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Greenhouse Gas Emissions and Australian Commutersí Attitudes and Behaviour Concerning Abatement Policies and Personal Involvement

by

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ABSTRACT: Public interest in the environment is building as we gain information about the deterioration in air quality and the potential threat of global warming. This research addresses the dichotomy between an individual's behavior and his or her attitudinal support for policies which are promoted as benefiting the environment. We study how responses to attitudinal survey questions are interrelated, and how such responses are related to actual travel behavior using data from a survey undertaken in six capital cities in Australia in 1994. A measurement model is used to establish a set of latent attitudinal factors, and these factors are related in a structural equations model to a set of behavioral variables representing commuterís mode choice and choice of compressed work schedules, conditioned by a set of exogenous variables. We find that individuals with a strong environmental commitment are more likely to be female, from smaller households with fewer cars, be either under 30 years old or over 50 years old, have high household income and be highly educated. However, women are likely to view the car as a status symbol, and this attitude is conducive to choice of solo driving. We also find that mode choice influences attitudes; commuters who use public transport are more likely to support policies aimed at reducing greenhouse gas emissions. Our conclusion is that switching commuters away from solo driving can have effects that transcend the benefit obtained from reduced vehicle use for the journey to work alone.

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INTRODUCTION

Public interest in the environment is building as we gain information about the deterioration in air quality and the potential threat of global warming. Public opinion, whether founded on fact or driven by an ideology about future prospects, has harnessed a powerful base of influence in placing pressure on governments to 'get more serious' about the potential consequences of deterioration in air quality and increases in greenhouse gas emissions. Lobby groups provide a very influential institutional setting within which governments listen, learn and often act in sympathy with the interests of such groups. Reduction in greenhouse gas emissions (GGEís) is an explicit goal in many countries, but as much as governments work to implement policies consistent with improving environmental quality, people are often hesitant to modify their behavior in response to incentives (*e.g.*, to adopt flexible working hours or carpooling).

This research addresses the dichotomy between an individual's behavior and his or her attitudinal support for policies which are promoted as conducive to environmental enhancement. Many of us want to see a cleaner environment, but are not prepared to give up many of the benefits of a particular lifestyle which transcend many more personal objectives than environmental preservation and enhancement.

Our objective is to determine whether attitudes concerning the threat of GGEís and attitudes concerning the effectiveness of incentive and disincentive schemes aimed at reducing vehicle emissions have any influence on travel behavior. If such attitudes are effective in promoting environmentally sensitive behavior, policies can be marketed to the public by providing information to influence public opinions. Our related secondary objective is to determine whether behavioral intention, expressed in terms of a driverís willingness to reduce his or her driving to improve air quality, serves as a guide in identifying travelers whose attitudes and behavior are conducive to environmentally friendly modifications.

In pursuing these objectives, we need to study how responses to attitudinal survey questions are interrelated, and how such responses are related to actual travel behavior that has environmental consequences. We hope that the results can be useful in assessing media campaigns and other market-research strategies aimed at promoting environmentally friendly behavior that is acceptable to travelers.

This paper draws on a survey undertaken in six capital cities in Australia in 1994 in which opinions were sought on a range of statements about the environment, together with data on actual travel behavior activity. Of particular interest is the relationship between attitudes which recognize the seriousness of global warming and support for abatement policies and the nature of modal activity for commuting. Do, for example, attitudes strongly linked to supporting reductions in global warming translate into behavior which is aligned to this support?

The paper is organized into five sections. We commence with our primary hypothesis on the linkages between attitudes, behavioral intent and actual behavior, followed by the method proposed to assess the causal structure. The background on data sources and the set of attitudinal variables collected is then presented. The response profiles for the nine attitude variables measured on a Likert scale are summarized, together with the behavioral variables for commuting mode choice and work practices. Next, the empirical structure of the measurement and structural model system is presented, estimated and interpreted. The key findings are summarised in a concluding section.

HYPOTHESES

We are concerned with how opinions regarding the environment are related to intentions to modify travel behavior, and how both environmental opinions and behavioral intentions are related to actual travel behavior. It is well known that there are mutually causal relationships between attitudes and behavior: attitudes are influenced by behavioral experiences and the conscious or subconscious desire to rationalize behavior; and strongly held attitudes also influence the decisions people make. Behavioral intention can be viewed as a special type of attitude that is positioned between opinions and behavior in terms of causal relationships.

Specifically, we are dealing here with attitudes concerning the threat posed by global greenhouse gas emissions (GGEís), the possibilities of GGE abatement through transportation incentive and disincentive policies, attitudes regarding the degree to which traffic congestion is a problem, and the degree to which a person thinks of his or her car as a status symbol. Our behavioral intention variable involves a personís commitment to improve air quality by reducing his or her own travel. Finally, our behavioral variables are mode choice for the journey to work and the choice of compressed work hours, the latter currently observed as the most popular flexible working arrangement (Brewer and Hensher 1996).

Our model system can be visualized in the flow diagram of Figure 1. We are interested in testing which of the causal relationships, represented by the arrows in Figure 1, are strongest and which, if any, are weak and possibly negligible. In the context of GGE and commuters in Australian capital cities, we postulate strong causal relationships in both directions between attitudes and behavioral intention and between behavioral intentions and behavior because the relationships between attitudes and behavior will be channeled through behavioral intention.

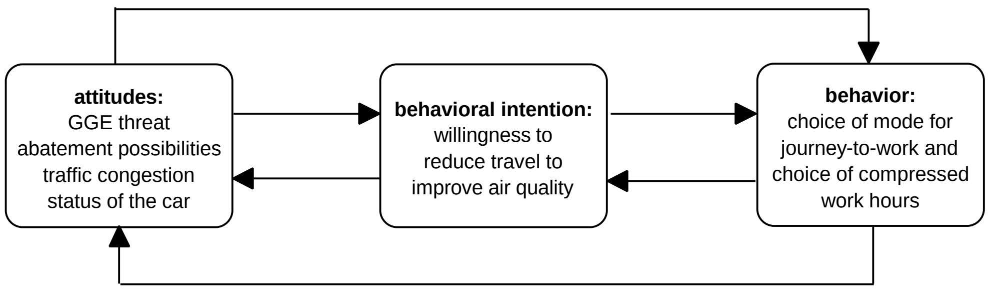

Figure 1: Conceptual Flow Diagram of Causal Influences

We test our concept of linkages between environmental attitudes and behavior by analysing attitudes and behavior captured in a survey of commuters in Australian capital cities in 1995. Attitudes are collected in terms of a series of indicator scales, each of which is designed to measure a respondentís level of agreement or disagreement with a statement expressing an opinion. These scales yield ordinal-level information, and attitudes are defined to be factors created by the linear combinations of scales. The method used to accomplish this is described in the following Sections.

METHODOLOGY

A simultaneous equations system framework is specified to test hypotheses involving multiple causal relationships between attitudes and behavior. This model system must be capable of handling latent variables (factors), specified as linear combinations of observed variables, because we will not be able to observe attitudes directly (Bollen, 1989). Because we have observed indicator scales that are ordinal and behavioral variables that are discrete choices, the estimation method must respect the non-normal distributional properties of the error terms of the endogenous variables in order to minimize biases in hypothesis tests. Structural equations models with latent variables, estimated using asymptotically distribution free weighted least squares (ADF-WLS) is the appropriate method to deal with this problem (MuthËn, 1984).

