TRESIS: A Transportation, Land Use and Environmental Strategy Impact Simulator for Urban Areas

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Abstract

The Institute of Transport Studies has recently developed a Transportation and Environment Strategy Impact Simulator (TRESIS) as a decision support system to assist planners to predict the impact of transport strategies and to make recommendations based on those predictions. A key focus of the simulator is the richness of policy instruments such as new public transport, new toll roads, congestion pricing, gas guzzler taxes, changing residential densities, introducing designated bus lanes, implementing fare changes, altering parking policy, introducing more flexible work practices, and the introduction of more fuel efficient vehicles. The appropriateness of mixtures of policy instruments is gauged in terms of a series of performance indicators such as impacts on greenhouse gas emissions, accessibility, equity, air quality and household consumer surplus. In this paper we introduce TRESIS for the first time to the research community, focussing on the structure of the system and the diversity of applications. Applications are presented to illustrate the diversity and richness of TRESIS as a policy advisory tool.

1 INTRODUCTION

Integrated software packages that focus on the interdependencies between land use, transport and the environment are promoted as useful decision support tools for evaluating many transport and non-transport policy instruments. Although such tools have been available for some time, most are user unfriendly and/or of a proprietary nature. Furthermore many such systems require substantial input from the developers to be able to fully utilise their capabilities. TRESIS (Transportation and Environment Strategy Impact Simulator) grew out of an opportunity six years ago to develop a user-friendly decision support system that was accessible on line to the research and practitioner community through a licence or subscription service (in which the access income is used to support ongoing research and maintenance of the package).

TRESIS is documented on line and currently used to investigate strategic-level policy initiatives for the Sydney Metropolitan Area. The modular structure has been designed to facilitate the import of local data such as networks, travel, location and vehicle demand model utility expressions, household profiles and GIS platforms, but has its own GIS and traffic assignment capability[1]. TRESIS as a modular system has a number of key components. These include:

1. the behavioural system of choice models for individuals and households based on mixtures of revealed and stated preference data: mode choice, trip timing, workplace location, residential location, dwelling type, vehicle type choice, fleet size, and automobile use by location
2. the highway and public transport (rail, bus, light rail, ferry, busway) networks and associated levels of service by time of day
3. the equilibration (or disequilibrium) capability in the travel, automobile and residential location markets
4. the automobile scrappage and price determination models
5. the generation of synthetic households used in application, including the interrelationships between workers in a household
6. the in-built GIS interface for data and application processing and presentation
7. the extensive electronic documentation (E-TRESIS) to enable on-line implementation from any global location
8. the extensive data bases of primary and secondary data for input into the behavioural models (currently updated to 1998)
9. the supply-side system of networks and locations, and
10. the sample generation facility for implementation of a complex system of many hundreds of zones and synthetic households.

In this paper we present the structure of TRESIS, focussing on the system and applications. Five applications are presented to illustrate the diversity and richness of TRESIS as a policy advisory tool:

[1] There is an option to use external GIS and traffic assignment capability such as Transcad.

Road (Congestion) Pricing: to illustrate the spatial dimension of TRESIS. It uses a sophisticated interface between TRESIS and an internal GIS code to recognise the geographical area and/or road links that will have congestion pricing imposed. One can study a user-specified spatial context (ie a set of links) and times of the day.
New Infrastructure: Many applications of interest to government involve adding new modal and road links. The most interesting ones are a tollway, a transitway and a heavy rail link. We show how easy it is for TRESIS to evaluate these potential new infrastructure projects.
Land Use Change: We all recognise the interface between transportation and land use. TRESIS can evaluate a selective set of land use policies at a zonal level. The most interesting one is the increasing density of residential dwellings. We adjust the total amount of dwelling stock and its mix in selective zones (ensuring that we increase medium-density dwellings in selective outer zones and high-density dwellings in selective inner zones).
Vehicle Technology: One of the most successful ways of reducing greenhouse gas emissions is to improve automobile technology, especially changes that impact on fuel efficiency and vehicle use. TRESIS has the capability of evaluating the implications of increasing fuel prices and introducing more fuel-efficient vehicles using conventional fuels, alternative fuels (CNG/LPG) and electricity.
Existing Public Transport Service Changes: Public transport authorities (rail, bus and ferry) continue to want to know what role changes in fares and service levels (ie components of travel time) have on the demand for public transport. We will increase and/or decrease fares and travel times for selective parts of the rail, bus and/or ferry network as well as for the network as a whole.

2 THE STRUCTURE OF TRESIS

TRESIS has been designed as a set of integrated modules that define a framework within which to evaluate a large number of policy instruments, singly and in combination. Driven behaviourally by a suite of interconnected spatial location, travel and vehicle choice models and patterns of automobile vehicle use, the behavioural system calls up data managed on a GIS platform to describe a base setting (currently 1998) and a proposed future policy environment (over a period from one to 25 years).

The data sources include the highway and public transport networks by three times of day, distinguishing bus, train, ferry, light rail and transitway; a zonal system (currently 904 zones for the Sydney Metropolitan Area), full specification of inter and intra-zonal service levels for each mode by time of day, socioeconomic profile of the residential population (represented by 672 synthetic or prototype households and workers in each household); zonal definitions in terms of residential dwelling stock (differentiated by plot ratio and dwelling density) and employment opportunities and the stock of automobiles (defined on a large number of physical and performance attributes) disaggregated by vintage and conventional fuelled vehicle classes, electric vehicle classes and alternative-fuelled classes.

2.1The Behavioural Choice System

The behavioural choice system is defined at a household and an individual worker level to recognise that specific choices are predominantly made by an individual or by a household.

