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Estimating economic impacts of transport investments using TREDIS: a case study on a National Highway Upgrade Program

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Abstract

Large transport projects have significant impacts on economic growth and productivity at National, State and regional levels. These impacts can be measured by the increases in Gross Domestic Product (GDP), employment, business output, wage income and taxation revenue. In recent years, there is a growing interest in Australian National and State jurisdictions in estimating the economy-wide and productivity impacts of transport investment. Indeed, a new chapter called the Productivity Metrics has been included in 2014 update of National Guidelines of Transport System Management. While such information is critical to justify investment and prioritise large projects that billions of dollars are required as initial capital costs, economic impact analysis is rare in practice even for national or state significant projects. The main reason was that such an analysis requires sophisticated models with intensive macroeconomic data that are not readily available to practitioners. In this paper, we will present a case study on economic impact analysis of a National Highway Upgrade Program. The paper will explain how transport investment affects regional economy and productivity. The Transport Economic Development Impact System (TREDIS) has been used for the analysis. The paper will report on use of the TREDIS model to estimate economic impacts including the model inputs and estimation approaches. We will present year by year impacts covering 20 year highway upgrade period and 30 year forecasting period, the total impacts for the entire analysis period by industry sector, and the multiplier effects of $1 million investment in construction and operating phases. The primary objective of the paper is to report the regional economic impacts for a typical national highway upgrade program with $2.6 billion capital injection and associated operational investment. The secondary objective is to demonstrate the TREDIS' potential and capability for undertaking economic impact analyses.

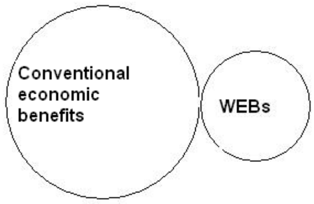
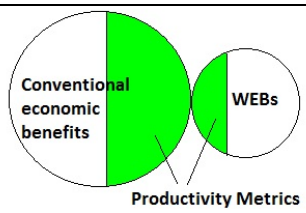
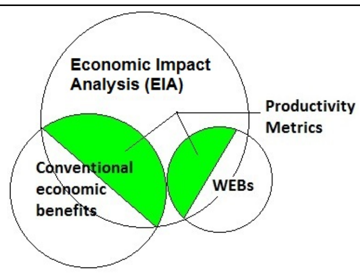
1. Introduction

One important task of economic appraisal of transport projects is to estimate the benefits to broad communities. Conventional economic benefits include value of travel time savings, vehicle operating cost savings, the benefits of transport accident reductions and the benefits of environmental impact mitigation from reduction in air pollution, Greenhouse Gas Emissions (GGE) and urban separations (Transport for NSW 2013).

In recent years, more and more transport economists have recognised that certain economic benefits have been missed out from the conventional economic benefit framework. Pioneered by Graham (2007), UK Department for Transport (2014) acknowledged additional three types of benefits: agglomeration, additional business output in imperfectly competitive markets and tax revenue of the increased labour participation and better job skill matches. These benefits are referred to the Wider Economic Benefits (WEBs) or Wider Economic Impacts (WEI). Assessments of WEBs have been done for Sydney North West Rail Link (Hensher et al. 2012; Legaspi et al. 2015) and Melbourne East West Link (Eddington 2008). The importance of WEBs is well recognised by Australian National and State Governments. The national guidelines on WEBs are developing and the work for estimating elasticities with respect to effective employment density for Australian capital cities and regions has been planned (KPMG 2015).

Figure 1 shows the measurements of economic impacts of transport projects. In conventional economic appraisals, user and non-user benefits including value of travel time savings, vehicle operating cost savings, safety benefits, environmental impact and freight efficiency gain are measured to estimate the Benefit Cost Ratio (BCR) and the Net Present Value (NPV).

Figure 1 Measurements of economic impacts of transport projects

Conventional economic benefits: • Value of travel time savings • Vehicle operating cost savings • Accident reduction savings • Environmental mitigation benefit • Freight efficiency	
Plus WEBs • Agglomeration • Additional Output in imperfectly perfect market • Welfare effects from labour market accessibility	
Productivity Metrics is part of conventional economic benefits and WEBs • Value of business travel time savings • Vehicle operating cost savings for business trips • Insurance premium savings for reduced crash claims • Agglomeration • Additional Output in imperfectly perfect market	
Economic Impacts overlap with Conventional Economic Benefits, WEBs and Productivity Metrics • Business output • Value added / GDP • Job creation • Wage income / compensation	

The WEBs are, at least in theory, additional economic benefits on top of conventional economic benefits. It is worth noting that there is no overlapping or double counting between conventional economic benefits and WEBs. In addition, both conventional economic benefits and WEBs measure “welfare effects”. Thus, conventional economic benefits and WEBs can be simply added together in cost benefit analysis in calculating the uplifted Benefit Cost Ratio (BCR) and the Net Present Value (NPV).

A concept known as Productivity Metrics has been evolving in Australian Federal and State Governments since 2013. It attempts to isolate the productivity contribution of transport investment from other impacts. The concept of productivity benefits is the measurement of effects on productive sectors of the economy, i.e., business operations. For that reason, only benefits to business and not welfare benefits for households are included here. A draft chapter on Productivity Metrics has been included in 2014 update of national guidelines (NGTSM 2014), where the Productivity Metrics are simply a subset of business trip related benefits among conventional economic benefits and the business benefits among WEBs.

Productivity is commonly defined as a ratio of outputs to inputs. Transport improvements enhance the productivity in two ways. Firstly, transport improvement reduces travel time and cost incurred in business operations. It raises the productivity by decreasing the denominator of the ratio. Secondly, transport improvement expands the market access to suppliers and consumers. It stimulates the business to increase outputs. However, as the outputs increase, the required inputs also increase. Productivity improves when the outputs are increased more than inputs due to economies of scale and scope.

