Evaluation of Penalty and Enforcement Strategies to Combat Speeding Offences among Professional Drivers: A Hong Kong Stated Preference Experiment

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ABSTRACT

Speeding has been a great concern around the world due to the occurrence and severity of road crashes. This paper presents an evaluation of the effectiveness of different penalty and camera-based enforcement strategies in curbing speeding offences by professional drivers in Hong Kong. A stated preference survey approach is employed to measure the association between penalty and enforcement strategies and drivers' speed choices. Data suggest that almost all drivers comply with speed limits when they reach a camera housing section of the road. For other road sections, a panel mixed logit model is estimated and applied to understand the effectiveness of penalties and enforcement strategies on driver's speeding behaviors. Driving-offence points (DOPs) are found to be more effective than monetary fines in deterring speeding offences, albeit there is significant heterogeneity in how drivers respond to these strategies. Warning drivers of an upcoming camera-based enforcement section increased speed compliance. Several demographic and employment characteristics, driving history and perception variables also influence drivers' choices of speed compliance. Finally, besides penalty and enforcement strategies, driver education and training programs aimed at addressing aggressiveness/risk-taking traits might help reduce repeated speeding offences among drivers.

Keywords: speeding, professional drivers, penalty, enforcement, stated preference survey, mixed multinomial logit

1. INTRODUCTION

Hong Kong is a city with high population density and limited road space. The ability of public transport to serve high density cities well, as well as the relatively high costs of private vehicle ownership and high operational costs (especially parking costs) resulting from the limited road space, has resulted, in Hong Kong, in the dominance of public transport as the primary mode for work-related as well as non-work travel. Of particular note is the relatively seamless integration of road-based and rail-based metro public transportation services in Hong Kong, with transfers between the two broad modes of public transportation commonplace. Overall, over 90% of commute trips as well as over 46 % of non-commute trips in the territory are undertaken by road-based and/or rail-based public transport (Transport and Housing Bureau, 2017; Transport Department, 2014).

The road-based public transportation modes (PTMs) in Hong Kong primarily include a regular bus mode (operated either publicly or privately), a light bus mode (or mini-bus mode that typically carries up to 19 passengers, again operated publicly or privately), and taxis (while the taxi mode may not be traditionally viewed as a public transportation mode, it is not uncommon in Hong Kong for the use of taxis to access bus stations and rail stations, making it an integral component of public transportation use in the country). The substantial dependence on PTMs contribute to, on a per capita basis, a low vehicle miles of travel (VMT) in Hong Kong. This low exposure, along with low speeds (due to high vehicle densities) and the protective cushion offered by large buses, has resulted in a relatively low number of crashes in Hong Kong, especially those resulting in serious injuries/death. In particular, there were 108 fatalities and 2214 individuals seriously injured in road traffic crashes in 2017 (Transport Department, 2017). Based on a population estimate of about 7.4 million in Hong Kong in 2017, this translates to a per capita fatality rate of 14.6 deaths per million population (relative to, for example, 28 road traffic fatalities per million population in the UK and 107 deaths per million population in the US).

Clearly, Hong Kong's traffic safety record, at least on a per capita basis, is superior relative to many other western nations. However, an issue of concern in Hong Kong is that, unlike many western countries, a vast majority of the vehicles being driven on the roads are by professional drivers (interestingly, ride-hailing services have yet to be legalized in Hong Kong, and, as indicated earlier, taxi rides are a common way to access PTMs, in addition to walking; and taxi drivers are carefully regulated in terms of licensing requirements). Thus, it is of concern in Hong Kong that the crash involvement rate of public transport vehicles is seven times higher than that of the private car (Transport Department, 2017). It certainly brings into spotlight the safety performance of professional drivers and the licensing regulations in place for such drivers. While professional driver-related crashes and the organization/travel culture has been examined at some length in the west and the middle-east (for example, see Mallia et al., 2015; Newnam et al., 2018; Öz et al., 2010a, 2010b; Rosenbloom and Shahar, 2007), there has been relatively little research into the causes and considerations associated with professional driver-related crashes in the far-east. This is particularly surprising, given that professional drivers make up more of the pool of overall drivers in Hong Kong relative to the west and the middle east.

In this paper, we examine the factors that influence the crash-risk of professional drivers in Hong Kong. Earlier studies in other regions of the world, such as those referenced earlier, suggest that driver aggressiveness, caused by high work and time pressure and resulting in a trade-off deliberation between traffic offence-penalties and potential income gains from saved time in the face of congested travel conditions, contribute to the high crash risk of professional drivers (Öz et al., 2010a; Rosenbloom and Shahar, 2007). In particular, speeding has been identified as a common aggressive driving behavior exhibited by professional drivers, and speeding has also been identified in many earlier studies as being the single most important factor impacting the occurrence and severity of roadway traffic crashes (Fitzpatrick et al., 2017; Watson et al., 2015; WHO, 2018). In this context, in some OECD countries, the proportion of drivers who self-report being guilty of excessive speeding is as high as 80% (WHO, 2018). The same situation manifests itself in Hong Kong, with speeding being one of the most common recorded traffic offences among professional drivers and drivers at large. According to the number of prosecutions against traffic offences in 2017, speeding accounted for over 42%, while red light running and drunk driving accounted for 13% and 0.17% of the total number of prosecutions in Hong Kong, respectively (Hong Kong Police Force, 2018). Admittedly, these statistics from Hong Kong do not necessarily reflect the relative prevalence of speeding compared to other illegal driving behaviors, because the statistics may simply be an indication of the type and intensity of resources dedicated to enforcing speed limits relative to other illegal driving behaviors. Even so, the very fact that more investment is made in preventing speeding relative to other behaviors is in and of itself an acknowledgment that countermeasures aimed at speed reduction are considered one of the most cost-effective ways to enhance traffic safety.

Monetary fine, driving disqualification and imprisonment are the common penalties to address and reduce speeding offence occurrences (as well as other driving offences; see Hössinger and Berger, 2012; Li et al., 2014). In Hong Kong, the Driving-offence Points (DOPs) system was introduced in 1984. Over 50 items of traffic offences carry DOPs in addition to a monetary penalty. As would be logical, more DOPs and higher monetary fines are issued as the level of speeding increases. Thus, a severe speeding offence (excess of speed limit by more than 30 km/h but less than or equal to 45 km/h) incurs five DOPs and HK$ 600 penalty (Transport Department, 2018). Under this DOP system, persons who have incurred 15 points or more within two years are disqualified from driving.

Some previous studies have revealed a significant negative correlation between the monetary fine level imposed and penalty points, and the occurrence of traffic offences (Hössinger and Berger, 2012; Li et al., 2014; Wong et al., 2008). For example, an increase of fine by 10 Euros is associated with the reduction in speeding frequency by 5% among Austrian drivers (Hössinger and Berger, 2012). However, there are studies suggesting that monetary fine levels and penalty points alone have only a relatively minor deterrent effect on the speeding offence (Elvik and Christensen, 2007; Fleiter et al., 2010; Langlais, 2008; Ritchey and Nicholson-Crotty, 2011; Sagberg and Ingebrigtsen, 2018). Specifically, these studies raise the issue of not only the level of the penalty on speeding deterrence, but the risk of being subjected to that penalty (Kergoat et al., 2017; Li et al., 2014; Tay, 2009). That is, the propensity for speeding depends on both the level of penalty as well as the prevalence of speed enforcement operations, with some studies finding that the latter is much more effective in curbing speeding offences than the former (see, for example, Gargoum and El-Basyouny, 2018; Lawpoolsri et al., 2007; Ryeng, 2012; Truelove et al., 2017). In other words, fines and DOPs penalty, according to these earlier studies, do not function very well when the level of speed enforcement is not adequate (and thus the risk of being subjected to the penalties is low). This finding also has backing in criminal justice-based deterrence theory (Gibbs, 1985), which stems from the notion that individuals effectively undertake a cost-benefit analysis of pursuing a "crime", and the effectiveness of a dissuasive mechanism originates from the costs being perceived as higher than the benefits. The cost-benefit analysis itself is conducted within a frame of three criteria: the certainty, celerity (swiftness or rapidity of imposition), and the severity of a sanction. While the relative contributions of these three criteria may vary based on the crime under question, lower "crime" activities (at least as viewed traditionally by society, such as illegal driving behaviors) are typically dominated by the "certainty of being apprehended" criterion in the cost-benefit evaluation of individuals (Høye, 2014; Watson et al., 2015). In the context of speeding, this "certainty" criterion is directly related to the level of enforcement of speed limits.

