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Transportation Research Part F 22 (2014) 25–38

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

Can psychological variables help predict the use of priced managed lanes?

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A R T I C L E I N F O

Article history:
Received 12 October 2012
Received in revised form 14 October 2013
Accepted 20 October 2013

Keywords:
Managed lanes
Psychological variables
Travel behavior
Stated preference surveys
Value of travel time savings

A B S T R A C T

This research examined the relationship between several psychological variables (conscientiousness, general locus of control, personal need for structure, financial risk tolerance, driving risk perceptions, risky driving style, and careful driving style), travel attribute preferences, carpooling attitudes, and preferences for priced managed lanes. Using data based on 664 respondents from three cities (Denver, Miami, and San Diego), mixed logit models indicated that several variables, particularly travel time, toll, sex, and income, were better predictors of managed lane use than the psychological variables. Of the psychological variables, significant results were obtained for only conscientiousness and risky driving style. Specifically, respondents with a higher risky driving style score reported a lower preference for carpooling on general purpose lanes. High conscientious individuals reported a lower preference for carpooling on managed lanes. Although the results for the psychological variables were generally not as strong as had been expected, aspects of the study design may have resulted in an underestimate of their effects. These aspects are acknowledged and their implications are discussed in the context of future research.

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1. Introduction

As of January 2013 there are 12 cities in the United States that have priced managed lanes (https://ceprofs.tamu.edu/mburris/pricing.htm) and many more cities are contemplating their use. These managed lanes (also sometimes referred to as "express lanes", and "high occupancy/toll lanes") generate revenues and manage traffic demand by offering a priced premium service. The managed lanes are usually situated in the middle of congested general purpose lanes and separated by striping or, in a few cases, concrete barriers. To ensure that the managed lanes offer a premium service and do not become congested, travelers typically must pay a toll or meet certain criteria (such as three or more occupants in a vehicle) to use them. The toll generally varies by time of day or by congestion level, increasing as demand for the lanes increases. Thus, travelers have to make a decision, often on the spur of the moment, between a tolled, free-flow trip or an untolled congested trip. The present study investigated the relationship between a number of psychological variables and the decision to use managed lanes in an effort to further the understanding of travel behavior and the ability to predict the potential usage of future priced managed lanes.

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http://dx.doi.org/10.1016/j.trf.2013.10.006

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Researchers often estimate the likelihood a traveler will use a toll road using stated preference surveys. However, a review of the limited research on this topic, suggests that stated preference surveys for managed lanes and high occupancy/toll lanes appear to underestimate the willingness to pay. For instance, recent analysis of Katy Freeway/Managed Lane travelers (see Devarasetty, Burris, & Shaw, 2012a,b) and I-394 Freeway/High Occupancy Toll lane traveler data (see Burris, Nelson, Kelly, Gupta, & Cho, 2012) has shown that many travelers pay to use these managed lanes when adjacent toll-free lanes are operating at nearly the same speed. Assuming that drivers are indeed cognizant of the fact that high occupancy tolled and managed lanes are traveling at nearly the same speed, it would seem that some travelers are paying for the use of these lanes for reasons other than travel time savings. Therefore, current models do not capture the full story. Consequently, this research examined whether pertinent individual difference variables (i.e., differences in personality, attitudes, and preferences) can contribute to an explanation and understanding of travelers' decisions to use managed lanes.

It has long been empirically established that individual differences play an important role in driving-related behavior and choices. However, the usual outcome variables of interest have been errors and violations as anomalous behaviors, typically operationalized as crashes and moving violations (i.e., tickets; Arthur & Day, 2009). Recent research has also began to pay some attention to driving anger expression as a potentially relevant driving outcome (e.g., Dahlen, Edwards, Tubré, Zyphur, & Warren, 2012). Regardless of the specific outcome, there are three general classes of variables considered as predictors of driving behaviors—demographic and exposure factors, cognitive and information processing variables, and personality traits (Arthur & Day, 2009). Conceptually, the viability of these variables as predictors of driving outcomes is concordant with the well-established relationship between knowledge, general mental ability, and personality traits and performance in the workplace (Barrick & Mount, 1991; Hunter, 1986). Although general mental ability and declarative knowledge of driving principles have not performed well as predictors of driving outcomes (e.g., see Arthur, Barrett, & Alexander, 1991; Arthur & Doverspike, 2001), personality traits have been shown to be successful predictors (Clarke & Robertson, 2005). Consequently, an investigation of the role personality variables play in the choices that travelers make to pay to use managed lanes is an important extension of this body of research. A review of the extant literature identified a cluster of variables as being theoretically germane to the domain of traveler choices. These are conscientiousness, locus of control, personal need for structure, risk tolerance, driving risk perceptions, and driving styles. The variables included in the present study have been shown to relate to other driving outcomes (e.g., crashes and tickets) which include the proclivity to engage in certain driving behaviors. Thus, the theoretical and conceptual basis for the role of the variables in the present study is based on a generalization from previous findings (e.g., Clarke & Robertson, 2005) to managed lane preferences as a novel, focal outcome variable. Therefore, the goal of the present study was to investigate the relationship between the specified psychological variables and travelers' preference for using managed lanes.

2. Literature review

2.1. Potential variables influencing managed lane usage

Numerous factors may influence a traveler's decision to use managed lanes. In the context of the present study, these can be broadly categorized in terms of (1) the characteristics of the driver, and (2) the characteristics of the trip. Although the primary focus of the present study is driver characteristics, we briefly review the relevant literature on both categories because we sought to investigate the ability of driver characteristics to predict managed lane choice over and beyond trip characteristics.

2.1.1. Characteristics of the driver

2.1.1.1. Socio-economic characteristics. Many socio-economic characteristics of travelers have been shown to influence their use of managed lanes, with the most important being income, whereby higher income travelers are more likely to use managed lanes more often (Sullivan et al., 2000). Additionally, females tend to use the lanes more often than males (for example see Devarasetty et al., 2012a).

2.1.1.2. Psychological variables. As previously noted, Arthur and Day (2009) distinguished between three categories of predictors of driving outcomes, specifically demographic and exposure variables, cognitive and information processing variables, and personality traits. In this section, we briefly review the research on predictor variables from the personality and non-cognitive literature, and provide the rationale for considering these variables in the present study. Along the same lines, a number of conceptually pertinent attitudinal variables are also introduced and described.

Some personality traits commonly used in personnel and organizational psychology research have been successfully used in the prediction of crash involvement and moving violations. For instance, Clarke and Robertson's (2005) meta-analysis revealed that extraversion, conscientiousness, and agreeableness are all valid predictors of crash involvement (corrected mean validities of .24, .26, and .21, respectively).

The documented role individual differences play in driving outcomes served as the impetus for considering and exploring the role they could play in travel choices. Consequently, on the basis of a detailed review of the extant literature, a number of psychological characteristics that seemed theoretically germane to driving choices were identified. These individual difference variables along with their posited relationship with managed lane use are briefly described in the following paragraphs.

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Conscientiousness was posited to be related to the choices individuals make when traveling because high conscientious individuals describe themselves as more careful, reliable, self-disciplined, detail-oriented, and organized. In contrast, low conscientiousness individuals describe themselves as careless, undependable, lazy, and disorganized (McCrae & Costa, 1987). Therefore, conscientious individuals may be more likely to make decisions ahead of time and thus allow plenty of time to travel and not require the use of managed lanes in order to arrive at a destination on time. By the same token, these individuals may also prefer the predictability in scheduling provided by the use of managed lanes. Consequently, we sought to investigate the magnitude and direction of the relationship between conscientiousness and managed lane use.

Locus of control represents the extent to which individuals perceive rewards or reinforcement as contingent on their own behavior, skills, or internal dispositions (Rotter, 1966). If a person consistently interprets rewarding events as resulting from his/her own actions or internal dispositions, then the person is said to have an internal locus of control. Conversely, if similar events are consistently perceived as the result of luck, fate, or some other external force, then the person is said to have an external locus of control. For instance, if a driver believes that crashes are the result of luck or other factors outside of the driver's control (i.e., an external locus of control), then he/she will regard safety-related behaviors as less important, and these behaviors will be less likely to be learned or enacted. Consistent with this, Arthur et al.'s (1991) meta-analysis obtained a mean validity of .20 for locus of control and crash involvement (i.e., externals had higher levels of crash involvement). Extending these locus of control findings to the use of managed lanes, it is posited that individuals who have an internal locus of control (i.e., they regard outcomes as dependent on their own behavior) are more likely to use managed lanes. These individuals prefer to exert personal control over their driving outcomes and are assumed to avoid traffic and other unforeseen events that may negatively impact their travel time and the potential to be late.