A structural equations model system with latent variables is defined by a measurement submodel and a structural submodel. We specify p observed endogenous (attitude and behaviour) variables and q observed exogenous variables. The measurement submodel is used to convert the p observed endogenous variables to $m < p$ latent variables given by

$$y = \Lambda \eta + \varepsilon \tag{1a}$$

where the latent attitude variables, denoted by the (m by 1) column vector η, explain the observed endogenous variables, denoted by the (p by 1) column vector y. The unexplained components of the observed endogenous variables (measurement errors) are defined by the (p by 1) vector ε, which has a variance-covariance matrix given by

$$\Theta = E\left[\varepsilon\varepsilon'\right] \tag{1b}$$

The structural submodel, which captures the causal relationships between the endogenous variables and from the exogenous variables to the endogenous variables, is defined by

$$\eta = \mathrm{B}\eta + \Gamma x + \xi \tag{1c}$$

in which the m latent endogenous variables are a function of each other and the q exogenous variables (denoted by the column vector x). The m ξ error terms, capturing the unexplained portions of the latent endogenous variables (the errors in equations), have a variance-covariance matrix given by

$$\Psi = E[\xi\xi'] \tag{1d}$$

The parameters to be estimated are those elements of the B, Γ, Θ and Ψ matrices defined to be non-zero according to our hypotheses. Identification requires that the matrix (I - B) must be non-singular. The conceptual hypotheses of Figure 1 are made operational in terms of this structural equations system once we have determined the specific variables that can be used to capture the attitudinal and behavioral concepts, which we explore in the following Section.

Estimation and hypothesis testing of the system defined by matrix equations system (1) is accomplished using the ADF-WLS method that is described in the transportation research literature by Golob and Hensher (1997) and Golob and McNally (1995). The method proceeds in three distinct steps. First, ordered-response probit models (Aitchison and Silvey, 1957, and Ashford,1959) are applied to the ordered categorical (ordinal) attitude scale variables and the discrete choice behavior variables in order to create unobserved "normalized" variables by estimating thresholds on normal functions. The discrete choice variables are special cases of ordinal variables with only two categories, and in these cases the ordered-response probit model reduces to the standard bivariate probit model.

The second step in the ADF WLS estimation method is to obtain estimates of the covariances or correlations among the normal variables corresponding to the ordinal and discrete choice variables and between each of these variables and the continuous observed exogenous variables in the system. When both y_i and y_j are dichotomous, the correlation coefficient estimated is known as a tetrachoric correlation (Kirk, 1973).

When both y_i and y_j are ordered categorical with at least one variable with three or more categories, the polychoric correlation is used (Olsson, 1979). When one variable is ordered categorical and the other is continuous, the polyserial correlation coefficient is used (Olsson, et al., 1982).

The final step in the ADF WLS method is to estimate the parameters in the B, Γ, Θ and Ψ matrices of system (1) using variance analysis (also known as the method of moments). Defining the vector of all parameters to be $\hat{\theta}$, it can be easily shown that the variance-covariance matrix of a combined set of observed endogenous and exogenous variables (with endogenous variables ordered first) implied by system (1) is

$$\Sigma(\theta) = \left[\begin{array}{c|c} \Lambda_y (I-B)^{-1}(\Gamma\Phi\Gamma' + \Psi)\left[(I-B)^{-1}\right]'\Lambda_y' & \Lambda_y (I-B)^{-1}\Gamma\Phi \\ \hline \Phi\Gamma'(I-B)^{-1'}\Lambda_y' & \Phi \end{array}\right] \qquad (2)$$

The parameters $\hat{\theta}$ are determined by making the model-implied covariance matrix $\Sigma(\bar{\theta})$ as close as possible to the sample covariance matrix, **S**, where **S** is composed of product-moment, tetrachoric, polychoric, and polyserial correlation coefficients determined in the previous step of the estimation. It is not appropriate to use normal-theory maximum likelihood estimation, which is the most common method of estimation, because the assumptions underlying this method do not hold for ordinal and dichotomous variables. Maximum likelihood estimation in this case will yield consistent estimates but not asymptotically efficient standard errors (z-statistics) and chi-square statistics.

The estimation method of choice is weighted least squares (WLS). The fitting function for WLS is

$$F_{WLS} = [s - \sigma(\theta)]' W^{-1}[s - \sigma(\theta)]$$

where s is a vector of product-moment, polychoric, and polyserial correlation coefficients for all pairs of latent endogenous and observed exogenous variables, $\sigma(\theta)$ is a vector of model-implicated correlations for the same variable pairs, and W is a positive-definite weight matrix. Minimising F_{WLS} implies that the parameter estimates are those that minimize the weighted sum of squared deviations of s from $\sigma(\theta)$. This is analogous to weighted least squares regression, but here the observed and predicted values are variances and covariances rather than raw observations.

The best choice of the weight matrix is a consistent estimator of the asymptotic covariance matrix of s:

$$W = ACOV(s_{ij}, s_{gh})$$

Under very general conditions

$$\mathbf{W} = \frac{1}{N}(\sigma_{ijgh} - \sigma_{ij}\sigma_{gh})$$

is a consistent estimator, where σ_{ijgh} denotes the fourth-order moments of the variables around their means, and σ_{ij} and σ_{gh} denote covariances. Browne (1982, 1984) demonstrated that F_{WLS} with such a weight matrix will yield consistent estimates which are asymptotically efficient with asymptotically correct covariances (leading to correct parameter z-statistics), and the model fit will produce correct chi-square test values.

We used the LISREL/PRELIS (versions 8/2) software package to implement this ADF-WLS estimation (JˆreskogandSˆrbom, 1993).

THE DATA

As part of a larger study designed to develop an integrated location-travel and vehicle passenger model system with a strategic focus for six capital cities in Australia (Sydney, Melbourne, Brisbane, Adelaide, Perth and Canberra), data was collected via a face to face home interview on attitudes towards global warming (see Table 2 below) and various policies which may assist in containing the amount of greenhouse gas emissions

(Hensher 1996, Hensher et al 1995). A supplementary self-administered commuter travel survey and a household questionnaire were left with the interviewed respondent (and collected after three days) in which details of current commuting activity (*e.g.*, travel modes, levels of service, costs) and household composition was collected. These three data sources provide the attitudinal and behavioral data needed to investigate the linkages between attitudes towards the environment and behavioral support for the environment.

The targeted sample size given in Table 1 by capital city is a stratified random sample of households, stratified by vehicle fleet size. A total of 963 commuters with complete information on the entire set of attitudinal and behavioral variables was selected for analysis.

Table 1: Number of Interviews for Each City

City	Interviews
Sydney	313
Melbourne	329
Brisbane	275
Adelaide	229
Perth	219
Canberra	163
Total	1527

Attitudes

Nine attitudinal questions were extracted from the survey concerning greenhouse gas emissions (GGE's). Each question was constructed in terms of a five-point scale measuring the level of agreement with a statement, with the scale categories being identified as ìstrongly disagree,î ìdisagree,î ìnot sure,î ìagreeî and ìstrongly agree.î In our analyses we assume only that each scale yields rank order (ordinal) data, because the assumption of equal intervals between scale points is heroic, and the meaning of the categories on such scales probably varies from person to person (the central category being particularly problematic). Eight of these nine statements involve opinions about air pollution and global warming issues, and one question concerns whether the respondent would be willing to modify his or her travel behavior to improve air quality/reduce greenhouse gas emissions. The statements are listed in Table 2 and the frequency distributions are graphed in Figures 2 through 10.