The model system on the demand side has a pre-specified sequential structure with feedback that was arrived at after extensive testing in line with compliance conditions underlying a paradigm of choice that requires the model system to be globally consistent with random utility maximisation. The demand module is summarised in Figure 1. The decision hierarchy is structured as a core and a set of off-core links. The core hierarchy has the following hierarchy of conditioning: residential location, workplace location, commuter mode choice, and commuter departure time choice[2]. There are three off-core linkage decisions: spatial and temporal work pattern choices conditioned by workplace location, residential dwelling type choice conditioned on residential location choice, and automobile fleet size and vehicle type mix choice (Hensher and Greene 2000) conditioned by commuter mode and departure time choice and conditioned on residential location.

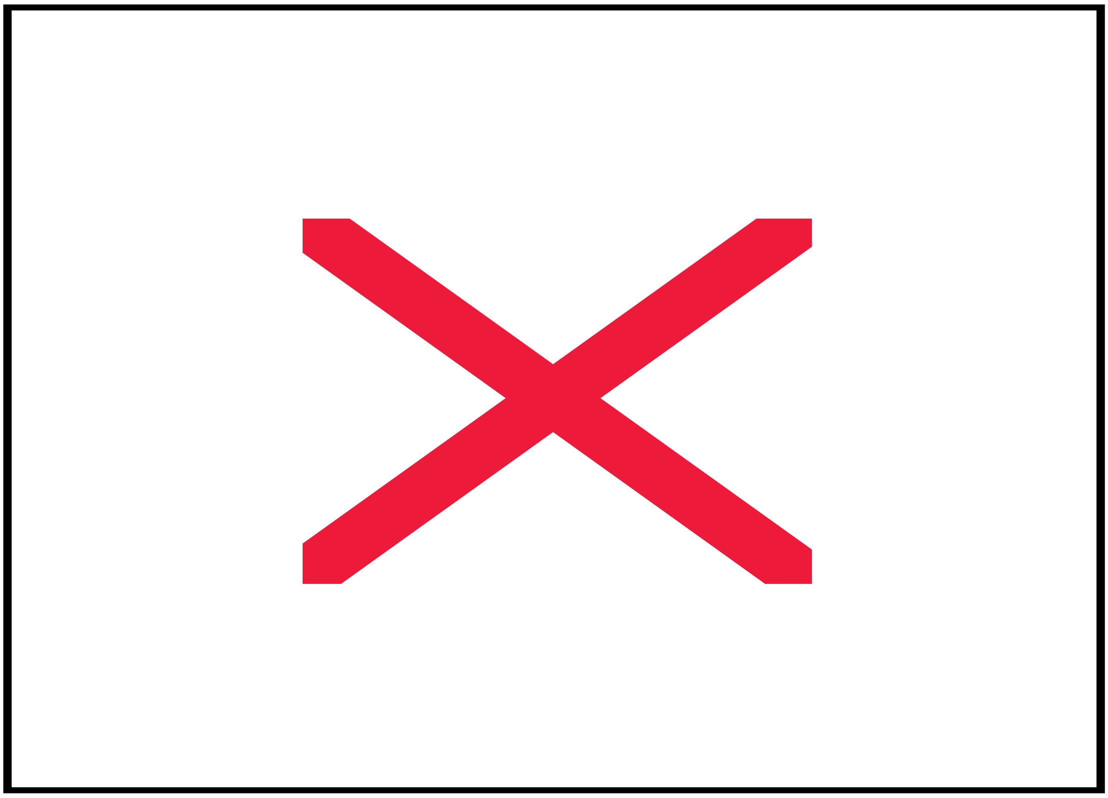


Figure 1 An Overview of the TRESIS Behavioural Demand System

2.2 Synthetic Households

A central feature of TRESIS applications is the concept of a synthetic (or prototypical) household. To give TRESIS locational generality the application process is likened to 'dropping' a sample of households into an urban area, each such household being described by

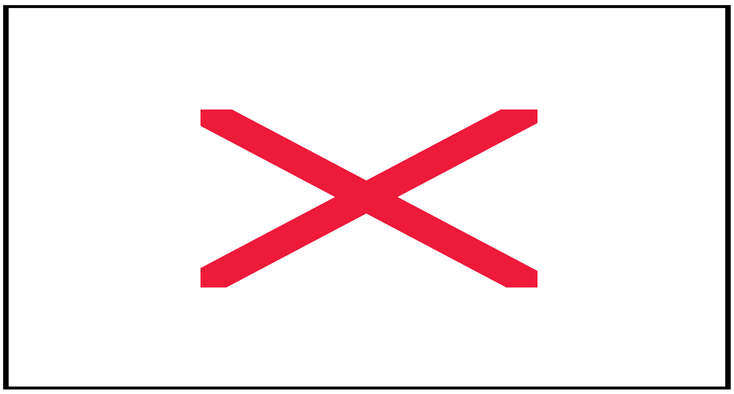
[2] A set of non-work travel choice models is under development to complement the commuter models. In the current version, non-commuting travel activity is represented by the vehicle kilometres of car use. A non-commuter mode and parking choice model is complete but awaiting implementation.

a bundle of socio-economic and demographic characteristics. These characteristics are influences in the suite of utility expressions representing the set of behavioural choice models. Together with the predefined transport network, dwelling type prices, automobile attributes and the physical zone system, the characteristics of each synthetic household are used to derive the full set of behavioural choice probabilities for the set of travel, location and vehicle choices and predictions of vehicle use. Each synthetic household carries a weight that represents its contribution to the total population of households. Through time we carry forward the base year weights or, alternatively, modify the weights to represent the changing composition of households in the population. The process of generating Synthetic Households is presented in Ton and Hensher (2001).

