"I will never know how of the build customer would be, so if I arrive to the pick up location, I will not be able to avoid picking them up." (bkk-8).*

Being one of a few female drivers among our participants in Bangkok, a 47 years old with 5 years SEARider driving experience expressed that there were times when she felt uncomfortable

having passengers in such close contact with her[4]. She said that she would appreciate having a female-only feature that gives female drivers the option to select a preference to pick up. However, she notes that regardless she would not be able to take advantage of such a feature as it would restrict her customer-base too much and would result in a loss of income.

> "If I happen to drive in the area where there is rarely any passengers, now I need the passenger to also be woman, I will then probably get fewer requests. [...] If there would be any restriction (to help) women drivers, I would say something about picking up passengers with small build and not being intoxicated. But by restricted to women drive for women would be too much of a restriction, and I will lose a lot of income." (bkk-9)

Drivers also note frequently being assigned intoxicated passengers which can be dangerous for both the driver and passenger. Drivers mentioned being physically assaulted (i.e. bitten) and sexually harassed by intoxicated passengers. In some cases drivers felt responsible for passenger's safety, going as far as to help passengers find a sober supervisor to guide them at their destination and even purchasing special harnesses to strap intoxicated passengers to their back to prevent them from falling off the back of the motorcycle. Despite all of these inconveniences, drivers choose not to cancel rides unless absolutely necessary.

> "If the customer is presented to be dunk and I have already accepted the request, I have no other option. Because if I cancel the request, I will lose my percentage (i.e., accepted/all ride) or they sometimes put a hold on me to make me wait longer. Often times if customers are not too drunk, I will drive them anyway. But if they are really drunk, I will have to cancel the pickup because I don't know what will happen on the way. They may fall off, and I have to be responsible for all of it." (cnx-5)

bkk-8, who has been driving with SEARider over the last 4 years, explained how they fear canceling rides as it could negatively impact customer rating. Similar to *bkk-9*, *bkk-8* felt that SEARider will consider the customer first and act on their judgements without questioning its validity or observing the driver's side of the story.

> "If I get a low-rating or low percentage (i.e., accepted/all ride), SEARider will ban me and sometimes it's not fair. Getting 1 star when you try really hard to drive safely for a long time is very discouraging. And it will take like a hundred of 5-star rides to raise it up where it was." (bkk-8)

Participants even directly admit they do not feel they have actual flexibility, referencing how opaque the algorithm's decision process really is.

> Yes, I have to [keep maintain the rating]. Asking myself if I actually do have the flexibility, I would not say so. I don't think I have full flexibility. For example, if I cancel ride requests too often, they (i.e., SEARider) will ban me for 3-5 days. I get penalized even just dropping a customer off slightly off from the pinpoint. That's why I said I actually don't have that full flexibility. (cnx-8)

The insights gained from our interviews illustrate how drivers regularly take on risk in their daily work, many of which are more readily apparent than those linked to pollution.

Lack of Agency Due to a Service-oriented Mentality. We found that most drivers held a certain amount of personal responsibility for ensuring a quality experience for passengers. This was often exhibited through drivers taking extra measures to accommodate tricky passengers (i.e. drunk,

[4]Passengers of a motorcycle sit directly behind the driver and often make physical contact with them both due to proximity of seats and often having to hold onto the driver for stability during the ride.

angry, impatient). This is likely a cultural artifact or social norm and was seen to lead to drivers feeling they were treated unfairly.

In separate interviews, the majority of passengers cited that they always have the expectation of the motorcycle app-based rideshares providing cheap, trackable, and especially faster service than other modes of transportation. They mentioned that they mostly use the service for time-dependent travels like getting to work. Being fast aligns with the driver's desire to minimize delay times and maximize income. Therefore, drivers tend to weave recklessly through traffic to ensure that the passenger arrives at the destination as soon as possible. However, drivers share an awareness of safety issues with this and fear of injury leading to medical bills. Even so, drivers can still drive recklessly, or sometimes even illegally (i.e. on the sidewalk or wrong direction on the street), to maximize customer approval and minimize wait time. As participant *bkk-8* explained his experience with office-worker passengers, *"[They] will often rush me. Sometimes they even tell me to drive through a red light."*. Even worse, a 52-year-old driver mentioned that he feels necessary to drive recklessly and violate a few traffic laws to increase customer satisfaction with the service. He specifically noted that he needs to provide the quickest pickup possible as he has past experience with a passenger cancelled a ride when he was only a few minutes late.