The automated speed enforcement camera (ASEC) system is generally considered as a promising and cost-effective enforcement technique that increases the certainty of being apprehended if speeding (Carnis and Blais, 2013; De Pauw et al., 2014a; Tay, 2009). Once the cameras are installed, such systems obviate the need for more costly human police patrols along roadways. Of course, some studies suggest that human police patrols are still effective, when combined with ASEC systems, because many drivers feel embarrassed when confronted by a fellow human (that is, a police person) who is perceived as passing a judgment on one's societal conduct. In addition, the fear of a verbal reprimand by the police also can add to the embarrassment factor, elevating the cumulative cost of being detained by a human police to be even higher than the fear of risking one's life or that of others through speeding (Kergoat et al., 2017; Silcock et al., 2000). But drivers also understand that human agents, even if equipped with hand-held radar/laser speed guns that provide accurate and reliable readings, can get fatigued over long periods of time in terms of holding and directing the speed guns in appropriate directions, and cannot have a consistent level of vigilance over extended periods of time, leading to speeding event “misses” (see Kergoat et al., 2017). On the other hand, properly functioning ASEC systems are more reliable in detecting speeding violations over extended stretches of time. Even so, there is the issue of driver ability to dodge the dangers posed by spatially fixed ASEC systems (that is, an ASEC with overtly announced camera locations, as opposed to covert or unpublicized camera locations). In particular, according to the integrative social-cognitive protection-motivation theory (PMT) (see Rogers, 1983), the effectiveness of a “threat” (that is, a speed enforcement mechanism in the context of roadway speeding) is based both on threat appraisal (by way of the certainty, celerity, and severity, as proposed by deterrence theory) as well as coping appraisal (that is, the ability to cope with and dodge the danger). As an individual’s self-efficacy (the ability to perform an action needed to dodge a threat) and the response efficacy (the efficacy of the response to actually dodge the danger) increase, there will be less incentive to not commit an offence based on a positive coping appraisal. In the context of a spatially fixed ASEC systems, drivers typically perceive more controllability and a positive coping appraisal (that is, a higher belief that they have the capability to effectively dodge the speeding enforcement threat) by simply reducing speeds in the immediate vicinity of the camera locations. This so-called “kangaroo effect” (abrupt reductions close to camera locations and abrupt speed jumps upstream and downstream of locations relatively removed from the camera range) has been well-identified in earlier studies (De Pauw et al., 2014a, 2014b; Elvik, 1997; Marciano et al., 2015). On the other hand, previous studies (see, for example, Cameron et al., 2003; Dowling and Holloman, 2008) have shown the higher effectiveness of covert (or unmarked and unpublicized) ASEC systems relative to fixed ASEC systems because of a lower coping appraisal and higher uncontrollability to dodge a threat on the part of drivers. However, such covert ASEC systems are not legally allowed in Hong Kong and many other countries, both due to privacy regulations as well as the notion that ASEC systems should be fundamentally aimed at preventing speeding rather than apprehending offenders (Høye, 2014).

1.1.The Current Paper

In the current paper, we examine the effectiveness of a fixed ASEC system in Hong Kong to deter speeding. While Hong Kong employs a combination of human agent-based mobile speed enforcement mechanisms as well as a fixed ASEC system, the focus will be on a fixed ASEC system in this paper. In Hong Kong, the shares of speed enforcement prosecutions based on human agent-based mobile speed enforcement and a fixed ASEC system are about the same (Hong Kong Police Force, 2018). From time to time, strong public sentiment has been expressed to expand the ASEC system as a means not only to enhance the deterrent effect, but also to reduce the costs associated with police human resources. In this context, it become particularly imperative to evaluate the impacts of alternative designs for such an expanded ASEC system. While there may be benefits to supplementing an expanded automation-based ASEC speed enforcement mechanism with a much smaller base (relative to today) of human-based enforcement mechanisms, examining the possible optimal combination of investments in such fused mechanisms is not considered here. In any case, society has consistently moved closer to automation in traffic operations, and it is not inconceivable at all that there will be a time in the near future when no human-based resources (police personnel) will be invested on the task of field monitoring of speed for enforcement purposes.

Four main attributes associated with threat and coping appraisals related to an ASEC system are evaluated in the paper: DOP penalty, fine levels, camera-to-housing ratio (explained in detail later), and the placement of the warning sign. Among these four attributes, the first three may be considered to be associated with threat appraisal, while the last may be considered to be associated with coping appraisal (for instance, if a warning sign is placed farther away from the camera location, it may provide individuals with more time to absorb the information and act to adjust their speed to comply with the speed limit before arriving within the range of the camera detection zone). A stated preference experiment is conducted by developing scenarios that combine the attribute levels of the four attributes just identified. The scenarios are presented to professional drivers, who are asked to respond by choosing a speed level at which they would travel on a 50 km/h road at each of three sections of a roadway (corresponding to a standard section with no enforcement and no warning, a warning section that starts from 23 meters ahead of the placement of a warning sign, and the camera housing section itself in which a camera detects speeding violations).

Driver perceptions regarding speeding consequences and driving history (current level of DOP points, whether received a speeding ticket in the past 12 months, and exposure to ASEC systems when driving), as well as driver demographic characteristics and employment characteristics, are also collected in the survey. These variables are considered as direct influencers of travel speed as well as moderating the impact of the four main attributes of the SP experiment (to capture inter-individual differences in perceptions of threat appraisal and coping appraisal of speed enforcement, as well as overall intentions to speed or not and general attitudes toward the risks travel speeding poses to society). In doing so, we attempt to recognize the direct and moderating effects of driver characteristics on travel speed levels, and contribute further to the literature on the effectiveness of speeding enforcement mechanisms. Many earlier studies of enforcement mechanisms, on the other hand, have considered drivers as a single monolithic group or considered variations across drivers in a relatively limited manner. In addition, unlike many other earlier studies on professional driver speed decisions, we consider unobserved individual-specific heterogeneity to accommodate unobserved individual factors that are likely to influence speed choices. Such heterogeneity is important to consider in travel choice and safety studies to ensure consistent estimation of model parameters (see, for example, Mannering et al., 2016).

The remainder of this paper is structured as follows. Section 2 discusses the methodology used for data collection as well as for our analysis. Section 3 provides a description of the sample used in the analysis. Section 4 presents the results. Section 5 concludes the paper with a summary of the findings, policy implications, and future research directions.

2. METHODOLOGY

The data used in the current analysis is drawn from a face-to-face survey conducted during the period from October 2018 to February 2019 (months inclusive). Our emphasis on a face-to-face survey is to avoid respondent biases that may accrue from less expensive web-based and other social media-based surveys. The professional driver participants were approached either at on-road parking areas (e.g. public bus, taxi, and public light bus stations) or outside the licensing offices of the Hong Kong Transport Department. The inclusion criteria were (1) having valid licences of bus, minibus, taxi or goods (cargo) vehicles, and (2) driving for income, either full-time or part-time. Prior to the survey, the ethical approval from the Human Subjects Ethics Sub-committee (HSESC) of the Hong Kong Polytechnic University was obtained.

The questionnaire had three sections: (1) SP questions regarding speed choices, (2) Driving history and safety perceptions, and (3) Demographics and employment characteristics of professional drivers. The SP part is discussed in the next section. The second section collected information on the involvement with traffic offences and crashes, attitudes towards different speed enforcement measures, and actual experience with speed enforcement. The third section collected information on driver demographics (gender, age, education, marital status, and income) and employment characteristics (salary system, driving hours per day etc.)