2.3 Heuristics to Accommodate the Temporal Adjustment Process

The model system is static and hence produces an instantaneous fully adjusted response to a policy application. In reality choice responses take time to fully adjust, with the amount of time varying by specific decision. We expect that it would take longer for the full effect of the change in residential location to occur and much less time for departure time and even mode choice. Two heuristics were considered - a *dynamic incremental approach* and a *block period approach*. The former involves the imposition of a discount factor that establishes the amount of a change in choice probability that is likely to be taken up in the first year of a policy. It removes the rest of the change and uses the new one-year adjustment as the starting position for the next year. Intuitively we are saying that if we had a fully dynamic choice model system, we would only observe the discounted impact after each year. The latter approach adopts a longer period such as five years as the block of time over which the full effect of a policy will occur. This is a maximum period since some decisions such as departure time choice will be fully adjusted over a short period in contrast to the residential location decision that we might assume would take the full five years to adjust. A set of (default) discount factors would be specified for each of the five years as illustrated in Figure 2.

Figure 2. The Temporal structure for a block period approach



Our preference is for the dynamic incremental approach. The default discount rates for the first year vary from 0.9 for residential location to 0.2 for departure time choice.

2.4 Equilibration in the Travel Market

The TRESIS core is seamlessly linked to an internal capability to undertake a number of processing tasks. One of these is traffic assignment on the highway and public transport networks by time of day. Changes in generalised cost (ie travel times and all financial outlays related to a trip) operate iteratively through feedback from the trip to the market to the trip etc. until a convergence limit is reached, as exogenously defined by a change which is less than a fixed percentage change. The exogenous variables must be capable of predicting changes in generalised cost due to the accumulated behavioural responses throughout the model system.

A generalised cost model for each time of day would have the following exogenous variables for each origin-destination pair: the number of trips, the road capacity, and base free flow conditions represented by distance/speed. This equation is *calibrated* on observed generalised cost and thus represents the base equilibrium conditions. Our approach is not limited to a 2-hour am peak network, which currently drives most urban areawide transport planning models in Australia and in most urban contexts throughout the world. The possibility of time of day commuter switching is very real in the TRESIS model system. To provide a reliable mapping between generalised cost and the three major exogenous variables given above, we use a network model to generate average travel times and cost components under a large number of mixtures of trip volumes, road capacities and distances.

The resulting database is used to obtain parameter estimates to represent the role of the volume capacity ratio in determination of predicted generalised cost. This enables us to impose an endogeneity condition on generalised cost at the aggregate level. That is, whereas each individual commuter cannot influence their own generalised cost once a time of day is chosen, the aggregation of individual choices (i.e. total trips) within a given network defined by capacity and the spatial network will influence average generalised costs. This gives an empirical relationship to facilitate revisions of components of generalised cost within the location-to-location matrix in arriving at revisions in the probabilities of household commuters choosing particular modes between particular residential and workplace locations, which are aggregated iteratively to adjust total trips and hence travel times and cost components, given distance and capacity. This procedure also provides a capability for evaluating the impact of changes in location-specific road infrastructure (e.g. a new toll road, a bus priority system). The introduction of rail infrastructure is handled via the commuter mode choice model where we can exogenously adjust the attribute levels of existing rail public transport or add in a new rail alternative (the latter by the inclusion of the light rail utility expression).

2.5 Equilibration in the Residential Location and Dwelling Type Market

Households adjust their residential location in response to changes in the transport system and for other reasons. Consequently any one of a number of strategies can influence the probability of a household both living in a particular location and the type of dwelling they choose to occupy. At any point in time there will be a total demand for dwelling types in each residential location. Excess demand will result in an increase in location rents and dwelling prices; excess supply will result in a reduction in the respective rents and prices. In TRESIS, dwelling prices are used to clear the markets for dwelling types and location, in the absence of data on location rents. The market clearing mechanism is linked into a set of impact indices that 'allocate' heuristically the impact of a strategy on the choice of residential location and dwelling type across time, so that, in the absence of a dynamically specified adjustment process within the behavioural model set, the temporal response profile is 'realistic' (as described above). Equilibration is secured for both the dwelling type market and the residential location market. Disequilibrium is allowed for when an injection of new dwellings creates excess supply given the number of households. Under this strategy the simulator needs only to ensure that the demand for dwellings by type in a residential zone does not exceed supply for the zone. Any additional dwellings will be left vacant in the particular year as an indication that property developers may have created too much stock at that time. In future years as households grow, the take up rate increases without creating increases in dwelling prices until the market is cleared.

It is important to observe the process of equilibration or disequilibration under the temporal allocation rule applied to a static model system as a proxy for a dynamic model specification. At the first iteration of equilibration, a set of choice probabilities are obtained and scaled according to the temporal allocation rule. The summed probabilities are used to identify the aggregate relationship between demand and supply for each type of dwelling in each residential location. A set of directional dwelling price adjustments are created as input into the second iteration prediction of dwelling prices; they reflect the partial adjustment of the market to the initial exogenous shock (i.e. strategy). A resulting set of new probabilities based on the adjusted prices are obtained. These second-round choice probabilities are assumed to represent further adjustments in the probabilities associated with the one-period temporally adjusted annual impact probability outcomes; however since the choice model still has the property of instantaneous response, a further temporal adjustment is undertaken in each subsequent iteration in the annual equilibration. Another way of expressing this is that iterations after the first iteration *fine tune* the adjustments applicable to a year's choice response. Where the adjustment is complete in one year (i.e. temporal allocation is 100% in one year), then the static model is essentially a dynamic model and the rules for each iteration are identical. This same logic applies to equilibration in all three markets - travel, location and automobiles.