> "I break a traffic law mostly on driving on the wrong side of the road. It happened to me where I went to pick up a customer, and I drove past them because the GPS was too slow. I went to make a u-turn, but the customer canceled the request while I was doing that. So sometimes it is necessary to drive on the wrong side of the road, on the sidewalk, and etc." (bkk-5)

No matter what happens, *"Drivers don't have a right to complain about customers" (cnx-3)*. Some passengers took this for granted. One of the Chiang Mai drivers experienced unwanted sexual harassment, not once but twice that,

> "Yes, I was harassed, it happened twice in that month. The first one was a woman wearing just a bra. I told her to wear a shirt otherwise I wouldn't drive her. She got on a ride but then bit me in the back. So I stopped driving and told her if she does it again, I will not continue driving her. Another one was a transwoman, they tried to get really really close to me with their face and body. I also stopped the motorcycle and told them that I wouldn't continue driving if they won't stop. So they stopped doing it because they realized that I wasn't happy about it." (cnx-6)

The SEARider rideshare drivers often perceive extra control over their work schedule as compared to desk jobs. But in practice, they have to accommodate demanding passengers and tolerate physical or even sexual harassment without support. Similar to their ranking in the "algorithm", drivers have to tolerate inappropriate behaviors from passengers to avoid complaints or poor ratings which may negatively impact their earning potential.

Lack of Agency Due to Conflict Avoidance with Local Taxi Services. Local mobility services like SEARider are on the rise in Thailand and local motorcycle taxis, who predate the proliferation of technology-mediated rideshare platforms, are in direct conflict for customers with SEARider and similar contemporary platforms. Previous research has highlighted this growing competition for customers in Jakarta [20]. Our drivers are aware of this competition and noted many instances of local taxi drivers threatening them (often physically) over customers. *bkk-8*, tells a story of how he got threatened in the process of picking up a passenger and was blocked their motorcycle by local motorcycle taxi drivers in an alleyway. The passenger was also forced to step off of the motorcycle to de-escalate the situation.

> "I have 4-5 motorcycle taxi drivers blocking the road. They told me that I cannot go and made my customer jump off the motorcycle. My customer got in an argument with them and told them that "I have the right to choose", but they told her that "No, you can't". So I eventually had to tell my customer that, "I'm sorry, I can't go.". Or sometimes I even have to warn other customers that if something like this happens again, I would like you to get off first and I will pick you up the next street." (bkk-8)

In fact, a majority of our participants mentioned how they use various strategies to avoid confrontation with local taxi drivers such as removing SEARider paraphernalia to avoid attracting attention. Some drivers work cooperatively with the passengers to avoid local taxi conflict by agreeing on a modified pick-up location to avoid local taxi hubs. From interviews with both passengers and drivers, we learn that local passengers empathize with drivers and understand the tensions as stories about SEARider drivers being physically assaulted by local taxi drivers appeared on national news. Participant *chon-7* notes,

> "Mostly I try to avoid picking up customers near the local motorcycle taxi stations. If I ever get a ride request near their stations, I will tell my customers to walk a little further away from them." (chon-7)

From the interviews, it is clear that there are conflicts between the flexibility that drivers feel and the agency they actually enact to make changes in their daily life. We found that many drivers work the same amount despite how poor the working conditions may get. While their reason for this is largely due to a desire to maximize income (as seen in Section 4.2.1), we further contextualize this in their fear of being de-prioritized by the algorithm, work-ethic, and conflict with local transportation services. In the following section, we investigate how these fears are prioritized against the fear of losing earning potential, with some drivers even taking action to protect themselves by changing their behavior.

4.2.3 ***Theme 3: Seeing is Believing: The Dangers that Matter are the Things that can be Seen, not Air Quality.*** A majority of the participants both passengers and drivers mentioned that most people in Thailand have already gotten used to the issue of air pollution. This shows that drivers sometimes don't want to change their behavior in high pollution because it is somewhat seen as a fact of life in Thailand. As one of the drivers in Chiang Mai said, *"People think that we have this air pollution every single year, and we still feel healthy just fine." (cnx-2).* Almost all of our drivers noted that the best that they can do is to wear protection such as face masks, keep a wet cloth to wipe the dust on their face, and prepare a bottle of water to watch their eyes frequently on a high PM2.5 day. But none of them expressed a willingness to change their driving behavior to further protect themselves from PM2.5 exposure.