An economic impact analysis (EIA) attempts to trace changes in spending and productivity on broader flows of income and revenue in the economy. Estimating the economic impacts of a project can help understand the scale of the potential benefits flowing to the local and regional economies. It has been well recognised that transport investment has flow-on economic benefits generating from spending in construction, maintenance and operation phases, and from improved accessibility to market and international gateways (airport and port). These flow-on benefits are usually expressed in business output, Gross Domestic Product (GDP), job creation and wage income. Economic impacts of transport investment are the focus of this paper, recognising their connection and difference between conventional economic benefits, WEBs and the Productivity Metrics.

2. Review of state of practice

The economic impacts of a transport project can be estimated using a variety of economic analysis tools. The most popular and well known are input-output multiplier analysis and CGE modelling. Input-output tables provide a comprehensive picture of the supply and consumption of all commodities within the economy, including detailed information on incomes, taxes and the source (domestic or foreign) of every commodity. I-O multipliers are summary measures generated from input-output tables that can be used for predicting the total impact on all industries in the economy. While I-O models are static accounting tables that show how changes in spending lead to broader income flows (and jobs) through the economy, they cannot predict impacts of changes in transport costs.

Most CGE models are dynamic simulations that predict impacts of changes in costs as well as impacts of changes in spending flows. Most economic impact analysis of large transport projects was undertaken with a CGE model thus the advantage is its proven credential. The fundamental difference is regarding the ability to predict how cost changes affect prices, and thus lead to price and competitiveness responses in the economy. The greater complexity of CGE models generally increases the cost of undertaking an analysis compared to using input-output multipliers but it enables a much broader range of economic impacts to be analysed within a single framework. Examples of CGE approach in Australia include:

- In New South Wales, a CGE model specifically developed for road projects was used for State and regional economic impact assessments since the 1990s. A CGE model, known as NGEM (NSW General Equilibrium Model), was created for previous NSW Roads and Traffic Authority (RTA, now RMS) (Swan Consulting 1995). The objective of the model was to evaluate economy-wide effects of highway investments.
- Acil Tasman (2010) conducted the economic impact analysis of Melbourne – Brisbane Inland Rail using a CGE model known as Tasman Global. The analysis estimated the effects on the GDP, real income and real private consumption. Uniquely, it analysed the crowding out implications as resources are potentially diverted from other productive activities to undertake the inland rail. It showed that, although its construction and operation will increase real Australian incomes, this is outweighed by the loss of incomes caused by diverting resources to build it regardless of whether the funding was sourced locally or internationally.
- Ernst & Young (2008) estimated the economic contributions of Sydney's toll roads. It found that Sydney toll roads would increase the NSW GSP by 0.89% or $3.4 billion in 2008 prices, by increasing real private consumption, real investment and overseas trade. The toll road network would also create 4,000 jobs by 2020. Ernest & Young (2010), using a CGE model known as The Enormous Regional Model (TERM), conducted the economic impact of the investment in road infrastructure in Victoria for

the period from 1996 to 2008, and found road investment increased the Victorian GSP by 3.24% in 2028.

This paper introduces the use of TREDIS for economic impact analysis. TREDIS is an econometric impact analysis system that includes cost and price-response elements and dynamic changes similar to CGE models. TREDIS has advantages as it has seamlessly combined transport costing and economic impact analysis enabling transport economists and planners to undertake economic impact analysis without advanced CGE modelling skills. Using TREDIS is cost effective as it can be subscribed online with a much lower cost than building a CGE model. TREDIS has been widely used in Canada and the US, and was previously used in Australia for the Bus Rapid Transit for Sydney Northern Beaches (ITLS and Economic Development Research Group 2012).

3. Transport improvement and economic impacts

Economic growth is often cited as a motivation and justification for major transport investments, based on the potential to enhance the connection and accessibility between business centres and to expand labour and delivery markets. Broadly, transport investment impacts the economy in two ways:

- Economy-wide impacts generated from capital and operational investments.
- Economic impacts from reduced travel cost, improved reliability and accessibility.

3.1 Capital and operational spending effects

Economic impacts from capital and operation investments are measured by incremental business outputs, GDP, job creation, wage income and taxation revenue (see Table 1). These impacts can be categorised into direct, indirect and induced impacts:

- Direct economic impacts of capital investment are generated from building roads, bridges, railway tracks, pavements, stations and signal systems. The construction will create jobs. The procurement of bus fleet, rollingstock and other equipment generates the demands for the manufacturing and service sectors.
- Direct economic impacts of operational investment are generated from asset maintenance, administration and management of transport systems.
- Indirect impacts from capital and operational investments are generated from increased demands for materials, plants, equipment, parts, energy and repairs. It leads to business expansion in related economic sectors such as manufacturing, wholesale trade, retail trade, property service, business and financing.
- Induced impacts are generated from additional wage spending. The above mentioned direct and indirect impacts create jobs. Wage spending provides cash injection to the broad economy creating demands for food services, property, agriculture, recreational services etc.

Those direct, indirect and induced effects will lead to broader changes in the regional economy that can affect both economic growth and multi-factor productivity. These changes occur through both supply side and demand side. For example, if demand is elastic to price changes, businesses may expand the production to meet the greater demand for their products. Alternatively, if demand is inelastic to price changes, businesses may produce the same output more cost-effectively. In many industries, the supply-demand situation is in-between those two extremes of elasticities thus a combination of both effects will occur.

