Economic Impacts of the State Highway 4 Outage – June 2015

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1 Background

In June 2015 the lower North Island experienced a significant flooding event that forced many people out of their homes in Whanganui and closed a number of State Highways around the lower North Island including: SH4 from Raetihi to Whanganui, SH4 from Vinegar Hill to Cheltenham, SH43 from Stratford to Taumarunui, and SH3 through the Manawatu Gorge.

Market Economics (M.E), in conjunction with GNS Science and Resilient Organisations are, under the Ministry of Business, Innovation and Employment (MBIE) funded Economics of Resilient Infrastructure (ERI) project, currently nearing the completion of a 'tool' known as 'MERIT' (Measuring the Economic Resilience of Infrastructure Tool). MERIT may be used to assess the economic impacts associated with infrastructure outages, including transport related outages. While the MERIT tool has already been developed and operationalised and tested for several types of infrastructure outage (e.g. electricity, water and port outages) each particular infrastructure outage requires specialised 'interfaces' to be built so as to capture the full extent of impacts arising. In the case of road outages this interface is still under construction.

The Ministry of Transport ('the Ministry') has commissioned M.E to apply the MERIT tool to assess the economic consequences of a closure in SH4 from Raetihi to Whanganui. It is important to note that the scope of this study varies from the event actually experienced in June 2015, which also involved other road closures. In particular, the road closures which cut off Whanganui from the rest of the North Island. Nevertheless, the study provides useful information on the economic importance of the SH4 road connection. This study also provides a general opportunity to test out and further develop the usefulness of MERIT in evaluating the economic consequences of transport outages.

2 Modelling Road Outages

2.1 Overview

MERIT is a dynamic, multi-regional and multi-sectoral economic model that contains all of the core features of a computable general equilibrium (CGE) model. CGE models tend to be the favoured approach and are 'state-of-art' in the modelling of regional- and national-level economic impacts. Among the advantages of this type of model is: (1) the whole-of-economy coverage; (2) the capture of *indirect* (i.e. the so-called upstream and downstream multiplier effects generated through supply chains) and *induced* (i.e. as generated through household consumption) economic consequences; (3) the 'general equilibrium' impacts that result from price changes in an economy; and (4) the ability to describe the distribution through time of impacts across different economic sectors and regions.

The construction of an economic model such as MERIT requires a significant investment of time and resources. The multi-regional Social Accounting Matrices (i.e. economic accounts) which establish the base conditions for the model, for example, took just over 18 months to complete. Development of MERIT itself took a further 24 months of full-time development. Furthermore, it is important to note that MERIT is only one part of the necessary steps required to model the economic impacts of a road outage. Figure 1 provides an overview of the steps necessary to translate information on a road outage into measures of economic impact. These steps are also briefly described in the remainder of this section.

