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Needs Assessment for Major Transport Infrastructure Investment

by

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ABSTRACT: Transportation infrastructure projects, like any investment, are ultimately accepted or rejected on a number of risk criteria. A most notable one is the revenue stream from the users of the facility. If the investment is to be justified on both commercial and social criteria, the risk is especially high; if there is an element of community social obligation (backed up by subsidy), then the revenue risk is of a different nature and typically much lower.

The primary focus of this paper is on the continuing challenge of establishing ways to increase the reliability of traffic forecasts as a primary input in the forecast of revenue and the continuing role of in-depth attitudinal/opinion surveys with stakeholders to establish the needs agenda. The secondary focus is on promoting the case for a richer strategic system-wide approach to forecasting traffic demand for projects which has the capability of ranking specific infrastructure projects against alternative ways of improving the performance of the transport system in urban areas.

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Introduction

Whatever set of obligations are in place, there is a good case to be made for "knowing the market" and establishing some rules for determining investment priorities. Much of what we see in our major urban areas is essentially a project-based infrastructure planning approach with limited consideration of the strategic implications of a broader set of potential 'solutions' to the transport problem. A broader strategic focus must be driven by the search for policy instruments (or mixtures of policy instruments) which, in accordance with a set of agreed measures of performance, would evaluate infrastructure investment as one of a number of possible ways of improving the performance of the transport system (Hensher 1998).

Establishing the Framework for Capturing Market Demand

Whenever a potential equity partner is approached to participate in a consortium to provide transport infrastructure such as a toll road, high speed rail, light rail or a tunnel, the first thing they ask about is the size of the market and the extent to which the proposal is 'bankable'. Until the market question is answered, the finessing of costs and other inputs into the determination of rates of return, while important, is secondary.

One of the major concerns that most if not all major transport infrastructure projects suffer from is the generally poor quality of primary and secondary data describing the existing market catchment, and the lack of behaviourally sensitive travel demand models. The latter is especially problematic where the infrastructure delivers a level of service substantially different from that currently available, as is the situation for many large infrastructure projects such as toll roads, transitways and high speed rail.

Specific examples of inadequate data in the transport sector are:

- origin-destination population traffic counts by vehicle type (car, truck, coach, plane and train) and occupancy for intercity and urban corridors
- origin-destination levels of service (e.g. travel time) by mode for all settings
- highly aggregated interzonal levels of service exhibiting high variances within each zonal pair
- non-passenger vehicle data on choice of route and trip frequency
- base data capable of modelling induced demand (associated with increased accessibility)
- sufficient sample sizes for travel survey data relevant to specific corridors to be able to undertake the necessary market segmentation to pickup the sensitivity of different markets to changing levels of service delivered through improved infrastructure.

The collection of such data is expensive and time consuming; however much of it has generic value to many transport projects. It might be argued that there is a strong case to be made for the ongoing central collection of much of this data to serve these continuing needs (the natural monopoly argument), supplemented where necessary to provide specialised detail appropriate for specific investigations. In the context of competitive bidding for the right to provide transport infrastructure, there are strong arguments for encouraging some element of market advantage through bidder-specific travel surveys, modelling and forecasting. But to argue about the amount of base traffic by a specific mode using a corridor seems a very unproductive activity. The great gains in value-added terms come from the way in which the specialised study builds on base data to explain future behavioural response in the presence of a specific set of infrastructure scenarios.

For example, the ongoing evaluation of the potential for high speed rail in the Sydney-Canberra corridor got bogged down in 1995/96 with a debate on the distribution of car occupancy. The original study undertaken by The Institute of Transport Studies in 1994 (Hensher 1997) had collected new travel data from a sample of corridor travellers. This revealed an average car occupancy for one-way non-business trips of about 2.1. A subsequent review of the corridor by an intergovernmental committee argued that the average vehicle occupancy for this segment was closer to 1.8. This difference has a very large impact on the total number of base year car person trips which are candidates for switching to high speed rail. After further investigations by the proponents of the higher average car occupancy, it was revealed that the lower estimate was derived from an Australia-wide study which involved visual counts of car occupancy as cars passed a number of locations on major roads throughout the country. Putting aside any political motivation for wanting lower occupancy levels, the important message is that there is sufficient important variation in real markets in respect of travel behaviour, that to have to use data from other contexts is potentially misleading, wastes a lot of time in the evaluation process, and can produce major errors in forecasts of traffic and hence revenue. A difference of 0.3 persons per car translated into many millions of dollars of annual revenue for high speed rail.

Infrastructure Needs in Perspective

Needs assessment is driven by a number of well articulated questions:

1. What are the set of criteria used to evaluate and justify (or not) a specific proposal?
2. What are the commercial and social consequences of the proposal?
3. How broadly based should the evaluation of the proposal be?
   This includes geographical coverage, forecasting period, market segments, and the set of alternatives to evaluate.
4. Is there a market for the proposal?
5. What is the risk profile of the set of alternatives?
6. What specific outcomes does each stakeholder seek from the proposal?
7. What role might government play in the evaluation process?
8. How might one develop and execute a marketing strategy to reinforce the forecasted market potentials between the point at which forecasts are established and the commencement of the project?