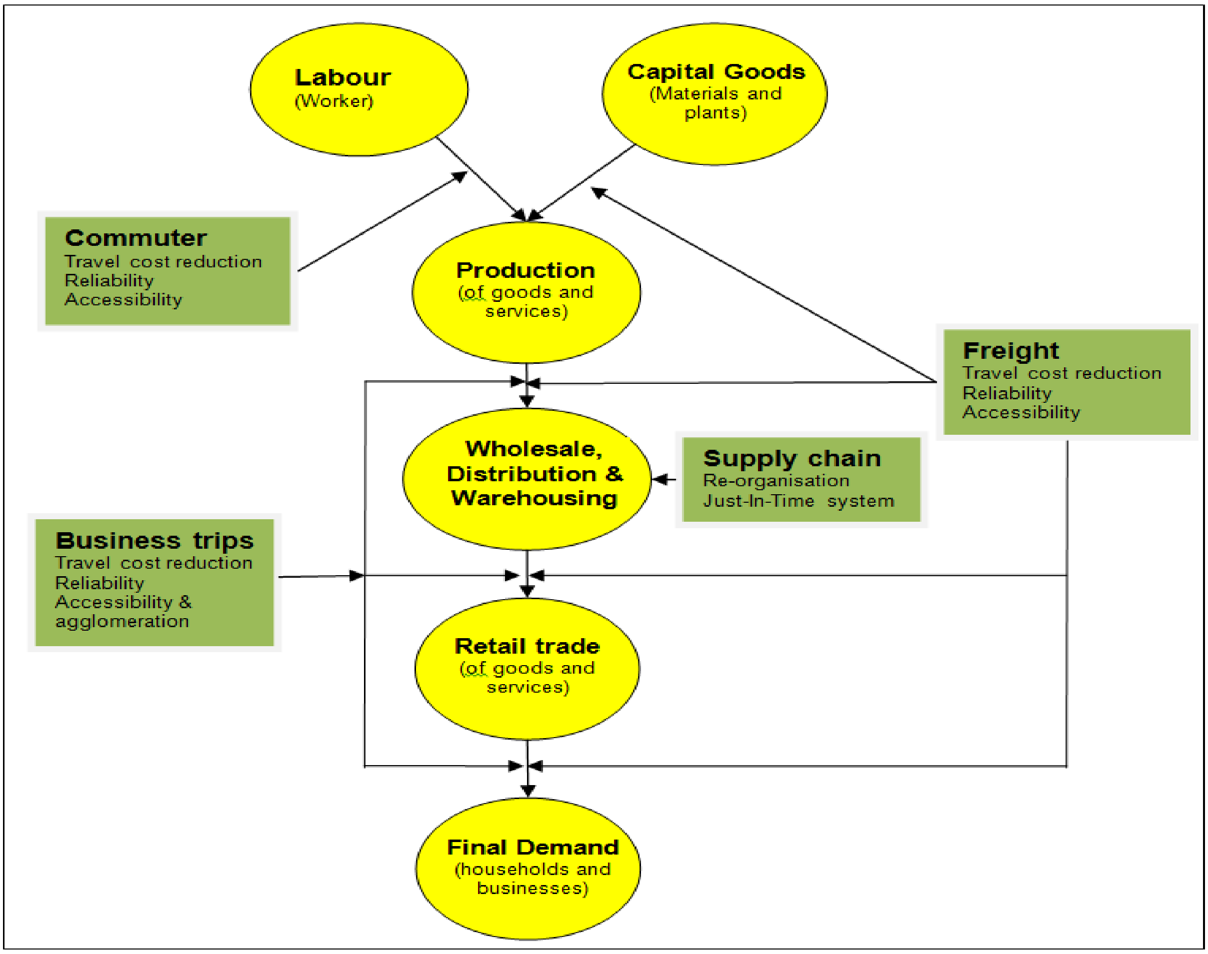
Table 1 Economic impact of capital and operational investments

<table>
<tr><th>Type of impact</th><th colspan="2">Capital investment</th><th colspan="2">Operational investment</th></tr>
<tr><td>Direct impacts</td><td colspan="2">• Build infrastructure (road, bridge, signal systems, tracks, stations etc.)
• Procure rollingstock
• Procure bus fleet
• Purchase other equipment</td><td colspan="2">• Maintenance of assets
• Management and administration
• Operational inputs such fuel, electricity, oil etc.</td></tr>
<tr><td>Indirect impacts</td><td colspan="4">• Increased demands for materials, parts and powers from supplier industries</td></tr>
<tr><td>Induced impacts</td><td colspan="4">• The above direct and indirect impacts create additional jobs
• Wages from these jobs result in additional spending that stimulates further economic activities</td></tr>
<tr><td rowspan="2">Overall economic impacts</td><td>Commodity Market Growth</td><td>Labour Market Growth</td><td>Increased Economic Activities</td><td>Business Expansion</td></tr>
<tr><td colspan="4">Economic impacts
(Business output, job creation, GSP, wage income and taxation revenue)</td></tr>
</table>

3.2 Transport cost reduction and market access effects

Figure 2 shows a simplified representation of the stages of the economy and the transport's role at each stage. The yellow ovals are levels of activity in various sectors of the economy, whilst the green rectangles are effects of transport system changes on them. Transport improvement affects flows between elements of the economy. Essentially, all economic activities depend on access to workers, input materials and customers.

Figure 2 Transport improvement and its impacts on economy



Source: Adapted from Weisbrod et al. (2014, p.7)

At the production stage where labour and capital are used to produce goods and services, transport system affects the labour supply through commuting travel time and cost reduction, travel time reliability improvement and better accessibility. The improvement in transport will make workers accessible to a large labour market and firms accessible to a bigger labour base, which will result in a better job-skill match and the enhanced labour efficiency[1]. Reduced commuting costs to an employment centre make working there more attractive. In the long run, workers may not require the same level of compensation (through wages) and people around the thresholds of working/not working may enter the labour market. Commuting travel time savings may lead to longer work hours. Based on labour economics, the reduced travel cost, which can be considered equivalent to a pay rise, will result in the increased labour supply. In Figure 2, commuter travel time is only represented in production stage. In fact, labour is an input to all stages of economy flow, thus commuter travel time savings could affect all stages of the economy.

At all stages, the economic activities will inevitably generate business trips. The internationally accepted method for valuation of the business travel time savings is the Cost Saving Approach (CSA), in that business travel time is assumed entirely unproductive and savings in business travel time converts the unproductive to productive time which is valued at worker's wage plus oncosts. Travel time and cost savings reduce production input costs, leading to an increased productivity. Business travel time reduction also brings firms closer to each other (measured in travel time), makes firms closer to their suppliers and consumers, and facilitates the knowledge and information exchanges. These changes result in an increased productivity which is commonly referred to as the agglomeration economic benefits.