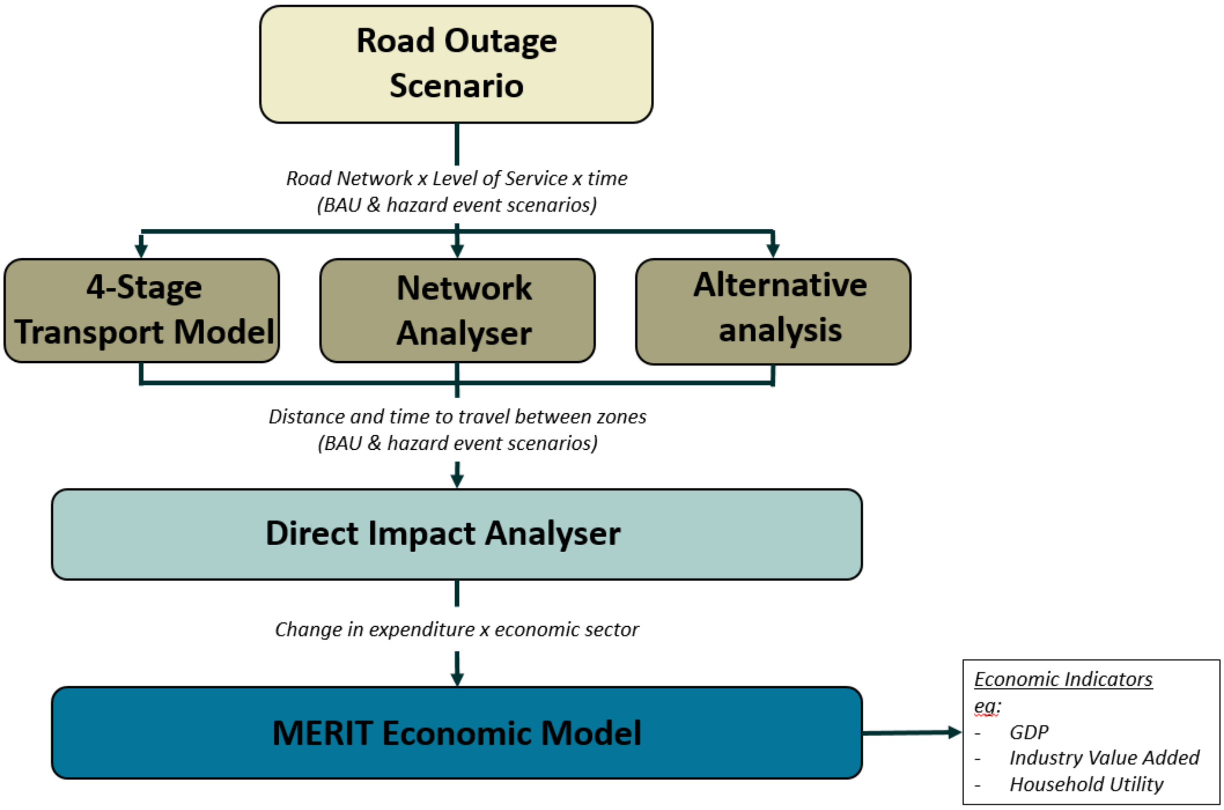

Figure 1 Modelling Road Outages using MERIT

Step 1: Generate description of a road outage scenario – The analysis begins with a description of the road outage. An outage can refer to full closure or a reduced level of service (e.g. one lane only). The outage may be hypothetical, or based on a real event. Typically, the outage is described by a series of Geographic Information System (GIS) maps that are 'time-stamped' so that it is possible to determine the period over which the outage lasts, improvements in the level of service provisioning that occur over the outage period, and when full level of service is returned. The economics of a road outage are usually measured by comparing against a 'counterfactual', 'base-case' or business-as-usual scenario, and, thus, is it is necessary to also clearly understand the road network and levels of service that would prevail without the outage.

Step 2: Transport Network Analysis – In the next stage of the modelling process it is necessary to ascertain how distance and time to travel between locations alters as a result of the road outage scenario. There are a number of approaches that could be employed, depending on the resources and time available for the analysis, and the nature of the likely impacts. One option is simply to utilise, on a case-by-case basis, expert knowledge of the road network, potentially coupled with desktop analyses. For analysis of an Alpine Fault scenario, as currently being undertaken within the ERI research programme, analysts separately estimated all of the likely route changes between Westcoast settlements that would occur as a result of road outages following the earthquake event.

Another potential approach is to utilise a 4-step transport model. These models break down study regions into small geographic units (i.e. transport zones), calculate the likely trip generation and destination for each unit, estimate likely trip distributions, calculate transport routes, and provide mode splits. A major advantage of applying a 4-step transport model is that there is an ability to take into account road capacities when estimating the likely re-distribution of trips following a change in the road network. Furthermore, it is important to note that the use of a 4-step transport model should also take into account changes in travel demand resulting from the outage i.e. the land use inputs into the transport model would need to be updated. These models, however, tend to require significant time investments to setup, calibrate and perform each model run, and there does not exist a single, consistent model for the whole of New Zealand.[1]

