Transport Behaviour Assessment for Adaptability

Montira Watcharasukarn, Susan Krumdieck
University of Canterbury, Department of Mechanical Engineering

Andre Dantas
University of Canterbury, Department of Civil Engineering

Richard Green
University of Canterbury, Computer Science Department

Personal travel demand behaviour (TDB) will change in the future due to a range of factors including high price, supply reduction, insecurity and perception. We have proposed that adaptation will depend on a new metric called *essentiality* as well as more common variables such as income and transport networks. A new type of virtual reality, immersive game travel survey has been developed with the purpose of probing adaptive behaviour change. There are two issues addressed by the survey tool; (1) rapid, low-cost travel surveys to track TDB change, and (2) a way to survey adaptation behaviour *before* fuel shortages.

Keywords: Travel Demand, Travel Behaviour, Resilience, Adaptability

1. Introduction

Understanding travel behaviour has always been important for transport planners and decision makers. Travel behaviour assessments are used in transportation engineering modelling for a wide variety of social objectives including urban mobility and improvement of environmental quality. Currently, travel demand surveys are time consuming and expensive, as they are long paper forms that must be filled out under the guidance of a trained surveyor. Location-specific and repeated or continuous travel demand surveys could greatly improve effectiveness of transport network engineers and land use planners.

The evidence is becoming clear that world oil production will begin to decline in the near future [1,2,3,4]. This "peak oil" situation will surely cause changes in all forms of transportation. The processes and models for including the fuel availability issue in future land use and transport network planning are not yet developed. These planning processes and models are urgently needed to investigate economically efficient adaptation of existing networks, analysis of risk to activity systems, and cost-benefit analysis for long term infrastructure investments. To a large degree, the resilience of modern society will depend on the adaptability of individuals to increasing fuel price and to fuel supply uncertainty. Travel behaviour data is the primary means for such an adaptability assessment.

Historically, we have learned that people will adapt themselves according to their needs and availability. Wakeley [5] described the reactance theory[1] that states that "changes in behaviour and mood can be predicted when the individual is exposed to an uncontrolled outcome (e.g. fuel shortage) and is unable to engage in a behaviour that the individual originally felt free to pursue" (e.g., drive to work). The bulk of historical research on travel behaviour change has been focused on inducing mode switching to reduce congestion or air pollution, and understanding the reasons why people don't change from single passenger automobile.

In terms of transport engineering, individual adaptability can be characterised by mode shifting, destination change, or curtailing trips. The decision involved in these changes is normally based on the individual's purpose and impacts. Dantas et. al [6], delineate trips into three levels of essentiality; Optional, Necessary, and Essential. The trip that can easily be eliminated without any harm to the individual's wellbeing is called an optional trip. A person will loose participation in important social, athletic, creative, or charitable activities if a necessary trip is interrupted during a fuel crisis. An essential trip is defined as a trip having an affect on the basic needs of a person's wellbeing, for example, working to earn income, seeking medical treatment, getting to school or accessing food.

2. Travel behaviour assessment tool

In order to assess travel behaviour change due to fuel price rise and fuel supply uncertainty, we propose a rapid travel demand and adaptation survey tool called *TACA Sim* (Travel Activity Constraint Adaptation Simulation). The tool is a virtual reality role-playing game. The game has been developed based on the idea of immersing the participant in a virtual environment which simulates their "normal" transport activity systems. As the game progresses, the situation changes as the fuel price rises and fuel shortages limit choices. The *TACA Sim* game has two principle aims: (1) to simplify the travel demand survey-conducting process by making it an entertaining game, and (2) to induce real decision making of the participant in response to price rises and fuel supply disruptions. The design of the travel demand data collection in *TACA Sim* is based on people's normal experiences associated with travel such as using a personal diary to schedule activities and using a familiar city map to navigate. The *TACA Sim* adaptability assessment structure is based on the concept that "each one of us has the responsibility to inform ourselves and evaluate our past and current actions in order to plan for the future" (Stewardship concept) [7].

[1] Reactance theory is the theory that predicts individual responses to the uncontrolled freedom.

TACA Sim is designed to bridge the link between high fuel price and travel demand so that adaptive travel behaviour change can be assessed. It has three progressive levels as shown in Figure 1.

