

Attributes affecting preferences for traffic safety camera programs

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A B S T R A C T

With just a few notable exceptions, research supports the concept that red light cameras (RLCs) improve safety. However, many communities that have implemented RLC programs have faced a firestorm of public opinion associated with the use of RLCs, with many communities having to remove the cameras. What makes or breaks a red light camera program? Because of the experimental design process, stated choice is recognized as a tool that can resemble a laboratory experiment for the public policy arena. In this research, a stated choice model was developed and used to explore public preferences for a RLC program through an internet survey and a convenience sample drawn from a typical college town. The results suggest while independently the opposite is true, that when there is an increase in both the fine for violators and the number of cameras together (i.e., the interaction of these two) there is a perceived public safety gain. The interacted variable positively increases utility from the selected RLC program we analyzed and could be key in generating public support for RLC programs. The results suggest some important deterrence theory implications for improving accident prevention through the use of RLC programs that are designed to avoid unnecessary public scrutiny.

1. Introduction

In this manuscript we present results from a stated choice model (SCM) of public preferences for a Red Light Camera (RLC) program. In 2008, more than 5 million traffic accidents occurred. Forty percent of those accidents were intersection related crashes (Choi, 2010). That same year, there were more than 34,000 fatal car accidents in the US, with approximately 8% of those accidents occurring at a traffic light (National Highway Traffic Safety Administration, 2010). With a primary safety-related goal of reducing the number of people who run the light, RLC programs are used in more than 480 communities (as of October 2010) across the U.S. (Retting et al., 1999; IIHS, 2010).

RLC programs typically involve videos or photographs taken of automobiles running red lights and the registered owner of the vehicle is sent a fine. Though the cost effectiveness of speed and RLCs might be questioned (Chen and Warburton, 2006), the U.S. Federal Highway Administration reports that national data support reductions in red-light violations and collisions through the use of cameras. However, red light cameras may increase minor rear-end accidents, a function of off-setting behavior (Connell, 2008; Obeng

and Burkey, 2008). A study of seven communities by the Federal Highway Administration suggests that dangerous broadside collisions were reduced by 25% at intersections with traffic cameras, while rear-end collisions increased by 15%, potentially caused by motorists who stop suddenly to avoid running a light at an automatically enforced intersection (Hernandez, 2010). Additional research suggests that internationally, RLCs may reduce red light violations by 40–50 percent (Retting et al., 2003).

The primary objective of this research is to identify, using experimental design, the factors that contribute to a public acceptance of RLC programs. To our knowledge, though some safety issues have been examined using a SCM (e.g., Rizzi and de Dios Ortúzar, 2003; Iragüen and de Dios Ortúzar, 2004), no one has examined preferences for RLCs using the SCM approach. From our results, implications for the impact of RLC programs on driver behavior and the controllable features of RLC programs are offered. This type of research is fundamental to linking the accident reduction properties of RLCs and public acceptance of RLC programs. In the remainder of the manuscript we first provide a brief review of related literature, then present the theoretical model underlying the stated choice model (SCM). Next, SCMs require careful experimental design, so this is discussed, followed by a description of the sample and survey. The data are then described, leading to the empirical model results and discussion of these. We offer some conclusions in the final section.

2. Background literature

Several researchers have now considered whether RCLs can be effective in reducing mortality, or at least crashes at intersections. Of particular concern are side-impact crashes from a vehicle running through an intersection, but rear-end collisions are also considered. By in large, the peer-reviewed literature suggests that red light cameras do, in fact, improve traffic safety (Aeron-Thomas and Hess, 2005; Lund et al., 2009).

Initially it seems that the public would be in favor of automated, unbiased enforcement programs because of enhanced safety. Nevertheless, a number of RLC programs across the U.S. have faced community complaints due to objections to paying a fine without due process, privacy invasion, and false accusation. In addition, concerns that the cameras are ineffective and that communities' are using the programs to simply generate revenue have led to increased public scrutiny with regard to red light camera programs. There have been highly publicized accuracy issues associated with RLC in Arizona, Maryland, Missouri, Oregon, Texas, Italy, and the UK. And RLC programs in New Mexico, Washington, Texas, Florida, and California have been put up to a public vote, resulting in a number of cities removing their RLC programs.

Arizona, as one of the first to adopt traffic-safety cameras, became the first to ban them, in response to activists who felt they invaded privacy, and were installed mainly as a revenue generating device. The state's department of public safety reported a 19% drop in fatal collisions in the first nine months of operation (Archibold, 2010). The controversy in Arizona unfortunately also involves the murder of a mobile speed camera van operator. The state actually collected payments on less than one third of the 1.2 million tickets which were issued, adding \$78 million to revenue. More than 400 local governments in the U.S. use traffic cameras, but fifteen states and 11 cities have now banned or restricted their use in response to controversy and the topic has made its way into political campaigns in several regions (Hernandez, 2010). This poses a real problem from a safety perspective; a tool has been identified to reduce both the number and severity of accidents associated with an inherently risky portion of our roadways, yet public pressures have worked against the use of this tool.