For the purposes of this study, M.E has applied a specially designed 'Network Analyser' to estimate the changes in transport routes between geographic units for the 2015 year. This models uses discrete mathematics (graph theory)[2] to assess alternatives routes based on a contiguous 2013 LINZ-produced road network layer for New Zealand[3]. This model is quick to implement and has been constructed for the whole country. A key limitation of the Network Analyser, however, is that it does not account for road capacity (i.e. the number of vehicles a road can support at a particular point in time) when estimating the likely alternative route taken by traffic during a road outage. If a road outage scenario is likely to result in significant additional congestion on the road network, these additional time costs will not be captured. Nor is any congestion of the alternative routes accounted for. Furthermore, and as noted above, travel demand will change in response to the outage – this has not been accounted for.

Step 3: Analysis of Direct Impacts – Once the net changes in travel distance and time between the census area units have been determined, the next step is to translate these cost changes into a set of altered expenditures for input into MERIT. Importantly, it is necessary to determine not only how much additional expenditure on transportation is required, but also the types of goods and services towards which the expenditure is allocated (e.g. petrol, road transportation services and so on), and the distribution of expenditure across different economic agents (i.e. different industry types and households). In order to do this, a 'Direct Impact Analyser' was created that incorporate estimates of not only the number of trips generated between census area units, but also the purpose of those trips (e.g. travel to work, freight and so on). Note that if a 4-step transport model had been used under Step 2, some of this information is likely to already be available. If, however, an alternative approach is employed then it is likely that this information will need to be separately estimated. Further information on the Direct Impact Analyser is contained in Section 2.2 below.

[1] Examples include the Auckland Regional Transport (ART), Wellington Transport Strategy Model (WTSM), and Waikato Regional Transport Model (WRTM). It is work noting that the University of Auckland, Engineering School is working on a transport model covering all of New Zealand.

[2] A Floyd-Warshall path algorithm is used to trace all routes between Census Area Units across all of New Zealand. Any road may be selected for an outage and, in turn, the Floyd-Warshall algorithm will, if it exists, find the next best alternative route based on travel time or distance.

[3] Ideally this 2013 layer would be updated to account for changes to the network and travel demand between 2013 and June 2015.

Step 4: Run MERIT – The final stage of an analysis is to run MERIT. Although economic simulation models such as MERIT come in many shapes and sizes, an application generally involves running the model twice: once without the 'economic shock' (i.e. excluding the direct impacts calculated under Step 3), and once with the shock. The 'net change' in model outputs between the two model runs, represents the economic impact. Further information on the MERIT model is provided in Section 2.3.

2.2 Calculating Direct Impacts

As explained above, MERIT has been developed under the ERI research programme. Two multi-infrastructure failure hazard scenarios have been devised as part of that programme, namely: an Alpine fault seismic event and an Auckland volcanic field eruption. Both of these scenarios involve significant disruption to road networks. The purpose of running these scenarios is to assist researchers in the development of MERIT, by helping to *inter alia* identify, assess and validate, transportation-related impacts.

Although the modelling of the two multi-hazard scenarios is still underway, we have completed a classification of the types of impacts that are likely to occur as a result of a road outage, for inclusion within the Direct Impact Analyser (Table 1). Furthermore, many of the more significant types of impacts have either already been included in the modelling or a process for inclusion has been identified. It is important to note that MERIT varies from a welfare or cost-benefit approach in that it is intentionally a dynamic simulation of the *market* economy. Non-market impacts, such as costs of greenhouse gas emissions and loss of scenic value are not intended to be included in the model. We would, however, like to extend the model to include the costs of additional travel time for households should the opportunity for further model development on this topic arise. Including such costs, which we can conceive as a 'loss of leisure time' is not uncommon within a CGE modelling approach.[4] The Direct Impact Analyser is an example of the type of infrastructure interface which must be built before impacts can be assessed within MERIT.