Although passengers expressed that they have more agency to prioritize their health, the majority of our passenger participants still think that the long-term health effects from the poor air pollution are not significant enough for them to alter their schedule. As one of them noted, *"It is only when I started to notice changes in my immunity that I would then start asking myself "Should I just stay home today?" (bkkp-8).* This is similar to our driver responses in that without immediate observable effects, people still do not change their behavior to protect themselves from pollution. Only a few of the passengers indicated their willingness to cut down on non-essential trips, remain at home with an air purifier running, and opt for food delivery services from SEARider in cases of severe pollution. This course of action helps reduce air pollution exposure for passenger while leaving the drivers remain endangered. This shows that, in most cases, the dangers of PM2.5 were imperceptible and therefore easy to overlook for both groups. This is true despite drivers noting that they sometimes receive updates or warnings of bad pollution from weather applications or

group chats with fellow drivers. In the remainder of this section we explore the different perceived dangers which drivers cited and elucidate a hierarchy of risks which drivers are willing to take on.

Perceivable Danger of Rain vs Overlooked Danger of PM2.5. While all drivers seem to overlook the long-term health effects of PM2.5 exposure – despite many participants understanding the danger – many drivers note a fear of driving in the rain due to the increased risk of car accidents or flooding.

A 52 years old SEARider driver in Bangkok who has been driving over the past 4 years, *bkk-8*, expressed that air pollution is often not a concern for him. Simply because *" I cannot see it [the air pollution particles] with my eyes."*, he continued,

> "I don't think I ever hesitate to go out and drive, even on quite polluted days, because I just have to make money. But I'll always have to save myself. "(bkk-8)

However, the same participant reflects on the dangers of rain later in the interview.

> "If it rains, I will not drive at all because it's dangerous. I'm afraid that I will be in an accident, especially I have a customer in the back of me. And I need to not break the phone because I need it." (bkk-8)

Majority of drivers mentioned that they will drive because there will always be customers even during extreme air pollution. This finding is corroborated by our passenger interview results. As the majority of our passenger participants are office workers in the Bangkok Metropolitan area, they mentioned that conducting work remotely was often not an option. Since there is rarely any noticeable change in ride requests, the drivers feel it would be a missed opportunity to not work, even in extreme pollution. One of the drivers even noted that *"The customers are the ones who choose for us [to drive or not], we can't choose." (bkk-2).* Returning to our observed theme of income maximization, one driver in Chaing Mai expressed how they would rather stay inside during heavy rain to avoid getting sick. Sickness could lead to multiple days off work which comes at a significant cost.

> "If it rains heavily, I will not drive at all because I am not very healthy. Like if I drive through the rain today, I may get sick and not be able to drive for another who knows how many days. It isn't like it will take a day or two to recover, it's really not." (cnx-8)

They additionally have expressed concern about having their equipment damaged by the rain, such as their phone. Damage to their phone could cost them hours or days of work. *"It's like we trade a 30-40 baht ride with our phones. If we couldn't protect the phone from rain properly and water leaks in, that will be the end. It is not worth the investment. " (cnx-7).* Interestingly, we did not see the same concerns for monetary cost of healthcare, despite referencing the potential need for future treatment due to driving in poor conditions.

> "I personally think that my body can still be cured because there will always be hospitals and doctors to go to. I am not so worried about the impacts in the future." (cnx-8)

On the contrary, those drivers note that while some drivers stop driving during rain, they will leverage the shortage of drivers to benefit from surge pricing, especially the period when it is about to rain or light rain. As the participant *bkk-5* noted that, *"When it rains here, in Bangkok, there will be a traffic jam. Then people will start requesting rides from SEARider Bike mainly."* This could be associated with the fact that passengers compete for rides before the rain starts to get heavy and fewer drivers to drive during these periods of time.