2.6 Equilibration in the Automobile Market

Identification of automobile scrappage rates and expected future prices of used vehicles are important features of TRESIS. In the base year (1998) we begin with an observed set of used and new vehicle registrations in each class (and vintage). For classes in subsequent application years we identify the number of vehicles on register in the existing and the new classes, the latter added over time at the annual rate of 10 conventional fuel classes (see Table 1) and six non-conventional fuel classes (if applicable - i.e. two fuels and three vehicle sizes). New vehicles should be introduced ideally in accordance with manufacturers' release plans; however such information is not readily available.

Table 1 Classification of Conventional-Fuelled Vehicles

	'Size' classes
C1.	Micro (≤ 4 cylinders, < 1400 cc)
C2.	Small (4 cylinders, 1400 - 1900 cc)
C3.	Medium (4 cylinders, > 1900 cc)
C4.	Upper Medium 1 (6 cylinders, < 3000 cc)
C5.	Upper Medium 2 (6 cylinders, ≥ 3000 cc)
C6.	Large (≥ 8 cylinders)
C7.	Luxury (specific makes and engine capacities). All of: Mercedes, BMW, Rolls Royce, Jaguar, Audi, Bentley, Lexus, Daimler and Eunos Plus: Honda Legend / NSX (> 3000 cc), Volvo ≥ 2300 cc, Saab > 2100 cc
C8.	Light Commercial (ABS bodytypes 30-39)
C9.	Four Wheel Drive (treated separately outside of ABS registrations)
C10.	Light Trucks (≤ 3.5 tonne, ABS body types 40-49)

Two approaches have been implemented to determine the demand for new vehicles each year. The first approach is fully implemented in the current version of TRESIS, which we call the *vehicle price relativity approach*; the second (*equilibration*) approach is coded in the software but not available outside of ITS[3]. The *vehicle price relativity approach* controls the relativities of vehicle prices by vintage via given exogenous new vehicle prices. The scrappage model is used only to identify the loss of used vehicles consequent on vintage and used vehicle prices, where the latter are fixed by new vehicle prices in a given year. The supply of new vehicles is determined as the difference between the total household demand for vehicles and the supply of used vehicles after application of the scrappage model based on used vehicle prices derived from a non-linear empirical equation which 'predicts' used vehicle prices, given exogenously provided new vehicle prices.

This approach ensures a predetermined relativity of prices of vehicles over all vintages within a class. Used vehicle prices in the model are set as depreciated new vehicle prices and reset each year for each vintage of a class, so that if the prices of new cars in all classes (or just one) rose, then the used car market would rise in price also. The used car prices of each age within a class are set as a constant function of new car prices to give a price decay to establish the relativity of used to new prices each year. These prices are then used in all demand calculations in type choice and fleet size models, as well as in the scrappage functions.

TRESIS requires an empirical scrappage model as well as a used price model that can be used to identify future stocks of passenger vehicles (by class) as at December 1998, December 2003, December 2008 and December 2013. A scrappage rate model of the following form is parameterised

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[3] The alternative *equilibration approach* treats new vehicle prices exogenously but allows a freely determined set of used vehicle prices that are arrived by equilibration in the vehicle market. To determine the total number of new vehicles to be released on the market each year the calculations are as follows: given exogenously defined new vehicle prices (cost-based), total demand for vehicles by class is determined through the application of the vehicle type choice and fleet size models; scrappage of used vehicles is also calculated using cost-based prices. A percentage of used vehicles leave the market for various reasons, typically associated with age and value. The difference between demand and scrappage gives the number of new vehicles *by class*. These new vehicles are then fed into the equilibration process for the base situation and for a policy application.

$$\frac{NR_{p-1}^{91} - NR_{p}^{92}}{NR_{p-1}^{91}} = \beta_0 + \beta_1 Price_{p}^{92} + \sum_{a=1}^{A} \beta_{2a} age_{ap}^{92} \qquad (1)$$

where

$\frac{NR_{p-1}^{91} - NR_{p}^{92}}{NR_{p-1}^{91}}$ is the scrappage rate (as a percentage) over a period *p*, NR_{z}^{y} is the number of vehicles on register in a class in year y and period z, $Price_{z}^{y}$ is the (expected future) price in year y and period p for a vehicle class, and the other exogenous variables are, for each class of vehicle, a series of dummy variables (1,0) representing ages of vehicles. In the current version of the simulator (Version 1.0), the scrappage rate model is implemented on annual data in 1997 and 1998, using a parameterised equation (1) based on registration data for 1991 and 1993.

The expected price in the loss rate model is a prediction from the expected price equation[4]. The combination of the two equations enables TRESIS to predict vehicle loss rates for each forecast year and to equilibrate on vehicle prices taking into account the role that vehicle prices have on loss rates. We have built in a recognition that retailers have been prepared to discount new vehicle prices in a particular class where sales are sluggish. The empirical equations are embedded within the equilibration subroutines of the simulator decision support system. The results of the 1998 fleet scrappage model are summarised in Table 2 and the age profile by vehicle class is shown in Figure 3.

Table 2 Scrappage model predictions by vehicle class.