[4] Note, however, that these impacts would only be evident in the household utility indicator. Other indicators produced by the model (e.g. industry value added, GDP) are market-based and therefore would not capture these non-market time costs for households.

Table 1 Types of Impacts Resulting from a Road Outage and Inclusion within the Direct Impact Analyser

Impact	In the model		Possible?	Not in the model	
	Complete	Method identified		Non-market	Outside scope
Freight					
Time costs	X				
Vehicle operating costs	X				
Emission costs				X	
Perisable commodities					
Loss of product			X		
Loss of product value			X		
Tourism					
Loss of tourism spend					X
Loss of scenic value				X	
Travel to work/school					
Time costs				X[1]	
Reduced supply of labour		X			
Vehicle operating costs	X				
Emission costs				X	
Shopping					
Time costs				X[1]	
Vehicle operating costs		X			
Emission costs				X	
Recovery and Rebuild					
Increased construction		X			
Opportunity costs of capital		X			

1. MERIT could be adapted to include but thus far only considers market impacts

We have also identified tourism-related impacts as an important gap within MERIT. A research application has recently been accepted under the QuakeCORE which aims to further our understanding of tourism-related impacts with the view of extending MERIT to capture these impacts.

In terms of the SH4 road outage that is the subject of this study, the main impacts from the outage, apart from tourism, are likely to be related to the transportation of goods/ commodities. This study has concentrated on quantifying the increased travel costs for freight as a result of needing to transport goods via longer routes. Although loss and degradation of perishable products are additional freight-related impacts possibly resulting from the outage, these types of impacts have not been incorporated in this study. It is envisaged that with further research it would be possible to extend the model to consider these impacts for some of the most significant perishable commodities (e.g. raw milk, flowers, vegetables etc.).

Although the increased costs of travel to work (but not work related travel during the day) are included, these are relatively small given the nature of the road outage. For future studies the Direct Impact Analyser could be extended to also estimate changes in costs associated with travel to school and for consumer shopping. For this study these impacts are however unlikely to be significant and have not been included. Furthermore, we have not attempted to include the economic impacts of reinstatement of SH4, as this is considered outside the scope of the study – although this is easily incorporated.

In order to estimate the direct costs of increased freight, the Direct Impact Analyser follows an approach that has many commonalities with a conventional (4-step) transport model: step 1 – estimate trip generation and attraction by geographic unit, step 2 – estimate the amount of movement between each geographic unit pair, and step 3 – calculate the routes or services within the network used for each Census Area Unit pair. Of course, it is possible to account for modal splits (step-4) – we have not done this due to budget constraints. In addition, once changes in freight transportation have been calculated, it is necessary to translate this information into changes in transportation costs (financial) for input to MERIT. These steps are described in detail below.

Stage 1: Estimate trip generation and attraction – As part of the development of the MERIT, M.E created a detailed set of economic accounts known as Social Accounting Matrices (SAMs) for New Zealand 16 regional council areas (Smith *et al*., 2014). These SAMs provided detailed information on the production and use of economic commodities within New Zealand. For each region the accounts are broken down by *inter alia* 205 different commodity types, 106 different industry types, and 5 additional categories of final consumption for commodities (exports, household consumption, local government consumption, central government consumption, and investment consumption). In order to estimate the origin and destination of freight at detailed spatial units across New Zealand we essentially undertake a task of further disaggregation of the commodity components of the regional SAMs into individual accounts for each Census Area Unit. The principal data used for disaggregation are Statistics New Zealand's Census of Population and Dwelling usual resident population estimates (adjusted using interpolation between 2006 and 2013, to estimate a 2007 base year population) and 2007 Business Directory employment (for the 106 industry types) data by census area unit. Information on commodity imports and exports through each New Zealand port (from New Zealand Harmonised System) also enables the commodity accounts to be extended to show the origin and destination of commodities to, and from, ports as a result of import/export trade.