Risk tolerance represents a person's generic orientation towards taking or avoiding a risk when deciding how to proceed in situations with uncertain outcomes. Weber, Blais, and Betz (2002) conceptualize risk taking within a risk-return framework wherein individual choices reflect a trade-off between risk (fear) and expected return (hope). In addition, Weber et al. regard risk taking as a highly domain-specific construct meaning that individual risk taking attitude is not necessarily consistent across different domains (i.e., the same individual may dislike investing money in uncertain markets but at the same time would take the risk of making unpopular statements in public). As previously noted, research has shown that managed lanes and adjacent toll-free lanes often travel at nearly the same speed (Burris et al., 2012). So, if managed lanes do not offer travel time savings, then why would drivers be willing to pay a toll? We think the key to understanding this issue is to acknowledge that although managed lanes are not faster *on average*, drivers may be willing to pay a toll because *for some days* managed lanes will be faster than toll-free lanes. This reasoning is consonant with Weber et al.'s risk and return framework in which paying for a toll involves a (small) financial risk along with an expected return on time savings which is not readily obvious. Consequently, our focus is on financial risk attitudes, which we posit to be related to an individual's travel decisions such that those with a high tolerance for financial risk are more likely to pay a toll. It is worth noting that drivers who choose to carpool are allowed to use managed lanes at no charge, and financial risk tolerance should not influence their decision to use managed lanes instead of general purpose lanes. Thus, we expect risk tolerance to influence solo drivers' decision to use managed lanes, but not carpoolers' decisions. Furthermore, from a purely economic perspective, it is unreasonable to use general purpose lanes if one is carpooling.

According to Neuberg and Newsom (1993), people create and use abstract mental representations of their experiences to reduce information complexity and lessen cognitive load. Accordingly, *personal need for structure* speaks to a preference for structure and simplicity in one's thinking. Consequently, individuals high in need for structure prefer consistent and routine situations because these situations are associated with lower levels of information complexity and cognitive demands. Individual differences in need for structure are posited to be related to managed lane use in that individuals with a higher need for structure are expected to prefer the confidence that comes from perceiving more stability when using a managed lane—that is, predictable travel time.

Driving risk perceptions comprise an individual's cognitive and emotional reactions to traffic safety. Prior research has shown driving risk perceptions to be related to speeding and crashes (Rundmo & Iversen, 2004). The indicators of risk perceptions are measured using both emotional- and cognitive-based aspects of perceiving risks while driving. Emotion-based risk perceptions pertain to the degree to which drivers are fearful of or anxious about traffic crashes, whereas cognitive-based perceptions concern the extent to which drivers think about the possibility of such outcomes. Driving risk perceptions may play a role in the choices and decisions drivers make concerning managed lanes. For example, focus groups and surveys of potential and current managed lane travelers have indicated that many feel managed lanes are safer due to reduced weaving (i.e., lane changes) and the absence of large trucks. In the survey conducted for the present study, 57 percent of managed lane users indicated one of the reasons that they used managed lanes was that they considered them to be safer and less stressful than the general purpose lanes. Consonant with this, it was expected that high risk perceptions will be associated with a higher likelihood to use managed lanes.

Driving styles pertain to the way drivers choose to or habitually drive (Taubman-Ben-Ari, Mikulincer, & Gillath, 2004). Researchers posit that the type of driving style is also an important determinant in predicting driving outcomes (Elander, West, & French, 1993). Because driving styles are behavioral tendencies, they may play a role in the choices drivers make with respect to the use of managed lanes. For example, the key feature of a risky driving style is a tendency to drive fast, and therefore get impatient in high traffic situations. Individuals with a risky driving style may prefer managed lanes over general purpose lanes because the former may permit higher speeds. Additionally, managed lanes are almost always located on high traffic roadways, increasing their appeal for drivers in a hurry. A careful driving style, on the other hand, is a

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tendency to experience anxiety while driving. Thus, a careful driving style may also be associated with reduced managed lane use if drivers view the tasks of entering and exiting the lanes as an additional source of anxiety.

The final set of individual differences that were investigated in the present study pertained to travelers' *carpooling attitudes* and *travel attribute preferences* with the latter speaking to the extent to which factors such as relaxation, comfort, low travel time, and reliable travel time (Van Vugt, van Lange, Meertens, & Joireman, 1996) are important considerations to the traveler in the planning and taking of trips. Thus, we sought to explore whether carpooling attitudes and the specified travel attributes would be related to preferences for managed lane use.

2.1.2. Characteristics of the trip

2.1.2.1. Travel cost. Travel cost refers to out-of-pocket expenses involved in taking a trip. It may include fuel cost, toll, and wear-and-tear of the vehicle (Lee & Burris, 2005). In this study, we are more interested in the effect of tolls on the mode choice, thus only toll is considered as one of the attributes defining the alternative (mode). Additionally, since travel mode in the present study is the automobile, there is little change in the other costs between managed lanes and general purpose lanes. Not surprisingly, studies have shown that travelers have a disutility for paying a toll; that is, travelers would prefer a lower tolled alternative over a higher tolled alternative, ceteris paribus (see Cherlow, 1981; De Jong, Tseng, Kouwenhoven, Verhoef, & Bates, 2007; Lam & Small, 2001; Small, Winston, & Yan, 2005).

2.1.2.2. Travel time and travel time reliability. One of the most influential attributes that affects a traveler's preference for managed lanes is the travel time savings offered by the lanes. A vast body of research has shown that travelers have a disutility for higher travel time and would prefer an alternative that has a lower travel time (for example see Becker, 1965; Devarasetty et al., 2012a,b; Ghosh, 2001; Hensher, Rose, & Greene, 2005). Studies have shown people value travel time savings and are willing to pay for reducing their travel time. There is abundant literature estimating the value of travel time savings, also referred to as the value of time. The value of travel time savings is the amount of money an individual is willing to pay to save a unit of travel time. The earliest studies on value of time date back to the 1960s (Becker, 1965; Beesley, 1965; Oort, 1969). Travelers' value of travel time savings is typically estimated using stated preference surveys. It is calculated from discrete travel choice models and is derived as the marginal rate of substitution between travel time and cost in the choice models (Georgia Department of Transportation, 2010).

Travel time reliability refers to the predictability or variation in the travel time of a particular mode/alternative. Higher variation in the travel time indicates that the mode is less reliable or less predictable. Research has shown that travelers have a disutility for unreliable travel time (see Small, Noland, Chu, & Lewis, 1999; Small et al., 2005; Tilahun & Levinson, 2010) and often are willing to pay for a mode that has a low variation in travel time, such as on a managed lane. However, to keep the survey questions relatively straight forward and focused on the psychological variables, we did not include travel time reliability in the survey.

3. Present study

The primary objective of the present study was to further the understanding of travelers' use of managed lanes by investigating the relationships between these behavioral choices and a number of psychological variables. To this end, a survey was conducted to collect information about travelers' standing on the specified individual difference variables, and their preferences for managed lane use.

3.1. Study area

The survey was conducted in three major cities where managed lanes have been operational for at least two years. The three locations were the I-25 express lanes in Denver, the I-95 express lanes in Miami, and the I-15 express lanes in San-Diego. It should be noted that express lanes are a type of managed lanes. These three locations referred to their managed lanes as "express lanes".

3.1.1. Express lanes in Denver

The I-25 High Occupancy Vehicle/Tolled Express Lanes in Denver opened on June 2nd, 2006. The facility spans 7 miles running from downtown Denver, Colorado, north to US 36. It is a reversible two-lane, barrier-separated facility. One of the lanes is reserved for high occupancy vehicles and buses to travel toll-free and the other is open to single occupancy vehicles for a toll. There are multiple access points at each end but no intermediate entrances or exits. Prices vary by time of day and range from $0.50 to $5.00. The toll is set higher during peak periods to ensure that the high occupancy vehicle/express lanes are never congested. The toll is collected through electronic toll collection or via reading the license plate of the vehicle (Colorado Department of Transportation, 2012).