The two most critical issues from this set of questions are the coverage of the needs study and the risk profile of the outputs. The other issues are important but are incorporated as interpretations of the information delivered from the market study. For example, the governments commitment to social obligations can be provided via output measures such as improved accessibility, reduced traffic congestion and improved air quality, which are associated with a forecast of changing traffic on the network in the presence of a specific infrastructure scenario. A range of scenarios can assist in both establishing the degree of risk attached to a specific traffic forecast as well as pin-pointing the preferred infrastructure scenario, given the set of criteria for measuring performance.

Analytical Perspectives

In establishing the case for a specific level of infrastructure input into the transport network, we become as dependent on the analytical approaches used in forecasting as we do on the data necessary to drive these analytical frameworks. Historically analysts have debated the merits of a bottom-up approach versus a top-down approach. The former requires a great deal more detail on markets, typically estimating models where the unit of analysis is the decision-making unit (ie an individual trip). This approach explicitly recognises the behavioural variability in the travel market and seeks to explain it in some detail, establishing through surveys using revealed and stated preference data the rich sources of behavioural explanation for each component of travel (eg mode choice, route choice, time of day of travel, destination choice, trip frequency choice). The richness variability increases the challenge of explaining the sources of behavioural variability and since we are preserving it at a maximally disaggregated level, the amount of overall variance explained is likely to be small. What is explained however will be truly causal and devoid of aggregation bias (which can - see below - turn the explanation into a false outcome - the fallacy of ecological correlation).

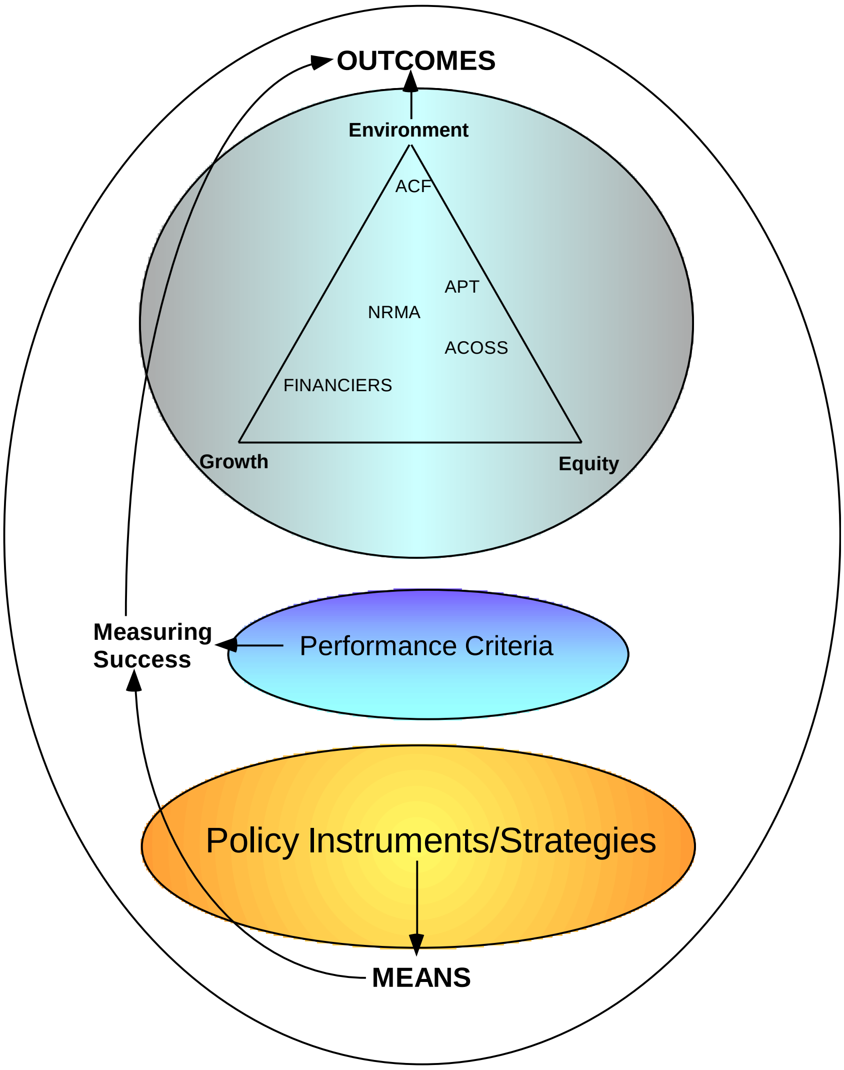
The top-down approach operates at a much more aggregate level using traditional zonal and interzonal information on travel behaviour. The variability in the data is driven by the aggregate size of the physical traffic zones which try to capture the full distribution of behavioural variability within and between zones by mean estimates (residing at a centroid). With less variability preserved in the aggregate data profile, there is a high likelihood that a model will be able to explain a higher amount of the remaining behavioural variability between the dependent variable (eg number of trips per person per zone by mode m) and the set of explanatory variables (eg average income per household per zone). The higher explanatory power is misleading because much of the rich behavioural variability has been removed by aggregation prior to model estimation.