Table 2: Attitudes Regarding Air Quality and Global Warming Issues Measured in Terms of Five-point Scale of Agreement with Statement

Statement Presented	Variable Label
The increase in global greenhouse gas emissions is a serious threat to life as we know it	y_1 Increase in GGE is a threat to life as we know it
Australia does not have to worry about global greenhouse gas emissions	y_2 Australia has to worry about GGE
Car pooling could be encouraged if employers provided free car parking for car pooling employees	y_3 Free parking for car poolers will help
Preferential parking at work locations for fuel efficient cars would help reduce air pollution	y_4 Preferential parking for fuel efficient cars will help
Taxing employer paid parking would be useful in reducing the no. of employees who commute alone	y_5 Taxing employer-paid parking will help
Tax rebates on fuel efficient cars and an additional tax on fuel inefficient cars would help to clean up the air in our cities	y_6 Tax rebates on fuel-efficient cars will help
I have to admit, for me, a car is a status symbol	y_7 I have to admit, for me, my car is a status symbol
Traffic congestion is not as bad as it is made out to be	y_8 Traffic congestion is not as bad as made out to be
I am willing to reduce the no. of kilometres I drive to improve air quality	y_9 I am willing to reduce the number of kms. I drive

Over 80% of the respondents see GGE as a serious problem and something that Australia should be concerned about. Less than 5% of the sample disagree with the statement that the increase in global GGE's is a serious threat to life as we know it (Figure 2); in contrast only 11% disagreed with the statement that Australia does not have to worry about global GGE's (Figure 3). We expect that there is a high degree of correspondence between these two ordinal variables, as demonstrated by a Spearman rank-order correlation coefficient of 0.38, which is highly significant (p = .00). We expect that these two items will load together onto one factor, which can be interpreted as ìGGE is a serious threat.î

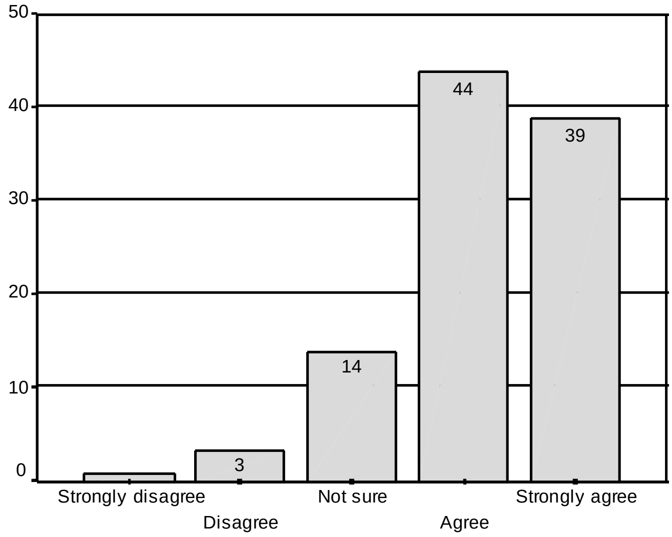

Figure 2: Responses to ìThe increase in greenhouse gas emissions is a threat to life as we know itî

The next four attitudinal variables concern potential policy initiatives aimed at reducing GGEís. Free parking provided by employers for car poolers strikes a supportive chord - 74% of the sample agree or agree strongly with this policy; however, only 23% agree strongly, and 13% have no opinion (Figure 4). Only 14% of the sample of 963 commuters in Australian capital cities disagree or disagree strongly that carpooling would be encouraged by free parking for carpooling employees.

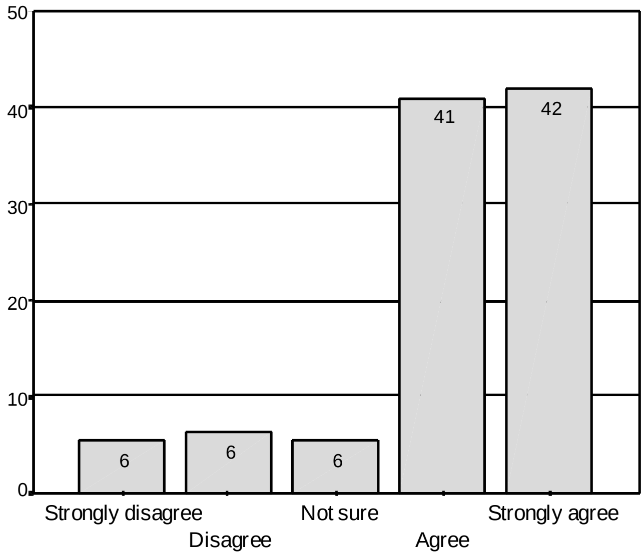

Figure 3: Responses to ìAustralia does have to worry about global greenhouse gas emissionsî

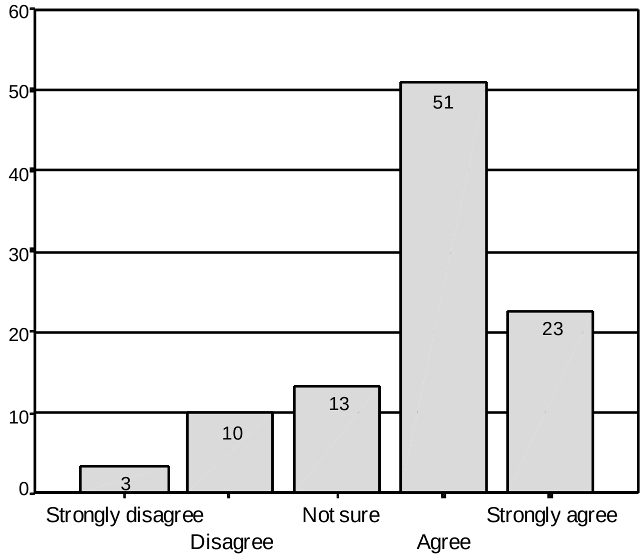

Figure 4: Responses to ìCar pooling could be encouraged if employers provided free car parking for car pooling employeesî

The potential role of tax rebates on fuel efficient vehicles and an additional tax on fuel inefficient vehicles as a mechanism for improving air quality finds only a 44% sample agreement, while 33% disagree with this statement (Figure 5).

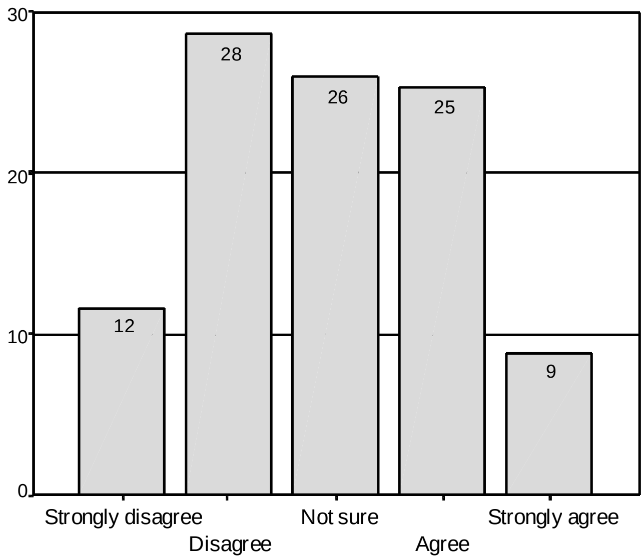

Figure 5: Responses to ìPreferential parking at work locations for fuel efficient cars would help reduce air pollutionî

When we look at other potential policies directed at reducing GGE, we see a polarisation of views. Only 33% agree that taxes on employer paid parking would be effective in reducing solo driving, while 43% disagree (Table 6). However, 48% agree that differential taxes linked to fuel efficiency would be effective, while 34% disagree (Figure 7). While taxes based on fuel efficiency appear to have the edge over taxes on employer paid parking, the median response in both cases is in the neutral category. This indicates that the public is essentially split on their assessments of the effectiveness of these two policies.