3.1.2. Express lanes in Miami

The I-95 Express Lanes project is being conducted in two phases. Phases 1A and 1B were completed in January, 2008. Phase 2 started in late 2011 and is expected to be completed in late 2014. During Phases 1A and 1B, a single northbound

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high occupancy vehicle lane (one of two directional high occupancy vehicle lanes) was converted into two northbound variably priced express lanes. Tolls vary dynamically with the level of congestion, with the goal of keeping traffic in the express lanes moving at least 45 mph. Registered vanpools, registered carpools of 3+, registered hybrid vehicles, and motorcycles can use the lanes without paying a toll. Buses of several types can also use the lanes toll-free. Tolls for all other express lane vehicles are collected electronically. This can be done by reading the vehicle's license plate and sending the traveler a bill in the mail or the preferred way of toll-paying travelers owning and displaying a SunPass transponder. Trucks of three or more axles are not allowed to use the express lanes (95Express, 2012). Typical tolls on express lanes can fluctuate from $0.25 to $3.50 depending on the traffic conditions, and in some extreme cases, they can be as high as $7.00.

3.1.3. I-15 Express lanes in San Diego

The I-15 Express Lanes facility in San Diego is a 20-mile, 4-lane (two in each direction) facility located in the middle of the I-15. Access to I-15 express lanes is available at every two to three miles to allow travelers to move on and off the main lanes to the express lanes. A Level of Service C, roughly equivalent to a 45-mph travel speed, or better is required by law to be maintained on the express lanes at all times. High occupancy vehicles with two or more occupants (carpools, vanpools, and buses), motorcycles, and designated hybrid vehicles are permitted to use the I-15 express lanes for free. Single occupancy vehicles may use the lanes by paying a toll. The toll is collected electronically, and single occupancy vehicles must carry a FasTrak pass to use the facility. The toll is charged on a per mile basis and is calculated dynamically based on the level of traffic in the I-15 express lanes, ensuring traffic flows freely in them. The toll ranges from $0.50 to $8.00 (Fastrack, 2012).

4. Method

4.1. Participants

The study participants consisted of an initial sample of 1,001 respondents who voluntarily completed an online survey. However, only 700 provided data that were useable (i.e., completed the survey to a point where their data could be used in the analyses). Furthermore, of these 700, 36 reported using a motorcycle or bus for their most recent trip. Consequently, they were also excluded from the analyses. Thus, the final study sample consisted of 664 participants (53.0% female). Most participants were between 35 and 64 years old (76.9%). The specific breakdown of participant age groups is as follows: 16–24 = 1.2%; 25–34 = 8.9%; 35–44 = 16.5%; 45–54 = 28.0%; 55–64 = 32.3%; 65 or older = 13.1%. Finally, in terms of distribution across cities, 209 participants were from Denver, 54 from Miami, and 401 from San Diego.

4.2. Measures

4.2.1. Psychological variables

The measures used to operationalize the psychological variables were obtained from the extant literature or created specifically for the present study. However, for those that were obtained from the extant literature, as a result of administrative constraints arising from the total length of the survey and the time required to complete it (some participant recruitment sites were unwilling to participate in the study unless the survey was shortened), a decision was made to shorten some of the measures to permit the project to proceed. Thus, a psychometric focus group was convened to complete the measures as participants and comment on the adequacy of the items and measures. The focus group ratings and judgments were then used to identify the best subset of items from the original measures in terms of adequacy to the research setting and their psychometric properties. Focus group participants were 24 doctoral students with expertise in psychometrics and scale development from the fields of industrial-organizational psychology ($n = 14$) and civil engineering ($n = 10$). Finally, to maintain consistency in the presentation of the surveys, with the exception of the locus of control measure, the response formats for all the measures were modified to a nine-point Likert scale, where warranted.

Conscientiousness was operationalized using the 10-item measure from Goldberg's (1992) personality markers. This measure was not shortened. Participants rated the extent to which each of the 10 statements was descriptive of them (1 = *very inaccurate*; 9 = *very accurate*; the response options were not modified). Example items are "Always prepared", "Like order", and "Follow a schedule". An internal consistency reliability estimate (Cronbach alpha) of .74 was obtained for the scores which were computed as the average of the item ratings.

A subset of 10 out of 23 forced-choice items from the Internal-External Locus of Control Scale (Rotter, 1966) was used to assess participants' *locus of control*. For this measure, participants were asked to choose between a pair of items, with each item reflecting either an internal locus of control (e.g., "Becoming a success is a matter of hard work; luck has little or nothing to do with it") or an external locus of control (e.g., "Getting a good job depends mainly on being in the right place at the right time"). Items were scored such that higher scores reflected an external locus of control. An internal consistency reliability estimate (Cronbach alpha) of .63 was obtained for this measure.

Risk tolerance was measured using the financial risk subscale from Weber et al.'s (2002) Risk Taking Scale. Weber et al.'s measure consists of five subscales of 10 items each that assess risk taking in financial, health/safety, recreational, ethical, and social contexts. Because the present study's focus was the paying of tolls to use managed lanes, only the financial risk taking

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scale was deemed germane, and so we used only this scale. However, all 10 items for the scale were used; this scale was not shortened. Participants responded to each item by indicating the likelihood that they would engage in the specified activity (1 = *extremely unlikely*; 9 = *extremely likely*; the response options were modified from a 1–5 point scale). Example items are "Spending money impulsively without thinking about the consequences" and "Taking a job where you get paid exclusively on a commission basis". An internal consistency reliability estimate (Cronbach alpha) of .74 was obtained for the scores which were computed as the average of the item ratings.

Need for structure was operationalized using Thompson, Naccarato, and Parker's (1989) 10-item version of Neuberg and Newsom's (1993) Personal Need for Structure Scale. Participants responded to the 10 items by rating their level of agreement with each (1 = *strongly disagree*; 9 = *strongly agree*; the response options were modified from a 1–6 point scale). Example items are "I enjoy having a clear and structured mode of life" and "I find that a consistent routine enables me to enjoy life more". An internal consistency reliability estimate (Cronbach alpha) of .84 was obtained for the scores which were computed as the average of the item ratings.

A *driving risk perceptions* measure which consisted of a measure of risk-taking cognitions (2 items from Fischer, Kubitzki, Guter, & Frey, 2007) and risk perceptions (3 items from Rundmo & Iversen, 2004) was created for the purposes of the present study. Participants responded based on the extent to which they agreed with each statement (1 = *strongly disagree*; 9 = *strongly agree*; the response options were modified from a 1–10 point scale [Fischer et al., 2007] and a 1–7 point scale [Rundmo & Iversen, 2004]). Example items are "I become anxious when driving too fast" and "I am worried about being injured in a traffic accident". An internal consistency reliability estimate (Cronbach alpha) of .84 was obtained for the scores which were computed as the average of the item ratings.

Two *driving style* measures—*careful driving style* and *risky driving style*—were developed specifically for the present study. The development of these measures was guided by a content review of the literature and the results of the focus group. As a result of these activities, *careful driving style* was operationalized as the composite of 11 items selected from Taubman-Ben-Ari et al.'s (2004) Multi-Dimensional Driving Style Inventory. Example items are "On a clear freeway, I usually drive at or a little below the speed limit" and "I plan long journeys in advance". Participants responded to the items in terms of the extent to which they agreed with each statement (1 = *strongly disagree*; 9 = *strongly agree*; the response options were modified from 1 = *not at all* to 6 = *very much*). Scale scores were computed as the average of the item ratings and an internal consistency reliability estimate (Cronbach alpha) of .65 was obtained for the scores.

Risky driving style was operationalized as the composite of 6 items also selected from Taubman-Ben-Ari et al. (2004). Items (e.g., "I enjoy the excitement of dangerous driving" and "In a traffic jam, I move to a faster lane as soon as I see the opportunity") were responded to on a 1–9 point scale (1 = *strongly disagree*; 9 = *strongly agree*). Scale scores were computed as the average of the item ratings and an internal consistency reliability estimate (Cronbach alpha) of .80 was obtained for the scores.