	Expected Price ($A)	Ln (expected price)	Vehicles leaving fleet	Vehicles remaining
Class1	9,315	9.13938	5,737	78,185
Class2	14,940	9.61180	28,443	441,502
Class3	22,102	10.00342	18,198	28,0763
Class4	25,115	10.13122	3,419	45,785
Class5	24,018	10.08656	17,653	27,4670
Class6	22,606	10.02597	3,555	81,059
Class7	40,857	10.61783	5,646	91,329
Class8	21,220	9.96270	10,688	16,6517
Class9	28,575	10.26029	2,810	76,941
Class10	7,125	8.87137	3,094	38,994
Total			99,242	1,575,746
Weighted Mean	20,825	9.94389	99,211	1,575,777

4 The expected price equation was estimated as a lagged dependent variable model using two stage least squares, with allowance for serial correlation. The loss rate equation was estimated as an ordinary least squares model with correction for heteroskedasticity.

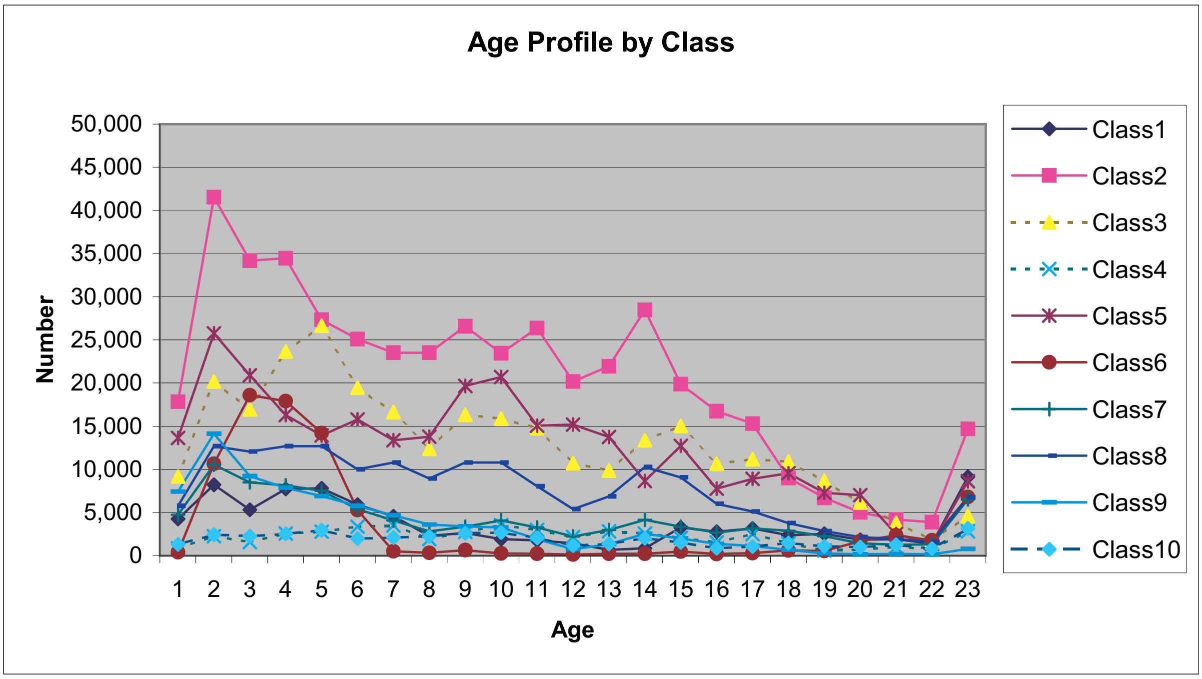

Figure 3 1998 age profile by class

2.7 Sampling Zones in Application

Nearly all large-scale urban models with comprehensive demand models, many traffic zones and highly disaggregated traveller and household units (such as synthetic households) implement a sampling strategy to run the models (otherwise one would be running the models for days). With a 904 by 904 zonal system and 672 synthetic households (with embedded single and multi-worker profiles) we have estimated that one policy application can take many hours (on a 550 MHz Pentium III running under NT4.0). Reducing the number of zones and/or synthetic households reduces running time exponentially. The challenge is to establish the loss of accuracy as we reduce the number of synthetic households through aggregation and traffic zones by sampling. After extensive experimentation, we have found that the loss of snythetic households is a greater price to pay in terms of loss of accuracy than sampling of traffic zones. Indeed the need to preserve as much household heterogeneity is to be encouraged, but sampling traffic zones (as distinct from aggregating such zones) from 904 right down to 50 appears to have little influence on the accuracy of policy outputs. A 50 by 50 sampled zonal system and 672 synthetic households has been selected[5], enabling a policy application to take approximately 1 hours per forecast year (see Ton and Hensher 2001a).

[5] We have also run the full 904 by 904 model with results reported in Ton and Hensher (2001).

3 CASE STUDIES

We have now completed the overview of the major components of TRESIS. The five application policy instruments were run over a 10 year period with 1998 as the base year. We have selectively chosen outputs from an extensive set (see Hensher 1999), focussing on the annual and accumulating impacts in respect of changes in CO_2 emissions and energy consumed, total end user costs (including travel time), modal shares, car use and end use consumer surplus. Figure 4 illustrates the complex interactions throughout the behavioural model system associated with a policy shock.