2.1 SP design

In this study, drivers' perceptions and attitudes towards the deterrent effect of enforcement and penalty against speeding was gauged using their stated speed choices in an SP survey design. SP surveys have been widely applied to evaluate the effects of enforcement strategies and speeding penalties on the propensity for traffic offences by measuring the driver's response under hypothetically constructed conditions (Hössinger and Berger 2012; Li et al., 2016; Ryeng, 2012; Wong et al., 2008). The SP questions in the current paper are based on the scenario of driving on an urban road with a speed limit of 50km/h. For each question, three speed choices are presented to drivers for each of three location sections. The location sections are defined as follows: (1) a standard section, defined as one with neither ASEC-based speed enforcement and nor warning signs of such enforcement, (2) a warning section, defined as the road section indicating the presence of speed camera housing unit ahead (this section starts 23 meters ahead of the warning sign and ends at the location of warning sign; the design of the section length is based on the vision standard for the driver licensing requirement in Hong Kong), and (3) a camera section, defined as being within the range of speed violation detection by the camera (this section starts 23 meters ahead of a camera housing unit and ends at the location of the housing; see **Figure 1**). The three speed choices (one to be selected) are: (1) comply with the prescribed speed limit; (2) exceed the prescribed speed limit by 15 km/h or less (traveling at 51-65 kms./hour, corresponding to speeding range 1); and (3) exceed the prescribed speed limit by more than 15 km/h but less than or equal to 30 km/h (traveling at 66-80 kms./hour, corresponding to speeding range 2). Thus, for each SP question presented, the respondent makes a speed choice at each of the three location sections, providing three choices.

In each of the SP questions presented to respondents, four attributes are used to characterize the choice context: (1) Driving Offence Points (DOP) for different ranges of speeding infractions, (2) Monetary fines for different ranges of speeding infractions, (3) Camera-to-housing ratio, and (4) placement of the warning sign that determines the distance of the warning section. A screenshot of the content and format of a sample SP question is provided in **Figure 1**.

The levels of the first attribute - DOP – were set by pivoting off the current DOP for each of the two speed infraction ranges (of course, there are no DOPs for being within the speed limit). The current DOPs are zero for speeding range 1 and three for speeding range 2. We used these base DOPs and also introduced a higher DOP level of two for speeding range 1 and a DOP level of five for speeding range 2. Thus, for each speeding range, there are two possible DOP levels, and across the two speeding ranges, there are a total of four possible DOP levels.

The levels of the second attribute – monetary fine – were also set based on the current fine levels of 320 HKD (about US $40) for speeding range 1 and 450 HKD (about US $57) for speeding range 2. Again, we used these base fine levels, and also introduced increased levels of 420 HKD (about US $54) for speeding range 1 and 550 HKD (about US $ 70) for speeding range 2. Across the two speeding ranges, there are a total of four possible fine levels.

In Hong Kong, not all the camera housings necessarily contain a speed camera, to save on costs (both installation and operating costs). Thus, while Hong Kong laws require that citizens be informed of any camera locations, it is not required that all the announced camera locations necessarily have an actual functional camera. Dummy camera housing boxes are allowed to be installed. However, the ratio of actual speed cameras to camera housings must be publicized. The current ratio of speed camera-to-housing is 1:6. In particular, there are 20 speed cameras and 120 housings across the entire territory of Hong Kong (Audit Commission of HKSAR, 2013). Four levels of the third attribute -- camera-to-housing ratio -- are set out by either increasing the number of housings or increasing the number of cameras: 20:240, 20:120 (status quo), 40:120, and 60:120. An analysis of how Hong Kong professional drivers respond to different camera-to-housing levels can inform speed enforcement strategies considering the economic constraints of the transport authority.

Finally, four levels of the fourth attribute associated with the placement of the warning sign are considered: 50 meters, 100 meters, 150 meters, and 200 meters upstream of the speed camera housing (see **Figure 1**). Exploring the effect of the placement of the warning sign helps better understand alternative coping mechanisms, and can provide insights regarding the optimal placement of the warning sign that can minimize the "Kangaroo effect" associated with speed cameras.

<Figure 1>

All the levels for each of the attributes were tested extensively for reasonability in pilot surveys, and several changes were made before arriving at the final levels. In all, the SP experiments have four factors, each with four levels. If the full factorial design were considered, there would be 256 ($4 \times 4 \times 4 \times 4$) combinations of factor attributes in total for the SP question. It is however not efficient and feasible to gauge the drivers' perceptions and attitudes if all the 256 combinations of scenarios are used. Therefore, an orthogonal fractional factorial design (Bhat and Sardesai, 2006; Hössinger and Berger, 2012; Lavieri and Bhat, 2019; Li et al., 2014) was adopted to reduce the number of combinations from 256 to 16. Further, our design enabled us to estimate models that are more general than the multinomial logit model by maintaining factor orthogonality within and between alternatives. Our design allowed for the estimation of main effects of attributes, as well as two-way interaction effects between attributes and respondent characteristics. Next, we developed a block design of four sets of four SP scenarios, because it would be too much burden to ask each respondent to answer 16 SP questions. Each participant was then presented with one of the four blocks of four SP scenarios in the survey. The entire survey instrument is available at http://www.baige.me/v?i=RxE.

2.2. Econometric modeling framework

In this paper, we formulate a panel mixed multinomial logit (or MMNL) model for the speed choice of professional drivers. The panel MMNL model formulation accommodates heterogeneity across individuals due to both observed and unobserved individual attributes, while also recognizing correlations among the different observations of a same individual. In the following discussion of the model structure, we will use the index q ($q = 1, 2, \ldots, Q$) for the decision-makers, i for the speed alternative ($i = 1, 2, \ldots, I$) and k for the choice occasion, *i.e.* SP choice occasions for a particular decision-maker, ($k = 1, 2, \ldots, K$). In the current study $I = 3$ (as indicated earlier, the choice alternatives are speed compliance, or speeding range 1, or speeding range 2) and $K = 4*3 = 12$ for all q. Within each of the four SP attribute scenarios presented, the respondents were asked to state their speed range choice in three different sections – standard, warning, and camera housing sections.

In the usual tradition of utility maximizing models of choice, we write the utility or valuation U_{qik} that an individual q associates with the alternative i (speed range) on choice occasion k as follows:

$$U_{qik} = (\beta' + \nu'_q)\ x_{qik} + \varepsilon_{qik}\,, \qquad (1)$$

where x_{qik} is a $(M \times 1)$-column vector affecting the valuation of individual *q* for alternative *i* at the k^{th} choice occasion, and that includes the following: (1) choice-occasion specific attributes (that is, the four attributes varied in the SP experiments), (2) alternative-specific constants for speeding ranges 1 and 2 (with no speeding being the base category), (3) individual-specific attributes (driving history and perception, driver demographics and employment characteristics), and (4) interactions within each of the choice-specific and individual-specific variables, as well as across the two sets of variables. β is a corresponding $(M \times 1)$-column vector of the mean effects of the coefficients of x_{qik} on speeding range valuations, and v_q is another $(M \times 1)$-column vector with its m^{th} element representing unobserved factors specific to individual *q* that moderate the influence of the corresponding m^{th} element of the vector x_{qik}. A natural assumption is to consider the elements of the v_q vector to be independent realizations from a normal population distribution; $v_{qm} \sim N(0, \sigma_m^2)$. ε_{qik} represents a choice-occasion specific idiosyncratic random error term assumed to be identically and independently standard Gumbel distributed. ε_{qik} is assumed to be independent of x_{qk}.

For a given value of the vector v_q, the probability that individual *q* will choose speed range *i* at the k^{th} choice occasion can be written in the usual multinomial logit form (McFadden, 1978):

$$P_{qik} \mid v_q = \frac{e^{\beta' x_{qik} + v_q' x_{qik}}}{\sum_{j=1}^{I} e^{\beta' x_{qjk} + v_q' x_{qjk}}} \tag{2}$$

The unconditional probability can then be computed as:

$$P_{qik} = \int_{v_q} (P_{qik} \mid v_q) d\boldsymbol{F}(v_q \mid \sigma) \tag{3}$$

where ***F*** is the multivariate cumulative normal distribution and σ is a vector that stacks up the σ_m elements across all *m*. The reader will note that the dimensionality in the integration above is dependent on the number of elements in the v_q vector.