Travel attribute preferences and *carpooling attitudes* were assessed using Van Vugt et al.'s (1996) measure (response options were modified from a 1–7 to a 1–9 point scale). Travel attribute preferences were assessed by asking participants to rate the importance of nine personal travel attributes (e.g., "Relaxation", "Comfort", and "Flexibility"). Specifically, participants responded based on the extent to which specified travel attributes were important to them (1 = *extremely unimportant*; 9 = *extremely important*). Previous research has shown that solo and non-solo drivers differ in the value they place on these attributes (Van Vugt et al., 1996). For instance, solo drivers tend to value relaxation, comfort, and low travel time more than non-solo drivers. *Carpooling attitudes* were assessed to measure participants' perceptions of traveling with others. Participants reported their perceptions of how easy it would be to carpool (1 = *extremely difficult*; 9 = *extremely easy*), preference for carpooling (1 = *very strong preference for driving solo*; 9 = *very strong preference for carpooling*), and carpooling intentions (1 = *no intentions to carpool*; 9 = *very strong intentions to carpool/I currently carpool*).

4.2.2. Stated preference question design

A total of three stated preference questions were presented to each participant. In each question, the respondent was asked to consider a realistic travel scenario on the major freeway in their respective hometown with four different modes of travel available. The modes were (1) single occupancy vehicle on the general purpose lanes, (2) single occupancy vehicle on the express lanes, (3) high occupancy vehicle on the general purpose lanes, and (4) high occupancy vehicle on the express lanes; and varied based on travel time, and toll values (see Fig. 1 for a sample stated preference question). The respondent was asked to select the mode that they would most likely choose if faced with the specified choices for their most recent trip.

Travel scenarios were largely created based on the details of the respondent's most recent trip on the major freeway toward or away from downtown. Roughly half of the respondents were asked about their recent trip toward downtown and the other half about their trip away from downtown. Trip details included the day of week of the trip, purpose of the trip, when it started, when it ended, the length of the trip, the type of vehicle they used for the trip, and the number of people in the vehicle.

Each of the freeways mentioned earlier have both managed lanes and general purpose lanes. On each of these lanes, travelers have the option of either driving alone or forming a carpool with others for travel (other options, such as transit, are also available but were not examined in the present study). Travelers will need to pay a toll if they want to travel as a single occupant vehicle on the managed lanes. Carpoolers need not pay any toll to travel on the managed lanes, with the exception of Miami where only pre-registered 3+ person carpoolers are allowed to travel for free on the managed lanes. With these

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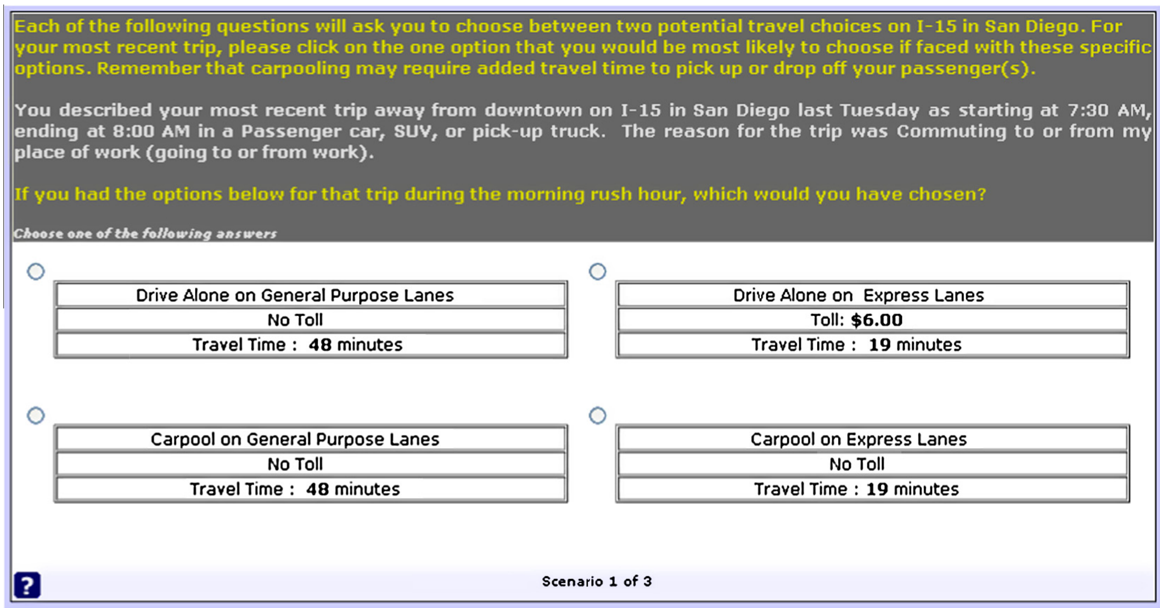

Fig. 1. Sample stated preference question for a respondent traveling on I-15 in San Diego.

available options, four modes of travel are possible—(1) drive alone on the general purpose lanes; (2) carpool on the general purpose lanes; (3) drive alone on the express lanes; and (4) carpool on the express lanes.

Two types of design techniques (1) D_b-efficient and (2) adaptive random (see Burris, Arthur, Devarasetty, McDonald, & Muñoz, 2012 for details on the designs used in the survey) were used to generate the attribute levels for the toll and travel time. The tolls vary considerably based on the survey design. Travel time on the managed lanes was adjusted to always be lower than or equal to the travel time on the general purpose lanes.

4.3. Procedure

4.3.1. Survey description

The online survey was conducted in the three cities mentioned in the previous sections. The online survey consisted of five sections. The first section asked respondents about their most recent trip on one of the major freeways with the express lanes: I-25 in Denver, I-95 in Miami, and I-15 in San Diego. Questions included queries about the purpose of the trip, day of the week of the trip, when the trip began, when it ended, the length of the trip, the type of vehicle, the number of passengers in the vehicle, and whether the respondent used express lanes for that trip. (See http://utcm.tamu.edu/publications/final_reports.stm [Burris et al., 2012] for the complete survey.)

In the second section of the online survey, the express lanes were briefly described to the respondents in case they were unfamiliar with the lanes. Respondents were then asked if they ever used them and their reasons for using or not using them. The third section consisted of the individual difference measures. As previously noted, to maintain consistency in the presentation of the surveys, the response formats for all the measures were modified to a nine-point Likert-type scale with the exception of the locus of control measure, which used a forced-choice response format as described earlier. The measures presented in this section were *conscientiousness*, *general locus of control*, *personal need for structure*, *risk tolerance (financial)*, and *driving risk perceptions* and *driving style*. The *carpooling* and *travel attribute preferences* measures were also presented in this section.

There were a total of 78 items across all the individual difference measures. Consequently, due to the practical limitations of administering a measure of this length under the extant circumstances (again, some participant recruitment sites were unwilling to participate in the study unless the survey was shortened), and to reduce respondent burden and thus increase the potential response rate, the decision was made to have each respondent receive and complete only 3 of the 6 measures (i.e., from 30–49 items). Thus, 20 versions of the survey were created with every three-measure combination without replacement or repetition occurring in one version of the survey. Participants were randomly assigned to complete one of the survey versions. Although these design decisions resulted in a more manageable subset of items to be completed by the participants, the implications of these decisions, in terms of the methodological trade-offs, are discussed in the Conclusion section.

The fourth section of the online survey contained the stated preference questions where respondents indicated their mode and lane choices when faced with different travel options. The fifth and final section of the survey gathered socio-economic data from each respondent.

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4.3.2. Online survey administration

The survey was posted on a Texas Transportation Institute server and was made available for public access through the www.TravelChoicesSurvey.org website. The data collection process started on February 14th, 2012, and continued until May 7th, 2012. Residents of Denver, Miami, and San Diego who use the I-25, I-95, and I-15 Freeways, respectively, were encouraged to participate in the survey. The existence of the survey was advertised to the public through online and news media. To increase the participation in the survey, one VISA gift card worth $250 was given to one randomly chosen respondent from each city (a total of three gift cards). The contact information for the drawing was stored separately and could not be linked to the survey responses.

In addition to the website ads, the agencies in charge of the Miami, Denver, and San Diego express lanes added a brief note regarding the existence of the survey to some of their monthly account e-notices. Each city sent notices about the survey's existence on different dates. Miami toll road authorities sent out notices on February 14th, 2012, and only to people who signed up for announcements/surveys. The survey duration for Miami was shorter than other cities; it ran from February 14th, 2012, to March 30th, 2012. Denver and San Diego toll road authorities sent out notices on March 15th, 2012, and April 18th, 2012, respectively as part of their monthly bill e-mails. For Denver and San Diego, the survey was active till May 7th, 2012. The ads for each city were published on the websites only after the agencies announced the survey's existence.