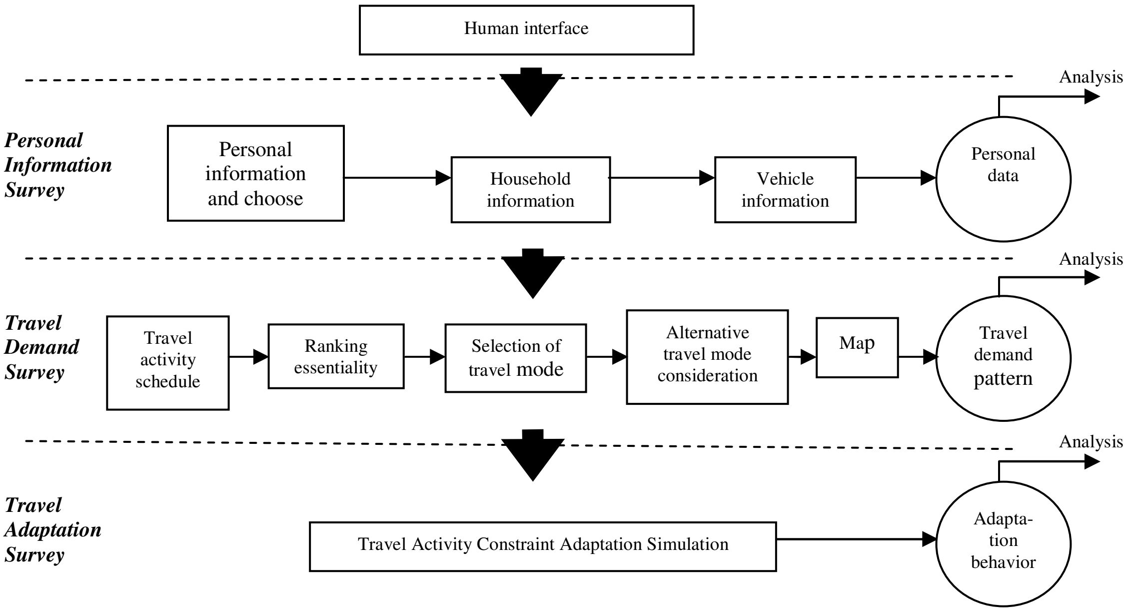

Figure 1: Three major levels of TACA Sim framework

The first level collects personal information relatively quickly and in an engaging way by having the participant choose a virtual character and tick appropriate boxes. The second level is a simple travel demand survey, but *TACA Sim* engages the participant's interest by familiar visual cues and selections. Daily travel activities are entered into a day-planner according to the time schedule, which should be more familiar to people than the normal trip purpose diary used in paper surveys. Subsequently, questions are asked about the impact/essentiality of each activity and the travel mode (e.g. car, bus, and bike). The participant points and clicks on a familiar map of the city to indicate the real locations of their homes, and destinations such as work, school, shopping. The participant moves a small car icon by the mouse to show their travel routes. The second level is also designed to probe the types of mode and destination options that the participant currently has for each activity. The third level is designed to use the full role-playing environment. The role of the participant is to make the key decisions about their travel activities and adapt themselves to the situations of high fuel price and fuel shortage. The *TACA Sim* game integrates the simulation of three fuel-price intervals i.e., $1.70, $4.70, $8.70 per litre in order to capture the change of trips for further analysis.

The feedback scene is displayed at the end of the second level of *TACA Sim.* The feedback scene gives several "scores" for the person's travel behaviour, e.g. total travel distance, distance travelled by fuel-using vehicle (FUV), fuel consumption, number of optional trips, number of necessary trips, numbers of essential trips in a week. The tool additionally calculates several indicators of travel demand behaviour:

- FUV dependence
- Fossil fuel intensity (or carbon footprint)
- Adaptability risk

These measures will be correlated to their decisions of behaviour changes in the last stage when the high fuel price and fuel disruptions are simulated. The feedback scene is shown in Figure 2. FUV dependence is calculated by taking the trip numbers travelled by FUV in a week, divided by total number of trips. For example, a person uses their bike to go 2 km to work every day for 5 days (total 20 km in a week), drives to the shops 5 km from home and drives to play golf at a course 25 km from home on the weekend. In a week, this person makes a total of 14 trips (10 trips by bike and 4 trips by car). This example person's FUV dependence for trips would be (4/14)x100 = 28.57%.