Stage 2: Estimate the distribution of freight movements between Census Area Units – This is undertaken in two steps. First, the regional commodity accounts are disaggregated to account for each territorial authority and a gravity model is used to estimate the level of trade between and within each territorial authority (refer also to Smith *et al*. (2014) for further information on this approach). The territorial accounts are then further disaggregated into Census Area Unit accounts. At this level, it is assumed that freight movements are distributed in direct proportion to the level of population/employment within each Census Area Unit.[5][6]

Stage 3: Calculate freight routes – As noted above, M.E has constructed a Network Analyser. This analyser determines the most efficient alternative routes, both in terms of distance and time, from each Census Area Unit to every other Census Area Unit in New Zealand.[7] To do this, the model simplifies the road network (it includes all roads classified as highways, arterial and collector roads[8] including their segments lengths, travel times and distances) into a series of 'nodes' connected via 'links'. Specifically, a Floyd-Warshall algorithm (Floyd, 1962) is used to calculate the fastest routes between nodes and the links. The algorithm is run twice, once with a full (non-impacted) road network and once with a reduced road network (i.e. the road outage).

Stage 4: Calculate net change in transport margins – The actual information used to 'shock' MERIT for the purposes of the road outage scenario are a set of ratios that describe the *net change* in transport margins, per $ of commodity purchased, for each study region (i.e. both the Manawatu-Wanganui region and rest of New Zealand (RoNZ)), and by different commodity types. In order to calculate these ratios we must first determine the net change in freight costs for each type of commodity and for each trip between a particular Census Area Unit to every other Census Area Unit. The generalised cost formula calculates changes in freight costs based on the weight of each commodity (we use average kg per $ of commodity) and the net change in transport time, and distance, between Census Area Units. The individual Census Area Unit to Census Area Unit trips are then combined into 'weighted-average' margin ratios for the two study regions. Note that to be consistent with the requirements of MERIT, it is necessary to calculate separate weighted-average transport margins for import commodities, export commodities, domestic commodities, and commodities traded between the study region and

[5] As a hypothetical example, imagine that the forestry industry in Territorial Authority 1 sells $1million of logs to the wood processing industry in Territorial Authority 2. Imagine also there are two area units in Territorial Authority 1, Census Area Unit 1 and Census Area Unit 2, and two area units in Territorial Authority 2, Census Area Unit 3 and Census Area Unit 4. If there are 10 people employed in forestry in Census Area Unit 1, 30 people employed in forestry in Census Area Unit 2, and 5 people employed in wood processing in Census Area Unit 3 (none in Census Area Unit 4), the estimated freight distribution would be $250,000 of logs from Census Area Unit 1 to Census Area Unit 3 and $750,000 from Census Area Unit 2 to Census Area Unit 3.

[6] When dealing with alternative origin and destination sites within a single Territorial Authority, it is likely that product differentiation (at a level more detailed than captured by the SAMs) is a more significant determining factor for determining trip distribution than differences in travel time. As it is impractical to obtain very detailed information on production and use of commodities for all different types of economic activities, it is considered most appropriate to simply assume that trips are distributed in proportion to population/employment.

[7] To reduce model running time, trips between Census Area Units that are unlikely to be impacted by the road outage are, however, first removed from the analysis.

[8] Local roads which are not connectors are currently omitted. It is possible to include all roads, irrespective of which type, however this adds significantly to the time overhead associated with the application of the Floyd-Warshall algorithm.

RoNZ. The domestic commodities refer to commodities that are produced by industries within a region and then consumed within that same region, either by other industries, government or households. Increases in transportation margins effectively cause the price of commodities experienced by purchasers to increase, but at the same time create additional demand for transportation goods and services. It is assumed that all additional demands for transportation are allocated to the road transportation industry. Given the purchasing patterns of the road transportation industry, this also leads to an increase in demand for fuel, vehicle maintenance services, driver labour, and so on.