In designing a RLC program that has the ability to withstand public scrutiny and impact intersection safety, it is important to understand the role of controllable factors (including camera location, number of cameras, and penalties for infractions) on driver behavior and driver perspectives of camera programs. The existing body of literature focuses largely on the effectiveness of the RLCs at reducing accidents and safety considerations associated with RLCs. Only a few studies delve into understanding how policy makers can effectively adopt automated enforcement programs (Martinez and Porter, 2006).

Red light camera effectiveness in 26 communities in Texas was studied by Walden (2008). With data from 56 traffic intersections, Walden (2008) found a 30% decrease in crashes after installation of the cameras. The author makes an important causality point about and does not claim that his findings prove that cameras reduce crashes at intersections, as he does not control for external factors that may have contributed to the reduction in crashes after cameras were installed. In another study, through the use of a nationwide survey, Porter and Berry (2001) obtained self-reported red light running behaviors and attempted to gauge opinion of red light running from drivers. Porter and Berry (2001) found that drivers often perceived the consequences of running a red light to be very low and suggested that the use of legal initiatives would help deter the behavior. While the results of the Porter and Berry (2001) survey are interesting, the full complexities associated with driver behavior cannot be captured with a typical "public opinion" survey (Louviere et al., 2000).

Stated choice and stated preference methods, using careful experimental design like ours here, attempt to overcome some of these challenges and reflect a more accurate assessment of human behavior. Wong et al. (2007) use a stated preference approach to deciphering the impact of the impact of various, controllable RLC enforcement criteria on driver behavior among a group of Hong Kong drivers with a high propensity to be involved in crashes. The researchers found that, in the presence of red light cameras, both the penalty and the infractions on the driver's record were successful at deterring red light violations.

3. Theoretical model¹

Stated choice models (SCMs) are increasingly used in modeling outcomes related to transportation, health, and environmental policies and are based on strong underlying economic theory of individual behavior. We do not review the vast amount of literature on SCMs here, referring the reader to two books on SCMs: Louviere et al. (2000) and a book focused on SCM design, edited by Kanninen (2006); there are other books as well.

In an SCM, an individual is offered a choice between two or more alternatives that consist of several key attributes and asked to choose between them. The alternatives might perfectly mimic actual alternatives that the individual faces in real life, such as two existing and frequently traveled transportation routes, or they might be hypothetical, such as two solar or electrically powered automobiles, neither of which is currently available on the market. SCMs are of great potential in situations where policy makers wish to gauge responses and public support to newly proposed transportation routes or facilities that may affect the demand for them.

SCMs are based on the random utility models (RUMs), which in turn are derived on the assumption that individuals are utility maximizers (Marschak, 1960). Within a RUM, attributes of the alternative or choice i are faced by the decision maker n during choice situation t , all denoted by x_{nit} . The modeler specifies a utility function that contains attributes (x) as arguments that are relevant to the individual's decision regarding possible choices.

McFadden (1974) demonstrated that if random errors are independent and identically distributed (*i.i.d*) and follow a type I extreme value distribution, then the probability P_{nit} has a closed form known as conditional logit distribution that can be expressed as:

$$P_{nit}(\beta) = \frac{e^{V_{nit}}}{\sum_j e^{V_{njt}}} \equiv \frac{e^{\beta x_{nit}}}{\sum_j e^{\beta x_{njt}}} \quad (1)$$

The conditional logit model, defined by Eq. (1), typically involves a linear utility function and is probably the most used specification by researchers in environmental economics, transportation economics, and marketing. As popular as it is, the conditional logit model has a fairly restrictive substitution pattern that corresponds to the independence of irrelevance alternative (IIA) property. IIA is not always a desirable property to impose on choices. Relaxing the IIA, as well as allowing for some heterogeneity in tastes across choice makers, leads to popular modern variants on the basic conditional logit model known as mixed logit or random parameters logit (RPL) models.

Recent research has shown that an individual respondent's ability to make choices between alternatives diminishes as the number of alternatives increases (Siikamaki and Layton, 2007). Rather than exposing respondents to the full combination of all factors and factor levels, the goal of experimental design is to determine the subset of alternatives given to respondents while maintaining desirable

¹ A brief overview of the theoretical model is provided here. For a more thorough description of SCM modeling and experimental design the reader is referred to Egbendewe-Mondzozo et al. (2010).

statistical properties. Ideal experimental design creates a subset selection of factors and factor levels such that the resulting analysis has the statistical power necessary to test the analyst's hypotheses.

Early work in design emphasized the need for an orthogonal design. Using orthogonal design, a linear model that relies on the data leads to parameter estimates using variables that are uncorrelated, and this may well result in coefficients that have the minimum variance (Kuhfeld et al., 1994). A lack of orthogonality can lead to correlation in variables, which can inflate the variance-covariance matrix which is used to determine the standard errors of the coefficients. Multi-collinearity is, of course, a thorny issue in ordinary least squares (OLS), a standard linear statistical or empirical model. More recent work in design has demonstrated that orthogonal designs are not possible, or even necessarily desirable for the problem at hand (using nonlinear discrete choice models), but that efficient (efficiency or minimum variance and covariance estimates for the parameters) designs that are non-orthogonal are still possible. Balance in design is also important (Huber and Zwerina, 1996), meaning here, that each level occurs equally often for each attribute. Balance in an experimental design ensures that attributes remain uncorrelated with the intercept, and the use of an unbalanced experimental design may cause a loss of consistency across the attributes being used.