5. Results

As previously noted, the online survey resulted in 664 completed responses from travelers in autos. There were 209 from Denver, 54 from Miami, and 401 from San Diego. Not all respondents answered every question, but many did answer all questions, and those that did not answer every question left only a few questions blank. Table 1 presents the descriptive statistics and intercorrelations amongst the primary study variables.

Several mode choice models of survey respondents were developed using the mixed logit modeling technique (Ben-Akiva, Bolduc, & Walker, 2001; Bhat & Castelar, 2002; Brownstone & Train, 1998; Greene, Hensher, & Rose, 2006; Hensher & Greene, 2003). The models were tested to incorporate multiple variables to provide a better understanding of the influence of all variables on mode choice. Previous studies have found that the mode choice models for express lanes should include the travel time and toll rate. They may also include the sex of the traveler, the income of the traveler, and other characteristics as previously discussed.

Mixed logit models were developed by including many of the variables found to be significantly different by mode through a crosstab analysis. Then variables that were not significant in the model or did not improve the models' predictive ability were removed in a stepwise fashion. Since the focus of the study was the impact of the psychological variables on mode choice, a model incorporating each of the psychological variables was developed. This was necessary since none of the psychological variables were significant in the model that incorporated several psychological variables.

The final model results are shown in Table 2. The models are developed for each mode (listed in the far left column) and a different model was developed for each psychological variable (columns 3 through 8). The second column includes the name of each variable in the model. The numbers in the table are the model coefficients with their p values in parentheses. Note that since each respondent could answer up to three stated preference questions, there was a maximum of 1992 (664×3) responses to those stated preference questions. However, since each respondent only received half of the psychological variable measures (i.e., three of six) the models incorporating psychological variables had a maximum of approximately 996 responses. Due to random distribution of the psychological variable measures (each of which had a different number of items), the maximum number of responses were sometimes larger or smaller than 996. Model results are interpreted as in the following example (Eq. (1)) for model 4 with financial risk tolerance:

Table 1
Descriptive statistics and intercorrelations amongst the study variables.

	M	*SD*	1	2	3	4	5	6	7	8	9
1. Sex	–	–	–	657	315	325	344	316	345	345	345
2. Age	4.22	1.20	−.02	–	317	327	344	318	347	347	347
3. Conscientiousness	7.38	1.01	−.04	.08	(.79)	121	133	131	132	132	132
4. Locus of control	0.32	0.21	−.11	**−.16**	**−.26**	(.63)	136	117	142	142	142
5. Need for structure	5.78	1.29	.00	−.10	**.32**	.07	(.84)	135	148	148	148
6. Risk tolerance	2.42	1.08	**.16**	.02	**−.27**	.00	**−.29**	(.74)	134	134	134
7. Driving risk perceptions	4.18	1.68	**−.19**	.02	−.12	**.21**	**.37**	−.03	(.84)	347	347
8. Careful DS	4.91	0.86	**−.18**	**.12**	.04	.11	**.31**	−.09	**.58**	(.65)	347
9. Risky DS	3.03	1.18	**.20**	**−.14**	**−.16**	.08	−.07	**.16**	**−.30**	**−.42**	(.80)

Note: Numbers in parentheses are the internal consistency reliability estimates for each measure. Correlations between study variables are below the diagonal and *ns* for each correlation are above the diagonal. Dummy codes for sex are male = 1 (N = 310) and female = 0 (N = 349). Age was measured using the following categories: 1 to 6 where 1 = 16 to 24; 2 = 25 to 34; 3 = 35 to 44; 4 = 45 to 54; 5 = 55 to 64; and 6 = 65 or older, which were subsequently coded as 1–6, respectively. Locus of control was scored such that higher scores reflect an external locus. DS = driving style. Correlations in boldface are statistically significant (p < .05, two-tailed).

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Table 2
Mode choice models.

Mode	Independent Variable	Model 1: No PSYC variables (n = 1811)	Model 2: Locus of control (n = 937)	Model 3: Driving risk (n = 973)	Model 4: Financial risk tolerance (n = 909)	Model 5: Need for structure (n = 998)	Model 6: Conscientiousness (n = 919)
All	Travel time (min.)	−0.59 (0.00)	−0.32 (0.00)	−0.29 (0.00)	−0.25 (0.00)	−0.25 (0.00)	−0.67 (0.00)
	Toll ($)	−1.21 (0.00)	−0.54 (0.00)	−0.49 (0.00)	−0.41 (0.00)	−0.54 (0.00)	−0.21 (0.01)
Drive alone – GPLs	–	–	–	–	–	–	–
Carpool – GPLs	ASC	−4.25 (0.00)	−3.62 (0.20)	1.66 (0.78)	−9.52 (0.00)	−16.1 (0.07)	−6.45 (0.02)
	Male	0.81 (0.05)	2.20 (0.23)				1.32 (0.03)
	Med. income		−4.64 (0.01)				
	High income		5.05 (0.01)				
	Recreational/shopping/errand trips						0.53 (0.36)
	Locus of control		−6.06 (0.16)				
	Driving risk perceptions			0.97 (0.10)			
	Careful driving style			−1.62 (0.28)			
	Risky driving style			−3.79 (0.00)			
	Risk tolerance (Financial)				0.16 (0.82)		
	Need for structure					−0.06 (0.93)	
	Conscientiousness						0.32 (0.38)
Drive alone – MLs	ASC	−1.90 (0.03)	−0.87 (0.08)	0.29 (0.85)	−1.33 (0.03)	−0.93 (0.28)	−1.32 (0.48)
	Male	−1.77 (0.02)	−0.85 (0.03)	−0.79 (0.04)	−1.31 (0.00)	−0.91 (0.01)	−0.53 (0.11)
	Locus of control		−0.52 (0.55)				
	High income			0.88 (0.02)	0.77 (0.07)	1.11 (0.00)	
	Recreational/shopping/errand trips						−0.92 (0.02)
	Driving risk perceptions			−0.21 (0.12)			
	Careful driving style			−0.10 (0.72)			
	Risky driving style			−0.12 (0.49)			
	Risk tolerance (Financial)				0.09 (0.62)		
	Need for structure					−0.01 (0.90)	
	Conscientiousness						−0.15 (0.53)
Carpool – MLs	ASC	−0.38 (0.00)	−4.27 (0.00)	−1.44 (0.77)	−3.41 (0.00)	−1.81 (0.37)	−0.65 (0.62)
	Weekday	−3.40 (0.00)		−3.43 (0.04)			
	Married w/o Children	1.07 (0.07)					0.53 (0.01)
	Locus of control		0.43 (0.82)				
	Driving risk perceptions			0.15 (0.64)			
	Careful driving style			0.01 (0.99)			
	Risky driving style			−0.27 (0.53)			
	Risk tolerance (Financial)				−0.08 (0.83)		
	Need for structure					−0.43 (0.20)	
	Conscientiousness						−0.38 (0.03)
Standard deviations	Travel time	1.18 (0.00)	0.39 (0.00)	0.20 (0.14)	0.20 (0.02)	0.11 (0.34)	2.11 (0.00)
	ASC-Carpool-GPLs	1.19 (0.00)	4.40 (0.05)	6.52 (0.00)	4.86 (0.00)	8.13 (0.05)	0.07 (0.99)
	ASC-Drive alone-MLs	5.18 (0.00)	1.80 (0.00)	2.06 (0.00)	2.36 (0.00)	1.94 (0.00)	2.32 (0.00)
	ASC-Carpool-MLs	7.37 (0.00)	5.98 (0.00)	7.10 (0.00)	6.69 (0.00)	7.50 (0.00)	0.25 (0.74)
Model results	Log likelihood	−1604.6	−821.2	−818.4	−791.1	−830.7	−948.8
	Log likelihood (restricted)	−2510.6	−1299.0	−1348.9	−1260.1	−1383.5	−1274.0
	Log likelihood (constants only)	−2014.8	−1041.6	−1067.3	−1017.1	−1096.0	−1019.1

(*continued on next page*)

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Table 2 (*continued*)

Mode	Independent Variable	Model 1: No PSYC variables ($n = 1811$)	Model 2: Locus of control ($n = 937$)	Model 3: Driving risk ($n = 973$)	Model 4: Financial risk tolerance ($n = 909$)	Model 5: Need for structure ($n = 998$)	Model 6: Conscientiousness ($n = 919$)
	Rho squared	0.36	0.37	0.39	0.37	0.40	0.26
	Rho squared (constants only)	0.20	0.21	0.23	0.22	0.24	0.07
	Value of travel time savings ($/h)	29.25	36.39	35.65	36.28	27.70	19.09
	Percent correct predictions	34.4	35.0	35.5	34.8	35.7	33.0

Note: GPL = general purpose lanes; ML = managed lanes; and ASC = alternative specific coefficient.