Table 2 Economic impacts of transport costs reductions (market access improvement)

	Passenger transport		Freight transport
	Commuter	Business travel	
Travel cost reduction Travel reliability improvement	• Reduced travel time • Reduced commuter travel cost • Reduced crashes • Reduced 'buffer time' due to reliability improvement	• Reduced business travel time. Time is money. • Business cost reduction • Business efficiency from travel time reliability	• Reduced freight travel time. • Freight cost reduction from lower transport cost and better safety • Freight efficiency gain due to reliability and higher productivity vehicle access
Accessibility improvement	• Better job matches • Business cost savings due to reduced labour premium paid for less accessible work locations • Increased employment • Work longer hours • Spending effects from additional employment	• Agglomeration benefits due to closer to suppliers, consumers and labour markets • Additional business output in imperfectly competitive markets	• Just-in-time inventory system and other technology adoption • Additional business output in imperfectly competitive markets • Freight re-organisational and supply chain benefits from warehouse amalgamation, lower 'safety' stocks
Overall economic impacts	Market access / agglomeration impacts Reorganisation of supply chains Inward investment effects		

[1] This overlaps with the agglomeration effect in WEBs

The most straight forward effect of transport infrastructure improvement is on the cost of transport related operations. Shorter distances, faster speeds and reduced incident delays can directly reduce labour, equipment and operating costs for workers and for freight shipments. These effects are typically captured by standard travel benefit evaluation methods. However, they can also lead to broader effects on businesses and the entire economy, as transport cost savings can lower the price of inputs to production and lower the cost of distributing products (or services) to markets.

Freight costs are reduced by transport improvements through reduced vehicle operating costs and labour costs. These changes may induce freight 'reorganisational' change in that some warehouse centres can be amalgamated. The benefit of reorganisation could be theoretically estimated in conventional CBA framework as part of the consumer surplus. In reality, this benefit is difficult to estimate due to lack to data on freight operation and its response to transport cost changes. Transport improvement is an enabler for adoption of new business operating processes and technologies. As an example, the just-in-time inventory management system leads to reduced 'safe' stock and less amount of capital holding for inventories. Enhancement in service scheduling, freight handling and coordination can improve supply chain performance. The economic impacts caused by passenger and freight transport cost reductions are summarised in Table 2. The columns 2 to 4 of Table 2 shows the effects of transport cost changes and matches to the effects shown in the green rectangles in Figure 2.

4. TREDIS approach

Section 3 showed there are clear economic impacts from transport improvement either from the capital and operational spending or from transport cost reduction. The question is how to measure these impacts. As discussed in Section 2, I-O tables tend to give linear results only which tends to ignores complex economic interactions. CGE models require intensive macroeconomic data thus is expensive to run. In this paper, we use a model known as TREDIS[2] for economic impacts assessment. Like traditional CGE models, it estimates dynamic economic responses over time to changes in transport, labour and capital costs caused by transport system changes. However, the responses are based on econometric equations, enabling the productivity impacts to depend on industry-specific responses to changes in travel times, reliability, labour markets and delivery markets. This allows the model to recognise how various sectors of the economy differ in their responses to various aspects of transport system performance. For instance, the size of same-day delivery markets is more important for manufacturing and wholesaling than for financial and professional services, whilst the reverse is true for access to large labour markets. In addition, TREDIS shows how the industry-specific economic impacts differ from CBA results that rely on the more traditional generalised costs of user travel benefit. The structure of the model is illustrated in Figure 3.

The TREDIS model consists of 4 interconnected modules being travel cost, market access, benefit cost analysis and economic adjustment.

1. The travel cost module estimates the travel cost for passenger and freight transport by mode (private car, business car, heavy vehicle, bus, train etc), under two scenarios: base case and with a transport project / improvement. These effects are shown in the first row in Table 2.
2. The market access module estimates the effects of agglomeration and economies of scale due to travel time savings and transport cost reduction, as shown in the second row in Table 2.

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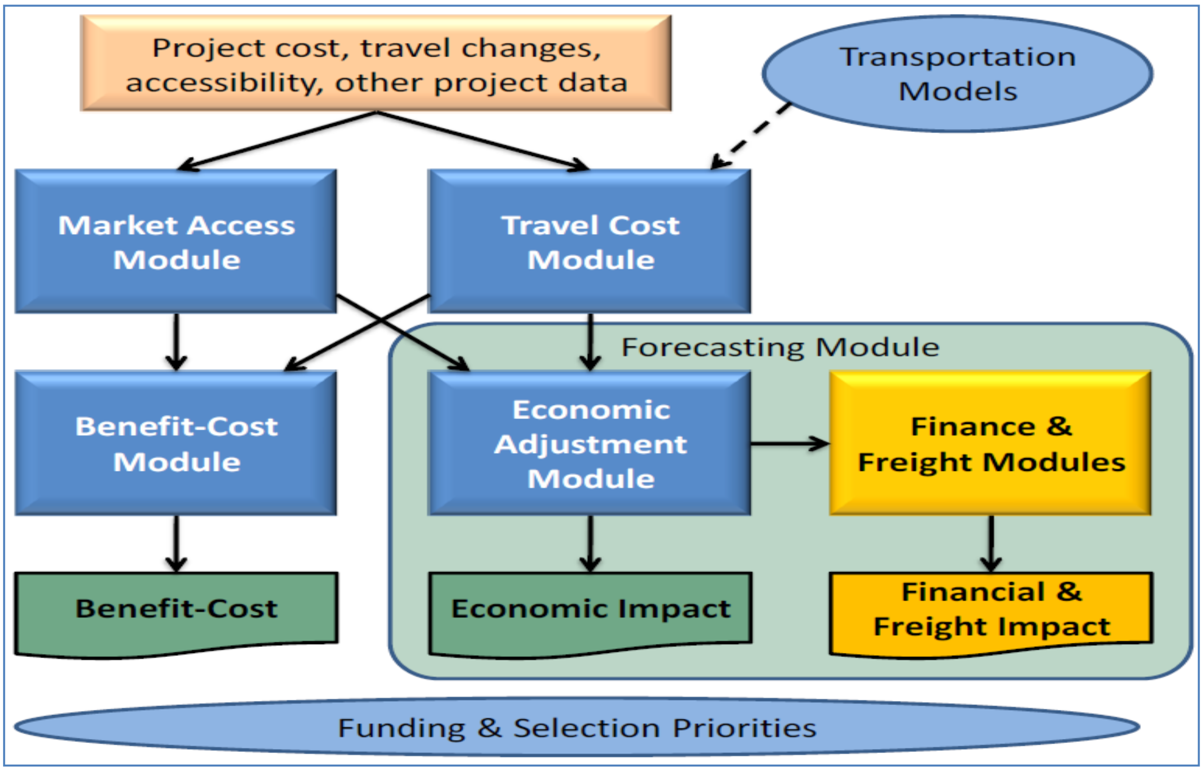
[2] TREDIS stands for **Tr**ansportation **E**conomic **D**evelopment **I**mpact **S**ystem. It was developed by the Economic Development Research Group (EDRG), Boston, USA.