Our experience suggests to us that the aggregate approach is acceptable to reproducing base levels of traffic (what Wilson (1998) has recently called ‘reproductive’ capability) but is a very poor model for evaluating the impacts of changes to the system. Since infrastructure projects often significantly impact on market demand, the aggregate approaches still used by most transportation modellers and planners are problematic and to be avoided. Indeed one might be so bold as to suggest that if transport modellers continue with this very aggregate mentality, they add fuel to the already burning reputation of the role of analytical support (Hensher 1998a).

Broadening the Dimensions of Need

A needs assessment process must look well beyond the users of the infrastructure and encapsulate the broad base of social implications. This involves both a determination of the impact of a transport project on the users as well as the other stakeholders, including community groups and government. Not only must we establish an appropriate set of criteria for judging the performance of the transport infrastructure in terms of the broad goals of management - efficiency, equity and environmental sustainability - we must also provide a capability of mapping these to stakeholders to identify what specific infrastructure opportunities are positively and negatively supportive by each stakeholder group.

The broad framework of goals and performance criteria consistent with goal achievement and hence need fulfillment are summarised in Figure 1 (Hensher 1998, Hensher and Brewer (1998)). A needs assessment framework must be capable of assessing the impact of the expansive set of potential policy instruments on levels of traffic, land use, the environment etc in accordance with a set of global performance measures such as improved accessibility, reduced traffic congestion, reduced global warming, increased air quality, and increased safety.



APT = Action for Public Transport, ACF = Australian Conservation Foundation, ACOSS = Australian Council of Social Security, NRMA = National Roads and Motorists Association

Figure 1: Integrating Outcomes, Means and Measures of Success

Source: Hensher (1996)

Identifying a Performance Evaluation Framework for Needs Assessment

Performance can usefully be gauged from a set of internal and a set of external criteria. The latter are of particular concern to public sector agencies but also for private enterprise who are increasingly encouraged to be more environmentally and socially responsible. For example, a policy to introduce higher public transport fares requires evidence not only that this is in line with increased costs, but that the market responsiveness is not against the interests of broad external criteria such as environmental and social sustainability. Where there is a case that the mapping of prices with costs produces a loss of net consumer benefit, governments often prefer to maintain loss-making (ie non-commercial) prices and to provide direct operating subsidies to cover the gap, in the name of community service obligations (CSO's) and/or competitive neutrality. The establishment of gains in net social benefit per dollar of subsidy, for example, is one very explicit performance measure which incorporates internal (ie cost efficiency) and external (ie social justice) criterion.

The challenge for a business subscribing to such external indicators of performance is to work on both best practice *cost efficiency* (ie delivering a given level of service for the lowest input cost) and identification of the externality impacts of specific practices. The latter provides the basis for determining the *effectiveness* of the organisation in achieving its stated objectives.

We define externalities very broadly to cover all dimensions of costs and the set of objectives which are not accounted for by the narrower commercial definition of cost efficiency. The latter is limited to identification of the set of internal inputs (labour, capital, materials, energy etc) used to produce a given level of output at the lowest cost under an essentially commercial objective. Externalities thus become as much a part of the internal processes of operating a business as they are about the focus on how a business responds to external influences. We strongly support the position that a necessary but not sufficient condition for an effective enterprise is that it is cost efficient. One has to recognise however that the final determination of effectiveness must be guided by more than cost efficiency. The essential inputs are (marginal) costs (assumed to be delivered efficiently, which can include outsourcing), direct and cross price elasticities of demand for services (which identify how the market responds to the goods and services on offer; hence and demand responsive), and the pricing strategy of the business (ie profit maximisation, social welfare maximisation and constrained social welfare maximisation, where the latter focuses on covering average total costs). The combination of these three 'inputs' overlaid by the rules of regulation and/or market forces, determines the price to charge in the market. It is essential that we consider performance indicators that embrace more than simply best practice in terms of cost efficiency.

These interlinking criteria are at the heart of a needs assessment, as summarised in Figure 2 (based on Hensher 1996, DeMellow 1996). Such a framework recognises the role of the customer, the internal business, financial commitments, innovation and learning (Kaplan and Norton 1992). Each perspective is defined by a hierarchy of critical success factors such as productivity gain, organisational learning, financial improvement and quality enhancement. The interlocking triangles in Figure 2 are a 'folded-out' performance pyramid in which measures of customer satisfaction, flexibility and productivity link the strategic vision of the transport sector to a set of underlying operational measures such as quality, delivery, process time and cost (Rouse et al 1997).