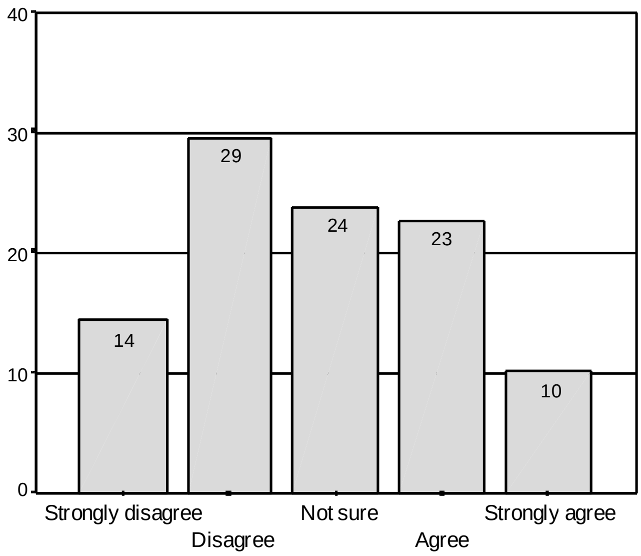

Figure 6: Responses to ìTaxing employer paid parking would be useful in reducing the number of employees who drive to work aloneî

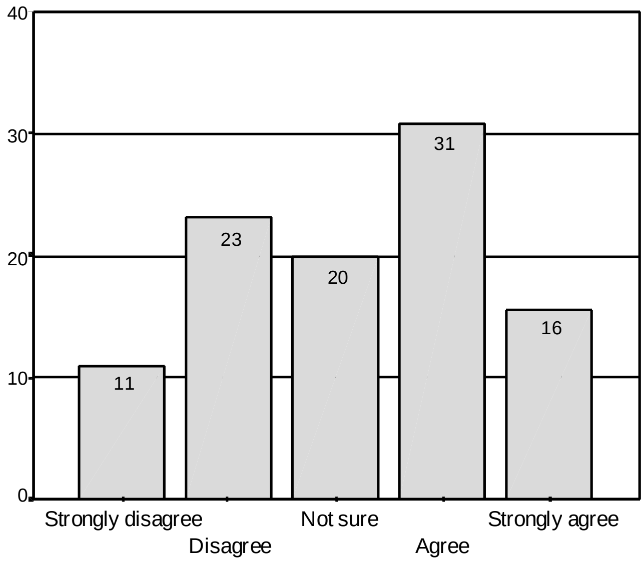

Figure 7: Responses to ìTax rebates on fuel efficient cars and an additional tax on fuel inefficient cars would help clean up the air in the citiesî

We expect that responses regarding the effectiveness of the four policies to reduce GGEís (the scales of Figures 4 through 7) are correlated, because they are four separate indicators of an attitude that GGE abatement is possible. Spearman rank-order correlations between the scale variables are listed in Table 3. Indeed, these correlation coefficients are significant at $p < .001$ for all variable pairs. The strongest relationships are between preferential parking for fuel efficient vehicles and taxing of employer-paid parking and between preferential parking for fuel efficient vehicles and tax rebates for fuel-efficient cars. The weakest relationship is between free parking for car poolers and tax rebates on fuel-efficient cars.

Table 3: Spearman Rank-order Correlation Coefficients Between Opinions Concerning the Four Policy Incentives to reduce GGEís

	y_3 free parking for car poolers will help	y_4 preferential parking for fuel efficient cars will help	y_5 taxing employer-paid parking will help
y_4 preferential parking for fuel efficient cars will help	0.391		
y_5 taxing employer-paid			

parking will help	0.344	0.536	
y_6 tax rebates on fuel-efficient cars will help	0.281	0.521	0.368

Attitudes towards the car and traffic conditions are also potentially important in explaining travel behavior and attitudes towards GGE abatement policies. Responses to the stimulus statement ìI have to admit, for me, a car is a status symbolî are graphed in Figure 8. While 77% of the respondents disagree with this statement, 17% admit that their cars are status symbols. We conclude that attitudes towards the status of the car should be included in attempts to explain behavior and attitudes concerning GGEís and GGE abatement policies.

A minority of commuters also agree with the statement that traffic congestion is not as bad as it is made out to be (Figure 9). Attitudes towards traffic might also be effective in explaining behavior and attitudes toward GGEís.

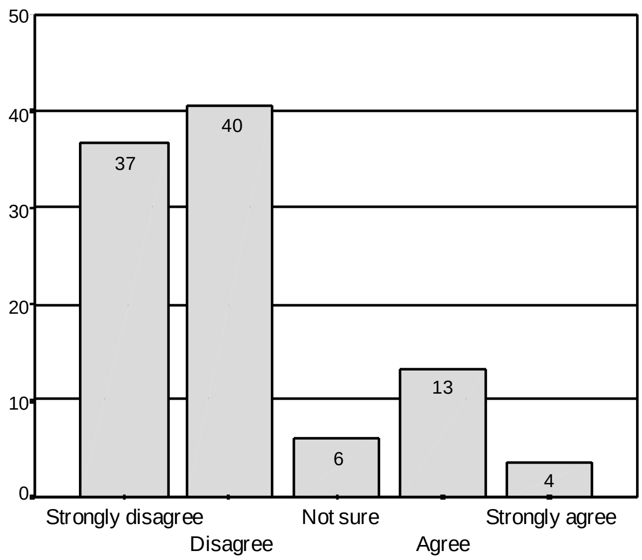

Figure 8: Responses to ìI have to admit, for me, a car is a status symbolî

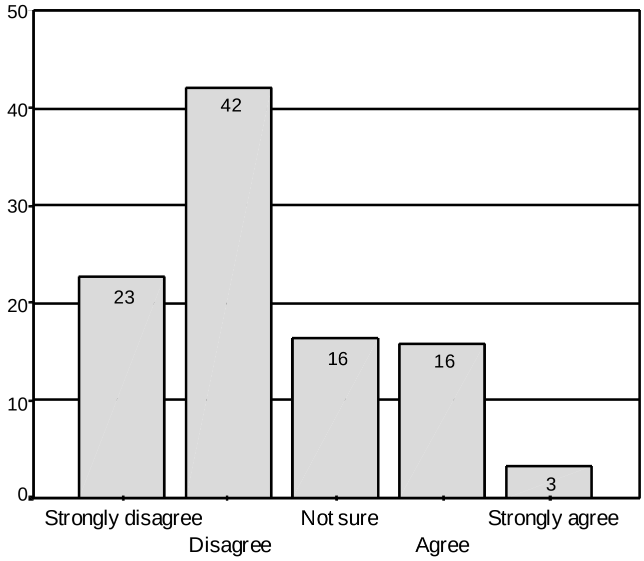

Figure 9: Responses to ìTraffic congestion is not as bad as it is made out to beî

When we consider specific issues associated with the environmental status of the capital cities of Australia, we find that a sizeable proportion of the traveling population claims that they are willing to reduce car use (42%), although 26% are unsure and 32% are not willing to do so (Figure 10).