> "When the rain is not too heavy, there will still be some customers using the service. Because once they see traffic, they will start to think that rain will cause a traffic jam

> for cars. So then customers will just be okay with getting a little soaked for those who go to school. But for people who take a ride home, it doesn't really matter." (cnx-4)

While drivers acknowledge the inherent danger of PM2.5, this shows that the immediate observable impacts of rain are weighed greater when deciding to drive. These include potential damage to equipment, the need to take sick days, or the risk of collisions on the road. Drivers then have the general tendency to prioritize immediate concerns and downplay the long-term health implications associated with PM2.5 exposure.

Perceivable Danger of Local Taxi Services vs Overlooked Danger of PM2.5. In a comparison of the overlooked danger of air pollution in terms of health risk, the drivers have expressed a much stronger sense of the danger in personal safety with respect to conflict with local taxi drivers. This has reduced drivers' flexibility in choosing where to drive and pick up customers as stated in Section 4.2.2. Drivers also have to ensure that they fit with the crowd of other motorcycle users by not wearing any SEARider-branded official merchandise and relying heavily on customer cooperation as one of the participant note:

> "I'll have to camouflage myself a little bit. If I come to pick up a customer, but there is a local motorcycle taxi station nearby, I'd call and ask my customer that, "There are motorcycle taxis stations near you and I'm not comfortable picking you up in front of them, would it be possible for you to walk slightly further away from the area?". And if the customer won't be able to walk further out, I'd ask them to cancel the ride. Because I drive alone, but they've got 7-8 people, I'd avoid getting in trouble as much as I could." (bkk-2)

We once again see that drivers have to constantly maintain extreme caution in determining their driving routes and how to drive. While drivers are always on the lookout for local taxis and avoid interactions with them at all costs, we did not observe a similar sense of urgency when it comes to prioritizing their health to reduce PM2.5 exposure.

Perceivable Discomforts vs Overlooked Danger of PM2.5. Again we see that drivers perceive the dangers of working for SEARider and take action to avoid it. This time drivers admit to avoiding driving at night to avoid robbery or only working courier services at night to avoid customer interaction.

> "I'm afraid of driving at night because of robbery and assault. Sometimes I drive for SEARider Express, I'd always be afraid of customers sneak in illegal packages as they'd be fully sealed and I would not be able to know what's inside. It's very risky." (cnx-4)

In this case, we see how drivers are willing to take action to avoid harm from passengers. This is in stark contrast to their lack of willingness or perceived agency to change their driving behavior during high PM2.5. It may be that drivers don't see the cost of prolonged pollution exposure as it is not as immediate or it may be the fact that drivers are so used to poor air quality given the high average PM2.5 in Thailand (or some combination of the two). The interviews show that drivers in fact have some self-agency to act on various potential harmful driving environment. What's considered dangerous is highly based on personal comfort, but long-term health impacts from air pollution exposure are commonly disregarded.

5 DISCUSSION

By conducting the interview and data analysis studies, we captured participants' decision making process when participating in rideshare economy and corroborate that with aggregate population data. While it is impossible to fully optimize for all measures of positive experience with rideshare platforms, we start this discussion by identifying the priorities of different stakeholders and the

interactions between them (i.e. priority of income coming at the cost of health). We then discuss the ethical implications of the current rideshare incentives system and its failure to support the autonomy and therefore well-being of its workers. Finally, we then provide recommendations on designing human-centered rideshare platforms which encourage healthier choices by both drivers and passengers.

5.1 Priority Hierarchies of Stakeholders in Rideshare

Driver and passengers interview responses indicated that users of the SEARider platform have a lot of experience with the effects of PM2.5 exposure, but are not motivated to make changes in their daily life to prevent prolonged exposure at the cost of reduced income. Instead, financial stability and meeting income targets are at the top of the hierarchy of considerations drivers take when making the decision to drive. Both drivers and passengers highlighted minimizing wait times as being a high priority for them. On the driver side, this is due to a desire to increase customer throughput and therefore income. On the passenger end, this is understood to be primarily about convenience. However, in the passenger case, a faster commute results in less PM2.5 exposure as their journey is complete faster. This benefit is not afforded to drivers as they will continue to drive customers throughout the day, even if they increase customer throughput. Any attempt to improve the health outcomes of this ecosystem must grapple directly with this reality; drivers at low socioeonomic levels will place the immediate benefits of revenue over the long-term negative effects of pollution (or other issues). This is not unique to motorcycle ride sharing; the world has a long history of marginalized workers mortally damaging their bodies for short term wages (e.g, occupational diseases such as "black lung" among coal miners in the US [12], the ”phossy jaw’ of matchgirls in the UK [34], or the innumerable sweatshops [36] around the world) . While completely resolving this at scale is (obviously) beyond the scope of this work, we do think that there are things that drivers, passengers, and SEARider could do to improve the situation.