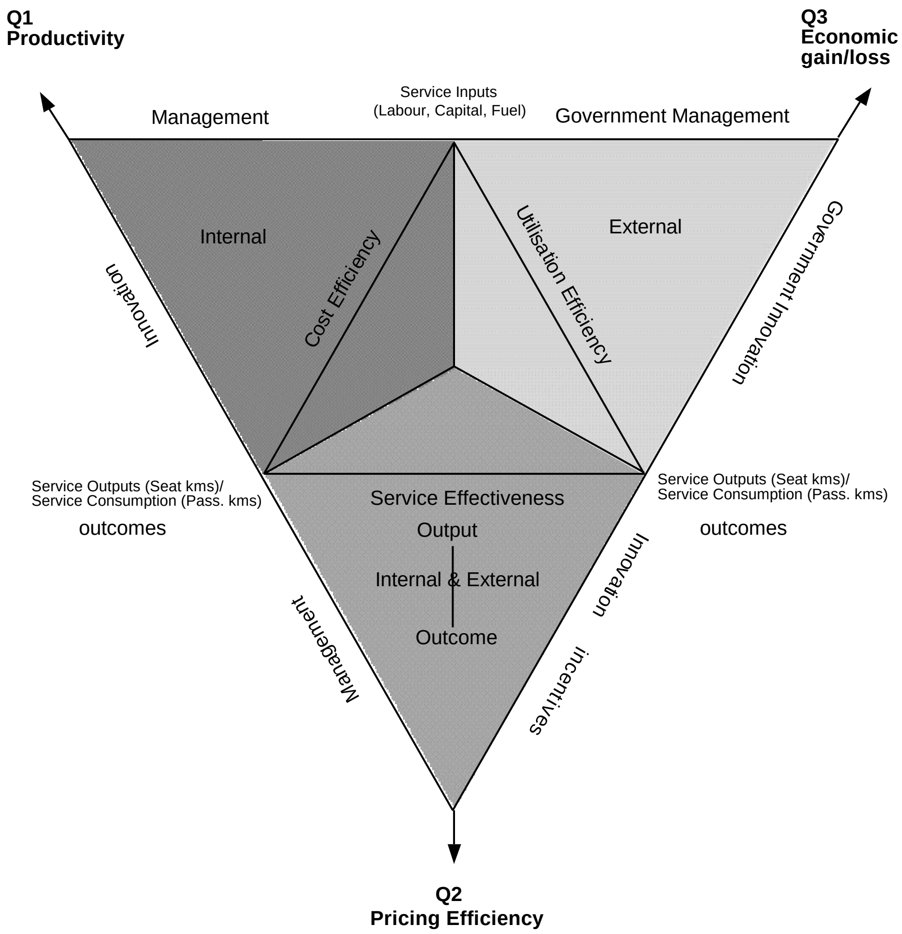


Figure 2. An Overview of the Components of Internal and External Performance Determination

Triangle Q1 measures the overall productivity of a transport entity (eg an infrastructure business) as defined by concepts such as total factor productivity (TFP). TFP measures the productivity of all heterogeneous inputs to the production process. Its strength lies in its ability to recognise that many heterogeneous factor inputs are used to produce a number of heterogeneous outputs. It links three dimensions of corporate performance, all essential inputs into a needs analysis: cost efficiency, management quality, and innovation. Management effectiveness depicts the relationship between service inputs and overall productivity. Innovative efficiency depicts the relationship between service outputs and overall productivity.

Q2 measures the market effectiveness of an infrastructure business through the idea of pricing efficiency. Market effectiveness depicts the relationship between output and the consumption of that output in the market place. As in Q1, two dimensions link pricing efficiency with output and consumption. First, the management dimension links output with pricing efficiency. Here, all the skills and quality of management come into play. As an entrepreneur, the manager must ensure that the pricing of goods/services brought to market are such as to ensure sufficient penetration of markets to enable a sufficient return on investment in the long run. Thus entrepreneurial versatility, fund-raising ingenuity, ambition, and judgement are all brought into play in the decisions leading to the pricing of output. This activity complements the equally important issue of input pricing by management, covered in Q1. Second, the innovation dimension links consumption and pricing efficiency. It represents the improvement in quality in the goods/services offered at the price which customers are willing to pay. The expertise in forecasting demand is a dominating theme.

The exigencies of relatively integrated policy making require that major activities such as provision of transport services be measured for the efficiency with which they utilise economic resources, to determine whether the provision of service results in an economic gain or an economic loss to society. Whilst it is important to measure service consumption, it is imperative to measure service output. This is particularly so in complex markets such as roads or public transport where overservicing is prevalent and caused by many factors. The final triangle, Q3, is labelled “economic gain/loss”. This is deliberately broad so as to avoid terms such as “consumer surplus” or “social benefit/cost ratio” and avoids argument of what should be included in weighing the benefits of service provision against its costs. Two further dimensions link service input and service output. First there is the management dimension labelled “government management” and covers the whole gamut of intervention including regulation, taxation, subsidisation, etc. It is useful for a business to know if it was winning or losing as the result of the impingement of government management upon its activities. This applies as much within the public sector for government business enterprises as forcefully as it does in the private sector, and possibly more so given the added complexity of multiple pricing strategies. Second, there is “innovation” which is government sponsored innovation aimed at expanding the efficiency of business. This innovation may take the form of major improvements in infrastructure, the implementation of total quality management principles etc.

Each triangle can be given an hierarchical feedback structure in a framework in which each triangle is represented by a surface which links the vision, goals and objectives of the business with managerial measures, as defined by the critical success factors, to a set of underlying process drivers. The feedback between goals and measures is critical in the monitoring of the effectiveness of particular process drivers (often referred to as policy instruments in the public policy literature). The pyramid paradigm recognises that process drivers or policy instruments associated with one triangle or plane of the performance pyramid can influence the other triangles and hence are cross-linked. Decomposition of each overall critical success factor associated with each triangle (eg TFP, net social benefit per dollar of subsidy, market price of services) to establish the influence of a range of process drivers (eg input mix, incentive plan, CSO obligations) and broad contextual effects (eg location, scale) can assist managers in understanding the impact of process drivers on one or more result areas. Analytical tools such as TFP, Data Envelope Analysis (DEA), travel demand models, Social Benefit-Cost Analysis (SCBA) all provide ways of quantifying the global status of performance within a framework designed to capture the commitment of a business to multiple objectives, goals and a vision.