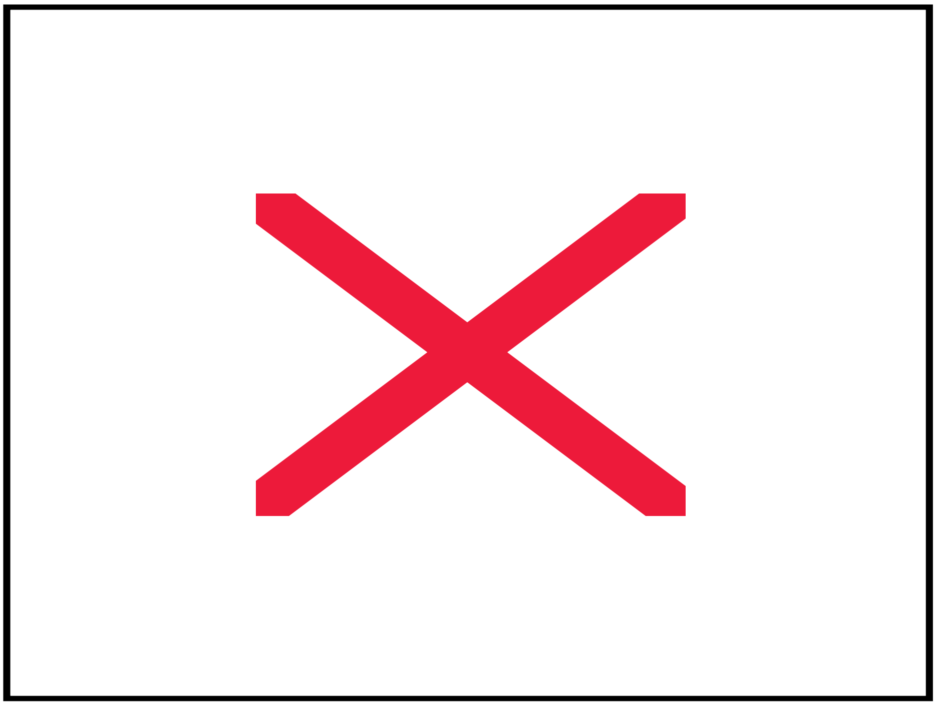

Figure 4. An Example of the Interactions in the Behavioural System from a policy shock

Table 3 summarises the impacts of each of the five policy shocks for illustrative levels of changes:

P1: Congestion Pricing: imposing a 50 cents per vehicle kilometre charge in the Central Area of Sydney from 2001onwards

P2: New Infrastructure: adding a cross-city tunnel in the Sydney CBD in 2005 with a $2 toll each way. Extra trips per hour capacity is 3,000.

P3: Land Use Change: increasing medium-density dwellings in selective outer zones (approximately 1000 dwellings) and high-density dwellings in selective inner zones (approximately 7,850 more dwellings) each by 20% effective 2005.

P4: Vehicle Technology: increasing the fuel-efficiency of conventional fuelled vehicles by 5% per annum from 2001 onwards.

P5: Existing Public Transport Service Changes: increasing fares for the bus and rail network as a whole by 20% in 2001 only with new fares in place thereafter.

Table 3. Summary Impacts of Five Policy Shocks

Percentage Change in Performance Indicators in 2007 (ie Base 2007 vs application 2007)

Performance Indicator	P1: Congestion Pricing	P2: Cross-City Tunnel	P3: Residential Density	P4: Fuel Efficiency	P4: PT Fare increase
VKM/vehicle	-.43	0.01	-.02	4.4	0.02
Vehicles/hhld	0	0	0.05	0.2	0.01
CO_2/vkm	0.01	0	0	-25.31	0
Energy(litres)/100km	0.01	0	0	-25.31	0
Vehicles/capita	0	0	0.05	0.2	0.01
TEUC($)/vkm	1.30	0.33	0.03	-12.44	0.28
TEUC($)/vehicle	0.87	0.32	0.01	-8.58	0.31
CMC-CS($)/capita	-0.06	-0.03	-.17	2.58	-0.13
RLC-CS($)/capita	0	0	-.37	0.01	0
FSC-CS($)/capita	0	0	0.02	0.06	0
WPU-CS($)/capita	0	-.01	0	0	0

Note: 0% is sufficiently small to approximate to zero.

Total End Use Carbon Dioxide from Automobiles (kg per annum)

Policy	1998		2001		2004		2007	
	Before	After	Before	After	Before	After	Before	After
P1	6754	6754	6826	6798	6848	6820	6881	6852
P2	6754	6754	6826	6826	6848	6848	6881	6880
P3	6754	6754	6826	6826	6848	6848	6881	6883
P4	6754	6754	6826	6540	6848	5860	6881	5380
P5	6754	6754	6826	6826.01	6848	6849	6881	6883

Total End Use Consumer Surplus ($ per annum)

Policy	1998		2001		2004		2007	
	Before	After	Before	After	Before	After	Before	After
P1	2774	2774	2864	2869	2957	2956.9	3054	3053.9
P2	2774	2774	2864	2864	2957	2957	3054	3053.9
P3	2774	2774	2864	2864	2957	2957	3054	3051
P4	2774	2774	2864	2864	2957	2960	3054	3054.1
P5	2774	2774	2864	2864	2957	2956.9	3054	3053.9

Total End Use Energy Consumed by Automobiles (litres per annum)

Policy	1998		2001		2004		2007	
	Before	After	Before	After	Before	After	Before	After
P1	2516	2516	2542	2532	2551	2540	2563	2552
P2	2516	2516	2542	2542	2551	2551	2563	2562.9
P3	2516	2516	2542	2542	2551	2551	2563	2564
P4	2516	2516	2542	2440	2551	2180	2563	2000
P5	2516	2516	2542	2542.2	2551	2551.4	2563	2564.1

Table 3 continued

Total End Use Cost ($ per annum in $93 present value)

Policy	1998		2001		2004		2007	
	Before	After	Before	After	Before	After	Before	After
P1	5163	5163	4239	4239.02	3489	3481.9	2871	2871.2
P2	5163	5163	4239	4239	3489	3489	2871	2872
P3	5163	5163	4239	4239	3489	3489	2871	2875
P4	5163	5163	4239	4240	3489	3510	2871	2900
P5	5163	5163	4239	4250	3489	3150	2871	2900