5.2 Ethical Implications of Current Rideshare Incentives

The current structure of the rideshare incentives does not offer the autonomy it promises and causes drivers to frequently make the choice between preserving income vs their health. Specifically, we saw drivers choosing to work in harmful conditions, such as on days with extremely high PM2.5, when many other people choose to stay indoors [11, 48]. They also worked long hours (as many as 36 consecutive hours) outside without any air filtration, unlike traditional car-based rideshare. We see throughout our interviews that the cost of supplies and consequences of long work hours are not immediately obfuscated when a driver takes up gig work. Many of the expenses are only made clear after drivers have already committed to this career. Drivers often cited the fear of the assignment algorithm de-prioritizing them if they stopped driving, and thus taking a day off, could have long-term negative impact on their income security. The fact that drivers are willing to change their work hours around rainy conditions indicate that drivers are aware of certain dangers but have deemed the risks of PM2.5 to be an acceptable risk. Most importantly, we found that drivers’ decision to drive on where and when is often based primarily or entirely on the income they would make. Given this, passengers’ decisions, preferences, and routines can similarly override drivers’ autonomy, especially when considering the impact of poor air quality on work decisions. These results highlight a need of more standardized ethical practices within the rideshare industry to educate drivers and raise awareness about the seasonal air pollution for both drivers and passengers. This could enable drivers to make well-informed decisions that aim for a healthy balance between securing their financial stability potentials without jeopardizing their health. Passengers, too, should also be encouraged to grasp the implications of their ride fostering a shared responsibility for the well-being of all participants in the rideshare ecosystem.

5.3 Potential Mechanisms for Reducing Drivers' Exposure to Air Pollution

As noted in prior work, rideshare platforms in low- and middle-income often formalize existing informal transportation systems [39]. However, they also run the risk of partaking in techno-colonialism by enforcing algorithmically defined control without responding to lived experiences of users on the ground [25]. This extends to air quality issues, where users feel pressured to use the platform despite significant documented health risks.

It may be possible to develop new structures, including modifications to algorithms or new incentives, that appropriately account for the costs of driving in air pollution of these populations. Naively, one could imagine simply paying drivers for the costs of driving in pollution; offsetting their future medical issues with upfront reimbursement. As seen in the interviews, this would almost certainly just increase the amount of time their drive in high PM2.5 as they are so revenue-focused. While largely left to future work, we describe some initial alternative ideas in this section.

5.3.1 Existing Efforts. We first note that many regional governments, and even our partner SEARider, have noticed and attempted to address air pollution concerns for motorcycle drivers. SEARider, for example, provides (branded) masks to drivers to help filter bad air (though notably, these could be problematic with the local taxi services). Similarly, some cities in the region have designated areas for motorcycle taxis to congregate, away from road pollution. And lastly, some countries have set stricter regulations that SEARider has undergone thorough scrutiny to unsure the well-being of drivers, such as Singapore and the Philippines, where motorcycle ride-sharing remains unauthorized. While these are positive and should be lauded, we feel that, given the data, they are insufficient to protect the population of drivers.

5.3.2 Providing Monetary Incentives to Stop Driving. An obvious solution may just be for SEARider to pay drivers not to drive during periods of high pollution. However, these marketplaces are largely demand-driven, and so long as passengers are requesting rides they will need accompanying drivers. Instead, it may be better to reduce overall exposure by encouraging drivers to cycle in and out during these periods. We could imagine the platform requiring periodic breaks, or even scheduling routes (with associated pay) through areas with lower pollution (such as near ocean breezes).

5.3.3 Algorithmic Transparency. Another clear element from the interviews was the drivers' feelings of a lack of agency. Even if they wanted to change their driving behavior due to extreme air quality days, many felt as though they could not without negatively impacting their future revenue prospects. SEARider could easily provide more visibility into their ranking and matching algorithms to alleviate this concern, perhaps allowing a user to explicitly "opt-out" during periods of high PM2.5. Companies like SEARider should also make efforts to more strongly convince partners that they do not penalize drivers for taking time off as noted in Section 5.4.