Whose Needs? Mapping between Stakeholders Needs and New Road Infrastructure

In any needs assessment, great store should be placed on the importance of establishing a mapping between the views on specific potential policy and strategic issues and the stakeholder domain from which various degrees of support and opposition might evolve. Government agencies can use this information in positioning specific strategies and developing marketing plans to ensure that stakeholder support is maximised. Such a formula is likely to be attractive to the political process.

Hensher and Golob (1998) have recently recognised the need to fomalise the accommodation of this gap between infrastructure opportunities and stakeholder support. Through this gap-filling method, presented below, planning information moves into the domain of stakeholder-political matching. To illustrate the value of this needs-based paradigm, we sought the opinions of 147 commercial freight operators in New South Wales (Figure 3) concerning four potential new road infrastructures: an orbital road around Sydney CBD about 30 kms out, another orbital road about 40 kms out, extension of the M5 east to Port Botany and Kingsford Smith airport, and the eastern distributor.

Their attitudes were measured on a five-point scale, with the scale point descriptors being (1) “very bad idea,” (2) “bad idea,” (3) “neither good nor bad idea,” (4) “good idea” and (5) “very good idea.” (Hensher and Golob 1998). Most respondents (71%) think that extension of the M5 east is a very good idea, and over 90% think it is either a good or very good idea. There are more diverse opinions about the other three new road infrastructure initiatives, and opinion is fairly even split about the merits of an orbital road around Sydney about 40 kms out from the CBD.

The mapping between infrastructure potentials and stakeholder support are illustrated in Figures 4 -5 in the context of the contribution of infrastructure options supportive of the needs of key stakeholder groups (Hensher and Golob 1998). Using canonical correlation analysis (CCA), a two-dimensional solution was chosen, with canonical correlations of 0.358 for the first dimension and 0.262 for the second. In a three-dimensional solution the canonical correlations are 0.348, 0.290, and 0.144, showing a substantial drop-off in explanatory power for the third orthogonal dimension.

The nonlinear CCA reveals that there is one dimension of policy support, skewed to the axes of the canonical variates, that has extension of the M5 east and an orbital road around Sydney 30 km out at opposite poles (Figure 4). An orthogonal dimension measure aligns with support for an eastern distributor. The pattern on the category scores plot (Figure 5) contrasts contract carriers against retail, wholesale, and distribution firms, and freight forwarders against manufacturing and extraction firms. Freight hauliers represented the segment with the least conspicuous pattern of attitudes.