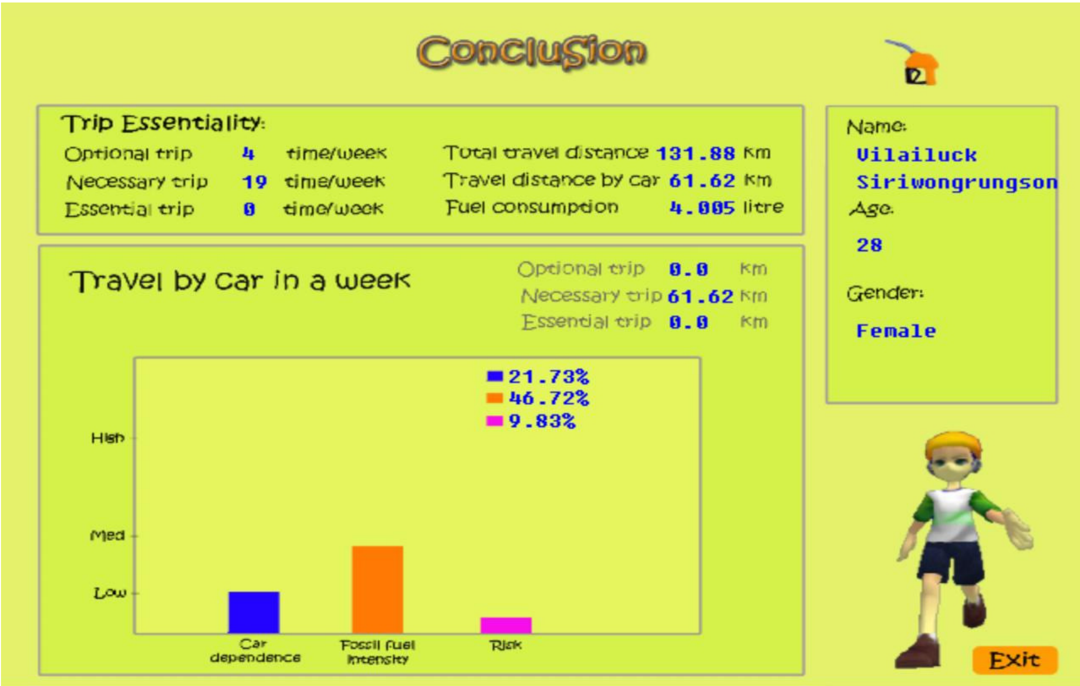

Figure 2: Feedback scene at the end of the travel demand data collection *TACA Sim* level 2.

Fossil fuel intensity takes into account the fuel efficiency of the modes used for weekly trips, compared to taking all trips using the car. The fossil fuel intensity is calculated by all percentage of kilometres travelled by FUV, times the fuel consumption rate. Obviously, if a person only rides a bike, their fuel intensity would be zero. On the other hand, if they only ever drive a car, their fuel intensity would be 100%. The person from the example above drives a car 60 km from the total of 80 km in a week, with the fuel consumption rate 8 litre per 100 km (0.08 l/km). This person would have (60x0.08/80x0.08)x100=75% fuel intensity. This person could lower their fuel intensity by taking a bus for their trip to golfing. With a fuel consumption of 0.01 l/km, their fuel intensity would be ((50x0.01 + 10x0.08)/80x0.08)x100 = 20%

Adaptability risk is a measure of the trips that inevitably require fuel. In the mode selection, people were asked if they had ever taken any other mode if they chose personal vehicle. A person who takes all essential trips by personal vehicle, and who has never taken any other mode has the highest risk. The adaptability risk is calculated by the percentage of alternatives deducted from numbers of FUV trips, weighted by essentiality score (1 for optional trip; 3 for necessary trip; 5 for essential trip). For example, a person conducts a total of 20 trips (including return trips) in a week. Four trips are optional (total 4 points), ten trips are necessary (total 30 points), and the rest are essential (total 30 points). All trips would total 64 points. Out of these 20 trips, ten trips are travelled by car. Two of car trips are optional (total 2 points). Four car trips are necessary (total 12 points) and another four car trips are essential (total 20 points). Total points are 34. If this person has indicated that they can shift two of optional trips (total 2 points), two of necessary trips (total 6 points), and two of essential trips (10 points) from car to bike or other non-fuel alternative, the total points of alternatives are 18. Therefore, this person's risk would be ((34-18)/64)x100=25%.

3. Experimental Results and Analysis

A small sample of 10 participants volunteered to play the first two levels of the *TACA Sim* game, up to the point of the feedback scene. The average time for completion of the travel demand survey was 20 minutes, with a minimum of 15 minutes and maximum of 30 minutes. The participants included postgraduate students, academic staff, and technical staff at the University of Canterbury as well as several other people.

Table 1: (a) Weekly travel demand data sample. (b) Modal split data. (c) Behaviour indicator results for first participant trial of *TACA Sim.*

(a)

Occu-pation	Residential location	Total travel distance (km)	Travel distance by FUV (km)	Total essentiality (time/week)			Essentiality of trips by FUV (time/week)			Alternatives (time/week)		
				Opt	Nec	Ess	Opt	Nec	Ess	Opt	Nec	Ess
Staff	Ilam	63.39	52.18	4	6	10	4	6	0	4	4	0

(b)

Mode							
FUV driver	FUV passenger	Bus	Bicycle	E-Bike	Walk	Skates	Other
10	0	0	10	0	0	0	0

(c)

Fuel consumption (litre)	FUV dependence (%)	Fuel intensity (%)	Risk (%)
4.017	50	82.31	8.33