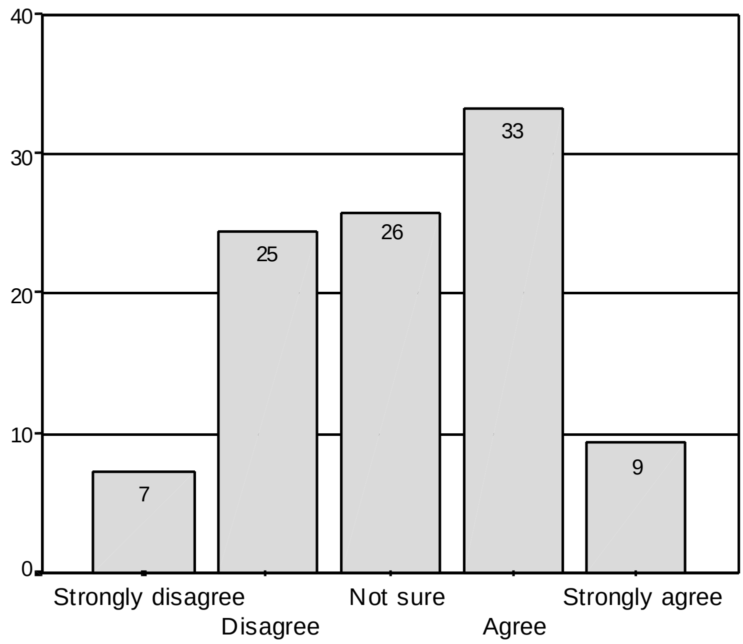

Figure 10: Responses to ìI am willing to reduce the number of vehicle kilometres I drive to improve air qualityî

Despite such strong support for a number of policies and a recognition that air quality and GGE's are important environmental issues which should concern us all, the challenge is to identify sets of policies which will secure changes in behavior compatible with improving the quality of the environment. An informative starting position is to investigate the extent to which the sampled population actually complies through its travel behavior with the opinions expressed in the set of attitudinal questions.

The Behavioral Variables

To determine whether or not attitudes concerning greenhouse gas emissions are related to commuting behavior, we have selected two behavioral variables which are known in

the literature to represent strategies associated with the potential to reduce GGE’s (Martin and Michaelis 1993, Hooper and Hensher 1996, Allen and Hawke, 1975). These are: (1) choice of a compressed work schedule, and (2) mode choice for the journey to work. For the sample of 963 commuters, 81, or 8.1 percent, chose to work a compressed schedule. Regarding mode, 55.9 percent chose to drive alone to work, 25.7 percent drive or ride with others in their vehicle, and 18.4 percent took public transport.

The Exogenous Variables

We found that thirteen exogenous demographic, socioeconomic and locational variables were effective in explaining at least one of the endogenous variables in our equation system. These variables describe the commuter and his or her household: gender, age (two categories and an excluded base category), education (two categories exclusive of a base category), household size, number of household vehicles, household income (three categories exclusive of a base category), and residential location. We used three locational categories: the Sydney Metropolitan Area, the Melbourne Area, and the Adelaide, Perth and Canberra Areas combined (given the smaller population base and general absence of congestion/pollution relative to the larger cities); the excluded category was the Brisbane metropolitan Area.

RESULTS

Model Specification

The model system is comprised of twelve observed endogenous variables and thirteen observed exogenous variables (p = 12 and q = 13 in model system (1)). These variables are listed in Table 4. We propose that the observed attitude scales (variables y_1 to y_7) are indicators of four attitude factors as identified in the measurement sub-model in Table 5 (and Figure 11):

1. ìGGE is a serious threat,î which is indicated by the first two observed attitudinal scales (y_1 and y_2);
2. ìGGE abatement is possible,î which is indicated by the next four policy assessment scales (y_3 through y_6) together with a negative linkage to y_2;
3. ìCar as a status symbol,î which is indicated primarily by its directly corresponding stimulus (y_7), but which should also be manifested on policies aimed at the car (i.e., negatively on observed variable y_5 and positively on observed variable y_6).

Table 4: Model Observed Variables

Endogenous Variables	Exogenous Variables
y_1 increase in GGE is a threat to life as we know it	x_1 gender = female
y_2 Australia has to worry about GGE	x_2 household size
y_3 free parking for car poolers will help	x_3 no. of vehicles in household
y_4 preferential parking for fuel efficient cars will help	x_4 age < 30 years old
y_5 taxing employer-paid parking will help	x_5 age >= 50 years old
y_6 tax rebates on fuel-efficient cars will help	x_6 household income $20-30,000
y_7 have to admit, for me, my car is a status symbol	x_7 household income $60-80,000
y_8 traffic congestion is not as bad as made out to be	x_8 household income > $80,000
y_9 am willing to reduce the number of kms. I drive	x_9 education up to secondary school
y_{10} working compressed work hours	x_{10} education university
y_{11} commute mode choice = solo driving	x_{11} location: Sydney Metropolitan Area
y_{12} commute mode choice = public transport	x_{12} location: Melbourne Area
	x_{13} Adelaide, Perth or Canberra Areas

In addition, we specify a set of latent variables in a one-to-one relationship with each of the final five observed variables: the attitude that traffic is not as bad as it is made out to be (y_8), observed behavioral intention to reduce vehicle kilometres to improve air quality (y_9), and the three behavioral variables (y_{10} through y_{12}). This passes these last four endogenous variables directly into the structural model.

Regarding the causal relationships, we began by assuming that all direct effects (free elements in the B matrix of equation system (1)) pass through the behavioral intention latent variable. As described below, the final model ended up to be more complicated

than that, but the basic premise of behavioral intention as a leading indicator of environmental appreciation was upheld.

Model Fit

The chi-square value for the estimated model is 186.35 with 151 degrees of freedom. This corresponds to a probability value of p = .027, which means that the fitted model cannot be rejected at the p = .01 level. The postulated factor structure was confirmed, and the causal structure is intuitive and consistent with expectations. We discuss and interpret these results in the remainder of the paper.

The model has 62 free structural parameters (eight parameters in the lambda matrix, eleven in the beta matrix, and 43 in the gamma matrix of equation system (1)); all parameters are significant at the p = .05 level. We also needed six non-zero error-term covariance parameters (in the theta matrix of system (1)) to accommodate associations among the observed endogenous variables that are not covered by our model system. As there are 66 off-diagonal elements in the theta matrix, we are satisfied to trade-off of a few extraneous error-term relationships for an elegant structural model.

Measurement Submodel

Our measurement submodel (1b) of the structural equations system involves confirmatory factor analysis (Jˆreskog, 1969; Bollen, 1982) with ordinal-scaled data (MuthÈn and Kaplan, 1985; Rigdon and Ferguson, 1991). With this factor analysis we reduce eight observed attitudinal variables to four latent variable. In addition, the measurement submodel defines four behavioral and behavior intention variables on a one-to-one basis with their observed variable counterparts. The lambda matrix elements are listed in Table 5. Each latent variable must be standardized in terms of one observed variable, and all freely estimated coefficients are significant at the p = .01 level.

The measurement model attitudinal factorial structure component is depicted in Figure 11. The first factor comprising two variables is most strongly represented by the observed variable ìAustralia does have to worry about global greenhouse gas emissions.î Individuals with high scores on this factor view GGE as a serious threat.

Individuals with high scores on the second factor feel that GGE is a less serious threat because abatement is possible. The factor is a weighted average of positive loadings on attitudes toward the effectiveness of four GGE abatement policies, combined with a negative loading on ìAustralia does have to worry about global greenhouse gas emissions.î This factor reflects the fact that the assessments of the abatement policies are highly correlated, so there is very little distinction between the four abatement policies in terms of factor loadings, but there is slightly less emphasis on tax rebates for fuel-efficient cars. The observed increase in GGE is something that Australia has to worry about.