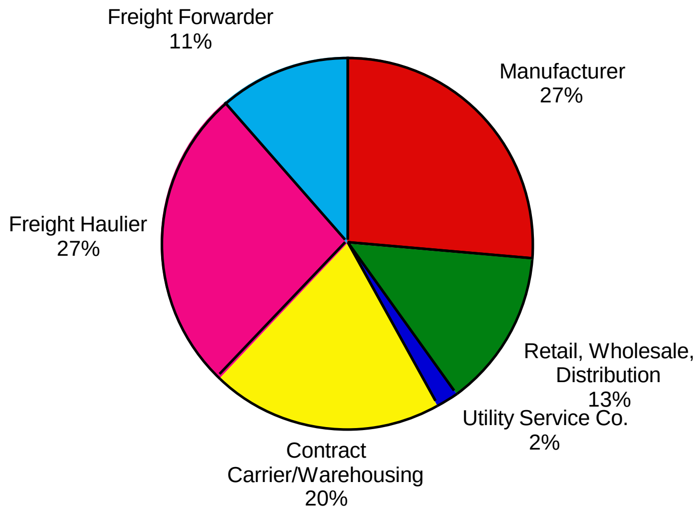


Figure 3 Breakdown of Sample by Industry Type

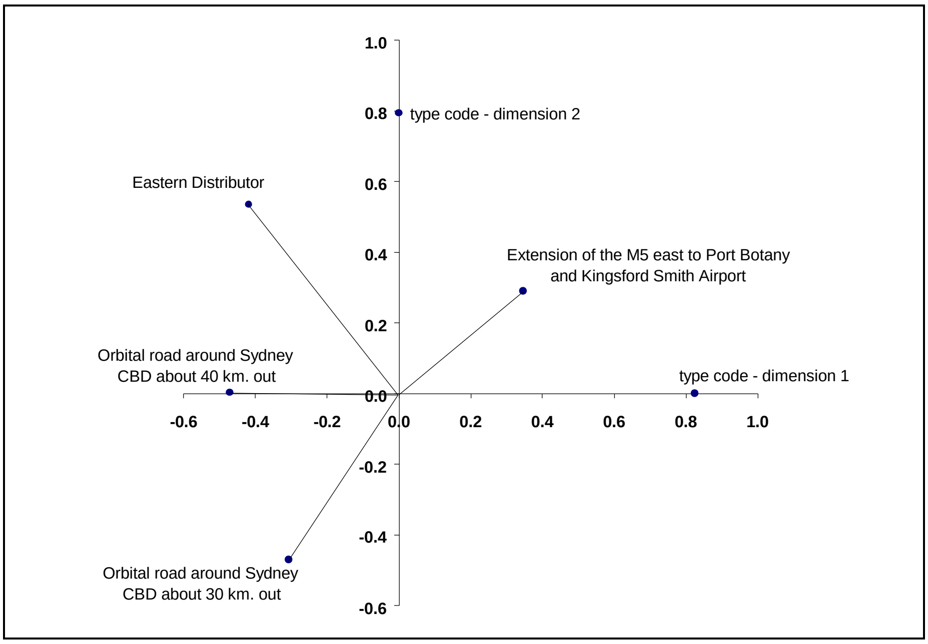


Figure 4 Non-linear canonical analysis of attitudes towards new road infrastructure versus business sector: Component loadings for the optimally quantified attitude scales

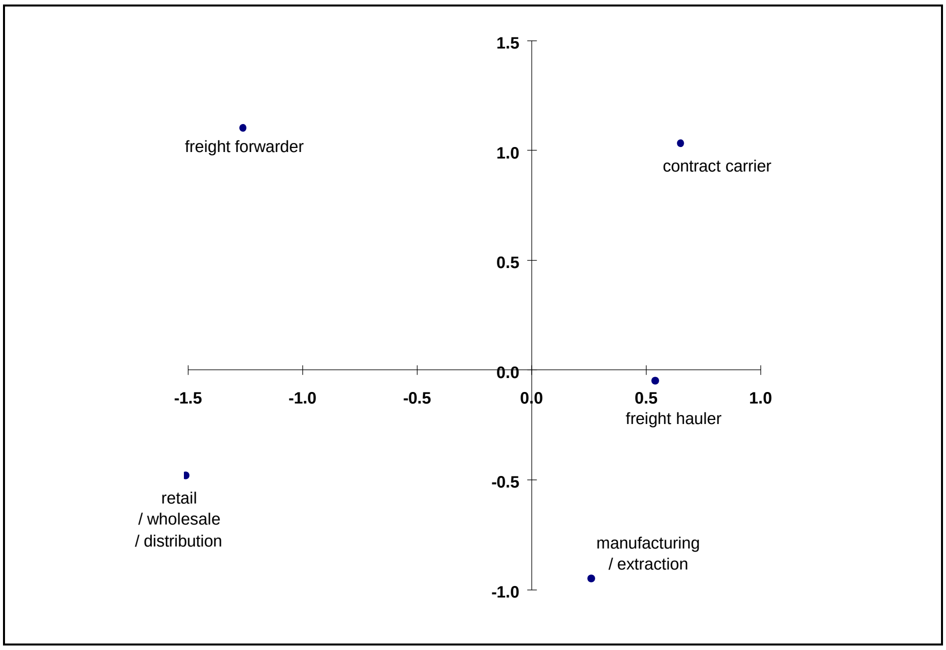


Figure 5 Non-linear canonical analysis of attitudes towards new road infrastructure versus business sector: Category scores for the business sector variable

An interpretation of the key results plotted in Figures 4 and 5 is listed in Table 1. Contract carriers and the retail, wholesale and distribution sector are at opposite ends of support for and against three of the new infrastructure policies, specifically the two orbital roads and the extension of the M5 Motorway east to Port Botany and the Kingsford Smith Airport. However these two industry types do not have outstanding views on a new Eastern Distributor Route. Freight forwarders support an Eastern distributor, while the manufacturing and extraction sectors are least in favour of this new road infrastructure.

Table 1: Summary of results of non-linear canonical analysis of attitudes towards new road infrastructure versus business sector (most prominent results underlined)

Policy	Strongest support	Weakest support
an orbital road around the Sydney CBD about 30 kms out	<u>retail/wholesale/distribution</u> manufacturing/extraction	<u>contract carriers</u>
an orbital road around the Sydney CBD about 40 kms out	retail/wholesale/distribution freight forwarders	contract carriers freight hauliers
extension of the M5 east to Port Botany and K.S. Airport	<u>contract carriers</u> freight hauliers	retail/wholesale/distribution

Eastern Distributor	freight forwarders	manufacturing/extraction

The method used to map attitudes about policy initiatives into the stakeholder domain provides an important framework for targeting (and hence marketing) specific policies in the market place. This marketing can be as much to reinforce the value of support for a specific policy or set of policies as it can be to more fully inform specific stakeholders about the benefits of specific policies where there is limited support. The implications in a political market of this process initially driven by an appreciation of stakeholder behavioural intent is very clear.

Concluding Thoughts

This paper emphasises the importance of a broad approach to needs assessment which looks beyond the interests of potential users of new transport infrastructure to accommodate the needs of the wider community of stakeholders. In expanding the needs agenda, we must recognise that while a consideration of traffic demand (and hence revenue flows) is a crucial interest of potential investors in infrastructure, that any decision to promote specific infrastructure investment must be subject to a comprehensive performance assessment. Furthermore we can learn a lot that is politically influential by seeking out mappings between the needs of stakeholders and the diversity of support emanating from a systematic review of these stakeholders. In this way we might reduce the risk of a good project being sunk by the failure to be political-wise.