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$$\begin{aligned} U_{DA-GPL} &= -0.25 \times TT_{GPL} \\ U_{CP-GPL} &= -0.25 \times TT_{GPL} - 9.52 + 0.16 \times FRT \\ U_{DA-ML} &= -0.25 \times TT_{ML} - 0.41 \times Toll_{ML} - 1.33 - 1.31 \times Male + 0.77 \times HInc + 0.09\ FRT \\ U_{CP-ML} &= -0.25 \times TT_{ML} - 0.41 \times Toll_{ML} - 3.41 - 0.08 \times FRT \end{aligned} \tag{1}$$

where U is the systematic portion of the utility of each mode; DA is drive alone; CP is carpool, GPL is general purpose lanes; ML is managed lanes; TT is travel time; FRT is 1 if the traveler exhibited financial risk tolerance, 0 otherwise; Toll is the toll rate; Male is 1 if the respondent was male; and HInc is 1 if the respondent had an annual household income greater than $100,000. Technically, toll rate is added to each mode, but since the GPLs have no toll it is not shown in these equations.

With the probability of a respondent taking any mode shown in Equation 2, below:

$$P_{it} = \frac{e^{U_{it}}}{\sum_{j=1}^{4} e^{U_{jt}}} \tag{2}$$

where P_{it} is the probability of traveler t choosing mode i, and j is the counter for each mode.

Thus, the higher the utility of a given mode, the greater the likelihood that a traveler will choose that mode. Therefore, a negative coefficient, such as male for the mode drive alone on the managed lanes, indicates that a male is less likely to choose to drive alone on the managed lanes than a female, ceteris paribus.

The first mixed logit model examined was the base model with no psychological variables included (see Table 2, model 1). The model yielded reasonable results with a rho squared value of 0.36 and a value of time of $29.25/h. The next set of models included locus of control. Locus of control made little difference in rho squared (0.37) or value of time ($36.39/h). Locus of control was not significant in any of the mode choice models (both the ones shown here in Table 2 and many others that were estimated).

The next set of models included the driving-related variables, specifically, (1) driving risk perceptions, (2) careful driving style, and (3) risky driving style. Risky driving style was the only significant variable in the models, displaying a negative impact on the utility of carpooling in general purpose lanes. These results provide support for the hypothesized effects which had posited that individuals with risky driving styles will prefer managed lanes over general purpose lanes; because amongst others, the former permit higher speeds. This model had a slightly better rho squared value of 0.39 than the base model.

Psychological variables were only significant in one other model. Conscientious drivers had a decreased utility for carpooling on the managed lanes. On the basis of the extant theoretical literature, it had been unclear what the direction of this relationship would be. As previously noted, on one hand, conscientious individuals may be less likely to use managed lanes because they are more likely to make decisions ahead of time and thus allow plenty of time for travel and subsequently, not require the use of managed lanes to arrive at their destinations on time. On the other hand, these individuals may also prefer the predictability in scheduling provided by the use of managed lanes. Hence, it would seem that the results obtained here are more in accord with the former proposition. Thus, it would seem that high conscientious individuals may have less need for managed lanes because they are organized enough to leave sufficient time in their schedule for travel on general purpose lanes. In addition, they may have a lower preference for carpooling because it is less structured and predictable mode of travel (i.e., associated with more travel time variability and other factors over which the individual has limited or no control [e.g., delayed riders, unscheduled stops]).

In general, the psychological variables did little to improve the models' ability to predict mode use. With the exception of the two instances noted above, the psychological variables were not significantly different from 0 at a 95 percent confidence limit. Therefore, based on these limited results, travel time savings, toll rate, sex and income were more likely to be indicators of a travelers' use of managed lanes than any of the psychological characteristics of those travelers.

Table 3
Means and analysis of variance results for the relationship between psychological variables and stated preference choice.

	n	DA-GPL (n = 102)	DA-ML (n = 61)	CP-ML (n = 173)	η^2
Conscientiousness	164	7.35 (52)	7.26 (30)	7.21 (82)	.00
Locus of control	153	0.32 (48)	0.31 (24)	0.32 (81)	.00
Need for structure	174	5.78 (52)	5.90 (30)	5.71 (92)	.00
Risk tolerance	174	2.50 (56)	2.29 (35)	2.34 (83)	.01
Driving risk perceptions	177	4.35 (55)	3.96 (34)	4.26 (88)	.01
Careful DS	177	4.97 (55)	4.75 (34)	4.97 (88)	.01
Risky DS	177	3.31 (55)	3.29 (34)	2.98 (88)	.02

Note: Stated preference choice was aggregated within individual only if their responses to each of the three scenarios were the same (e.g., always chose DA-GPL). DA = driving alone; CP = carpool; GPL = general purpose lane; ML = managed lane; η^2 (or eta-squared) is an effect size metric that reflects the amount of variance in a dependent or outcome variable that is explained by the independent variable or predictor. Numbers in parenthesis are the ns per cell. No results are presented for carpooling on general purpose lanes (CP-GPL) because only one respondent chose this option. None of the effects were statistically significant ($p > .05$).

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Table 4
Means and analysis of variance for the relationship between travel attributes preferences and carpooling attitudes and stated preference choice.

	N	DA-GPL (n = 102)	DA-ML (n = 61)	CP-ML (n = 173)	η^2
Travel attribute preferences					
Concerns about the environment	160	5.98 (42)	5.93 (28)	6.36 (90)	.01
Low travel costs	162	7.36$^{\mathbf{AB}}$ (42)	6.82$^{\mathbf{A}}$ (28)	7.76$^{\mathbf{B}}$ (92)	.04*
Companionship	158	3.33$^{\mathbf{A}}$ (39)	3.82$^{\mathbf{AB}}$ (28)	4.83$^{\mathbf{B}}$ (91)	.07**
Relaxation	161	5.64 (42)	6.39 (28)	6.43 (91)	.03
Safety	161	7.60 (42)	8.07 (28)	7.92 (91)	.01
Comfort	160	7.45 (42)	7.68 (28)	7.19 (90)	.01
Low travel time	162	7.69 (42)	8.21 (28)	7.61 (92)	.02
Reliable travel time	163	7.64 (42)	8.45 (29)	7.76 (92)	.03
Flexibility	163	8.07 (43)	7.93 (28)	7.45 (92)	.03
Carpooling attitudes					
Easy to carpool	165	1.70$^{\mathbf{A}}$ (43)	1.80$^{\mathbf{A}}$ (30)	3.95$^{\mathbf{B}}$ (92)	.18**
Preference for carpooling	165	2.77$^{\mathbf{A}}$ (43)	2.80$^{\mathbf{A}}$ (30)	5.22$^{\mathbf{B}}$ (92)	.24**
Carpooling intentions	165	2.37$^{\mathbf{A}}$ (43)	1.77$^{\mathbf{A}}$ (30)	5.46$^{\mathbf{B}}$ (92)	.30**

Note: Stated preference choice was aggregated within individual only if their responses to each of the three scenarios were the same (e.g., always chose DA-GPL). DA = driving alone; CP = carpool; GPL = general purpose lane; ML = managed lane; η^2 (or eta-squared) is an effect size metric that reflects the amount of variance in a dependent or outcome variable that is explained by the independent variable or predictor. Means that share the same letter superscript (e.g., both A) are not statistically different. Numbers in parenthesis are the ns per cell. No results are presented for carpooling on general purpose lanes (CP-GPL) because only one respondent chose this option.

* $p < .05$.