3. The economic adjustment module applies dynamic, multi-regional economic impact simulations to estimate impacts of business output, GDP, employment and wage income. These effects are shown in the third row in Table 2.

4. The benefit cost module calculates the Net Present Values and Benefit Cost Ratio. The separate finance and freight modules estimate taxation revenues and commodity flows and additional consequences of the economic growth impacts.

Figure 3 TREDIS modelling structure



Source: Economic Development Research Group (2011, p. 2)

5. The case study

The main purpose of the case study is to demonstrate the methodology of undertaking economic impact analysis of the transport project. The case study is based on the analysis of a national highway upgrade program. TREDIS NSW Version has been developed which has been calibrated with NSW economic appraisal parameters (2014 values). The macroeconomic databases and elasticities used in the MONASH CGE model reflecting Australian economy in 2014 have been used in TREDIS.

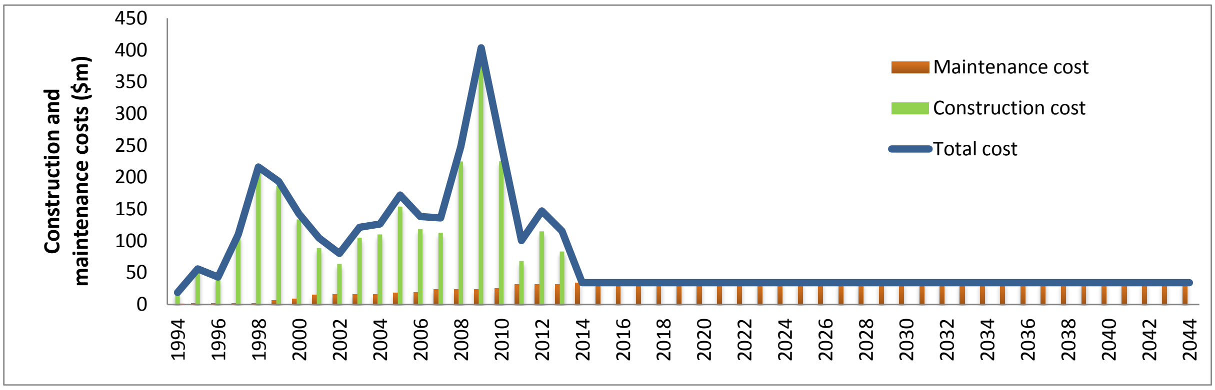
5.1 Model inputs

5.1.1 Capital spending effects

The highway upgrade started in 1994. During 1994 to 2014, there have been 19 upgrade projects to convert a 216.8 km highway section from 2-lane regional highway into dual carriageway (4-lanes in 2 directions). By 2014, all upgrade projects were completed and the entire highway section is now in freeway standards.

From 1994 to 2014, total capital investment for the highway upgrades amounts to $2,608m. The total incremental maintenance cost amounts to $1,383m. The incremental maintenance cost (the project case – base case) was caused by the increased lane kilometres after upgrades, and the need for maintaining existing highway if town bypasses have been built. The construction and maintenance cost profile is provided in Figure 4.

Figure 4 Construction and maintenance cost profile



5.1.2 Conventional transport system impacts

The transport network in the study area includes a parallel freight railway and a parallel highway. The vehicle types in the analysis include car, rigid truck, articulated truck, combination vehicle and freight rail. The tonnes carried by rail accounts for 3% of total tonnages in the corridor. The highway carries a high volume of traffic with the proportion of heavy vehicle accounting for 20% of total traffic. Traffic volumes vary between road sections with the average traffic around 15,000 AADT.

Travel speed for car increased from 81.4 km/h without upgrades to 100.7 km/hr with upgrades. The travel speed for heavy vehicles also increased from 75.7 km/h without upgrades to 97.0 km/h with upgrades. Highway upgrades also shortened the road section length by 3.7 km from 220.5 km to 216.8 km. These changes lead to travel time savings for both passengers and freight. The total vehicle hour travelled (VHT) is reduced by 3.7 million vehicle hours with the upgrade program, representing a 22% reduction. The value of travel time savings is $15.14 per person hour for private trips and $48.45 for business trip. The additional freight travel time savings include $7.39 per vehicle hour for 3 axle rigid trucks, $20.7 for articulated trucks and $43.13 for B-Doubles.

The highway upgrades reduce the vehicle operating costs (VOC) in three respects. Firstly, newly built pavement has a higher ride quality with better smoothness. Secondly, upgrading highway from 2-lane regional highway into dual carriageway doubles road capacity thus relieving road congestion. Finally, the upgraded highway is shorter. The TREDIS requires the inputs of vehicle operating costs for free flow, congested and idle conditions. The estimated VOC ranges from $0.30 to $0.39 per km for cars and from $1.21 to $1.42 for heavy vehicles depending on road and traffic conditions.

Actual road crashes before and after highway upgrades were extracted from NSW Crashlink database, enabling the estimate of crash reduction due to highway upgrades. On average, highway upgrades will reduce 5 fatal crashes, 53 injury crashes and 73 non-injury crashes per annum. The costs per crash using the willingness to pay (WTP) approach are available as standard economic parameters in the Transport for NSW Economic Appraisal Guidelines.