The parameters to be estimated in the model of Equation (3) are the *β* and *σ* vectors. To develop the likelihood function for parameter estimation, we need the probability of each individual's sequence of observed SP choices. Conditional on v_q, the likelihood function for individual *q*'s observed sequence of choices is:

$$L_q(\beta \mid v_q) = \prod_{k=1}^{K} \left[\prod_{i=1}^{I} \{P_{qik} \mid v_q\}^{\delta_{qik}} \right], \tag{4}$$

where δ_{qik} is a dummy variable taking the value of 1 if the q^{th} individual chooses the i^{th} speed range in the k^{th} occasion, and 0 otherwise. The unconditional likelihood function for individual *q*'s observed set of choices is:

$$L_q(\beta,\sigma) = \int_{v_q} L_q(\beta \mid v_q) dF(v_q \mid \sigma) \tag{5}$$

The log-likelihood function is $L(\beta,\sigma) = \Sigma_q \ln L_q(\beta,\sigma)$. We apply quasi-Monte Carlo simulation techniques to approximate the integrals in the likelihood function and maximize the logarithm of the resulting simulated likelihood function across all individuals with respect to the parameters *β* and *σ*. Under rather weak regularity conditions, the maximum (log) simulated likelihood (MSL) estimator is consistent, asymptotically efficient, and asymptotically normal (see Hajivassiliou and Ruud, 1994; Lee and Carter, 1992; McFadden and Train, 2000).

In the current paper, we use Halton sequences to draw realizations for v_q from its assumed normal distribution. Details of the Halton sequence and the procedure to generate this sequence are available in Bhat (2001, 2003).

3. DATA AND SAMPLE USED

A total of 401 professional drivers completed the questionnaire survey. Therefore, the dataset has a total of 401x12=4,812 SP choice occasions, with 1604 choice occasions at each of the three location sections (standard, warning, and camera). The distribution of the dependent variable was as follows within the 1604 choice occasions, as also shown in **Table 1**: (1) Standard section – Not speeding (14.1%), Speeding Range 1 (71.2%), and Speeding Range 2

(14.7%), (2) Warning section – Not speeding (57.2%), Speeding Range 1 (40.0%), and Speeding Range 2 (2.8%), (3) Camera housing section – Not speeding (99.8%), Speeding Range 1 (0.2%), and Speeding Range 2 (0%). As can be observed from these descriptive statistics, drivers combine their threat and coping appraisals due to which a large proportion of them are generally willing to speed at the standard section (at least at speed range 1), but are more likely to adhere to the speed limit at the camera housing section. Indeed, there is literally no variation in adherence at the camera housing section regardless of the levels of DOP, monetary fine, camera-to-housing ratio, warning sign placement, as well as driver characteristics. Thus, we drop the 1604 choice occasion observations corresponding to the camera housing section in our analysis, because they do not contribute to understanding the effects of independent variables on speeding ranges. The final sample for analysis includes the 3208 choice occasions at the standard and warning sections.

<Table1>

Table 2 shows cross-tabulations of the four SP attributes with speed choice percentages at each of the standard and warning sections. As expected, increasing the DOP penalty by two points decreased the percentage of drivers choosing for speeding range 1 and speeding range 2 in the standard section. Further, increasing the DOP penalty by two points for both speeding levels led to a greater percentage of drivers complying with speed limit. The descriptive statistics do not show a clear trend of the speed choices with respect to increasing monetary fines. Interestingly, in the standard section, it seems that a greater proportion of drivers choose to speed when the fine is increased. More discussion on this will follow in the model results section. In the context of camera-to-housing ratio values, an increase in the ratio from status quo (20:120) to 40:120 shows a greater decrease in the percentage of drivers choosing speed ranges 1 or 2 than that from increasing the ratio further to 60:120. It appears that the bang per buck is greater for increasing the ratio from 20:120 to 40:120 than that to 60:120. As for the placement of warning sign, there is a monotonous trend of increasing percentage of speed

compliance choice with decreasing distance between the warning sign and the camera housing location.

Of course, the discussion above does not consider differential effects of the SP attributes based on observed and unobserved driver characteristics, which is the focus of the multivariate model results in Section 4.

<Table 2>

3.2. Driver demographics and employment characteristics

Table 3 presents the demographic and other characteristics of the 401 participants, beginning with the demographic characteristics in the first set of rows. All participants of this study are male. This is consistent with the distribution of employed persons by occupation and gender in the population census dataset, which indicates that 97% of workers in the machine operation sector are male (Census and Statistic Department, 2018a). Although the information on the official registry of professional drivers in Hong Kong is not available, male drivers are believed to dominate the transport sector. The age distribution of our sample is close to that of the driving licensing record of general drivers in Hong Kong (Transport Department, 2017). In terms of educational background, 79% of the drivers in our sample have attained at least secondary education (the closest possible comparison at the Hong Kong-wide level is that 89% of male workers in Hong Kong have attained secondary education (Census and Statistic Department, 2018b). In our sample, 73% of the drivers were married (the closest possible comparison is the most updated marital status statistics in Hong Kong, which indicates that 62% of the males are married (Census and Statistic Department, 2018c). Interestingly, almost all (395 of the 401) drivers provided their monthly income values. For the remaining six drivers who did not provide this information, we imputed the income values based on the procedure discussed in Bhat (1997). A little over 31% of the drivers have a monthly income below HK$ 15,000 and a little over 21% of the sample earn over HK$ 20,000.

Drivers' employment characteristics are presented in the next set of rows in the table. The salary system of professional drivers is stratified into three categories: (i) trip-based (34% of the sample), (ii) monthly-based (31%), and (iii) others (hourly or shift based, 35%). The trip-based drivers are self-employed, and their incomes vary greatly with the number and distance of trips made (e.g. taxi, red minibus and light van drivers). The drivers who are paid on a monthly basis are usually regular employees of a large corporation or transport operator, such as the franchised bus companies and logistic firms. The hourly or shift based drivers are usually (full-time or part-time) employees of small transport operators, such as the green minibus. Their salaries vary greatly with the daily working time. As for the daily driving hours, 8% of our sample drive for less than or equal to 7 hours per day while 42% of them drive for more than 9 hours daily. The corresponding statistic from official reports is not accessible. The closest possible comparison is that 51% of bus drivers in Hong Kong drive for more than 9 hours daily (Legislative Council of HKSAR, 2018). In terms of weekly working hours, 46% of drivers in our sample work for 48 hours or less per week, which is comparable to the 50% of employees in the transport sector who work for less than or equal to 48 hours a week. However, only 9% of our sample work for more than or equal to 63 hours per week, while the corresponding percentage in the transport sector is close to 25% (Census and Statistic Department, 2018b). The commercial vehicles driven by our sample are categorized into four types – bus, green minibus, taxi and red minibus, and goods vehicles (accounting for 17%, 14%, 39%, and 30% of the sample respectively). The official distribution for the vehicle types of the commercial vehicle fleet in Hong Kong is not accessible.

Overall, the characteristics of drivers in the sample are reasonably close to general expectations for Hong Kong professional drivers, at least based on the latest statistics gleaned from the Census. Of course, one cannot be conclusive of the true representativeness of our sample because there is no official registry of professional drivers in Hong Kong, and the closest comparison we are able to make is with the population census demographics for people employed in the transport sector.

3.3. Driver history and safety perceptions

The last set of rows in **Table 3** report the descriptive statistics for driving history and safety perceptions of the 401 participants, which might influence how they would respond to the SP choice questions. As can be observed from these rows, 25% of the interviewed professional drivers have received at least one speeding ticket in the recent past. 70% of the drivers perceived speeding as a cause of injury while only 1.5% perceived a small effect of speeding on traffic injuries. As for the perception on effectiveness of cameras, 67% of drivers believed that speeding cameras are effective in catching offenders, while a smaller percentage (6%) perceived low effectiveness of this enforcement technique. The frequency of drivers sighting camera housings was also collected in terms of the number of times a driver would sight camera housings in 10 trips. It appears that a majority (62%) of the drivers do usually visually locate camera housings at a frequency of at least 7 times in 10 trips.

All the above driver history and perception variables are likely to influence drivers' responses to the SP choice questions. Also, while we make no claim of our sample being representative of the population of professional drivers, there is no reason to believe that the individual-level relationship we develop between speed range choices and SP attributes/driver characteristics would not be applicable for the general population of professional drivers.