** $p < .01$.

To further investigate the relationships, the mean differences between the psychological variables were analyzed using a univariate analysis of variance (ANOVA) with the travel mode as the grouping variable and each psychological variable as the dependent variable (see Tables 3 and 4). These analyses were limited to only those respondents who chose the same mode in all three stated preference questions. The results of the ANOVA showed significant effects for some of the travel attribute preferences and all the carpooling attitudes (see Table 4). Specifically, the effect of low travel costs ($\eta^2 = .04$, $p < .05$) and companionship ($\eta^2 = .07$, $p < .01$) were statistically significant. Post hoc analyses using the Tukey procedure indicated that drivers who prefer carpooling on managed lanes value low travel costs more than drivers who drive alone on managed lanes. Also, drivers who prefer to carpool on managed lanes ascribe more importance to companionship over solo drivers on general purpose lanes. And as previously noted, carpooling attitudes consistently differentiated between travel mode choice, with drivers who carpool on managed lanes reporting it to be much easier to carpool ($\eta^2 = .18$, $p < .01$). In addition, they also have a higher preference for carpooling ($\eta^2 = .24$, $p < .01$), and stronger intentions to carpool in the future ($\eta^2 = .30$, $p < .01$).

6. Conclusions

The present study investigated the relationship between a number of conceptually grounded psychological variables and the decision to use managed lanes in an effort to further the understanding of travel behavior and the ability to predict the potential usage of priced managed lanes. Building on the extant driving behavior literature, a number of psychological variables as well as attitudes and perceptions were identified and posited to be related to managed lane use. The results of stated preference survey data, analyzed via mixed logit models indicated that only conscientiousness and risky driving style displayed significant relationships with the stated preference questions. Specifically, in accordance with the posited relationships, individuals with higher risky driving style scores were less likely to choose carpooling on general purpose lanes. That would be the mode which afforded the least ability to drive faster or in a riskier style, which could be the reason individuals with higher risky driving style scores were less likely to choose the mode.

Individuals with higher conscientiousness scores were less likely to choose to carpool on the managed lanes. The results for conscientiousness—that it was one of the psychological variables that showed an effect—are interesting in that they are consonant with a vast volume of literature in industrial/organizational psychology and other applied domains that show that of the five dimensions of the fact-factor model of personality, conscientiousness is routinely and consistently the most robust and valid predictor of a wide range of behaviors of interest (Barrick & Mount, 1991; Bogg & Roberts, 2004; Clarke & Robertson, 2005; Hurtz & Donovan, 2000; McAbee & Oswald, 2013; Oswald & Hough, 2011). But, these findings were not supported in follow-up ANOVA tests of the mean differences between the psychological variables and travel mode choice. However, as illustrated in Table 3, the sample sizes for these particular analyses were fairly small ranging from 153 to 177.

In reference to travel attribute preferences and carpooling attitudes, the results of the ANOVA tests indicated that respondents who chose carpooling in managed lanes also reported (a) having a higher preference for carpooling, (b) finding it easier to carpool, and (c) also having greater intentions to carpool in the future. Although the correlational nature of the present design makes it impossible to determine which variable is the antecedent and which is the consequence, there is a long and rich literature in social psychology demonstrating the causal effect of attitudes and intentions on actual behavior (e.g., Ajzen, 1991; Ajzen, 2001; Ajzen & Fishbein, 2005; Sheeran, 2002). For instance, according to the well-established theory

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of planned behavior (Ajzen, 1991) intentions are the proximal predictors of behavior and mediate the influence of attitudes on behavior.

As noted in the introduction, the authors have examined empirical data from several managed lanes (including some data not yet published) and have consistently found a significant percentage of travelers paying for ML use when saving little or no travel time. So it appears that there are more factors involved in choosing to pay for a ML than travel time savings. Other logical factors include travel time reliability, a feeling of safety, psychological traits of the traveler, etc. Consequently, the accurate prediction of managed lane use will continue to be a challenge until there is a fuller and better understanding of the factors that play a role in, and influence this choice. However, we suspect that the transportation industry will likely continue to focus on the value of travel time savings to estimate usage – despite the evidence that there is much more behind a traveler's decision to use managed lanes.

5.1. Limitations and Suggestions for Future Research

An objective of the present study was to investigate the extent to which the psychological characteristics would account for variance in managed lane choice over and beyond that explained by trip (e.g., toll, time savings), and non-psychological traveler characteristics such as income and sex. The results indicated that at least in the present data, trip and non-psychological traveler characteristics had a much greater impact on managed lane use than the psychological variables noted above. Consequently, one conclusion arising from the present study is that at the present time, on the basis of the results obtained here, it may be premature to include psychological variables in stated preference surveys as a new tool for traffic and revenue estimation for managed lanes. However, because of a number of design features and characteristics of the present study, said conclusion could also be characterized as too strong and that such a conclusion needs to be bounded by these design limitations. One such limitation is that the measures used to operationalize some of the psychological variables were designed specifically for the present study and one measure, the locus of control measure, was a shortened version of the original. Although the measures had acceptable levels of internal consistency reliability estimates and the pattern of intercorrelations presented in Table 1 were all in the expected conceptual direction, additional data is called for to further demonstrate and establish their construct validity.

Another characteristic of the present study that serves as an important boundary condition for interpreting the results for the psychological variables is that each participant did not complete all measures. Specifically, to shorten the length of the online survey, the decision was made to have each participant complete only 3 of the 6 measures (i.e., 30–49 items). Consequently, as previously noted, 20 versions of the survey were created with every three-measure combination without replacement or repetition occurring in one version of the survey. Participants were then randomly assigned to complete one of the survey versions. The methodological implication of this decision is a design weaker than a true complete within-subjects design, which characterizes most correlational designs. In contrast, for the non-psychological variables analyses, all participants provided responses to all the stated preference questions.

In summary, given the limitations noted above, it could be argued that the results presented here may underestimate the effects of the psychological variables. Given these boundary conditions, the results obtained here could be described as promising and the call for future research that addresses the noted methodological limitations—using a true within-subjects design in which each respondent completes all the measures, and providing additional construct validity for the measures—would be warranted to permit stronger and more conclusive statements about the relationship between psychological variables and preferences for priced managed lanes.

Acknowledgment

Support for this research was provided in part by a grant from the U.S. Department of Transportation, University Transportation Centers Program to the University Transportation Center for Mobility™ (DTRT06-G-0044). We greatly appreciate their financial support. The authors also appreciate the guidance from our project monitor, Ginger Goodin. Several people helped get the message out about our surveys in the various cities: Rory Santana, Jim Udvardy and Alicai Torres in Miami; Stacey Stegman and Jo Snell in Denver; and Samuel Johnson in San Diego. Michelle Hoelscher at TTI was very helpful in advertising the survey in the various cities. During the completion of this research Gonzalo J. Muñoz was supported by grants from the Ministry of Education of Chile through its program "MECE Educación Superior 2", and University Adolfo Ibáñez, Santiago, Chile.

References

95Express. (2012). *I-95 Express Lanes*. <http://www.95express.com/index.asp> Accessed 15.04.12.
Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*, 179–211.
Ajzen, I. (2001). Nature and operation of attitudes. *Annual Review of Psychology, 52*, 27–58.
Ajzen, I., & Fishbein, M. (2005). The influence of attitudes on behavior. In I. Ajzen & M. Fishbein (Eds.), *The Handbook of Attitudes* (pp. 223–271). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.
Arthur, W., Jr., Barrett, G. V., & Alexander, R. A. (1991). Prediction of vehicular accident involvement: A meta-analysis. *Human Performance, 4*, 89–105.
Arthur, W., Jr., & Day, E. A. (2009). Information processing, personality, and demographic variables as predictors of crashes and moving violations. In H. Bédard & G. Delashmit (Eds.), *Accidents: Causes, analysis, and prevention* (pp. 125–148). New York: Nova Science Publishers.

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Arthur, W., Jr., & Doverspike, D. (2001). Predicting motor vehicle crash involvement from a personality and a driving knowledge test. *Journal of Prevention and Intervention in the Community, 22*, 35–42.

Barrick, M., & Mount, M. (1991). The Big Five personality dimensions and job performance: A meta-analysis. *Personnel Psychology, 44*, 1–26.

Becker, G. S. (1965). A theory of the allocation of time. *The Economic Journal, 75*, 493–517.

Beesley, M. E. (1965). The value of time spent in travelling: Some new evidence. *Economica, 32*, 174–185.

Ben-Akiva, M., Bolduc, D., & Walker, J. (2001). *Specification, identification, and estimation of the logit kernel (or continuous mixed logit) model*. MIT Working paper.