4. Experimental design and application

The RLC program used in this research was initiated in January 2008 by the city of College Station, TX with the installation of four RLCs. College Station is one of two college communities the surround Texas A&M University known collectively as Bryan-College Station (BCS). The SCM developed allows respondents to choose among various options for a RLC program, limited by what was already in place in this RLC program at the time of the study. Experimental design is the critical foundation for the use of frameworks such as the SCM (Kuhfeld et al., 1994; Louviere et al., 2000; Sándor and Wedel, 2002). Therefore, this integral component was an area of emphasis for this research application. The specific design needs to be catered to the model that the researcher plans to use.

Four factors were identified as being of interest to our analysis: the cost of the ticket or fine incurred by red-light runners, the number of cameras in place, the location of the cameras, and the speed on the roads. These factors were identified as impacting resident perception of the red light camera program through our focus group discussions with community members.

Levels for each factor were selected based upon the initial RLC program implemented and focus group discussions. As there were already four functioning red light cameras in the area, we felt (and focus groups confirmed) that depicting a hypothetical choice that had no red light cameras would be confusing to respondents. The RLC program was implemented with citations of \$75 for red light violations and four red light cameras. We used citations slightly above and below the initial citation, resulting in levels of \$50, \$75, and \$100. Red light camera levels were selected at four, eight, and twelve cameras. The exact location of the cameras and the speed on roads were considered as categorical variables. Rather than specifically identifying the intersections, we opted to label the desired characteristic associated with the intersection. The locations we incorporated into the design were the current locations (i.e., the four cameras in their existing locations), high volume intersections, high pedestrian intersections, and intersections that had a mix of high volume and high pedestrian characteristics. Speed levels were incorporated at the current speed and a decrease of 5 mph. Table 1 provides a complete summary of the factors and the factor levels.

Using the four attributes with two, three, and four levels, the full factorial set of 72 combinations was generated ($3 \times 3 \times 4 \times 2 = 72$).

Table 1
Summary of choice characteristics.

Attributes	Description of the levels	Levels
Cost of the ticket	50, 75, 100	3
Number of cameras	4, 8, 12	3
Locations	Current, high traffic, high pedestrian, mixed	4
Speed on the roads	Current, decrease of 5 mph	2

However, while using a full factorial is tempting as it provides an efficient design if one can present all respondents with all combinations, it is not necessarily a wise approach. The importance of using choice pairs that are both realistic and logical-economic alternatives, particularly when respondents will see more than one pair of choices is emphasized by Breffle (2009). Out of the full factorial matrix we had, 30 combinations of factors and factor levels were scrutinized and deemed unrealistic or non-feasible and were thus removed, leaving us with 42 feasible choice alternatives. Egbendewe-Mondzozo et al. (2010) provide other details about the design (see also, Johnson et al., 2006) and the survey.

The final survey questionnaire consisted of four "warm-up" questions to assess the individual's prior knowledge of the RLC program that existed at the time of the study, 8 stated choice questions, 19 scaled attitudinal questions (statements with which the respondent could strongly disagree to agree, on a 1–5 scale), several questions on commuting patterns, and demographic questions. The attitudinal statement topics were selected using concerns raised in focus groups and from what we saw in prior research (see Lum and Wong, 2003; Retting and Williams, 1999; Ruby and Hobeika, 2003).

Included in the scaled attitudinal questions were: respondent driver safety perceptions, general driver behavior of the respondent, perceptions of other drivers, perceptions of other driver's behaviors on the roads, perceived effectiveness of traffic safety laws, perceived enforcement of traffic laws, perception of this RLC program as a tool for revenue generation, and perceptions of the safety of intersections for driving, bicycling, and walking.

5. Survey implementation and response results

The survey was hosted on a departmental web server and made available to residents of the Bryan-College Station community. College Station is dominated by college students and might be representative of many college towns in the United States, while in neighboring Bryan, the city has a more diverse population of all ages and a significant non-student population. Potential respondents were contacted via email, given a brief overview of the survey that was "designed to gauge public opinion" of the cities' RLC program, and were asked to access the survey webpage to anonymously participate. A total of 261 survey responses were generated and, as will be seen below, was fairly representative of the surrounding community.

With a decline in the number of land line telephones and an increase in the availability and use of the internet (census reports from 2007 indicate that nearly 70% of Texans had access to the internet), web based surveys are an increasingly common method of surveying. They have been used in transportation safety studies (e.g., Iragüen and de Dios Ortúzar, 2004; Beck et al., 2009; Shi et al., 2010). However, in using this, and almost any internet approach for a study survey, concerns are raised about the nature of the sample versus some relevant population. The immediate concern is that those who have internet access are different from a more general

Table 2
Comparison of sample of respondents to census data for College Station, Texas.