The third factor, ìcar is a status symbol,î is composed of three variables. It is measured in terms of the propensity to agree with the statement ìI have to admit, for me, my car is a status symbol.î This factor is also associated positively with attitudes regarding taxes on fuel efficient cars, and negatively with attitudes regarding taxing employer-paid parking. The final attitudinal factor is measured in terms of the single variable: ìtraffic congestion is not as bad as made out to be.î

Table 5: Measurement Submodel Relating the
Latent and Observed Endogenous Variables
(z-statistics in parentheses)

observed variable	latent variable							
	η_1	η_2	η_3	η_4	η_5	η_6	η_7	η_8
y_1 increase in GGE is a threat to life as we know it	0.537 (5.89)							
y_2 Australia has to worry about GGE	1.00	-0.992 (-2.85)						
y_3 free parking for car poolers will help		1.05 (22.8)						
y_4 preferential parking for fuel efficient cars will help		0.900 (23.0)						
y_5 taxing employer-paid parking will help		1.00	-0.284 (-3.19)					
y_6 tax rebates on fuel-efficient cars will help		0.793 (13.7)	0.287 (2.97)					
y_7 have to admit, for me, my car is a status symbol			1.00					
y_8 traffic congestion is not as bad as made out to be				1.0				
y_9 am willing to reduce the					1.0			

number of kms. I drive								
y_{10} working compressed work hours						1.0		
y_{11} commute mode choice = solo driving							1.0	
y_{12} commute mode choice = public transport								1.0

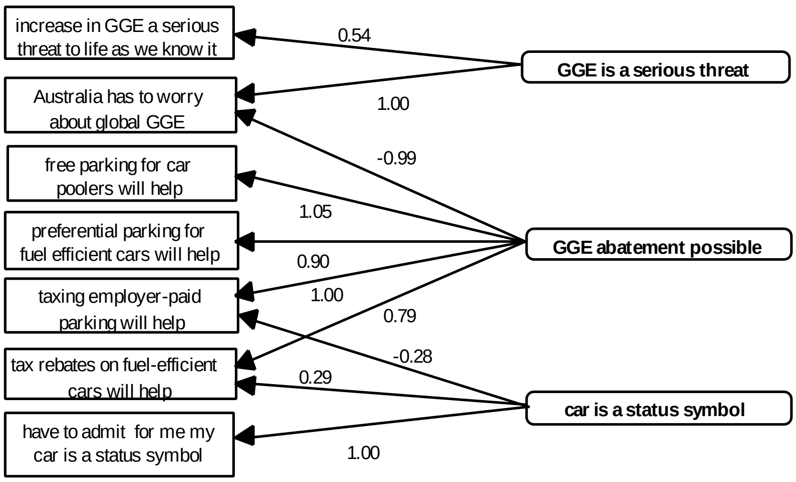

Figure 11: Flow Diagram of the Measurement Submodel Factors

Endogenous Variable Causal Structure

Our model has eleven direct causal effects between the eight endogenous latent variables. Each effect corresponds to a freely estimated element of the beta matrix of Equation System 1 and is represented by an arrow in the flow diagram of Figure 12. For each effect, an arrow points from the causal variable, defined by the column index of the beta element, to the variable it affects, defined by the row index of the beta element. The element coefficients and their *z*-statistics are listed in Table 6. All coefficients are significant at the *p*=.05 level.

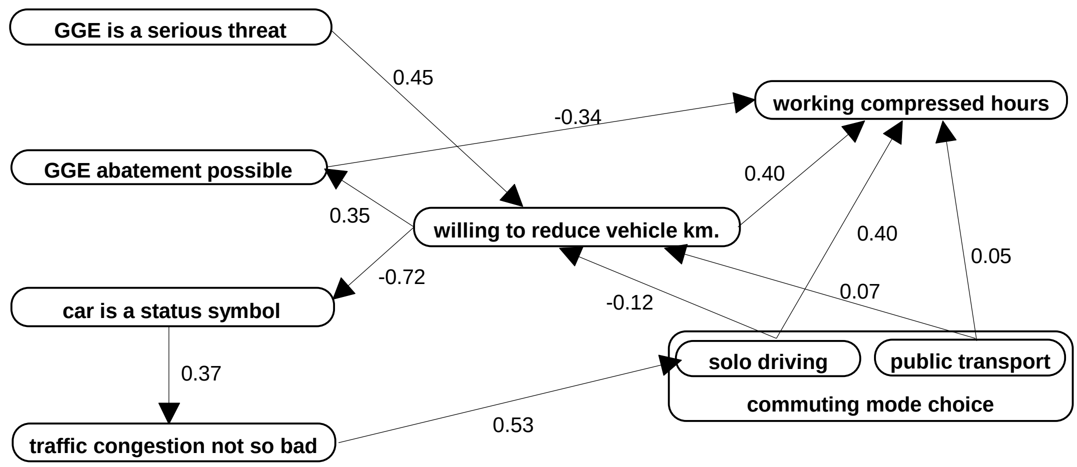

Figure 12: Flow Diagram of the Causal structure of the Endogenous Variables

The results in Figure 12 (and Table 6) suggest that commuters who feel that GGE is a serious threat are more willing to claim that they will reduce their future vehicle travel. Furthermore, if an individual rationalizes that GGE abatement is possible, he or she is less likely to be a public transport commuter. However, those persons who are *more* willing to reduce vehicle kilometers of travel feel that GGE abatement is possible. If an individual feels that a car is a status symbol, he or she is more likely to feel that traffic congestion is not so bad.

However, those persons who are *less* willing to reduce vehicle kilometers of travel feel that the cars is a status symbol.

Interestingly, commuters who participate in a compressed work week (typically a 9-day fortnight) are more likely to be drive-alone commuters and less likely to be willing to reduce automobile kilometres. This raises important questions about the gains from working flexibility at the price of less environmentally supportive commuting behaviour. When combined with a view from the drive-alone commuters that traffic congestion is not so bad in contrast to the non-drive-alone commuters, we see an apparent very strong potentially self-justification of solo-driving. Looking ahead to Table 8 we see however that the support for the statement that "traffic congestion is not so bad" is strongest for cities with less traffic congestion (namely Canberra, Adelaide and Perth).

These results suggest a division between two types of commuters: Group one consists of those who believe that reductions in GGE can be achieved by a set of policy instruments. This translates into a willingness to reduce automobile commuting, but this does not translate into a propensity to use public transport. Rather, commuters tend to make adjustments in working days or to share rides. Group two consists of commuters who see GGE as a sufficiently serious threat that they are willing to reduce automobile commuting kilometres regardless of what abatement policies are in place.

Table 6: Direct Effects Between the Endogenous Latent Variables
(z-statistics in parentheses)

affected variable	influencing variable							
	η_1	η_2	η_3	η_4	η_5	η_6	η_7	η_8
η_1 GGE is a serious threat								
η_2 GGE abatement is possible					0.350 (4.44)			
η_3 car is a status symbol					-0.715 (-3.02)			
η_4 traffic congestion not so bad			0.366 (3.04)					
η_5 willing to reduce vehicle km.	0.453 (5.86)						-0.119 (-7.76)	0.068 (3.85)
η_6 working compressed hours		-0.336 (-1.84)			0.398 (2.04)		-0.037 (-2.17)	0.053 (3.69)
η_7 mode choice = solo driving				0.525 (15.6)				
η_8 mode choice = public transport								

Each latent endogenous variable affects another latent endogenous variable according to the specific estimated beta matrix element listed in Table 6. However, the total effect of any latent endogenous variable on another latent endogenous variable is the sum of the

multiplicative effects over all the paths which link the two variables through intermediate endogenous variables. The matrix of total effects is defined by

$$T_h = \sum_{k=1}^{\infty} B^k = B + B^2 + \ldots + B^k \tag{3}$$

Adding the Identity matrix to both sides of (3) and multiplying by (I-B):

$$(I - B)\,(I + T_h) = (I - B)\,(I + B + B^2 + \ldots + B^k) = I - B^{k+1} \tag{4}$$

For a non-explosive model in which total effects can be defined, the modulus or absolute value of the largest eigenvalue of B must be less than one, which means that B^k will converge to zero as $k \to \infty$. Thus, $B^{k+1} = 0$, so:

$$(I - B)\,(I + T_h) = I \tag{5}$$

or

$$T_h = (I - B)^{-1} - I \tag{6}$$

The estimated total effects given by equation (6) are listed in Table 7.