Bhat, C. R., & Castelar, S. (2002). A unified mixed logit framework for modeling revealed and stated preferences: Formulation and application to congestion pricing analysis in the San Francisco Bay area. *Transportation Research Part B – Methodological, 36*, 593–616.

Bogg, T., & Roberts, B. W. (2004). Conscientiousness and health-related behaviors: A meta-analysis of the leading behavioral contributors to mortality. *Psychological Bulletin, 130*, 887–919.

Brownstone, D., & Train, K. (1998). Forecasting new product penetration with flexible substitution patterns. *Journal of Econometrics, 89*, 109–129.

Burris, M., Arthur, W. Jr., Devarasetty, P., McDonald, J., & Muñoz, G. J. (2012). *Understanding traveler behavior: The psychology behind managed lane use*. <http://utcm.tamu.edu/publications/final_reports.stm>. Texas Transportation Institute, The Texas A&M University System, College Station, TX.

Burris, M., Nelson, S., Kelly, P., Gupta, P., & Cho, Y. (2012). Willingness to pay for HOT lanes – Empirical analysis from I-15 and I-394. *Journal of the Transportation Research Board*, TRR # 2297, p. 47–55.

Cherlow, J. R. (1981). Measuring values of travel time savings. *Journal of Consumer Research, 7*, 360–371.

Clarke, S., & Robertson, I. T. (2005). A meta-analytic review of the Big Five personality factors and accident involvement in occupational and non-occupational settings. *Journal of Occupational and Organizational Psychology, 78*, 355–376.

Colorado Department of Transportation. (2012). *I- 25 HOV express lanes*. <http://www.coloradodot.info/travel/tolling/i-25-hov-express-lanes/> Accessed 15.04.12.

Dahlen, E. R., Edwards, B. D., Tubré, T., Zyphur, M. J., & Warren, C. R. (2012). Taking a look behind the wheel: An investigation into the personality predictors of aggressive driving. *Accident Analysis and Prevention, 45*, 1–9.

De Jong, G., Tseng, Y., Kouwenhoven, M., Verhoef, E., & Bates, J. (2007). The value of travel time and travel time reliability. *Technical Report, Significance – Prepared for the Netherlands Ministry of Transport*, Public Works and, Water Management.

Devarasetty, P., Burris, M., & Shaw, W. D. (2012a). The value of travel time and reliability-evidence from a stated preference survey and actual usage. *Transportation Research Part A, 46*, 1227–1240.

Devarasetty, P., Burris, M., & Shaw, W. D. (2012b). Do travelers pay for managed lane travel as they claimed they would? A before-after study of Houston Katy Freeway travelers. *Journal of the Transportation Research Board*, TRR # 2297, p. 56–65.

Elander, J., West, R., & French, D. (1993). Behavioral correlates of individual differences in road-traffic crash risk: An examination of methods and findings. *Psychological Bulletin, 113*, 279–294.

Fastrack. (2012). *I-15 express lanes*. <http://fastrak.511sd.com/san-diego-toll-roads/i-15-express-lanes> Accessed April 2012.

Fischer, P., Kubitzki, J., Guter, S., & Frey, D. (2007). Virtual driving and risk taking: Do racing games increase risk-taking cognitions, affect, and behaviors? *Journal of Experimental Psychology, 13*, 22–31.

Georgia Department of Transportation. (2010). Atlanta regional managed lane system plan. *Technical Memorandum 6: GDOT Tolling & Traffic Revenue Primer*. Prepared by HNTB Corporation.

Ghosh, A. (2001). *Valuing time and reliability: Commuters' mode choice from a real time congestion pricing experiment*. Dissertation, University of California at Irvine.

Goldberg, L. R. (1992). The development of markers for the Big-Five factor structure. *Psychological Assessment, 4*, 26–42.

Greene, W. H., Hensher, D. A., & Rose, J. (2006). Accounting for heterogeneity in the variance of unobserved effects in mixed logit models. *Transportation Research Part B – Methodological, 40*, 75–92.

Hensher, D., & Greene, W. (2003). The mixed logit model: The state of practice. *Transportation, 30*, 133–176.

Hensher, D. A., Rose, J. M., & Greene, W. H. (2005). *Applied choice analysis: A primer*. Cambridge, MA: Cambridge University Press.

Hunter, J. E. (1986). Cognitive ability, cognitive demands, job knowledge, and job performance. *Journal of Vocational Behavior, 29*, 340–362.

Hurtz, G. M., & Donovan, J. J. (2000). Personality and job performance: The big five revisited. *Journal of Applied Psychology, 85*, 869–879.

Lam, T. C., & Small, K. A. (2001). The value of time and reliability: Measurement from a value pricing experiment. *Transportation Research Part E – Logistics and Transportation Review, 37*, 231–251.

Lee, D., & Burris, M. (2005). HERS-ST Highway Economic Requirements System – State Version: Technical Report Appendix C: Demand Elasticities for Highway Travel. Federal Highway Administration. <http://www.fhwa.dot.gov/asset/hersst/pubs/tech/tech11.cfm> Accessed June 2012.

McAbee, S. T., & Oswald, F. L. (2013). The criterion-related validity of personality measures for predicting GPA: A meta-analytic validity competition. *Psychological Assessment, 25*, 532–544.

McCrae, R. R., & Costa, P. T. (1987). Validation of the five-factor model of personality across instruments and observers. *Journal of Personality and Social Psychology, 52*, 81–90.

Neuberg, S. L., & Newsom, J. T. (1993). Personal need for structure: Individual differences in the desire for simple structure. *Journal of Personality and Social Psychology, 65*, 113–131.

Oort, C. J. (1969). The evaluation of travelling time. *Journal of Transport Economics and Policy, 3*, 8.

Oswald, F. L., & Hough, L. M. (2011). Personality and its assessment in organizations: Theoretical and empirical developments. In S. Zedeck (Ed.), *APA handbook of industrial and organizational psychology*. *Selceting and developing members for the organization* (Vol. 2, pp. 153–184). Washington, DC: APA.

Rotter, J. B. (1966). Generalized expectancies for internal versus external control reinforcement. *Psychological Monographs: General and Applied, 80* (1, Whole No. 609).

Rundmo, T., & Iversen, H. (2004). Risk perception and driving behaviour among adolescents in two Norwegian counties before and after a traffic safety campaign. *Safety Science, 42*, 1–21.

Sheeran, P. (2002). Intention-behavior relations: A conceptual and empirical review. *European Review of Social Psychology* (Vol. 12, pp. 1–36). Chichester, UK: Wiley.

Small, K. A., Noland, R., Chu, X., & Lewis, D. (1999). Valuation of travel-time savings and predictability in congested conditions for highway user-cost estimation. National Cooperative Highway Research, Report 431, Transportation Research Board, National Research Council, Washington, D.C.

Small, K. A., Winston, C., & Yan, J. (2005). Uncovering the distribution of motorists' preferences for travel time and reliability. *Econometrica, 73*, 1367–1382.

Sullivan, E., Blakely, K., Daly, J., Gilpin, J., Mastako, K., Small, K., & et al. (2000). *Continuation study to evaluate the impacts of the SR91 value-priced express lanes: Final report.* California Polytechnic State University at San Luis Obispo, December. <http://ceenve.ceng.calpoly.edu/sullivan/SR91>.

Taubman-Ben-Ari, O., Mikulincer, M., & Gillath, O. (2004). The multidimensional driving style inventory-scale construct and validation. *Accident Analysis and Prevention, 36*, 323–332.

Thompson, M. M., Naccarato, M. E., & Parker, K. (1989). *Measuring cognitive needs: The development and validation of the personal need for structure (PNS) and personal fear of invalidation (PFI) measures*. Paper presented at the annual meeting of the Canadian Psychological Association, Halifax.

Tilahun, N., & Levinson, D. (2010). A moment of time: Reliability in route choice using stated preference. *Journal of Intelligent Transportation Systems, 14*, 9.

Van Vugt, M., van Lange, P. A. M., Meertens, R. M., & Joireman, J. A. (1996). How a structural solution to a real-world social dilemma failed: A field experiment on the first carpool lane in Europe. *Social Psychology Quarterly, 59*, 364–374.

Weber, E. U., Blais, A.-R., & Betz, N. E. (2002). A domain-specific risk-attitude scale: Measuring risk perceptions and risk behaviors. *Journal of Behavioral Decision Making, 15*, 263–290.