As already explained, changes in travel-to-work costs for households are also included in this study, although the impacts are not significant. To estimate these impacts we also use the changes in transport costs between Census Area Units (both in terms of distance and time) as calculated by the Network Analyser (see Stage 3 for freight above), combined with information from Statistics New Zealand on work place and residence locations and travel to work. As also explained above, we only concentrate on calculating changes in vehicle operation costs for households, as increases in travel time are non-market impacts. When incorporated these within MERIT, increased transportation costs for households for travel to work (and for school and shopping) effectively reduces households' disposable income, and thus lead to across-the-board reductions in household expenditure on goods and services.[9]

2.3 The MERIT Model

The MERIT model is currently being described in a detail technical report (Smith *et al*., 2016), and thus only a concise summary is provided here. Figure 2 provides a schematic of MERIT. As already explained, MERIT contains the core features of a state-of-art CGE model. Among the important features are:

- For each region, the model describes the behaviour of representative agents (46 industries, households, local government and central government). Each industry agent chooses the quantity and type of commodities to produce, based on the prices of those commodities relative to the costs of production. Household and government agents receive income from a variety of sources (including from wages and salaries, business profits, dividends, taxes and transfers from other agents), and then allocates this income towards a variety of expenditure options (purchases of goods and services, savings, taxes, transfers to other agents).

[9] If households face significant additional costs for travel to work it is likely that some workers will choose to stay home. Where this occurs the costs of travel to work will also be directly experienced by businesses in the form of reduced access to labour. These are market impacts and MERIT is ideally suited to the incorporation of such behaviours in the analysis of economic impacts. Further information is, however, required to help set appropriate behavioural parameters in the model.

- The model incorporates 'price' variables for all commodities and factors of production (i.e. types of labour and capital). 'Nested' production functions allow the economy to react to imbalances between supply and demand in commodities/factors through substitution of demands and/or production. For example, the constant elasticity of substitution (CES) function describes the way in which demand for New Zealand-manufactured goods can be substituted for demand for goods produced overseas, if the price of domestic goods becomes too expensive relative to foreign goods. A separate CES function also describes the substitution between locally-manufactured goods (i.e. produced within the same region) and goods produced in the RoNZ.
- The model also includes accounts that keep track of financial flows between New Zealand and the rest of the world (i.e. balance of payments). When the demand for New Zealand currency starts to outstrip supply this causes the exchange rate to rise. Changes in the exchange rate decrease/increase the price of New Zealand goods relative to overseas goods, thus influencing demand and supply relationships.
- MERIT incorporates the dynamics of economic growth by keeping track of stocks of capital held by each industry. Capital stocks accumulate via investments in new capital and are diminished via the ongoing process of depreciation.