This table reveals some very strong causal linkages between attitude, behavioural intent and actual travel behaviour. Most notably, solo drivers do not see GGE as such a serious threat as ride-sharers and public transport commuters, they tend to see the car as a status symbol, feel traffic congestion is not so bad, are less willing to reduce automobile use, are more likely to work a compressed work week compared to other commuters. Individuals taking advantage of a compressed work week are relatively more inclined to view GGE as a serious threat, but they believe that abatement is possible, and they tend not to see the car as a status symbol (using it presumably because of its functionality when working hours are more flexible). These people also see traffic congestion as so bad; but they are willing to reduce their vehicle kilometres (possibly linked to greater adaptive opportunities for reducing commuting activity) although solo driving is more popular with such a segment than the rest of the commuting population.

Table 7: Total Effects Between the Endogenous Latent Variables
(z-statistics in parentheses)

affected variable	influencing variable							
	η_1	η_2	η_3	η_4	η_5	η_6	η_7	η_8
η_1 GGE is a serious threat								
η_2 GGE abatement possible	0.161 (2.90)		-0.008 (-2.26)	-0.022 (-4.10)	0.355 (4.44)		-0.042 (-4.19)	0.024 (2.98)
η_3 car is a status symbol	-0.329 (-2.77)		0.017 (2.96)	0.045 (3.15)	-0.727 (-3.00)		0.086 (3.16)	-0.050 (-2.93)
η_4 traffic congestion not so bad	-0.120 (-2.89)		0.372 (3.02)	0.017 (2.96)	-0.266 (-3.00)		0.032 (2.99)	-0.018 (-2.88)
η_5 willing to reduce vehicle km.	0.460 (5.88)		-0.023 (-2.62)	-0.064 (-6.77)	0.017 (2.96)		-0.121 (-7.68)	0.070 (3.88)
η_6 working compressed hours	0.131 (2.04)	-0.336 (-1.84)	-0.014 (-2.76)	-.038 (-7.35)	0.290 (2.15)		-0.071 (-7.87)	0.073 (6.98)
η_7 mode choice = solo driving	-0.063 (-2.78)		0.195 (2.93)	0.534 (15.4)	-0.140 (-2.97)		0.017 (2.96)	-0.010 (-2.90)
η_8 mode choice = public transport								

In a non-recursive structural equations model such as this, an endogenous variable can affect itself through feedback loops. It can be seen in the flow diagram of Figure 12 that our model has one loop involving the four variables ìcar is a status symbol,î ìtraffic congestion is not so bad,î ìmode choice = solo driving,î and (linked negatively) ìwilling to reduce vehicle kms.î The total effects of each of these variables on itself, which are not separately identifiable, is estimated to be significantly greater than zero. This means that these attitudes and the choice of solo driving are reinforcing. For instance, choice of solo driving leads to a decreased willingness to reduce vehicle use, which in turn leads to an increased attitude that the car is a status symbol, which leads to an increased attitude that traffic is not so bad, which has a positive feedback justifying choice of solo driving. This feedback loop is consistent with the psychological phenomena of cognitive dissonance (Golob, *et al.,* 1978).

Exogenous Variable Effects

To gain a better understanding of the types of individuals and their geographic circumstance, we next investigate the estimated effects of the exogenous variables in the model. We investigated a large number of sociodemographic variables and found significant statistical discrimination attributable to gender, household size, number of vehicles in the household, age, household income and education. In addition the city grouping has an important influence, supporting the view that there are noticeable locational differences in attitudes, behavioural intentions and travel behaviour.

The direct effects from the exogenous variables are listed in Table 8; these are the coefficients of the gamma matrix in equation system (1). The total effects of the exogenous variables on the endogenous latent variables, also known as the coefficients of the reduced-form equations, can be easily developed from equation (1b) following a development along the lines of equations (3) to (6) (Bollen, 1989). The equation for the matrix of total exogenous effects is given by

$$T_x = (I - B)^{-1} G$$

These total effects are listed in Table 9.

Table 8: Direct Effects of the Exogenous Variables
(z-statistics in parentheses)

exogenous variable	affected latent endogenous variable							
	η_1 GGE is a serious threat; η_2 GGE abatement is possible							
	η_3 car is a status symbol; η_4 traffic congestion not so bad							
	η_5 willing to reduce vehicle km.; η_6 working compressed hours							
	η_7 mode choice = solo driving; η_8 mode choice = public transport							
	η_1	η_2	η_3	η_4	η_5	η_6	η_7	η_8
x_1 gender = female	2.04 (5.96)	0.655 (7.78)	1.04 (4.60)	0.412 (6.92)				0.317 (23.1)
x_2 household size						0.028 (2.46)	-0.161 (-9.61)	0.059 (4.28)
x_3 no. of vehicles in household						0.045 (3.30)	0.471 (29.8)	-0.511 (-36.8)
x_4 age < 30 years old		0.059 (3.02)	0.080 (2.17)			0.076 (4.77)	-0.127 (-8.20)	0.066 (5.44)
x_5 age >= 50 years old				0.115 (5.70)	0.049 (2.64)	-0.037 (-3.40)	0.039 (4.41)	0.039 (4.41)
x_6 household income $20-30,000						0.106 (11.1)	0.042 (2.88)	-0.135 (-12.5)
x_7 household income $60-80,000			0.070 (2.25)				-0.063 (-4.53)	
x_8 household income > $80,000			0.085 (2.96)				-0.057 (-3.58)	0.038 (3.74)
x_9 education up to secondary school							-0.053 (-3.37)	0.088 (6.78)
x_{10} education university	-0.367 (-4.68)	-0.132 (-4.68)	-0.351 (-6.26)	-0.119 (-3.35)		-0.066 (-5.67)		-0.081 (-6.33)
x_{11} location: Sydney Metropolitan Area					-0.063 (-2.96)			0.089 (7.48)
x_{12} location: Melbourne Area						-0.072 (-7.56)	0.095 (7.54)	
x_{13} Adelaide, Perth or Canberra Areas				0.174 (8.39)		-0.119 (-11.4)		-0.024 (-2.18)

Most of the exogenous direct effects (Table 8) are directed toward the three behavioural variables (η_6 through η_8). In contrast, the four attitude factors (η_1 through η_4) are differentiated on only a few exogenous variables: Women hold stronger positive opinions than men on all of the factors, while more highly educated persons are more moderate on all four factors. Persons under thirty are more likely to view the car as a status symbol and are MORE likely to feel that GGE abatement is possible; persons over fifty are more likely to feel that traffic congestion is not as bad as it is made out to be. Finally, the car as a status symbol is a view more likely to be held by persons in higher income households. Importantly, the only significant direct exogenous effects on willingness to reduce vehicle kilometres to reduce emissions are from persons over fifty (positive) and residents of the Sydney Metropolitan area (negative).

Total effects of the exogenous variables are substantially more numerous than direct effects, because of the numerous path linkages between the endogenous variables. Mode choice is the catalyst which translates exogenous effects to all other variables, with the exception of attitude concerning the seriousness of GGE as a problem. As depicted in Figure 12, this intermediate role of mode choice is due to the direct causal effects from the two mode choice variables to compressed work hours and from these same two variables to willingness to reduce vehicle kilometres, then from willingness to reduce vehicle kilometers to some of the attitudinal variables (Figure 12).