	Sample	Bryan, TX ^a	College Station, TX ^a
Age	32	28	22.3
Percent male	48%	49%	52%
Percent single	52%	43%	60%
Percent married	43%	45%	30%
Percent divorced	4%	9%	6%
Households, child <16	21%	36% (<18)	22% (<18)
Annual income (<\$10,000)	23%	14%	25%
(\$10,000 to \$50,000)	47%	49%	41%
(\$50,000 to 100,000)	30%	34%	34%
Education – some college	24%	17%	17%
Education: high school +	98%	77%	94%
Education: more than B.S.	67%	27%	57%
Drive alone to work	67%	76%	76%
Carpool to work	8%	16%	8%
Walk to work	3%	1%	4%
Travel time to work (average minutes)	16.8 min	16.8 min	15.9 min
Full time student	53%	–	–
Full time employed	46%	–	–

^a Source: U.S. Census, 2007, Bryan and College Station, Texas.

population that includes people who do not have such access, but as this project is about automobile safety, the most relevant population might focus on automobile users. We know of no study that has analyzed the characteristics of internet users and automobile users in the population to see how they are similar or different.

There are trade-offs in using the internet, as opposed to some other method, such as the telephone (see [Chang and Krosnick, 2009](#)), and these include some advantages (such as less social desirability bias) that the internet would have over a telephone survey, for example. A number of studies have attempted to identify biases in internet surveys. In a survey on driver behavior and beliefs, [Beck et al. \(2009\)](#) found that web-based respondents tend to be more likely to be male, white, and younger relative to telephone survey respondents. However, other studies have found no significant differences in either demographics or elicited responses between web-based and mail surveys ([Fleming and Bowden, 2007](#)). Moreover, after doing a comparison of an intercept survey and a web-based survey, [Shi et al. \(2010\)](#) report that internet surveys appear to produce valid data and hold a promising future.

We make no claim that the sample is representative of any population in the United States, but the survey results obtained do suggest that the sample was representative of the population surveyed. [Table 2](#) compares survey data from the web based sample obtained to similar estimates for the cities of Bryan and College Station, Texas, collected from the 2007 census. Despite the use of the internet and its potential biases, the sample is similar to both populations in many important ways. The sample is more educated, especially at the higher level, than Bryan's population, and has a higher proportion of people earning in the bottom income bracket, as might be true for students. As compared to College Station, the sample is older, on average, again, more people in it have a higher

level of education, and fewer people in the sample drive by themselves to work. However, income statistics, commute time, and the percent who walk to work are quite similar between the sample and the population in College Station. The role that higher education for the sample plays in the analysis of preferences for red light cameras is uncertain as more educated people might have more knowledge of safety issues, but also might feel less concerned about due process. Although the web based approach and the sample size present limitations, the authors felt that the sample represented the community and that the model estimation and results would be worth pursuing.

At the time of the survey, there were already four RLCs in operation in the study area, and most in the sample were familiar with their existence, at least. With regard to knowledge of the RLC program, 60% of the respondents said they go through at least one of the RLC intersections daily. However, 58% of the respondents could not precisely identify more than two intersections with RLCs.

The scaled attitudinal questions also revealed some interesting characteristics about the survey sample respondents. A majority of the respondents felt they were generally safe drivers (as measured by responses to questions on being focused on the road, following the posted speed limit, and in general considering themselves safe drivers), while at the same time the majority of respondents believed that other drivers are not safe (as measured by responses to other drivers being focused on the road and in general being safe drivers).

With regard to the RLC program and its perceived impact on traffic safety, the majority of sample respondents didn't agree or disagree that the RLC program would make roads safer, that additional red light cameras will make roads even safer, or that in general red light cameras make roads safer. Interestingly, 40% of the respondents either agreed or strongly agreed with the statement that the RLC program was primarily designed to generate revenue for the city of College Station.

An interesting additional check in similarities between the sample and the population of College Station can be made by examining the November, 2009 vote on eliminating or retaining the RLCs. Naturally, only those most interested in these types of issues go out and vote, especially in a year where no prominent national election is taking place, so consistency between the sentiments of our sample and the voters is not proof of whether the sample is representative of the College Station population. However, there were many issues being voted on, not just red light cameras, and turnout was high (12,664 people out of 85,500 registered voters actually voted). At the time of the vote, there were nine cameras in College Station (five were added in May of 2009), and the majority of people (4081–3809) voted to have them removed ([Smith, 2009b](#)).

6. Data for choice model estimation and estimation results

The data set obtained from the experimental design portion of the survey was used to estimate the choice model. Due to incomplete responses on the often challenging stated choice questions, some individuals were removed from the sample because they did not complete all answers to the choice questions. The sample used in the estimation is 206 subjects, or the large majority of the original 261 sample members. [Table 3](#) contains key summary statistics on the estimation variables. The number of cameras (*CAMERAS*) and (*COST*) are continuous variables. Speed limit (*SPEED*, where 1 indicates a decrease from the current speed limit and 0 indicates the current speed) and the location variable (*LOC*) enter the utility function as 0,1 dummy variables and may either influence a constant, a slope parameter, or both. The camera locations are divided into four dummies as it can be seen in the summary statistics (see [Table 4](#)). High pedestrian intersections (*LOCHP*), high traffic

Table 3
Summary statistics.