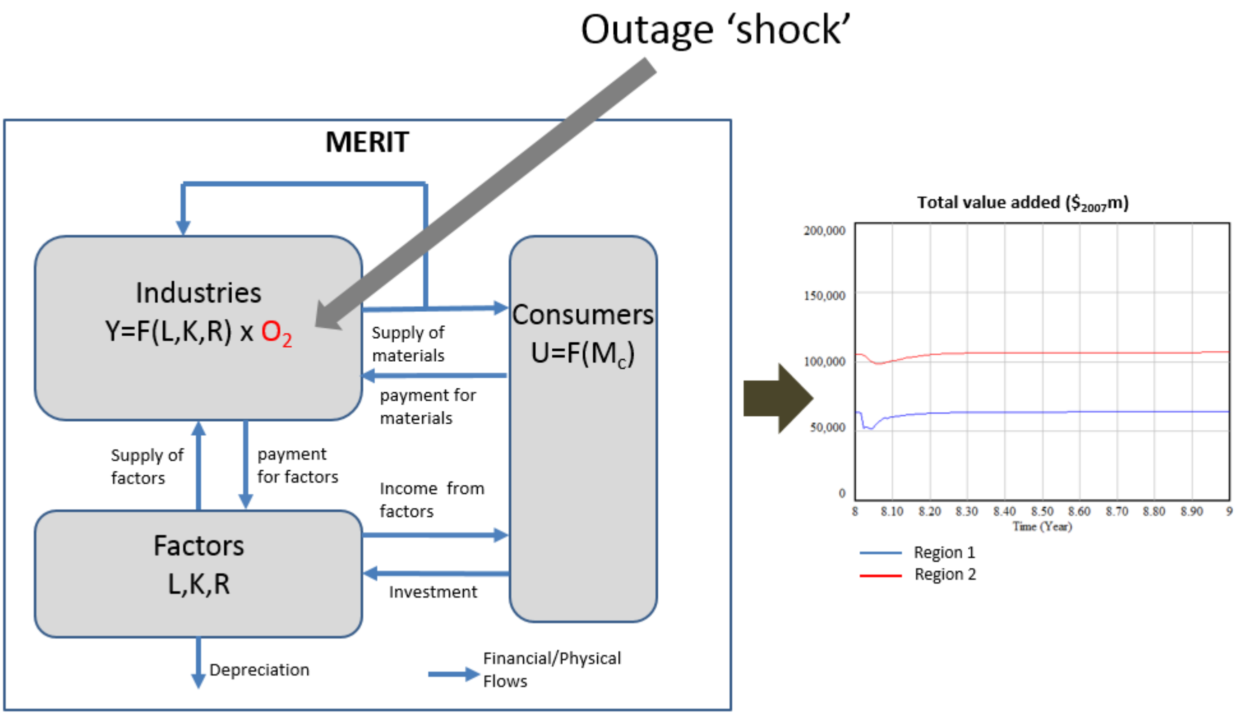

Figure 2: Measuring the Economic Resilience of Infrastructure Tool (MERIT). Note: Y = output, L = labour, K = capital, R = natural resources, U = Utility and Mc = materials/commodities. The 'F' represents is a function of.

It is important to note that while MERIT incorporates core features of a CGE model, it differs from a 'standard' CGE model in that it is a formulated based on System Dynamics, which uses finite difference equations. This is an innovative extension to economic modelling undertaken to improve our ability to capture the impacts of infrastructure outages. Standard economic models are 'equilibrium' models that describe conditions existing in an economy when a set of pre-determined conditions are met (normally prices equilibrate when supply = demand for all commodities and factors, and income = expenditure for all economic agents). For the analysis of infrastructure outages, however, an equilibrium-based analysis may not be helpful, as the time to reach equilibrium will often be longer than the actual length of the infrastructure outage, and during the period of disruption the economy is likely to be exhibiting non-equilibrium behaviour e.g. industries may be operating at a loss. MERIT is a *simulation* model that shows a *transition pathway* towards equilibrium. It is not necessary that an equilibrium is actually achieved, and indeed the equilibrium towards which the economic system is moving may continue to change over time.

2.3.1 Key Advantages of MERIT

To complete this section we provide a brief summary of some of the other key advantages of MERIT compared to alternative approaches that may be employed in the analysis of impacts of an infrastructure outage:

- Once direct impacts are estimated, MERIT simulates all of the flow-on impacts through the rest of the economy, sometimes referred to as 'cascading' or 'higher-order' impacts. This includes successive rounds of changes in demand for goods and services as a result of production supply chains (i.e. 'indirect' effects) and changes in consumer spending as a result of changes in household income (i.e. 'induced' effects) as typically captured by an input-output analysis. However, because MERIT also captures price changes and substitution, it is not subject to the same problems of impact overestimation as typically encountered in an input-output analysis.
- MERIT is able to produce a variety of indicators to help us evaluate the impacts of an infrastructure outage, including GDP, regional value-added (similar to a regional equivalent of GDP), value of exports and imports, and household utility. It is worthwhile noting that the latter indicator is conceptually consistent with measurements that are sought to be calculated in a cost-benefit analysis. MERIT thus has the potential to be used for cost-benefit analysis as well as economic impact simulation.
- Properly accounting for distributional impacts is a long-standing issue for economics. When undertaking cost-benefit studies it is often simply assumed (improperly), either implicitly or explicitly, that if benefits are greater than costs this is overall good for society. However, if there are distributional impacts (i.e. some people benefit while others experience costs) this is not necessarily justified in economics.[10] While there is still significant work to be undertaken in the analysis of distributional impacts, MERIT does provide some information on the distribution of economic impacts, i.e. across different study regions and across different economic industries.[11]
- When we apply the MERIT model we required to undertake a series of simulations looking across the entire economy. The nature of this process helps to ensure that some cross checking of results occurs. It is our professional opinion that compared with more *ad hoc* methods (particularly cost-benefit analysis which typically involves a series of