Women are more likely to use public transport, which in turn implies that women are more likely to work compressed work hours and are more willing to reduce vehicle kilometers. On the other hand, women tend to view the car as a status symbol, which implies that they are also more likely to choose solo driving, *ceteris paribus*.

These results have mixed implications for solving the greenhouse gas emissions problem. There clearly is a group of commuters who are supportive through attitude and opinion of policies consistent with environmental sustainability and who translate this into modified travel behaviour by way of using public transport for commuting and participating in compressed working hours. For support of public transport, these commuters are best described as more likely to be female, smaller household size, fewer cars in the household, under 30 years old and over 50 years old, high household income, highest education as secondary and living in Sydney. Individuals living in Adelaide, Perth or Canberra are less likely to support public transport use, reinforced by

individuals with a university education and household incomes less than $30,000 per annum.

Table 9: Total Effects of the Exogenous Variables

(coefficients of the reduced form equations)
(z-statistics in parentheses)

exogenous variable	affected latent endogenous variable							
	η_1 GGE is a serious threat; η_2 GGE abatement is possible							
	η_3 car is a status symbol; η_4 traffic congestion not so bad							
	η_5 willing to reduce vehicle km.; η_6 working compressed hours							
	η_7 mode choice = solo driving; η_8 mode choice = public transport							
	η_1	η_2	η_3	η_4	η_5	η_6	η_7	η_8
x_1 gender = female	2.04 (5.96)	0.973 (22.4)	0.384 (11.0)	0.553 (16.3)	0.909 (33.3)	0.041 (3.51)	0.290 (15.8)	0.317 (23.1)
x_2 household size		0.008 (3.93)	-0.017 (-3.12)	-0.006 (-3.05)	0.024 (6.79)	0.044 (3.89)	-0.164 (-9.67)	0.059 (4.28)
x_3 no. of vehicles in household		-0.032 (-4.02)	0.066 (3.39)	0.024 (3.27)	-0.092 (-7.64)	-0.025 (-2.76)	0.483 (31.1)	-0.511 (-36.8)
x_4 age < 30 years old		0.059 (3.02)	0.067 (2.17)	0.024 (1.79)	0.018 (6.21)	0.071 (7.58)	-0.114 -7.60)	0.066 (5.44)
x_5 age >= 50 years old		0.016 (2.18)	-0.033 (-2.36)	0.103 (5.31)	0.046 (2.45)	-0.024 (-3.43)	0.054 (5.41)	0.039 (4.41)
x_6 household income $20-30,000		-0.005 (-3.12)	0.010 (3.00)	0.004 (2.96)	-0.014 (-4.40)	0.093 (10.0)	0.042 (2.98)	-0.135 (-12.5)
x_7 household income $60-80,000		0.002 (2.79)	0.065 (2.10)	0.024 (1.85)	0.006 (3.30)	0.004 (3.38)	-0.050 (-3.79)	
x_8 household income > $80,000		0.003 (2.72)	0.079 (2.78)	0.029 (2.20)	0.008 (3.30)	0.006 (3.63)	-0.042 (-2.92)	0.038 (3.74)
x_9 education up to secondary school		0.004 (3.23)	-0.009 (-2.88)	-0.003 (-2.81)	0.012 (4.23)	0.010 (5.24)	-0.055 (-3.41)	0.088 (6.78)
x_{10} education university	-0.367 (-4.68)	-0.188 (-6.05)	-0.237 (-7.84)	-0.206 (-8.34)	-0.159 (-6.86)	-0.066 (-7.15)	-0.108 (-7.88)	-0.081 (-6.33)
x_{11} location: Sydney Metropolitan Area		-0.020 (-2.24)	0.041 (2.20)	0.015 (2.11)	-0.058 (-2.69)	-0.012 (-1.46)	0.008 (2.11)	0.089 (7.48)
x_{12} location: Melbourne Area		-0.004 (-3.66)	0.008 (2.96)	0.003 (2.78)	-0.011 (-5.18)	-0.079 (-8.34)	0.096 (7.53)	
x_{13} Adelaide, Perth or Canberra Areas		-0.004 (-3.60)	0.009 (3.04)	0.178 (8.37)	-0.013 (-5.61)	-0.127 (-12.3)	0.093 (8.06)	-0.024 (-2.18)

Compressed working hours are more likely to be taken up by females, commuters from larger households, with fewer automobiles and individuals under 30 years old.

Individuals over 50 years old are less inclined to a compressed work week (possibly due to the nature of work and/or seniority).

Conclusions

Individualsí attitudes and opinions are powerful prescriptors in influencing government policy; policy makers frequently listen to the voice of the public. Yet to what extent does the sentiment of the public translate into overt action for travel behaviour which supports better environmental practices? In this paper we have investigated the nature of the links between commutersí attitudes toward policies aimed at improving air quality and reducing global warming, and behavioural opportunities to be environmentally more responsible.

There are some important messages for environmental sustainability and the extent to which attitude and opinion surveys are adequate indicators of overt behavioural support for principles of conservation. Drive-alone commuters, whose travel behaviour that is less supportive of environmental sustainability, see global warming as less of a serious threat, have a stronger belief in the role of abatement policies, see traffic congestion as not so bad compared with the rest of the commuting population, and are less willing to reduce vehicle kilometres.

However, drive-alone commuters do show a greater preparedness for compressed work schedules. Compressed work weeks may on face value appear to be an appealing policy instrument contributing to environmental sustainability; yet we find that commuters working compressed work weeks tend to have a higher incidence of solo driving while at the same time being more prepared to reduce vehicle kilometres (while preserving their drive-alone status) than other solo drivers. Furthermore we find an absence of any statistical link between compressed work week practices and use of public transport. The implication is that compressed work week practices support increased drive-alone commuting activity (borne out by other recent surveys in Sydney) while enabling some reduction in vehicle kilometres for commuting since less days of commuting are involved.

On balance this may be a plus or a minus depending on what travel activity (by car) occurs for non-commuting on the freed workday. Hung (1996) suggests an increase in total automobile use.

There is a causality between attitudes towards environmental sustainability and overt travel behaviour; however it is incomplete. Drive-alone commuters do not see a serious global warming threat because they believe in abatement policies to assist in the resolution, except when it comes to reductions in commuting automobile use which, in our studies context, are likely only to occur as a consequence of adopting compressed workweek behaviour.

We find that individuals with a strong environmental commitment are more likely to be female, from smaller households with fewer cars, be either under 30 years old or over 50 years old, have high household income and be highly educated. However, women are likely to view the car as a status symbol, and this attitude is conducive to choice of solo driving. A media campaign aimed at demonstrating how images of the car as a status symbols are in conflict with the goal of reducing global warming and other emissions problems should be effective in reducing solo driving and encouraging people to otherwise reduce their driving.

Finally, we conclude that mode choice influences attitudes, probably through experience and psychological phenomena such as cognitive dissonance. Commuters who use public transport are more likely to support policies aimed at reducing greenhouse gas emissions, *ceteris paribus*. Switching commuters away from solo driving can have effects that transcend the benefit obtained from reduced vehicle use for the journey to work alone. While we do not find a significant causality between the propensity to use public transport and the attitude concerning the severity of the greenhouse gas emissions problem, we do find a link from choice of public transport to intention to reduce vehicle kilometres of travel, and through such behavioral intention to a propensity to adopt compressed work schedules and to the attitude that greenhouse gas emissions abatement is possible. Our results show that public transport use, like solo driving, is self-sustaining because attitudes that are consistent with choice are reinforced by the choice. Because these attitudes include environmental concerns, policy makers intent on increasing public transport ridership are advised to use advertising campaigns that focus on the environmental benefits of using public transport instead of solo driving. The car as a status symbol can be countered by public transport as an environmental symbol.

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