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Appendix I - Empirical Illustration: Forecasting the Timing of Traffic Using a Toll road

There is growing government interest in private sector supply and operation of new tolled motorways as witnessed by the M2, M4, M5 in Sydney and the CityLink in Melbourne. The banking sector is keen to identify how long it takes for the traffic volume to reach a certain level and settle down, so they can obtain the best estimate of revenue required to make the investment financially attractive. Traditional forecasting procedures are not able to advise on this matter. It is an issue of the timing of change, and is well suited to duration modelling using event history data.

We illustrate the use of event history methods in the context of a new toll road opened in Sydney in the early 90's. For each sampled individual we were able to identify the precise date of switching to the new toll road after its date of opening. There is no left censoring since the toll road state did not exist prior to the known commencement date. Right censoring exists since the end point of the last episode of an individual cannot be observed. We allow for right censoring in model estimation.

Over the period of observation, an individual can move in and out of a state as they accumulate experience. For a toll road this is quite likely in the early weeks as individuals experiment with the toll road and the non-tolled alternatives, recognising that the presence of the toll road affects the levels of traffic on all competing routes. The endogenous variables in our application describe (i) the length of time that it takes a traveller to use the toll road after the opening date, and (ii) the amount of time a traveller is in the toll road use state over the period of observation. The two states are *toll road use* and *non-toll road use*. The data profile looks like Figure I for a number of individuals. Individual 1 uses the toll road immediately it is open, individual 2 takes a little while before switching while individual 3 used it at commencement date, switches back to the non-tolled route after a period and switches again to the tolled road at a later date.

We have a data set which measures the traffic over 24 months since the opening of the toll road. For a sample of 170 car drivers, we have data on the date at which they switched to the toll road. Some drivers have not used the toll road to date, but many have switched within the first six months. In all instances, we have a single state single episode situation where a driver when switching stays with the toll road. The multi-state event has not yet been observed in the sample. The exogenous variables are recorded at eight points in time.

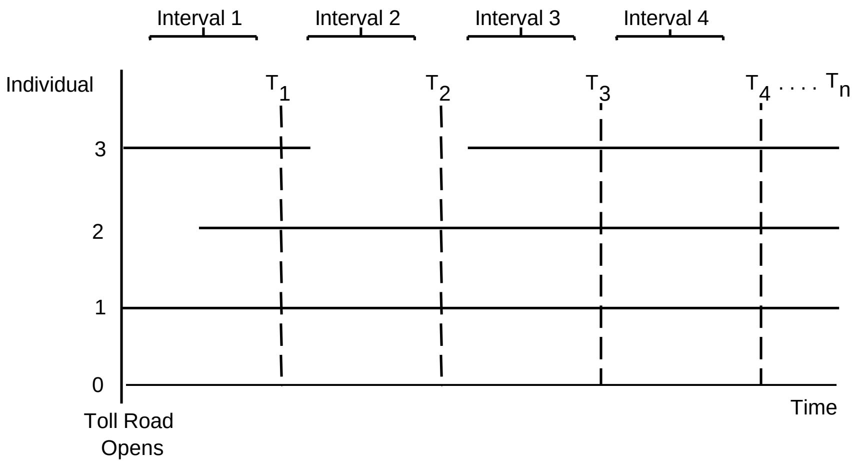

Figure I. An Event History Profile for a Toll Road

We have one time-varying exogenous variable, the time difference between the tolled route and the non-tolled route, over 8 discrete time periods converted to 32 continuous time periods. The other exogenous variable is time invariant, namely the registration status of the automobile being used. A parametric duration model has been estimated in which the "survival time" is defined as the time from the commencement of the tolled route until the sampled individual switched to the tolled route. That is, the length of time until the user fails to continue with the free route. The aim is to estimate a duration model to obtain the distribution of non-tolled route use time lengths and to identify the influence that a time-varying effect (i.e. travel time difference between the two routes) and a time-invariant effect (i.e. ownership status of the automobile - private or company car) might have on non-switching time length. We have allowed for right-censoring under the assumption that over the period of monitoring a number of individuals are still in the non-switching state.

The empirical results suggest that the greater the time savings in using the tolled route, the less time an individual stays with the existing free route. That is the probability of failure increases. Likewise, individuals driving a company car are more likely to switch earlier than an individual driving a privately-registered automobile. The company car effect reduces the duration on non-switching. The distribution of times until switching suggest that at the sample means of the exogenous effects, that in the model assuming a homogeneous survival function, 95 percent of the sample remain in the state of non-switching 4.56 weeks after the commencement of the toll route, dropping to 75% after 10.34 weeks, 50% after 15.71 weeks and 25% after 21.83 weeks. When we allow for possible heterogeneity of the survival distribution across the sample, the survival periods for the four percentiles are shortened marginally respectively to 4.34, 9.97, 15.36 and 21.81 weeks. What we are observing is the timing of change and the role that the time savings and use of a company car have on the probability of staying in the state of no-switch. This is very important information for private financiers of major infrastructure where the revenue base is use-related. The importance of the particular application to the introduction of universal road pricing is also clear.

Table I. Results for the Weibull Single Risk Model of Toll Route Switching Allowing for Right Censoring and Null Switching (Endogenous Variable = ln(duration)).