The highway bypasses divert traffic away from local towns thus reducing the impacts of air pollution and noise. Improved traffic flow will reduce the Greenhouse Gas Emissions (GGE). The external costs are needed in TREDIS inputs for free flow, congested and idle traffic conditions.

5.1.3 Wider economic impacts including market access /agglomeration impacts

TREDIS requires the inputs of local and regional market sizes in terms of population and employment. The TREDIS NSW Version relies on the input-output tables developed by the Centre of Policy Studies at Monash University (Weisbrod 2014). In addition, travel times to regional airport terminals and international gateways (major port) were also required as

TREDIS inputs for estimating regional market access impacts. Local job market, same-day delivery market and intermodal connectivity all fall within market access effect category.

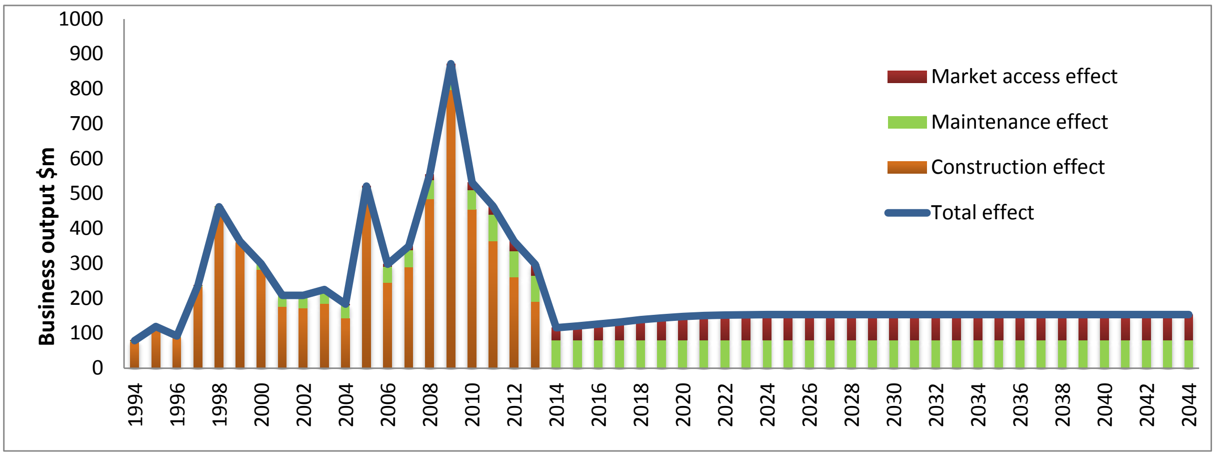
5.2 Economic impact outputs

Regional economic impacts can be measured by business output, GDP, job creation and wage income.

5.2.1 Business output

Business output is a measure of the revenue from product sales. A transport improvement can increase the business output from the additional outputs from the business travel time savings, commute travel time savings leading to longer working hours and better job-skill matches, additional labour supply, transport-induced agglomeration and clustering and output multiplier effects associated with patterns of supplier purchases and consumer spending. The additional business outputs in NSW from the highway upgrades are presented in Figure 5. From 1994 to 2014, the business output was predominantly affected by construction capital injections. After 2014, the effects are shifted to operational investment and improved market accessibility. In total, the highway upgrades will generate $11.3 billion in additional business outputs from the construction capital injection (accounting for 52% of total effect), operation and maintenance investments (28%) and market accessibility (20%).

Figure 5 Additional business outputs generated from highway upgrades, NSW

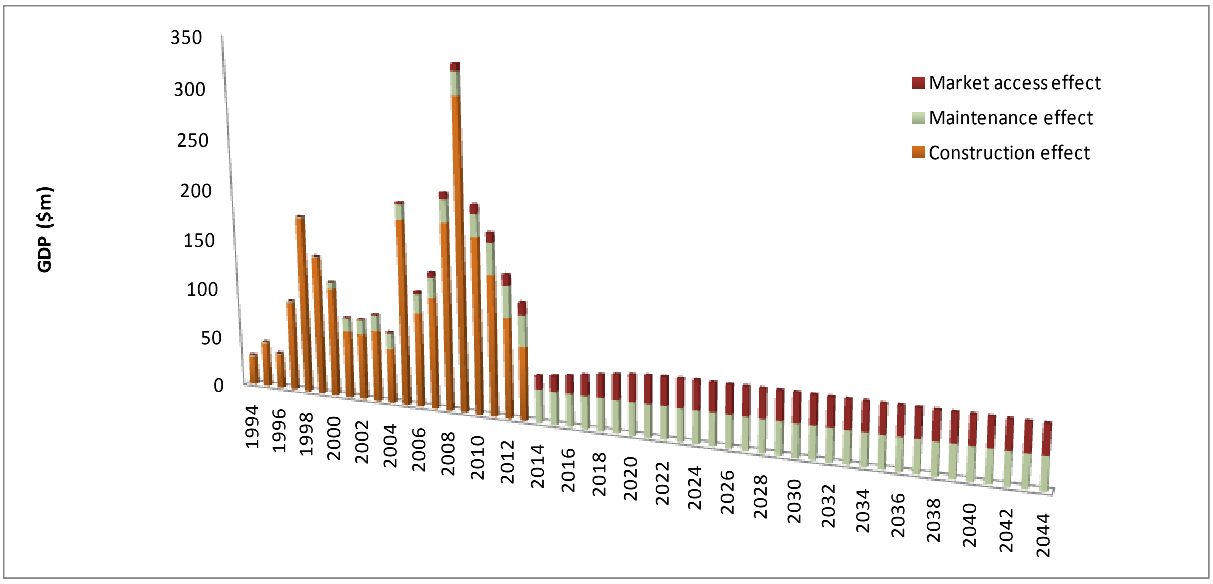


5.2.2 Value added

Value added is a measure of business output minus the cost of inputs used to produce the products. The value added has also been referred to as the Gross Domestic Product (GDP), or Gross State Product (GSP) or Gross Regional Product (GRP) at national, state or regional levels. Effects of business output from transport have been discussed above. Transport also reduces the input costs through direct travel cost savings, potential savings of wage premiums paid by employers, cost savings from freight efficiency due to better accessibility such as permitting B-Doubles for a wider network, and induced supply chain reorganisation for example by merging warehousing and logistics centres.