Commuter Modal Share for Car Drive Alone

Policy	1998		2001		2004		2007	
	Before	After	Before	After	Before	After	Before	After
P1	53.1	53.1	52.98	52.97	52.84	52.81	52.69	52.66
P2	53.1	53.1	52.98	52.98	52.84	52.84	52.69	52.66
P3	53.1	53.1	52.98	52.98	52.84	52.84	52.69	52.67
P4	53.1	53.1	52.98	52.99	52.84	52.87	52.69	52.83
P5	53.1	53.1	52.98	53.03	52.84	53.04	52.69	52.99

Commuter Modal Share for Car Ride Share

Policy	1998		2001		2004		2007	
	Before	After	Before	After	Before	After	Before	After
P1	19.89	19.89	19.84	19.83	19.78	19.77	19.72	19.719
P2	19.89	19.89	19.84	19.84	19.78	19.78	19.72	19.73
P3	19.89	19.89	19.84	19.84	19.78	19.78	19.72	19.719
P4	19.89	19.89	19.84	19.84	19.78	19.79	19.72	19.78
P5	19.89	19.89	19.84	19.85	19.78	19.86	19.72	19.84

Commuter Modal Share for Bus

Policy	1998		2001		2004		2007	
	Before	After	Before	After	Before	After	Before	After
P1	10.3	10.3	10.36	10.37	10.44	10.45	10.52	10.53
P2	10.3	10.3	10.36	10.36	10.44	10.44	10.52	10.521
P3	10.3	10.3	10.36	10.36	10.44	10.44	10.52	10.525
P4	10.3	10.3	10.36	10.36	10.44	10.42	10.52	10.41
P5	10.3	10.3	10.36	10.34	10.44	10.33	10.52	10.35

Commuter Modal Share for Train

Policy	1998		2001		2004		2007	
	Before	After	Before	After	Before	After	Before	After
P1	16.7	16.7	16.82	16.83	16.94	16.96	17.07	17.09
P2	16.7	16.7	16.82	16.82	16.94	16.94	17.07	17.08
P3	16.7	16.7	16.82	16.82	16.94	16.94	17.07	17.09
P4	16.7	16.7	16.82	16.81	16.94	16.92	17.07	16.97
P5	16.7	16.7	16.82	16.78	16.94	16.77	17.07	16.81

Total Automobile Vehicle Kilometres per annum

Policy	1998		2001		2004		2007	
	Before	After	Before	After	Before	After	Before	After
P1	22.51	22.51	23.28	23.19	24.1	24.0	24.92	24.81
P2	22.51	22.51	23.28	23.28	24.1	24.1	24.92	24.91
P3	22.51	22.51	23.28	23.28	24.1	24.1	24.92	24.923
P4	22.51	22.51	23.28	23.5	24.1	24.8	24.92	24.96
P5	22.51	22.51	23.28	23.5	24.1	24.8	24.92	26.1

The case study impacts in Table 3 are a select set from the larger set of performance indicators (summarised in Appendix Table A1). Many of the strategies evaluated are limited to specific locations in the Sydney Metropolitan Area and as such have a relatively small impact overall.

For example, a congestion charge of 50c/km in the Central City Area reduces total annual vehicle kilometres by 0.43%, increases total end use costs (in $93PV) by 1.3% and reduces aggregate consumer surplus through modal switching by 0.06%. The impact on all sources of consumer surplus is almost negligible (as measured by RLC-CS/capita). However, changing residential densities has almost no impact on vehicle use (-0.02%) but has a noticeable effect on overall consumer surplus (-0.37%) but negligible impact on any of the other selected performance indicators.

Improvement in the fuel efficiency of automobiles (after 2001 of 5% per annum), has some sizeable impacts, especially on vehicle use (4.4% increase in vehicle kilometres), carbon dioxide emissions (and energy consumed) per vehicle kilometre (decreasing by 25.31%), total end user cost ($93PV) - decreasing by 12.44% per vehicle kilometre or 8.58% per vehicle, and an increase in consumer surplus associated with modal switching of 2.58%. Importantly the aggregate impact after all consumer surplus impacts only increases by 0.01%. Public transport fare increases have almost no influence on automobile use (reducing vehicle use per vehicle by 0.02%). Finally, the introduction of a new cross-city tunnel has a very small impact of the overall performance of the metropolitan area (even though it may have a significant impact on the performance of the local traffic stream), with a toll of $2 per one-way trip and slightly improved travel times, increasing total end user cost ($93PV) per vehicle kilometre by 0.33% while having no impact on overall consumer surplus and a slight reduction in modal consumer surplus per capita of 0.03%. If the primary objective is to reduce enhanced greenhouse gas emissions, then only Policy 4 has a noticeable impact; however it comes at a noticeable cost to end users.

4 CONCLUSIONS

This paper presents a new modelling capability for investigating the impact of mixtures of strategies on the performance of the transport system in an urban area. An extensive set of performance indicators are provided so that analysts and decision makers can gain a broad appreciation of the positive and negative impacts of specific strategies. Ultimately decisions will be taken based on the trading off of the diversity of impacts. TRESIS provides a rare opportunity to formalise these trade-offs, acting as much as a point of reference for debate as a tool for forecasting likely impacts. Additional TRESIS modules under development include a full suite of travel choice models for non-work activity, and an air quality assessment and reporting module.

ACKNOWLEDGMENTS

Many individuals have contributed to the development of TRESIS. In particular we thank the core team of Tu Ton, Jeff Leal, Cam Ngo, Kirk Bendall and Freddy Santori. The Bureau of Transport Economics provided partial financial support at various stages in the development of TRESIS and is currently a registered licence holder. TRESIS is a major output of the funding received under the Australian Government's program of Key Centres.