Variables	Mean	SD	Minimum	Maximum
<i>SPEED</i>	0.50	0.50	0	1
<i>COST</i>	75	19.76	50	100
<i>CAMERAS</i>	7.25	2.90	4	12
<i>LOCHP</i>	0.31	0.46	0	1
<i>LOCMIX</i>	0.31	0.46	0	1
<i>LOCHV</i>	0.13	0.33	0	1
<i>BCOLLEGE</i>	0.20	0.40	0	1
<i>STUDENT</i>	0.66	0.47	0	1
<i>AGE</i>	31.68	12.49	17	99
<i>SAFED</i>	4.46	0.64	2	5
<i>RDCMSAFE</i>	3.05	1.28	1	5
<i>CAREV</i>	3.26	1.27	1	5
<i>ACCIDENT</i>	0.69	0.46	0	1
<i>CHILDREN</i>	0.19	0.39	0	1
<i>GENDER</i>	0.49	0.50	0	1

volume (*LOCHV*), and mixed high volume and high pedestrian locations (*LOCMIX*) dummy variables are used, with the current camera location situation being the base case in the model.

In addition, Table 3 shows that the dummy variable (*BCOLLEGE*) equals 1 if the individual lives in College Station and 0 otherwise (about 20% live in College Station; most of the rest of the sample lives in Bryan); the variable student (*STUDENT*) equals 1 if the individual is a student and 0 otherwise. Other variables used in the model include the individual's age (*AGE*), the variable (*SAFED*) which equals 1 if the individual thinks that she is a safe driver (0 otherwise), and the variable *RDCMSAFE*, which is scaled from 1 to 5 to reflect how strongly the individual agrees with the sentiment that the road cameras make conditions safer. The variable (*CAREV*) is also a scale variable from 1 to 5 and indicates how strongly the individual believes that the RLC program is design mainly to collect revenue for the city. For both of these variables, one can see a middle (3) average response, suggestive of at least a neutral sentiment on both cases. Approximately 26% (15%) of the sample responded with a 3 (1 – strongly disagree) for the *RDCMSAFE* variable and 30% (10%) responded with a 3 (1 – strongly disagree) for *CAREV*, while the proportions of those who strongly agreed in each case (response = 5) were 16% and 22%, respectively.

Several other variables directly relate to safety perceptions or conditions. The variable *ACCIDENT* is set to equal 1 if the respondent has ever been involved in an accident and 0 otherwise. The variable *CHILDREN* is set equal to 1 if the respondent has children under 18

Table 4
Results.

Variables	Coefficients	SE	Asymptotic-z	$P > z $
Mean				
<i>LOCHP</i>	2.318	0.429	5.400	0.000
<i>LOCMIX</i>	2.375	0.535	4.430	0.000
<i>LOCHV</i>	0.971	0.317	3.060	0.002
<i>ACCIDENT</i> × <i>CAMERAS</i>	0.051	0.081	0.630	0.530
<i>GENDER</i> × <i>CAMERAS</i>	-0.066	0.076	-0.860	0.388
<i>CHILDREN</i> × <i>CAMERAS</i>	0.076	0.100	0.760	0.446
<i>AGE</i> × <i>CAMERAS</i>	0.010	0.003	3.040	0.002
<i>STUDENT</i> × <i>CAMERAS</i>	0.013	0.100	0.130	0.896
<i>COST</i> × <i>CAMERAS</i>	0.007	0.002	2.590	0.010
<i>CAREV</i> × <i>COST</i>	-0.013	0.003	-3.480	0.000
<i>CAMERAS</i>	-1.243	0.326	-3.800	0.000
<i>SPEED</i>	-1.514	0.229	-6.600	0.000
<i>COST</i>	-0.077	0.031	-2.500	0.000
Standard dev.				
<i>CAMERAS</i>	0.431	0.049	8.300	0.000
<i>SPEED</i>	1.831	0.180	10.170	0.000
<i>COST</i>	0.049	0.193	-7.140	0.000
<i>LR</i>	245.270			0.000
<i>LogL</i>	-811.228			
Observations	3296			

years of age and 0 otherwise. The motivation for including a variable representing the number of children at home was that people with children might have stronger preferences for safety and thus more support for the RLC program. Finally, the variable *GENDER* takes 1 if the respondent is a male and 0 if she is a female as prior research has suggested that there may be gender differences in terms of safety behaviors and perceptions.

7. Estimation results

Results are presented in Table 4. To economize on space, we present only the most robust and best fitting specification of the estimated models, based on the goodness of fit criteria used (*LR*, *LogL*). Having made the assumption that the parameters on all of the attribute variables might have individual heterogeneity, we found that the standard deviation on the location variables were insignificant. This indicates that a fixed coefficient variable can be used in the model, as would be true in the conventional conditional logit specification. In other words, there is no indication of individual, unobserved heterogeneity for these variable coefficients. Nevertheless, the standard deviations on the other key variables are significant, supporting the use of a mixed logit or RPL model, and heterogeneity for these parameters. Another way of thinking about this heterogeneity is that tastes for some attributes randomly vary across individuals.

We assumed that the coefficients on the variables *SPEED*, *CAMERAS*, and *COST* were normally distributed. The normality assumption accounts for heterogeneity in tastes for these variables, but makes no assumption about the sign of the variable (direction of influence). A log-normal assumption for the distribution would rule out negative certain domains, but some researchers use this or the triangular distribution instead of the normal.²

The location dummy variables are all significant and positive indicating a preference for cameras located in the pedestrian, high volume, and mixed locations relative to the current location. From the magnitude of the coefficients, the results show that the location with a high volume of pedestrians is most preferred. Estimation results show that the variables *CAMERAS*, *SPEED*, and *COST* are significantly different from zero and provide negative marginal utility. Perhaps oddly, people prefer fewer to more cameras. However, cameras capture not only other people, increasing one's own safety, but increased cameras may also increase an individual's own likelihood of being fined. So on average, people in the sample dislike more cameras, holding other attributes constant. This finding is likely touching on the sentiment among drivers that a portion of red light running is done unintentionally.