The additional value added / GDP generated from highway upgrades are presented in Figure 6. In total, the highway upgrades will generate $4.4 billion in additional value added from capital, operation investment and market access improvements. The TREDIS model estimates inward investment effects in that the source of funding is external to the project impact area. The GDP and other effects are positive in all years of the analysis period. This is different to CGE models which would show overall negative impacts on GDP during the construction period and positive impacts afterwards (for example, see Acil Tasman 2010) because of crowding out implications as resources are potentially diverted from other productive activities.

Figure 6 Additional GDP generated from highway upgrades, NSW



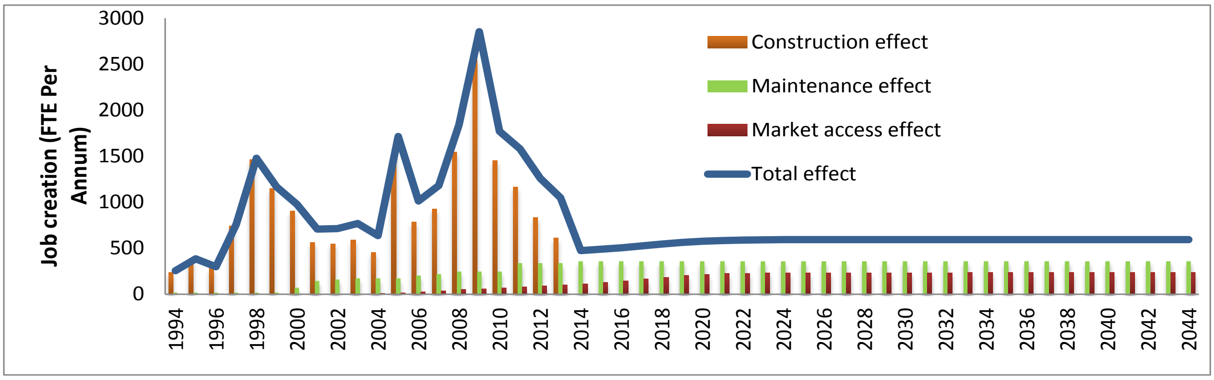
5.2.3 Employment

It is well known that infrastructure investment creates jobs. Infrastructure investment has been widely used as means for economic stimulus during economic downturn such as Global Financial Crisis (GFC) in 2008-2009. Technical and construction labour is needed for construction, maintenance and operation of the infrastructure. The reduced transport cost and improved accessibility stimulate the business expansion that also creates additional jobs.

TREDIS analyses the employment growth by industry sector at a State or national level. This is affected by changes in market access. TREDIS can accept measures of effective density, but for purposes of analysing the national highway program, it was found useful to distinguish labour market access effects for passenger travel from same-day delivery access for freight travel. The population within a 40 minute travel time was selected as a proxy for the labour market potential, while the employment located within a 3 hour drive time was used as an indicator of regional business activity occurring within a same-day delivery area. Transport projects can cause changes in relative business attractions at local or regional level, which induces the spatial shift of economic activities and employments between regions. That includes effects of relative cost changes that lead to spatial and business sector shifts in trade flows, investment flows and business locations. The employment growth of high productivity sectors and the decline of low productivity sectors contribute to gross productivity growth. However, employment shift between regions is not a growth. As the analysis is undertaken at the National or State level, the employment relocation effect at local level is excluded thus double counting is avoided.

The employment growth generated from highway upgrades are presented in Figure 7. The highway upgrades will generate 2,800 jobs at the peak of construction in 2009, or 600 jobs in operation period. In total, 40,349 jobs (for a period of one year) would be created, and among it, 46% by construction investment, 36% in operation and maintenance and remaining 18% by market access improvement. TREDIS estimates the employment demand which can be interpreted as job creation assuming the perfect elastic labour supply at the current compensation for various occupations. In some cases, the demand may attract skills from external regions. It is generally assuming that the labour market is competitive thus the additional demand created from a project would not push up the salary.

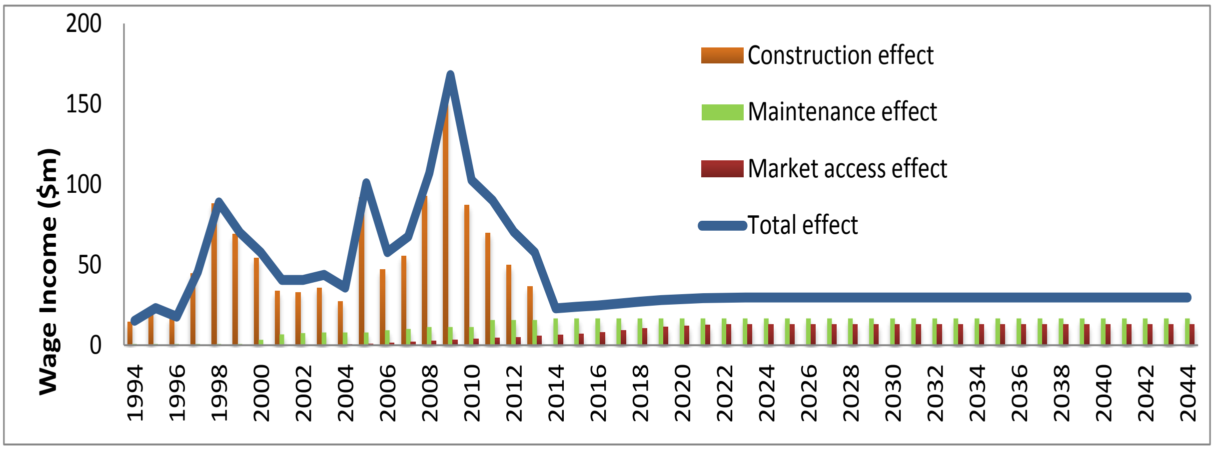
Figure 7 Jobs created from highway upgrades, NSW



5.2.4 Wage income effect

Wage income effect refers to the salaries and other benefits for jobs created by the transport investment. While GDP is a relatively well known macroeconomic aggregate, wage income is a better measure of the welfare benefit to residents. Wage income is occasionally used in combination with jobs to show whether an investment or policy creates high-wage or low-wage jobs. It can also be used to calculate the income taxation revenue. As a rule of thumb, wage income typically represents between one third and two third of GDP depending on the mix of industries present. The wage income generated from highway upgrades are presented in Figure 8. In total, highway upgrades will contribute to $2.19 billion in wage income, earned by new jobs generated by construction capital injection, the operation and maintenance investments and market accessibility. Wage income represents 49% of additional GDP of $4.4b. On average, the wage income is estimated at $54,373 per worker per annum for newly created jobs.