4. RESULTS AND DISCUSSION

Table 4 presents the results of a panel mixed multinomial logit model estimated on the afore-mentioned 3,208 observations – 1604 for the standard section and 1604 for the warning section[1] – with normal distributed random coefficients[2]. The dependent variable is speed choice (i.e.

[1] Recall from the descriptive analysis of the SP choice data for the camera housing section that only a single alternative (speed compliance) was chosen 99.8% of the times. So, these data were not included in the model as the speed choice is deterministic in the camera housing section. This observation is consistent with the findings of previous studies that drivers would slow down when they notice or are warned of cameras (De Pauw et al., 2014a; De Pauw et al., 2014b; Elvik, 1997; Marciano and Norman, 2015).

[2] We also explored alternative distributional assumptions such as log-normal for the random coefficients, but the model with normal distribution provided the best fit. Besides, other distributions did not offer substantive interpretations that were very different from the model with normal distributions.

speed compliance, speeding range 1, or speeding range 2; with speed compliance considered as the base alternative). For each independent variable, a common coefficient was estimated for both standard and warning sections as well as a difference coefficient was introduced to account for the differential effect of that variable on the warning section compared to the standard section. In Table 4, the parameter estimates reported under the "Standard section" column are that of the common coefficients, which may also be interpreted as coefficients for the standard section. The parameter estimates under the "Difference between Warning and Standard section" column are the difference coefficients. For a given variable, a sum of its common coefficient and the difference coefficient would give its coefficient for the warning section. The parameter estimates are interpreted and discussed next in **Sections 4.1-4.4**. The coefficients on the constants indicate a general aversion to speeding, especially at level 2, at both the standard and warning sections. This aversion is typically higher in the warning section than in the standard section, though there is unobserved heterogeneity (captured by the significant standard deviation estimates on the constants) in these general trends (the panel nature of the data allows us to estimate the standard deviations on the constants in the table).

An important note is in order here. All results in this paper pertain to the influence of variables on the reported speed choices in our stated experiments, not actual speed choices in the real world. But, for presentation ease and tightness, we do not belabor over this distinction in the rest of this paper and use the general word "speeding". However, all our statements should be viewed in the context of stated speed choices, not actual speed choices.

< Table 4>

4.1 Effects of penalty level and enforcement strategy

Among the SP attributes for penalty and enforcement, the DOP variable shows a statistically significant deterrence on speeding in both standard and warning sections, with higher deterrence in the warning section than in the standard section. Professional drivers are indeed, generically speaking, sensitive to the increase in DOPs since incurring DOPs may lead to disqualification of driving license, which is the source of their livelihood (Wong et al., 2008). However, there is significant heterogeneity in the influence of the DOP variable both due to observed and unobserved factors. Specifically, drivers who were recently issued a ticket are more likely than their peers to be deterred by DOPs when traveling in the warning section. Considerable unobserved heterogeneity also exists in the influence of DOPs on drivers' speeding choices in both standard and warning sections. Interestingly, the standard deviation of the DOP coefficient in the warning section is higher than in the standard section, implying that the deterrent effect of an increased DOP penalty tends to be more diverse in the warning section despite its greater deterrent effect on average. This finding could be attributed to the heterogeneity in driver's threat and coping appraisals of the warning messages (Kergoat et al., 2017), as well as the effects of drivers' characteristics on the comprehension of traffic signs (Ng and Chan, 2008). For example, different drivers may perceive the self-efficacy of avoiding the speeding penalty differently when forewarned about camera enforcement. Thus, some drivers may actually initially increase their speeds as soon as they encounter the warning section (to compensate for the fact that they have to reduce speeds at the downstream camera section) because they feel confident in their ability (self-efficacy) to estimate where the camera section will begin and in their ability to decelerate at the right time to avoid speeding penalties in the camera section. Other drivers may immediately reduce their speed upon encountering the warning section because they feel less confident in their ability to take evasive speed reduction actions later downstream to avoid penalties in the camera section. Such variations in self-efficacy are likely to get magnified as the DOP penalty increases in the camera section, leading to the higher speed variance in the warning section as the DOP penalty increases.

Unlike the deterrent effect of DOPs, the monetary fines variable turned out to have a marginally positive coefficient in the standard section suggesting an increase in the propensity for speeding with an increase in fines. While this may be a coping mechanism to "make up" time in the standard section in anticipation of lost time due to adherence to speed limits in the warning section, we noted that this effect had a strong interaction with the length of the warning section. Thus, we chose to drop this variable and include the length of the warning section as the primary determinant variable in our model (more on this warning section length effect later). In the warning section itself, monetary fines are associated with a negative coefficient for a majority of the sample (obtained from the mean and standard deviation of the corresponding random coefficient), suggesting a deterrent effect of monetary fine when it is combined with a warning of speed enforcement ahead for a majority of the drivers. Furthermore, there is heterogeneity in response to fines in the warning section based on driver characteristics. Specifically, in warning sections, monetary fines have a larger deterrent effect (in the context of speeding) for drivers who are paid on a per-trip basis and those with a recent speeding ticket relative to other drivers. These results are again an illustration of the interplay between drivers' threat and coping appraisal mechanisms, where drivers respond to the threat of a monetary fine when they are made aware of the cameras that will increase the likelihood of them being fined. And such interplay appears to vary across drivers based on both observed and unobserved factors.

In the context of camera-based enforcement strategy, reducing the camera-to-housing ratio from the status quo (i.e., from 20:120 to 20:240 camera-to-housing ratio) did not show a statistically significant effect on the drivers' stated speeding choices. However, drivers were less likely to opt for severe speeding (range 2) in both the standard and warning sections when the camera to housing ratio was increased from the status quo. This is presumably because an increase in the number of camera installations would result in an increased "threat" of being apprehended for speed limit violations. Interestingly, the standard deviation associated with the coefficient of a minor increase in camera-to-housing variable suggests that a small fraction (9%) of the drivers tend to choose speeding with an increase in camera-to-housing. This result may be attributed to the risk-taking behaviors of such individuals as well as heterogeneity in perceiving a threat of apprehension due to a minor increase in the number of cameras. However, with a major increase in the camera-to-housing ratio, this risk-taking behavior reduces, perhaps due to a greater perception of the threat of apprehension.

The placement of the warning sign – that is, the distance of the warning sign from the camera housing location – exhibits an influence on speeding in the warning section. Specifically, reducing the distance between the warning sign and the housing unit leads to lower speeding tendencies (for both speeding ranges). This is intuitive as individuals may want to start slowing down (or at least not speed) to avoid sudden decelerations just before arriving at the camera housing. In fact, the presence of a warning sign (upstream of a fixed speed camera) has been found to be associated with reductions in mean driving speed and proportion of more severe speeding (Retting et al., 2008; Høye, 2014). Kergoat et al. (2017) postulated that the distance between warning sign and speed camera should be increased to weaken the "Kangaroo effect". However, the parameter estimates for speeding range 2 suggest a heightened increase in the propensity to choose that speeding range when the warning sign is installed 150m or 200m upstream of a camera housing. That is, our results suggest that the deterrent effect of a warning sign could in fact be diminished when the distance between the warning sign and the housing unit increases excessively. That is, as drivers learn that the warning signs are placed farther away from the housing, they speed up because they know they have a larger cushion to decelerate and they also want to make up some time in anticipation of slowing down closer to the actual camera housing location. Basically, as warning signs are placed farther away from the camera housing, professional drivers start to view the early part of the warning section as a "standard" section. This indicates a need for optimal placement of warning sign that can tradeoff between the "Kangaroo effect" and effectiveness of the warning sign in deterring speeding behavior.