(i) Homogeneous survival distribution (log-likelihood = -215.99)

Variable	**Parameter Estimate**	**t-statistic**	**Mean**	**Standard Deviation**
Time Difference	-0.05456	-2.62	5.747	2.298
Company Car Dummy	-2.3328	-4.29	0.435	0.497
Constant	3.2418	22.69		
σ	0.47503	11.62		
Variable	**Parameter Estimate**	**Standard Error**	**Lower Confidence Limit**	**Upper Confidence Limit**
$\exp(-\beta \mathbf{z}_i)$	0.05349	0.00284	0.0479	0.0591
$\frac{1}{\sigma}$	2.10515	0.18121	1.7500	2.4603
Split	0.67915	0.01221	0.6552	0.7031
Median of distribution	15.7074	0.83530	14.070	17.345

(ii) Gamma Heterogeneous survival distribution (log-likelihood = -219.19)

Variable	**Parameter Estimate**	**t-statistic**	**Mean**	**Standard Deviation**
Time Difference	-0.05601	-2.36	5.747	2.298
Company Car Dummy	-1.6439	-2.96	0.435	0.497
Constant	3.2109	19.82		
θ (theta)	0.10944	1.62		
σ	0.47880	10.36		
Variable	**Parameter Estimate**	**Standard Error**	**Lower Confidence Limit**	**Upper Confidence Limit**
$\exp(-\beta \mathbf{z}_i)$	0.05563	0.00339	0.0490	0.0623
$\frac{1}{\sigma}$	2.08856	0.20163	1.6934	2.4838
Split	0.64716	0.01338	0.6209	0.6734
Median of distribution	15.3610	0.93575	13.527	17.195
Item	**25th percentile**	**50th percentile**	**75th percentile**	**95th percentile**
Survival	0.25	0.50	0.75	0.95
Time - Homogeneous	21.83	15.71	10.34	4.56
Time - Heterogeneity	21.81	15.36	9.97	4.34

Average predicted failure probability for model (i) is 0.679 and for model (ii) it is 0.647.

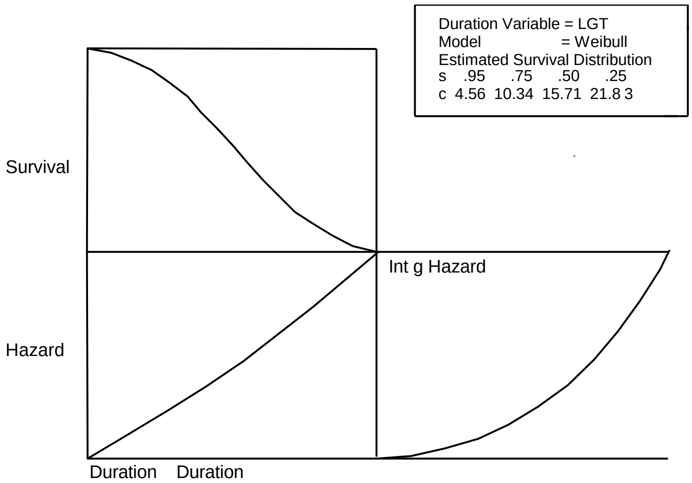

Figure 12 Empirical Survival and Hazard Distributions
(Not Allowing for Heterogeneity)

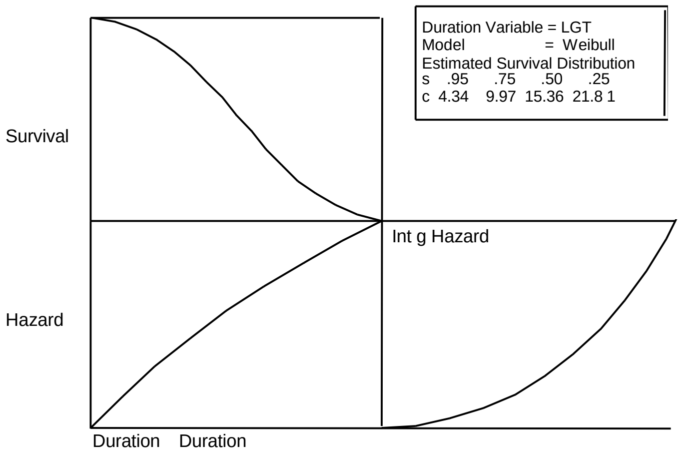

Figure 13 Empirical Survival and Hazard Distributions
(Allowing for Heterogeneity)

The heterogeneity is accommodated in the model by scaling the survival function by a random variable, distributed as gamma with a mean of 1 and a variance of theta. We can see from Table I (ii) that this variance has a t-value of 1.62, which is marginally statistically significantly different from zero at an acceptable level of significance. The compay car effect however moves quite markedly, reducing the negative impact of the availability of a company car on the failure to switch. The Weibull hazard has a risk parameter greater than 1 for both models, which implies that the longer a traveller does not switch to the tolled road, the *more* likely it is that they will switch. That is, the hazard is monotone increasing.

This illustrative application of duration modelling motivates the importance of the timing of change. The most challenging features of this approach are the availability of high quality data in continuous time or a substantial number of discrete time periods; and the ability to forecast the historical relationships into the future.

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