Considering that College Station is a college town, with younger drivers who may tend to drive relatively fast, it is not surprising to find that the results show that a higher (current) speed limit is preferred to lower speed limits. In addition, the resulting estimation shows that citation level is of expected negative sign when considered alone (all other attributes held constant).

Of the numerous interaction effects between demographic (individual) variables and main attributes tried in the model estimation, the only significant interactions were between the variables *CAMERAS* and individual-specific *AGE*. Older people respond to increasing cameras in a positive fashion. Age has been previously identified as predictor a red light running behavior (Martinez and Porter, 2006): younger drivers may be more likely to run red lights than older people, perhaps because of less experience, distractions, or because they drive faster.

² For an extensive review on the lognormal distribution in such models, the reader is referred to Casella and Berger (2002).

In another study of self-reported red light running experiences, Porter and Berry (2001) found that age was the only significant demographic variable that could be used to predict the likelihood of a recent red light running experience. If older individuals are in fact less likely to be running red lights than younger individuals, then an increase in the number of cameras has the ability to improve the safety of intersections, with limited fear of being negatively impacted by an increase in the number of cameras, making the results of this interaction variable consistent with expectations.

When the variables CAMERAS and COST were interacted, a positive influence on utility and choice was identified. This suggests that if cameras are increased simultaneously with citation levels, the probability of choosing that alternative increases. The CAREV variable and the COST variable were also interacted in the estimation. The negative sign and significance on that interaction suggests that those who believe the cameras are being used for city revenue generation have an even stronger negative reaction to the citation levels. The log-likelihood value achieved a higher maximum when we entered interaction terms than without them (-813.884 as compared to the one reported -805.75), thus, even though only a few interacted variable combinations are significant, they improve the overall fit of the model.

8. Discussion: implications of results

Given the challenges RLC programs have faced with regard to public perceptions, this research presents some potentially valuable implications on program attributes that impact preferences for RLC programs. Although the survey sample has some limitations, this research is one of the first to apply the lab experiment like design features of stated choice to gain a fuller understanding of public perceptions of RLC programs.

The model estimation suggests, perhaps not too surprisingly given what RLC programs across the country have experienced, that individuals prefer fewer cameras and lower fines. However, understanding preferences for RLC programs is not that simple. When the number of cameras and the fines for violation increase simultaneously, individuals have a positive utility gain. This interaction effect suggests that there may be a threshold level of commitment at which the RLC program must be implemented prior to achieving public acceptance. Although not tested with the rigor of stated choice or stated preference, Thorpe et al. (2000) found similar acceptance through a threshold level of interaction between policy attributes with regard to public acceptance of travel demand program options in the UK.

The positive relationship between public utility for RLC programs and the combination of the number of cameras and the penalty for violation appears to be further supported by deterrence theory. Classic theories on effective deterrence rely on the individual's perception of the certainty of punishment, the swiftness of punishment, and the severity of punishment (Homel, 1986). While the citation level clearly influences the severity of punishment, the impact of the number of cameras is less clear.

Due to an innate aversion to ambiguity and an inability to make rational decisions under ambiguity, there is a positive relationship between deterrence and ambiguity (Sherman, 1990). When the number of cameras implemented in a RLC program is relatively small, the "intentional" red light runner is more likely to be certain which intersections have the cameras in place and thus simply avoid that behavior at those intersections. However, as the number of intersections that have cameras increases, so does the inability of a red light runner to be certain that a particular intersection is being monitored with a camera. Therefore, it is plausible that the spillover effects of RLC programs are not linearly related to the number of cameras, but instead must first reach a threshold level before a pos-

itive relationship ensues [further discussion of spillover effects are available in Shin and Washington (2007) and Martinez and Porter (2006)]. This finding has the potential to add in another consideration in the calculation of an *optimal* number of RLCs (Obeng and Burkey, 2008), i.e., a number that is large enough to increase safety, but not so large that the public rebels to their presence.

The increase in utility that stated choice participants indicated from the RLC program when cameras and citation levels are increased simultaneously likely indicates that the program was thought to be implemented rigorously enough such that their perceived level of safety from the program increased. The combined deterrence effect of citation severity and the increased intersection ambiguity associated with a relatively high number of cameras was thought to be enough to influence driver behavior and thus improve roadway safety. Whereas, on their own, the controllable program variables are not seen as enough deterrent to yield the public good of improved safety.

9. Conclusions

Stated choice models (SCMs) are increasingly used in the analysis of new programs and policies and are an ideal methodological tool to discover preferences for variables in complicated decision making settings, as in many transportation settings. Recent SCM studies have shown that choice set design considerations are critical in evaluating the meaning of the results. Naturally, this is due to the attributes of the choices, their levels, and their frequencies in choices that sample members in a study face being selected by the researcher. In our consideration of design issues, we found that naively assuming that all attributes should be used in a simple fashion that avoids correlations was not the most efficient way to design the choice sets for the analysis.