5.3.4 Air Quality Education. We note that many of the drivers had limited knowledge about the long-term negative impacts of exposure to air pollution. In many markets, SEARider is required to train their drivers on various elements of the local regulations, and this training could be expanded to include a thorough background on the dangers of high pollution and potential mitigations.

5.3.5 Demand-driven Changes. One conclusion from this work is that work on these sorts of platforms are strongly demand driven; drivers have little agency to make substantive changes in their routes or practices on their own. We could consider a body of demand-side changes, such as mechanisms for passengers to indicate a desire for a less polluted route (though they may not often take it) or for them to take alternative travel plans (or even stay home) during periods of high PM2.5. This could be done through similar education initiatives, detailing the risks of driving

during pollution and on polluted roadways. we believe this path is promising given that **some** of the passengers did describe changing their behavior during pollution events, even if that was sometimes ordering delivery food (which would increase the risk to delivery drivers). Many of the above suggest mechanisms could similarly apply to passengers; for example paying them (in credits) to not take the service during high pollution events. Simply raising prices may not, as that would either (1) incentivize drivers to drive more due to higher wages or (2) take advantage of drivers if not raising wages. We leave this path to future work.

5.4 The SEARider Feedback

Within this publication, we engaged in a discussion with SEARider regarding our findings. Given drivers' frequent mention of the inevitability of driving in areas with poor air quality, we explored the feasibility of alternative "low-pollution routes" with SEARider. However, they noted that such solotion may not be feasible due to a lack of street level pollution data. SEARider also wanted readers to understand that their platform is not a primary driver of pollution in Thailand. The main sources of pollution in Thailand is regional seasonal crop and foliage burning.

One interesting area of future work is on communication and algorithmic transparency. As previously noted, extended breaks from driving, negative customer reviews, and reporting customers were perceived by drivers to negatively affect their ride assignments. Hence, drivers indicated a constant fear of of losing earning potential when taking breaks or making healthier choices. In contrast, SEARider expresses strongly that drivers' absences have no negative consequence on their performance and that drivers are welcome to take whatever breaks they consider helpful. We believe that SEARider has an opportunity to increase transparency regarding their operations/calculations, which could encourage drivers to consider prioritizing their health, especially on days with poor air pollution. These straightforward yet crucial messages reveal a substantial communication gap that impacts drivers' decisions to drive and their priorities. Addressing these issues requires a combination of improved communication strategies, transparency in server-side operations, and a comprehensive understanding on drivers' perspectives from SEARider. By fostering both drivers' health and their financial well-being, we can work towards a more sustainable and equitable motorcycle ride-share industry in the future.

5.5 Study Limitations

Despite the breadth of our mixed-methods study, there are a few concerns that we could not mitigate without significant changes. These include both structural elements as well as components of the quantitative and qualitative analysis.

5.5.1 Air Quality Data and Motorcycles. First, we note, while our ride data is compiled via geohashes of about 1 square kilometer, each district has just one or two air quality sensors for the whole area. This makes it impossible to correlate subregional pollution events (e.g., congested road or clearing from a sea breeze) and instead only correlate driving across the entire daily dataset. While this is a limitation, changes in the results from these broad measurements do indicate general increases in pollution and drivers do cross the city when working, so we expect the results of the study to be valid.

Similarly, a major concern is about the pollution exposure drivers and passengers receive from simply being on the road. A variety of studies have shown how simply being colocated with cars dramatically increases pollution exposure [18, 29] (with a specific study of motorcycle taxi drivers in Benin [26]). As such, it's unclear if such exposure to car emissions dominates the regional pollution events evaluated in this work. Unfortunately, we cannot address this concern in this study; we

simply do not have fine-grained enough measurements to differentiate latent regional exposure versus acute roadway exposure.

We plan to explore all these questions through the deployment of individual sensors with drivers in follow-on work, allowing us to study individual driver decisions and observe hyperlocal effects of PM2.5 exposure.

5.5.2 SEARider Data. First, we note that, our data is anonymized and aggregated across time at the hour level making, making it impossible to track the decisions of the same drivers in various air quality conditions across time. However, it is still possible to analyze the aggregate behavior of the driver population.