Figure 8 Wage income changes for jobs created in highway upgrades, NSW



5.2.5 Economic impacts by industry sector

Highway upgrades have the greatest impacts on construction and related services, which account for 49% of total GDP effects (Table 3). The second largest impact is on property and business services, accounting for 14% of the total impact. Manufacturing, mining and farming account for 9% of the total effect. Transport, utilities and telecommunications account for only 5% of the total impact, reflecting the fact that transport induced market access usually have bigger impacts on other economy sectors such as accommodation, services, wholesale and retail trades than the transport sector itself.

Table 3 GDP effects by industry, NSW

Industry sector	GDP effects in the evaluation period	
	Amount ($m)	Percentage (%)
Construction services	$1,500	34%
Construction	$662	15%
Property & business services	$602	14%
Manufacturing, mining & farming	$393	9%
Accommodation, food & other services	$337	8%
Finance & insurance services	$332	7%
Wholesale & retail trades	$282	6%
Transport, utilities & telecommunications	$223	5%
Government, education & social assistance	$118	3%
Total	**$4,447**	**100%**

5.2.6 Multipliers of $1m investment

For each $1 million investment in highway upgrades, the business output is more than doubled (Table 4). Maintenance and operation spending generates a slightly higher business output ($2.35m), compared to construction investment ($2.26m). Each $1 million investment can generate $0.90 GDP / value added. Again, maintenance and operation spending will have a higher effect. The business output and GDP due to capital and maintenance spending was analysed year by year in constant dollar 2014 (in that discounting to present value is unnecessary). Each $1 million investment can generate 8 full time equivalent jobs (for one year, or 1 FTE job for 8 years). Maintenance and operating spending creates higher number of jobs (10 FTEs), compared to construction investment (7 FTEs). This suggests that maintenance and operation of highways are labour intensive while the construction is relatively capital intensive. Each $1 million investment in highway upgrades creates the wage income of $0.45 million for newly created jobs.

Table 4 Economic impacts of $1 million investment

	Business output ($m)	Value added (GDP) ($m)	Employment (FTE for a year)	Wage income ($m)
Construction investment	2.26	0.87	7.23	0.43
Maintenance and operation investment	2.35	0.95	10.48	0.48
Overall of construction and operation (a mix of 65% construction and 35% operation)	2.29	0.90	8.35	0.45
Additional market access impacts for $1m construction or maintenance investment	0.02	0.01	0.06	0.003

6. Concluding remarks

While the cost benefit analysis is still the tool used most often to support transport investment decision-making, community, stakeholder and decision makers want to know wider economic impacts at national, state and regional levels in particular on job creation and GDP. TREDIS is capable for both the standard CBA and the economic impact analysis. Its outputs can be potentially used for estimating WEBs and productivity metrics by separating the business components from the total economic impacts. Estimating economic outcomes for transport projects in terms of GDP and employment now forms an essential component in the transport assessment guidelines in England, Scotland, and Wales (Economic Development Research Group 2013). In Australia, the updated national guidelines (NGTSM 2014) discuss supplementing the standard CBA assessments with wider economic benefits (WEBs) and Productivity Metrics.

The standard outputs from TREDIS for economic impact analysis include business output, GDP, employment and wage income for regions, states and the whole nation. These indicators can also be estimated using a Computable General Equilibrium (CGE) model. TREDIS was specifically developed for transport investment evaluations while a typical CGE model is often designed for analysing economic shocks such as taxation policy changes.

The case study in this paper provides useful insights on likely economic impacts of highway upgrades. The economic impacts are significant, with each $1 million investment generating more than $2 million business output, $0.9 million GDP, $0.45 million wage income and creating 8 jobs. It is important to note that these impacts are not mutually exclusive thus cannot be added together. For example, the GDP forms part of the business output. Job creation and wage income are also correlated.

Although economic effects from construction, operation and maintenance and market access can be separately estimated, there are certain limitations in using TREDIS. The first concern is related to its 'black box' operations. TREDIS is an internet based application in that remote servers solve thousands of simultaneous equations to reach a modelled equilibrium. While economic models used for NSW projects are based on rigorous economic theory and localised I-O tables by adopting the Monash CGE model[3] database and elasticities reflecting the Australian economy, TREDIS does not open the underlying database, equations and elasticities to users thus the author found it difficult to explain causal relationships from inputs to outputs.

The second concern is related to its spatial aggregation at the State level. The economic impacts of a transport project are rarely contained within the local economy. Construction and maintenance contracts are more likely to be offered to large companies with nation or state wide operations. Job creation can be easily 'leaked' beyond local or regional areas. While it is preferable to estimate the impacts in local, regional, state and national levels, TREDIS for NSW version does not provide such flexibility at this stage because of limitations on the availability of detailed economic data at a finer level of spatial detail. It is expected that this limitation can be overcome for the NSW version in the future. TREDIS is fundamentally designed so that it actually can be used to distinguish local, regional, state and broader national effects, and it has been used that way in Canada and the US. From the standpoint of national macroeconomic growth, some local effects may be dismissed as inter-regional "shuffling." However, at the local level, this "shuffling" is very important as it can make the affected local area more competitive for business attractions albeit at the expense of other locations.

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