4.2 Effects of demographic characteristics of professional drivers

Driver age does not have a strong association with speeding behavior in the standard section. This could be because all professional drivers, regardless of age, tend to be more aggressive when there is no speed enforcement and no warning (Öz et al., 2010a, Wong et al., 2008). In contrast, in the warning section, older drivers are less likely to speed up to range 1 and younger drivers are more likely to speed up to range 2. These results suggest that the likelihood of speeding offences decreases with driver age, perhaps because older drivers tend to be more cautious (Ram and Chand, 2016; Rosenbloom and Shahar, 2007) but younger people are more likely to be sensation- and thrill-seeking (Delhomme et al., 2012; Fernandes et al., 2010; Tseng, 2013). In the context of education background, individuals with up to primary level education are more likely to speed up to range 1 in both standard and warning sections. Previous studies also suggest that professional drivers with higher education attainment are less likely to commit traffic offences (Mallia et al., 2015; Mehdizadeh et al., 2018; Tronsmoen, 2010). Married drivers (relative to those who are single) are less likely to speed in both the standard and warning sections (see Mehdizadeh et al., 2018 and Wong et al., 2008 for similar findings), perhaps because married individuals, due to their familial responsibilities, tend to be more responsible in driving than single individuals.

Individuals with high monthly income (>20K), *ceteris paribus*, are more likely than others to choose to violate speed limits in warning sections. This is perhaps because they can afford to pay the fines. Also, recall from earlier discussion that the maximum fine of HK$550 for speeding range 2 is a rather small percentage of HK$ 20K per month. In contrast, the maximum monetary fine for speeding can reach 50% of average monthly incomes of taxi drivers in the United States (United States Department of labor, 2018) and 35% in the United Kingdom (Sentencing Council, 2017), respectively. In road safety research, deterrence theory is widely used to investigate driver's perception of the sanctions (in terms of severity, certainty and celerity) for traffic offences (Kergoat et al., 2017; Li et al., 2014; Tay, 2005a, 2005b, 2005c, 2009). It is based on the idea that people avoid committing a crime due to the threat and fear of being legally punished, which also involves an evaluation of the costs and benefits of the crime (Gibbs, 1985). In this sense, the ratio of the cost (monetary fine) to the benefits (possible income) of speeding offence is indeed quite low in Hong Kong.

4.3 Effects of operational characteristics of professional drivers

As discussed earlier, drivers who earn on a per-trip basis (i.e., trip-based salary) are more likely to be deterred by monetary fines in the context of speeding in warning sections. Regardless of the level of monetary fines, the coefficients of the trip-based salary dummy variable suggest that such drivers are more likely than others to commit speeding offences in both the standard and warning sections. Since their earnings depend on the number and distance of the trips made, trip-based salaried drivers have a higher incentive to speed up to arrive at the destination quickly. In Hong Kong, trip-based drivers (these are typically drivers of taxis, light vans, red minibuses etc.) are generally self-employed and are not well-regulated (Meng et al., 2017; Wong et al., 2008). In contrast, the monthly-salaried drivers are typically regular employees of large transport operators and logistics firms with good safety culture and driver management systems (Newnam et al., 2004; Öz et al., 2010b, 2013) including GPS-based tracking of vehicle speeds. These factors also have a bearing on the salary system-based differences in speeding choices.

Individuals who drive for more than nine hours per day have a lower inclination than others to violate speed limits. This could be attributed to the possible driver fatigue caused by a prolonged driving time. Drivers may adopt a compensation strategy by reducing their speed to lower their risk of fatigue-related crashes (Williamson et al., 2002). In contrast, individuals who drive for less than eight hours per day are associated with a greater likelihood (than others) of violating speed limits in the warning section. This finding will need further investigation to assess its robustness.

In the context of vehicle type, drivers of all types of vehicles other than buses have a higher tendency of speeding up in both standard and warning sections, albeit they are relatively less likely to speed up in warning sections than in standard sections. Indeed, minibus drivers and taxi drivers in Hong Kong have been recognized as problematic and risk-taking groups (Meng et al., 2017; Wong et al., 2008). On the other hand, goods vehicle drivers are paid to drive for the transport of goods while bus drivers are to drive for the transport of passengers. A greater sense of social responsibility on bus drivers might make them less aggressive (at least in a stated preference setting) than the drivers of other types of vehicles (Paleti et al., 2010).

4.4 Driver history and safety perceptions

Driving history and safety perceptions have a substantial influence on the participants' stated speed choices. For instance, drivers who recently received a traffic ticket are associated with a greater likelihood of speeding in both standard and warning sections (albeit the tendency for speeding range 2 is lower in warning sections than that in standard sections). Further, as discussed earlier in the context of interaction between this variable with the SP attributes, increasing fines or DOP appears to reduce the speeding tendency of these drivers in warning sections. However, even at the highest level of fine and DOP values presented in the SP experiment, these drivers show a higher tendency (than others without recent tickets) to violate speed limits. These results suggest that risk-taking behavior and aggressive driving styles of these drivers overshadow any deterrent effect from receiving a speeding ticket (Sagberg and Ingebrigtsen, 2018). It appears that simply imposing fines or DOPs might not suffice to reduce the aggressive driving traits of such drivers. This result suggests a need for additional investigations to assess the effectiveness of combining DOPs and fines with driver training programs aimed to reduce risk-taking and aggressive driving traits.

Individuals who perceive that speeding does not cause injuries have a higher tendency of opting for speed range 2 in both standard and warning sections. This aligns with the previous findings that drivers with lower risk perception tend to be associated with aggressive driving behaviors (Cestac et al., 2011; Rosenbloom, 2003). In addition, drivers who perceive that cameras are highly effective in catching offenders are associated with a lower tendency of speeding in speed range 2 in the warning section, while their disposition for speed range 1 is not statistically different from compliance. Individuals who sight speed enforcement camera housings more frequently (in at least 7 out of 10 trips) have a lower tendency of speeding in range 2 (in both standard and warning sections). This could be attributed to the perceived higher level of enforcement, which may contribute to the decrease in driver's speeding intention (Blincoe et al., 2006; Hössinger and Berger, 2012) at least in the high-speed range.

4.5 Marginal effects due to changes in SP attributes

The model was applied to estimate marginal effects on market shares (of speed choice) in response to changes in the SP attributes. As shown in **Table 5**, the marginal effects were computed for both the standard and warning sections. According to these results, an increase in the DOP by 1 point resulted in greater than 4% increase in compliance in both the sections. In the context of monetary fines, a 10% increase resulted in only a 1.73% increase in compliance. Such a low marginal effect is consistent with the discussion of model estimation results that monetary fines alone might not significantly deter professional drivers from speed violations. Note that the percentage reduction in the share of drivers who would opt for speeding range 2 is high (13.02%). However, such a high percentage reduction is an artifact of a rather small proportion of drivers choosing this option in the base case.

Increasing camera-to-housing ratio from the status quo (20:120) to 40:120 shows a considerable (at least 29%) decrease in the share of drivers choosing speed range 2. However, the decrease is not substantial when the ratio is increased to 60:120. This suggests that the marginal benefit from increasing the camera-to-housing ratio beyond 40:120 might not be substantial. Furthermore, since the proportion of drivers choosing speed range 2 is itself very small (1%), even a 32% decrease in this share due to increasing the ratio to 60:120 does not appear to hold practical effectiveness.

In the context of the placement of warning sign, increase in the distance between the warning sign from 100m is associated with a substantial increase in the proportion of drivers choosing to speed in the warning section. Even if we neglect these increases for speed range 2 (due to a rather small base market share for this alternative), the increases in the proportion of people choosing speed range 1 is substantial when the distance is increased. These results suggest the need for an optimal placement of warning sign that can tradeoff between the "Kangaroo effect" and effectiveness of the warning sign in deterring speeding behavior.

<Table5>

5. CONCLUSION

This study applied a stated preference survey and a panel mixed logit model to evaluate the deterrent effects of penalty and enforcement strategies – DOP penalty, monetary fines, and speed enforcement cameras along with a warning of such enforcement – on the propensity and severity of speeding among professional drivers. In doing so, the study controlled for the effects of driver demographics and operational characteristics as well as driver history and safety perceptions. As importantly, observed and unobserved heterogeneity were incorporated in drivers' responses to penalty and enforcement strategies. A panel mixed logit model is estimated and applied to understand the effectiveness of penalties and enforcement strategies on driver's speeding behaviors.