Furthermore, we only had access to a year and a half of data. It may be the case that ridership fluctuates from year to year based on growing driver population, growing passenger population, different levels of tourism, different weather extremes, etc. While we tried to capture these effects by comparing data from the 6 months of 2018 to the same 6 months of 2019, there is still potential for trends to be out of the ordinary.

Finally, our data was provided as origin-destination pairs rather than individual paths. This made it impossible to compare days with different pollution levels based on driver route. While it was still possible to compare locations that were used as origins and destinations in high and low PM2.5, we were keen to examine whether drivers alter their routes to avoid traffic-congested highways.

5.5.3 Driver and Passenger Interviews. First, we note some tension with our research staff and method; though our interviews were conducted independently, only one team member was fluent in Thai (with the other needing the assistance of a translator). While this is a concern, we note that the native Thai speaker conducted a majority of interviews (all of Bangkok, Chiang Mai, and passengers) giving us a locally grounded base for our interviews. Additionally, all interviews were recorded and evaluated by this team member, again increasing grounding.

Secondly, there was some issue with the sampling of drivers. Our methodology used social media posts and recruitment of drivers from drives. We note that some drivers refused to participate, fearing we were affiliated with SEARider (despite assurances we were not). Some other drivers may have softened their responses for the same reason, being worried that their negativity may make it back to SEARider. These issues likely introduced some selection bias, but given the breadth of negative responses, we believe it would not be large. Lastly, the listed issues with Chonburi interviews also likely introduced a bias; given that SEARider is not popular there at the moment we had to recruit from personal networks.

6 CONCLUSION

In this study, we conduct semi-structured interviews with 25 motorcycle rideshare drivers and 9 rideshare passengers in 3 different provinces of Thailand. We supplement this rich qualitative study with a quantitative analysis to corroborate the findings. In this mix-methods study we show that despite Thailand suffering from poor air quality for much of the year and drivers demonstrating an understanding of health risks of prolonged exposure to PM2.5, few drivers change their work schedule to avoid work during extremely poor air quality. Similarly, the ATE of poor air quality on rideshare trips was found to have confidence intervals containing zero. Given these findings that drivers largely do not change their work schedule to mitigate exposure to harmful pollution, we further explore the potential risks drivers face and the specific factors which prevent them from exercising their autonomy as a contractor to avoid them. We find that in all cases, drivers prioritize income security over mitigating physical harm, whether it arises from environmental factors or interactions with passengers (with the caveat that heavy rain is perceived as dangerous

enough to change their driving behavior). We identify two interesting themes: Lack of Agency, and a Hierarchy of Perceivable Dangers.

7 ACKNOWLEDGEMENT

We would like to thank SEARider and See-Kiong Ng, University of Singapore, for the rideshare data. We also thank Sukumal Kitisin and Adisorn Lertsinsrubtavee in brainstorming interview questions and helping us with drivers' recruitment in Chonburi province. Lastly, the anonymous reviewers for the helpful feedback. This work was supported by the National Science Foundation (NSF) award 2025022.

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A APPENDIX

A.1 Interview Questions for SEARider Drivers

A.1.1 Demographics:

1. What is your name? How old are you? What is your preferred gender/pronounce?

Driver Profile:

1. What made you start driving for SEARider?
2. Do you deliver food more or do you drive more?
3. How long have you been driving for SEARider?
4. Is driving for SEARider your primary source of income?
5. How do you feel about the compensation that you receive per day?
   - How much do you make a day? Roughly below or above the minimum wage? Worst case, Average, Peak day.
6. How do you feel about your working condition (i.e., working on the roadside)?
   - Have you ever felt uncomfortable or threatened under the current working conditions? Safety conditions, accident insurance, benefits etc.?
   - Working status and benefits (e.g., social security, pension)
7. Do you live alone or with a family?
   - Are you the primary breadwinner of the household or are there others in your family who share the responsibility of making money?
8. How many hours a week do you drive for SEARider?
   - How do you spend most of your time? Driving vs Waiting? Worst case, Average, Peak day.