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APPENDIX

Table A1. Explanation of the Range of Outputs Produced by the Strategy Simulator for Base, Application and Comparison
(note: many of these outputs can be summarised by zonal location, vehicle class, and socioeconomic group - household income and lifecycle)

Output Dimension	Acronym	Units
Total annual carbon dioxide	TCO2	kilograms (kg)
Total annual end-use money cost	TEUC.MC	dollars ($)
Total end-use money cost in present value terms	TEUCPV.MC	dollars 93 ($93)
Total annual end-use commuter travel time cost	TEUC.TC	dollars ($)
Total end-use time cost in present value terms	TEUCPV.TC	dollars 93 ($93)
Total annual end-use commuter travel time	TEUC.Time	minutes (min)
Total annual expected maximum utility from each model system for each of the model components defined by the upper level xx of the linkage: residential location (RL) links, fleet size (FS) links, work practices (WPU) links.	TEMUxx	dollars ($)
Accessibility Indicators (Consumer Surplus measures in utility units)	ACCxxx	Utility units
Total annual passenger vehicle kilometres	TVKM	kilometres (km)
Total annual passenger vehicle kilometres: to/from work and as part of work	TVKMTwAw	kilometres (km)
Total annual passenger vehicle kilometres: other urban	TVKMOU	kilometres (km)
Total annual passenger vehicle kilometres: non urban	TVKMNonU	kilometres (km)
Average operating cost of autos	AvOpCost	c/km
Annualised automobile capital cost	VehAnnCost	dollars ($)
Total annual auto operating costs	VehOpCost	dollars ($)
Total passenger vehicles	Tvehicles	number
Total energy consumed by passenger vehicles	Tenergy	litres
Total government revenue from auto. ownership	TgovtVehReg	dollars ($)
Total government revenue from fuel excise	TgovtExcise	dollars ($)
Total government revenue from carbon tax	TgovtCarbT	dollars ($
Total government revenue from sales tax	TGovtSales	dollars ($
Total revenue from toll roads	TTollRev	dollars ($)
Total revenue from parking strategy	TGovtPark	dollars ($)
Total revenue from congestion pricing	TR Cong	dollars ($)
Total government revenue from public transport use	TGovtPT	dollars ($)
Total government revenue from vehicle purchase cost	TGVehPurCost	dollars ($)
Total cost of Vehicle maximum age buyout	TvehMaxAge Value	dollars ($)
Total government vehicle rebate cost	TGVehRebCost	dollars ($)
Total number of households	THhld	number
Total number of people resident in each city	Tpop	number
Total number of workers (p/t and f/t) in each residential location	TWrkrRes	number
Total number of workers (p/t and f/t) in each workplace	TWrkrWork	number
Commuter modal share for car drive alone	TDA	proportion
Commuter modal share for car ride share	TRS	proportion
Commuter modal share for train travel	Ttrain	proportion

Commuter modal share for bus travel	Tbus	proportion
Commuter modal share for light rail travel	TLrL	proportion
Commuter modal share for busway use	Tbwy	proportion
Total number of annual car drive-alone commuter trips	TDA(PA)	number
Total number of annual car ride-share commuter trips	TRS(PA)	number
Total number of annual train commuter trips	TTrain(PA)	number
Total number of annual bus commuter trips	TBus(PA)	number
Total number of annual light rail commuter trips	TLrL(PA)	number
Total number of annual busway commuter trips	TBwy(PA)	number
Vehicle Class Share Class 1	VehClass01micro	proportion
Vehicle Class Share Class 2	VehClass02small	proportion
Vehicle Class Share Class 3	VehClass03med	proportion
Vehicle Class Share Class 4	VehClass04umed1	proportion
Vehicle Class Share Class 5	VehClass05umed2	proportion
Vehicle Class Share Class 6	VehClass06large	proportion
Vehicle Class Share Class 7	VehClass07lux	proportion
Vehicle Class Share Class 8	VehClass08Lcom	proportion
Vehicle Class Share Class 9	VehClass094WD	proportion
Vehicle Class Share Class 10	VehClass10Ltruck	proportion
Vehicle Class Share Class 11	VehClass11EVsm	proportion
Vehicle Class Share Class 12	VehClass12EVmed	proportion
Vehicle Class Share Class 13	VehClass13EVlge	proportion
Vehicle Class Share Class 14	VehClass14AFsm	proportion
Vehicle Class Share Class 15	VehClass15AFmed	proportion
Vehicle Class Share Class 16	VehClass16AFlge	proportion
Vehicle kms per vehicle	RVKMPVehicle	Vkm/veh
Vehicle per household	RVehiclePHld	Veh/hld
CO2 per vehicle kilometre	RCO2PVKM	CO2/vkm
Energy per 100 vehicle kilometres	RenergyP100VKM	Litres/100vkm
Vehicle per capita	RVehPCapita	Veh/capita
Total end use cost per vehicle kilometre	RTEUCPVKM	$/vkm
Total end use cost per vehicle	RTEUCPVeh	$/veh
Commuter Mode Choice Consumer surplus per capita	REMUCMCPCapita	$/capita
Residential Location (total) Consumer surplus per capita	REMURLCPCapita	$/capita
Fleet Size Choice consumer surplus per capita	REMUFSC PCapita	$/capita
Work Practices consumer surplus per capita	REMUWPUPCapita	$/capita

Notes: Toll, parking and congestion charge revenue is separated from government revenue since the collector of such revenue may be a private organisation. Operating cost excludes spatial strategies such as tolls and congestion charges. It includes fuel-related strategies such as fuel efficiency, fuel excise and carbon tax.