The stated choice survey developed was applied to a sample of people living in around Bryan-College Station to evaluate the preferences of proposed alternatives for a RLC program. We found that, on average, people in our sample want fewer, not more cameras, prefer the actual speed limit to a proposed decrease, and prefer cameras in high pedestrian use locations, high volume intersections, or a mixed high-volume/high-pedestrian location, relative to the current location placements. The sentiment to want fewer cameras reflects the vote in the referendum election, where the majority voted to have the cameras removed (Smith, 2009b). Although the model results suggest that individuals get a disutility from independent cost and cameras increases, we found that an increase in both the cost and cameras together (i.e., the interaction of these two variables) is seen as having a positive utility gain for the RLC program among respondents and a probable safety gain.

As with any study, there are limitations to what can be said from the results, and we close by offering a few caveats. First, the sampling and SCM approach we took, including the design, could be improved upon. Naturally more choice combinations can be handled with larger samples of individuals because opportunities for blocking arise. Obtaining an appropriate sample for a particular design is important (Bliemer and Rose, 2005), but we could not optimize in that dimension because of budget issues. Too many blocks with a relatively small sample overall means that few individuals are exposed to any one block of choices and problems may arise with statistical analysis and inference. While the sample has limits, we believe the results provide important insights into how RLC programs are designed and their impact on public acceptance.

Finally, it may have been fruitful to examine direct safety-related attributes such as injuries or deaths for traffic intersections, such as considered for routes on the road by Hensher et al. (2009), rather than the simple presence of the cameras, perhaps tying the former safety attributes to cameras indirectly. This would be inter-

esting future research, but would require solid data on the injury and death statistics for a long period of time, perhaps many years after installation of the cameras.

It should be noted that after the completion of this research, the RLC program in the area analyzed had become so controversial in the area that a special referendum election was called to see if voters wanted the cameras eliminated. Local newspapers carried stories of a resident filing an ethics complaint against the College Station city manager, for misuse of public funds related to the election (Smith, 2009a). The highly publicized and hotly debated days leading up to the referendum ultimately resulted in voters indicating that they wanted the cameras in the RLC program taken down. This series of events make the authors wonder if a different set of RLC program attributes (i.e., more cameras and higher fines) would have changed the outcome.