A.1.2 Driver Preference:

1. Are there any reasons you might choose not to drive on a given day (or drive less)? For example? What are the exempt days?
   - Are there weather conditions that cause you to not drive for a day (or drive less)? During the air pollution or rain?
   - Are there holidays or events that would cause you to stop driving for a day (or drive less)?
2. Are there any reasons why you might feel especially interested in driving on a given day (or drive less)? Which day of the week is the busiest?
3. Are there areas in which you prefer to pick up or drop off riders? Why?
4. Are there areas that you prefer to avoid when picking up or dropping off riders? (Rush hours?)
   - Are there areas that seem underserved or easy to ignore?
5. Are there particular passengers which you prefer to pick up? Do you have regular passengers?
6. Are there particular passengers which you prefer to avoid?
7. Is there any penalty from rerouting?
   - Do you usually go through the suggested routes?
8. Do you often diverge from the suggested route?
   - If so, by how much, and why?
   - Are there consequences of diverging from the suggested route?
9. Where do you choose to start your route of the day? Why and how?

10. Have you ever violated traffic rules? If so, why?

A.1.3 Perceived Rider Preference or Environmental Qualities:

1. Do you personally pay attention about air quality of the day? Do you think people try to go places more when the AQI is worse?
2. Are there days when you notice fewer passengers using the app and calling rides?
   - Do you find this happens more during certain weather conditions?
   - Do you find this happens more during certain other events?
   - Do you find this happens more in certain areas?
3. What types of trips do passengers often make?
   - Do you take people to work?
   - Are there any patterns that you see from the requested rides?
     - Time of the day?
     - Day of the week?
4. Health conditions before / after start driving for SEARider
   - Stress wise
   - Respiratory system

A.2 Interview Questions for SEARider Passengers

A.2.1 Demographic.

1. Intro: Name? Gender? Age? What do you do?
2. Income range?
3. Living situation? Apartment / Home?
   - Alone or with family? Share a room with a roommate?
4. Which area in the city do you live?

A.2.2 Usage of the SEARider Service.

1. What are the main transportation methods that you use?
   - For which purpose?
   - What is a factor to choose one or the other?
2. What service of SEARider do you use? (show verification on the App, if possible)
3. How long have you been using SEARider?
   - How often do you take a ride with SEARider per week?
4. What are other ride services that you use?
   - How are you deciding on which service/app to use? The differences? Factors?

A.2.3 Preference of taking a ride during air pollution.

1. Knowledge about the negative implications of the air pollution
   - Do you have an allergy?
   - Could you explain what the air pollution situation looks like in the city you live in? How do you think it impacts your health?
   - Where do you receive the news about air pollution?
2. How do you feel air pollution is disrupting your daily activity?
3. How have you best avoided the situation?
4. Can you put me in the situation (or the day) that you have the polluted air?
   - In details: what do you do (differently), what do you where, how to you go to work, how to you go back home
   - Strategies to limit the exposures
5. Have you ever taken a ride during the air pollution?

- When roughly in the year was it?
- What was the experience like?
- Did you experience any personal health risks?
- Did you take any precautions or use any protective measures?

6. Do you see a difference in wait time or the number of SEARider (motorcycle rideshare service) during these time periods?
7. Do you feel like you have a choice whether or not to take a ride? Why or why not?
8. Have you ever felt concerned about personal safety taking a ride during such air quality?
9. Have you ever heard complaints from SEARider about the air pollution situations?

A.2.4 Preference of taking a ride.

1. Are there any reasons why you might not choose to take a ride on a given day? For example? What are the exempt days?
   - Are there weather conditions that cause you to not ride for a day (or ride less)? During the air pollution or rain?
2. Are there holidays or events that would cause you to stop taking a ride (or ride less)?
3. Is there any pattern of taking a SEARider (motorcycle rideshare service)?
   - Day of the week?
   - Time of the day?
4. Do you have a preference in taking a ride during what time of the day?
   - Have you ever felt concerned about your personal safety taking a ride during a specific time?
5. Any areas that you avoid or prefer to take a SEARider (motorcycle rideshare service)? Why?
6. Have you ever taken a SEARider (car rideshare service)?
   - [if yes] What are the factors that would make you consider which one to take (i.e. SEARider (car rideshare service) or SEARider (motorcycle rideshare service))?
7. Do you have any preference of who the drivers should be?
   - How do you feel about taking a ride with an opposite gender? Age?
   - [if women] have you ever chosen to call a ride for a woman driver? How often?

Received January 2023; revised October 2023; accepted January 2024