The travel demand data and travel behaviour indicators for one of the participants, a staff member, are shown in Table 1. From the Table 1(a), the UC staff member travelled a total of 63.39 km in a week. Out of the total travel distance, 52.18 km was travelled by car. Ten short trips (less than 2 km) were conducted by bicycle from home to work. Considering the staff's residential area, it is approximately 1 km from university, which is in the walk-able and bike-able zone. Although numbers of trips travelled by car and bicycle are the same (table 1(b)), the distance travelled by car in a week is longer. Thus, it can be said that the staff member had more kilometres travelled by car than bicycle. This causes 82.31 percent for fuel intensity as shown in Table 1(c). FUV dependence is 50 percent as the number of trips travelled by car is half of the total trips. The results show that the staff will drive a car only for non-work purposes, i.e., go to movie, shopping, volleyball and church. Two necessary trips cannot shift from car to another mode.

It is probably because the person needed a car to carry a bulk of foods after shopping and they travelled with other passengers such as family members or friends to participate in those activities. However, the results present that this staff has only 8.33 percent of risk, which is quite a low level.

The results from the trial with 10 participants show that *TACA Sim* can collect travel demand data efficiently in a short time. An 'activity copy' function was included which allows participants to repeat trips that occur on subsequent days (like going to work) without having to fill in more information. This is equivalent to several pages of work in the conventional paper study. The colourful design of each scene persuaded the participants to complete the survey without becoming bored. Finally, the participants realised their current travel behaviour such as fuel consumption, FUV dependence, fossil fuel intensity and adaptability risk with some surprise in the feedback scene. The staff member whose data is given in Table 1 had considered themselves to be a "sustainable traveller" since they use the bike every day to get to work. The person was quite surprised at how far they actually drove to access several particular activities. The person wished to re-play the game and take the bus for those activities in order to get an improved score. This kind of response is not normally associated with conventional paper travel demand surveys.

4. Future Work

The *TACA Sim* tool will be deployed at the University of Canterbury for a random sample of participants in June 2008. The surveys will coincide with a paper travel demand survey which is done at the university every 4 years. The use of an immersive virtual reality computer game as a travel demand survey tool will be verified by comparing the paper survey results to the *TACA Sim* results.

A further, more comprehensive study is proposed which will survey samples of university academic staff, students, and general staff. This should give information about differences in travel demand behaviour between people of different income levels who all participate in the same activity and travel using the same transport network. Because the tool is low-cost and relatively fast, we are also planning on conducting random surveys of these sample groups over the course of a year in order to track travel behaviour change as fuel prices rise. This data can be used to verify that the choices indicated in the role playing level 3 of *TACA Sim* reflect real choices.

5. Conclusion

Fuel constraints have a negative impact on the individual's access to activities. People will make decisions about mode change or curtailing their trips depending on the impact to their wellbeing. Travel behaviour and adaptability data are important to transport engineering in forecasting and planning the future transportation networks and land use. In order to obtain and assess travel behaviour *TACA Sim* has been carefully designed with the perspective of the participant in mind. The software is engaging, simple and fun, with a feedback score at the end. An early trial of the prototype software shows that the average time to achieve weekly travel demand data is 20 min. Adaptability behaviour for travel demand will be assessed for the first time using the full range of the software platform. *TACA Sim* has been developed with a sufficient scope to immerse participants in a fuel constrained situation: high fuel price and fuel shortage. With the Stewardship concept, *TACA Sim* provides the feedback to participants evaluate their travel behaviour and the risks to themselves. The software then lets people evaluate their own options and choices and make decisions about what changes they will make. These changes are recorded in a database for further analysis.

References

1. Deffeyes, K. S. (2001). Hubbert’s peak: the impending world oil shortage. Princeton, N.J.: Princeton University Press, USA.
2. Guseo, R., Dalla Valle, A., Guidolin, M. (2006). World Oil Depletion Models: Price effects compared with strategic or technological interventions. Technological forecasting and social change.
3. Campbell, C. J., Laherrère, J. H. (1998). The end of cheap oil. Scientific American. p. 78-81.
4. Bureau of Transport and Regional Economics (2005). Is the world running out of oil?; Department of Transport and Regional Services; Australia Government; Canberra, Australia.
5. Wakeley, H. (1980). Predicting Consumer Response to Gasoline Shortage. Special report 191: Considerations in transportation energy contingency planning. Transport Research Board.
6. Dantas, A., Krumdieck, S., Page, S. (2006). Energy risk to activity systems as a function of urban form. Land Transport NZ Research Report 311, 75pp.
7. Habermann, J. L. (1980). Consumer Reactions to the 1979 Gasoline Shortage. Special report 191: Considerations in transportation energy contingency planning. Transport Research Board.

This paper was peer reviewed and orally presented at the NERI ETS Symposium