References

- Aeron-Thomas, A.S., Hess, S., 2005. Red-light cameras for the prevention of road traffic crashes. In: *Cochrane Database of Systematic Reviews*, Issue 2, Art. no. CD003862. The Cochrane Collaboration, Oxfordshire, England.
- Archibold, R.C., 2010. Arizona halts photo enforcement of speed laws. *New York Times*, July 15th.
- Beck, K., Yan, A., Wang, M., 2009. A comparison of web-based and telephone surveys for assessing traffic concerns, beliefs, and behaviors. *Journal of Safety Research* 40, 377–381.
- Bliemer, M.J., Rose, J.M., 2005. Efficiency and sample size requirements for stated choice studies. Working paper, University of Sydney, Institute of Transport and Logistical Studies (ITLS-WP-05-08).
- Brefle, W., 2009. In pursuit of optimal design: a guide for choice experiment practitioners. *International Journal of Ecological Economics and Statistics* 14, 3–14.
- Casella, G., Berger, R., 2002. *Statistical Inference*, Duxbury Advanced Series, 2nd ed. Chang, L., Krosnick, J.A., 2009. National surveys via RDD telephone interviewing vs. the Internet: comparing sample representativeness and response quality. *Public Opinion Quarterly* 73, 641–678.
- Chen, G., Warburton, R.N., 2006. Do speed cameras produce net benefits? Evidence from British Columbia, Canada. *Journal of Policy Analysis and Management* 25 (3/Summer), 661–678.
- Choi, E., 2010. Crash Factors at Intersection-Related Crashes: An On-Scene Perspective. National Highway Traffic Safety Administration, Washington, DC.
- Connell, R., 2008. L.A. Red Light Cameras clicking for safety or revenue? *Los Angeles Times*, May 20th, <http://www.latimes.com>.
- Egbdendewe-Mondzozo, A., Higgins, L.M., Shaw, W.D., 2010. Red light cameras at intersections: estimating preferences using a stated choice model. *Transportation Research Part A* 44 (July), 281–290.
- Fleming, C., Bowden, M., 2007. Web based surveys as an alternative to traditional mail methods. *Journal of Environmental Management* 90, 284–292.
- Hensher, D.A., Rose, J.M., Ortúzar, J.D., Rizzi, L.L., 2009. Estimating the willingness to pay and value of risk reduction for car occupants in the road environment. Discussion paper, Institute of Transport and Logistic Studies, University of Sydney, ITLS-WP-09-03 (February).
- Hernandez, R., 2010. Traffic-camera Debate Heats Up Campaign Trails. *New York Times* August 7th.
- Hommel, R., 1986. Policing the Drinking Driver: Random Breath Testing and the Process of Deterrence. Federal Office of Road Safety, Canberra.
- Huber, J., Zwerina, K., 1996. The importance of utility balance in efficient choice designs. *Journal of Marketing Research* 33, 307–317.
- Insurance Institute for Highway Safety, 2010. Communities using red light or speed cameras. http://www.iihs.org/laws/auto_enforce_cities.aspx.
- Iragüen, P., de Dios Ortúzar, J., 2004. Willingness-to-pay for reducing fatal accident risk in urban areas: an internet-based Web page stated preference survey. *Accident Analysis and Prevention* 36, 513–524.
- Johnson, F.R., Kanninen, B., Bingham, M., Ozdemir, S., 2006. Experimental design for stated choice studies. In: Kanninen, B. (Ed.), *Valuing Environmental Amenities Using Stated Choice Studies*, pp. 159–202.
- Kanninen, B. (Ed.), 2006. *Valuing Environmental Amenities Using Stated Choice Studies: A Common Sense Guide to Theory and Practice*. Kluwer Press, Boston.
- Kuhfeld, W.F., Tobias, R.D., Garratt, M., 1994. Efficient experimental design with marketing research applications. *Journal of Marketing Research* XXXI (November), 545–557.
- Louviere, J., Hensher, D., Swait, J., 2000. *Stated Choice Methods: Analysis and Application*. Cambridge University press, Cambridge.
- Lum, K.M., Wong, Y.D., 2003. A before-and-after study of driver stopping propensity at red light camera intersections. *Accident Analysis and Prevention* 35 (1), 111–120.
- Lund, A., Kyrchenko, S., Retting, R.A., 2009. Caution: a comment on Alena Erke's red light for red light cameras? A meta-analysis of the effects of red-light cameras on crashes. *Accident Analysis and Prevention* 41, 895–896.
- Marschak, J., 1960. Binary choice constraints on random utility indications. In: Arrow, K. (Ed.), *Stanford Symposium on Mathematical Methods in the Social Sciences*. Stanford University Press, Stanford, CA, pp. 312–329.
- Martinez, K., Porter, B., 2006. Characterizing red light runners following implementation of a photo enforcement program. *Accident Analysis and Prevention* 38, 862–870.
- McFadden, D., 1974. Conditional logit analysis of qualitative choice behavior. In: Zarembka, P. (Ed.), *Frontiers in Econometrics*. Academic Press, New York, pp. 105–142.
- National Highway Traffic Safety Administration, 2010. *Fatality Analysis Reporting System*. <http://www.fars.nhtsa.dot.gov/>.
- Obeng, K., Burke, M., 2008. Explaining crashes at intersections with red light cameras: a note. *Transportation Research Part A* 42, 811–817.
- Porter, B., Berry, T., 2001. A nationwide survey of self-reported red light running: measuring prevalence, predictors, and perceived consequences. *Accident Analysis and Prevention* 33, 735–741.
- Retting, R.A., Williams, A.F., 1999. Characteristics of red light violators: results of field investigation. *Journal of Safety Research* 27 (1), 9–15.
- Retting, R.A., Williams, A.F., Farmer, C.M., Feldman, A.F., 1999. Evaluation of red light camera enforcement in Fairfax, Virginia, U.S.A. *Institute of Transportation Engineers Journal* 69 (8/August), 30–34.
- Retting, R.A., Ferguson, S.A., Hakkert, A.Sh., 2003. Effects of red light cameras on violations and crashes: a Review of the International Literature. *Traffic Injury Prevention* 4, 17–23.
- Rizzi, L.L., de Dios Ortúzar, J., 2003. Stated preference in the valuation of interurban road safety. *Accident Analysis and Prevention* 35 (1), 9–22.
- Ruby, D.E., Hobeika, A.G., 2003. Assessment of red light running cameras in Fairfax County, Virginia. In: Paper Presented at Transportation Research Board Annual Meeting, Washington, D.C., January 2003.
- Sándor, Z., Wedel, M., 2002. Profile construction in experimental choice designs for mixed logit models. *Marketing Science* 21 (4), 455–475.
- Sherman, L.W., 1990. Police crackdowns: initial and residual deterrence. In: Tonry, M., Morris, N. (Eds.), *Crime and Justice: An Annual Review of Research*, vol. 12. University of Chicago Press, Chicago, pp. 1–48.
- Shi, J., Ban, Y., Ying, X., Atchley, P., 2010. Aberrant driving behaviors: a study of drivers in Beijing. *Accident Analysis and Prevention* 42, 1031–1040.
- Shin, K., Washington, S., 2007. The impact of red light cameras on safety in Arizona. *Accident Analysis and Prevention* 39, 1212–1221.
- Siikamaki, J., Layton, D., 2007. Discrete choice survey experiments: a comparison using flexible methods. *Journal of Environmental Economics and Management* 53, 122–137.
- Smith, C., 2009a. CS city manager considers ethics complaint baseless. *The Eagle*, Friday, October 9th. Available at <http://www.theeagle.com>.
- Smith, C., 2009b. Traffic cameras voted down. *The Eagle*, Wednesday, November 4th.
- Thorpe, N., Hills, P., Jaensirisak, S., 2000. Public attitudes to TDM measures: a comparative study. *Transport Policy* 7, 243–257.
- Walden, T.D., 2008. Analysis of the effectiveness of photographic traffic signal enforcement systems in Texas. Report prepared for the Traffic Operations Division, Texas Department of Transportation. (Austin, Texas: November).
- Wong, S.C., Wong, C.W., Sze, N.N., 2007. Attitudes of public light bus drivers to penalties to combat red light violations in Hong Kong. *Transport Policy* 15, 43–54.