The results indicate that an increase in DOP penalty is more effective as a deterrent against speeding than increasing monetary fines. This could be attributed to the higher sensitivity of professional drivers to the increase in DOPs since incurring more DOPs may lead to disqualification of the driving licence. Monetary fines were not found to be very effective, perhaps because the monetary fine levels were very low relative to the income levels of the drivers. It remains to be explored if increasing the quantity of fines combined with appropriate warning messages (such as "Check speed—fines up to $1000") can help increase the effectiveness of monetary fines. Significant heterogeneity was found in the influence of the DOP variable both due to observed and unobserved factors. Specifically, while increasing DOP deters all drivers from speeding, doing so when combined with a warning (i.e., in the warning sections) appears to more strongly deter those who recently received a speeding ticket than others. However, the unobserved variation in the warning section is greater than that in the standard section, perhaps because of differences in drivers' threat and coping appraisals of the warning messages, as discussed in section 4.1.

In the context of camera-based enforcement strategy, increasing the ratio from status quo (20:120) to 40:120 showed a considerable effect (29%) on reducing the percentage of drivers opting for severe speeding, albeit it should be noted that the base percentage of drivers in this category is only 1%. Increasing it further to 60:120 did not show a substantial effect in the policy simulations we conducted. Further, reducing the ratio from the status quo (20:120) to 20:240 did not show a significant effect on the drivers' stated speeding choices.

The placement of the warning sign – that is, the distance of the warning sign from the camera housing location – exhibits an influence on speeding behaviors in the warning section. Placing it close to the camera housing location decreases the likelihood of speeding but can potentially increase the “kangaroo” effect. And placing it too far from the camera location would substantially increase the percentage of speeding behaviors. These findings suggest a need for the optimal location of warning signs. Alternatively, information on the penalty level can be added to the warning signs to increase the threat appraisal of the driver for reducing speeding behaviors in warning sections.

The demographic characteristics of drivers such as age, education, income have an influence on how drivers respond to strategies aimed at increasing speed compliance. Similarly, the drivers’ operational characteristics, driving history and perceptions have a substantial bearing on the efficacy of speed compliance strategies. Therefore, targeted driver educational and training campaigns might help increase the speed compliance rates in the population. For example, drivers with a recent history of traffic tickets continue to demonstrate a greater tendency for speeding even for high levels of DOP and monetary fines. It appears that simply imposing fines or DOPs might not suffice to reduce the aggressive driving traits of such drivers. A combination of DOPs and fines with driver training programs aimed at addressing risk-taking and aggressive driving traits may be needed to increase safe driving tendencies among these drivers. Further, higher penalties may be considered for repeat offenders to enhance the deterrent effect of the penalties (Watson et al., 2015). Similar penalty strategies have been applied for repeat offenders of drink driving in Hong Kong (Li et al., 2014).

Speeding and other traffic offences may be attributed to drivers’ goals of travel time saving and revenue maximization (Cestac et al., 2011; Peer, 2010; Tarko, 2009), while safe driving performance and social responsibility may be lower in the hierarchy of professional drivers’ goals (Hatakka et al., 2002). Therefore, inclusion of positive motives and goals in the education/training and licensing of professional drivers may be beneficial. In addition, technology-based interventions, such as GPS-based automated speed surveillance and related automated speed enforcement mechanisms, may aid in reducing speeding behaviors.

The results from this study help enhance the current understanding and effectiveness of penalties and speed-enforcement strategies (i.e. penalties, warning signs, camera housings, etc.). Yet, this study is limited to the assessment of a few demographics and operational characteristics of professional drivers. It would be worth exploring the possible effects of latent characteristics on speeding propensity and severity, when more comprehensive information on the physiological and psychological metrics of the participants is available. Moreover, results of this questionnaire survey are derived from a scenario of a typical city road with a speed limit of 50km/h. It would be interesting to explore the effect of other road environments, such as an expressway with a speed limit of 70 km/h or higher, on the speeding behavior of professional drivers. Further, it would be helpful to undertake a study that evaluates the effectiveness of combining speeding penalties with driver education/training campaigns in reducing risk-taking and aggressive driving. Also, the separation between the placement of a warning sign and the camera housing unit was expressed as a distance in the current study. Perhaps a time separation rather than a space separation would be a better approach to capture how individuals respond to warning signs before entering monitored roadway section. Yet another line of research would be to investigate whether fixed ASEC systems, when complemented with a small human police force, would have a higher impact in reducing speeding than a fixed ASEC system alone. And, if so, what may be the optimal combination of investment in human-based and machine-based enforcement mechanisms. Perhaps most importantly, all the results and recommendations in this paper are based on self-reported speed indications within stated experiments, which clearly can influence the reliability and accuracy of the relationships estimated. A study based on an actual field experimental design and field observations of speed at different sections would be more credible.

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TABLES AND FIGURES

Table 1 Distribution of speed choices by location type

Section	**Speed choice**					
	Speed compliance (≤50 km/h)		**Speeding range 1 (51-65 km/h)**		**Speeding range 2 (66-80 km/h)**	
	Count	*%*	*Count*	*%*	*Count*	*%*
Standard	226	14.1	1142	71.2	236	14.7
Warning	918	57.2	641	40.0	45	2.8
Camera Housing	1600	99.8	4	0.2	0	0

Table 2. Crosstabulation of SP attributes with speed choices at plain and warning sections

Factor	**SP attribute level for different speeds (<50kmph, 51-65kmph, 66-80kmph)**			**Speed choice %**					
				Standard section			**Warning section**		
				Speed compliance	**Speeding range 1**	**Speeding range 2**	**Speed compliance**	**Speeding range 1**	**Speeding range 2**
	≤50	**51-65**	**66-80 km/h**						
DOPs	0 **(status quo)**	0	3	13.2%	69.6%	17.2%	54.6%	2.6%	2.8%
	0	0	5	12.0%	73.6%	14.4%	52.5%	3.8%	3.7%
	0	2	3	13.2%	68.6%	18.2%	53.7%	4.3%	2.0%
	0	2	5	15.5%	73.1%	11.4%	68.1%	9.2%	2.7%
Monetary fine (HK$)	0 **(status quo)**	320	450	11.8%	73.3%	14.9%	54.8%	1.3%	3.9%
	0	320	550	15.2%	64.6%	20.2%	57.4%	9.9%	2.7%
	0	420	450	14.5%	78.6%	6.9%	59.9%	8.7%	1.4%
	0	420	550	15.0%	67.3%	17.7%	56.9%	0.1%	3.0%
Camera-to-Housing ratio	20:240			12.7%	71.8%	15.5%	57.9%	8.7%	3.4%
	20: 120 **(status quo)**			13.5%	67.3%	19.2%	55.6%	0.1%	4.3%
	40:120			13.7%	72.6%	13.7%	58.4%	8.7%	2.9%
	60:120			16.2%	72.1%	11.7%	56.1%	2.4%	1.5%
Placement of warning sign	50m upstream			--	--	--	77.8%	2.2%	0%
	100m upstream			--	--	--	65.3%	1.2%	3.5%
	150 m upstream			--	--	--	43.1%	3.9%	3%
	200m upstream			--	--	--	42.6%	1.6%	5.8%

Table 3 Distribution of the sample

Variable	Count	%
Demographics		
Gender (Male)	401	100%
Age		
Older (>55 years old)	98	24.4
Younger (<45 years old)	151	37.7
Mid-aged (46-55 years old)	152	37.9
Education		
Primary or below	84	20.9
Secondary or above	317	79.1
Marital status		
Married	293	73.1
Unmarried	108	26.9
Monthly income		
less than 15K	127	31.7
Between 15K and 20K	183	45.6
More than 20K	85	21.2
Operational characteristics		
Salary system		
Trip-based	136	33.9
Monthly-based	126	31.4
Others (hourly or shift based)	139	34.7
Daily driving hours		
More than 9 hours	168	41.9
Less than 8 hours	39	9.7
8 to 9 hours (normal working hours)	194	48.4
Work time per week		
less than or equal to 48 hours	184	45.9
more than or equal to 63 hours	37	9.2
Others	179	44.9
Vehicle type		
Bus	67	16.7
Taxi and Red Minibus	157	39.2
Green minibus	56	14.0
Goods vehicle	121	30.2
Driver history and safety perceptions		
Received speeding ticket(s)		
Yes	99	24.7
No	302	75.3
Perceive speeding as a cause of injury		
High	281	70.1
Low	6	1.5
Neutral	114	28.4
Perceive speeding cameras are effective		
High	270	67.3
Low	24	6.0

Neutral	107	26.7
Frequency of sighting cameras		
High (7-10 times in 10 trips)	250	62.3
Medium (4-6 times in 10 trips)	98	24.4
Low (0-3 times in 10 trips)	53	13.3

Table 4 Parameter estimates of a panel MMNL model for the speed choice of professional drivers*

			Standard section			Difference between warning and standard sections	
les			**Speed compliance**	**Speed range 1**	**Speed range 2**	**Speed range 1**	**Speed range 2**
		Mean	0 (Fixed)	-1.35 (-2.52)	-10.14 (-1.77)	-5.59 (-3.71)	-13.16 (-4.64)
		SD	3.82 (10.73)	1.24 (2.46)	7.55 (6.5)	1.41 (1.67)	1.91 (2.18)
SP) attributes							
		Mean		-0.17 (-1.96)	-0.17 (-1.96)	-0.48 (-1.80)	-0.48 (-1.80)
		SD		0.15 (1.82)	0.15 (1.82)	1.19 (5.20)	1.19 (5.20)
vith recent speeding ticket				IS	IS	-0.17 (-2.17)	-0.17 (-2.17)
)		Mean		Dropped	Dropped	-0.11 (-1.76)	-0.11 (-1.76)
		SD		-	-	0.14 (2.13)	0.14 (2.13)
0) x drivers with trip-based salary				IS	IS	-0.13 (-2.43)	-0.13 (-2.43)
0) x drivers with recent speeding				IS	IS	-0.23 (2.05)	-0.23 (2.05)
g ratio *quo* *)*	Minor increase (40/120)	Mean		IS	-1.92 (-2.7)	IS	IS
		SD		-	1.33 (2.8)	IS	IS
	Major Increase (60/120)	Mean		IS	-2.03 (-3.6)	IS	IS
		SD		-	IS	IS	IS
g sign ion)	50 m			-	-	-2.09 (-6.44)	-3.91 (-1.72)
	150 m			-	-	2.42 (6.64)	4 (1.96)
	200 m			-	-	2.31 (6.5)	9.2 (4.6)
l and perception characteristics							
ge 46-55	Older drivers (> 55 years)			IS	IS	-0.70 (-2.13)	IS
	Young drivers (<45 years)			IS	IS	IS	3.75 (2.1)
dary and	Up to primary level			1.81 (2.99)	IS	IS	IS
rried)	Married			-0.45 (-2.56)	-2.59 (-2.68)	IS	IS

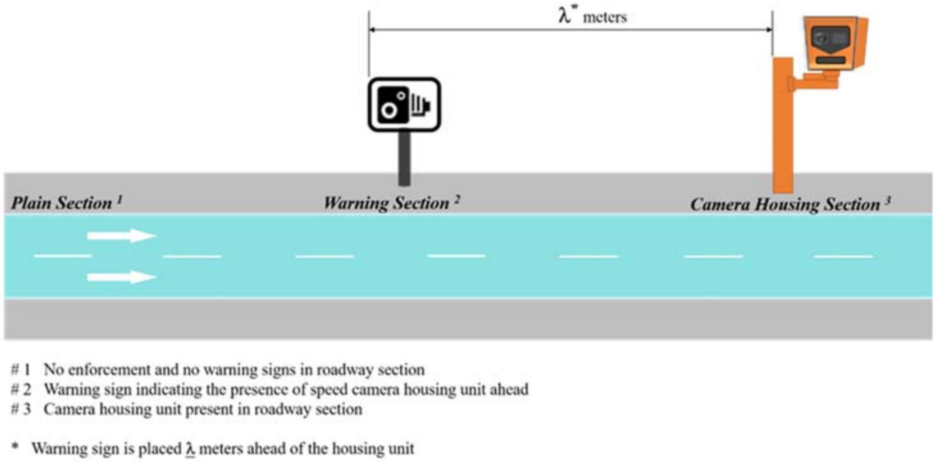
n HK$) *an 15K)*	Between 15K and 20K			IS	IS	IS	IS
	More than 20K			IS	IS	1.78 (2.49)	7.86 (1.94)
	Trip-based			1.37 (2.07)	10.32 (5.90)	IS	IS
)	Monthly			IS	IS	IS	IS
s	More than 9 hours			IS	-2.41 (-1.91)	-1.16 (-1.98)	-11.36 (-2.4)
	Less than 8 hours			IS	IS	0.57 (2.71)	2.45 (2.32)
	Green minibus			5.19 (5.77)	IS	-2.71 (-2.6)	IS
	Goods vehicle			7.30 (7.87)	5.02 (2.35)	-3.06 (-3.4)	-3.31 (-2.58)
	Red minibus and Taxi			5.77 (4.41)	IS	-2.23 (-1.95)	IS
recently received speeding				7.16 (2.93)	10.74 (3.35)	IS	-5.02 (2.16)
ding as a *al and*	Low			IS	6.00 (2.84)	IS	IS
tiveness *nd*	High			IS	IS	IS	-2.30 (-1.79)
ng *um (4- 0))*	High (>7 times per 10 trips)			IS	-3.61 (-3.25)	IS	-7.15 (-1.95)
sures:							
			3208				
rs			56				
nstants only model			-2911.09				
avergence			-1279.21				
n Criterion			3010.53				

npliance; IS: Statistically Insignificant at 90% confidence level.

Table 5 Marginal effects due to changes in the SP attributes

Variables		Percentage change in market shares					
		Standard section			Warning section		
		Speed Compliance	Speed range 1	Speed range 2	Speed Compliance	Speed range 1	Speed range 2
DOP	Market share in base case	16.96%	78.64%	4.40%	66.27%	32.88%	0.85%
	Change in market share upon increment by 1 point	4.22%	-0.64%	-4.85%	4.63%	-9.01%	-12.74%
Fines	Market share in base case	16.96%	78.64%	4.40%	66.27%	32.88%	0.85%
	Change in market share upon increment by 10 percent	0.00%	0.00%	0.00%	1.73%	-3.16%	-13.02%
Camera-to-Housing ratio (Base case: 20/120)	Market share in base case	16.89%	77.78%	5.34%	66.20%	32.80%	1.00%
	Change in market share upon change from base case to minor increase (40/120)	0.83%	2.11%	-33.39%	0.20%	0.50%	-29.52%
	Change in market share upon change from base case to minor increase (60/120)	0.96%	2.40%	-38.06%	0.22%	0.55%	-32.80%
Distance of warning sign from camera housing unit (base case: 100m)	Market share in base case	18.01%	80.91%	1.08%	73.50%	26.41%	0.09%
	Change in market share upon change from base case to 50m	0.00%	0.00%	0.00%	14.18%	-34.37%	-50.09%
	Change in market share upon change from base case to 150m	0.00%	0.00%	0.00%	-23.02%	63.56%	143.85%
	Change in market share upon change from base case to 200m	0.00%	0.00%	0.00%	-22.81%	59.00%	1277.90%

Scenario 1:



Background information		**Speed (km/h)**		
		< 50	**51 - 65**	**66 - 80**
Penalty for speed violation	➢ DOPs ➢ Fine	0 0	0 HK$ 320	3 HK$ 450
Camera-to-Housing ratio		20 cameras in 240 housing units		
Location of the warning sign		Warning sign placed 50 meters ahead of housing unit		

If you are at the **Standard section**, at which speed range would you travel? (choose one option from below)

☐ **≤ 50 km/h** ☐ **51-65 km/h** ☐ **66-80 km/h**

If you are at the **Warning Section**, at which speed range would you travel? (choose one option from below)

☐ **≤ 50 km/h** ☐ **51-65 km/h** ☐ **66-80 km/h**

If you are at the **Camera Housing Section**, at which speed range would you travel? (choose one option from below)

☐ **≤ 50 km/h** ☐ **51-65 km/h** ☐ **66-80 km/h**

Figure 1 Illustration of the location type and a hypothetical scenario for the Stated Preference game