[10] For example, if a scenario/policy under investigation results in a gain of $100 to individual A and a loss of $50 top individual B, we cannot assume that social welfare has increased; for if A is rick and B is poor, it may be that the loss of satisfaction to B of $50 is far greater than the gain of $100 for A.

[11] Our research team is currently preparing an application for a second round of MBIE funding. Among the outcomes that are described in the proposal will be further development of MERIT to allow for better understanding of the distribution of impacts, e.g. among households of different income classifications.

separate analyses for different benefits and costs), applications of MERIT are less-likely to result in the overestimation of impacts through double-counting,[12] and encourage consideration of the co-generation of costs and benefits from any economic change (e.g. while additional freight charges are a disadvantage for those purchasing commodities, they are a benefit for the road transport sector).[13]

12 When undertaking a welfare or cost-benefit analysis of a road outage it would, for example, be easy to double-count the costs of additional travel to work, both as a loss of leisure time and reduction in labour.

13 One error sometimes encountered in economic impacts studies is the treatment of a loss of tourism expenditure as a result of some inability to access tourism services as a net loss for the economy. Although this may be valid when considering international tourism, for domestic tourists the reduction in expenditure may simply be balanced by expenditure at alternative sites or regions and/or increased consumption of alternative commodities. The spatial extent of the society/community considered is important (i.e. whether the impacts analysed are for a particular local community, a region, or the whole nation).

3 Results

To provide some insight to the 'inner-workings' of MERIT, we have included in this results section a series of screen shots taken directly from the Vensim® version of MERIT (Figure 2). These screen shots depict the time-dependant pathway for a few economic indicators derived from just a few of the numerous variables contained within the model. Note that the scales on these graphs vary between indicators. Furthermore, since the y-axis scales do not begin at zero this tends to exaggerate the appearance of the impact as well as the general pattern of upwards growth characterising the scenarios.

Although the SH4 outage scenario is for a one-month period, the impacts simulated by MERIT extend over a longer period. Once the outage begins, it takes a little time for industries to adjust production, in part because firms are constrained by existing factors of production and also because the model incorporates some lag time for changes in firm production decisions (Table 2). At around one month after the start of the outage, the loss of commodity production within the Manawatu-Wanganui region is estimated to be relatively modest at around $1.7 million.[14] As already described these estimates do not, however, include any loss or degradation of value in perishable products. The majority of estimated loss in the region's commodity production is associated with food products. When the impacts are summed over 2 and then 6 months, the estimated loss of food products does not increase substantially compared with the impacts summed over just the first month. By contrast it is interesting to note that some of the other commodities continue to face losses in production that are as significant, or even greater than that experienced during the time of the actual road outage. This is because it takes time for some impacts to 'trickle' through the economy through reductions in consumer spending, changes in capital accumulation, and so on.

Clearly the impacts of the SH4 outage are not confined to Manawatu-Wanganui region. The RoNZ also experiences some adjustment in commodity production as a result of the event. One interesting outcome is that wholesale and retail trade in the RoNZ are expected to benefit from the event. This is largely because the event causes some change in the relative prices of goods and hence a slight increase in the market share of retail and wholesale trade for RoNZ. Although the outage ceases after one month, it takes firms some time to readjust, and the additional profits received in RoNZ as a result of the outage enables a slight increase in capital accumulation for retail and wholesale trade in RoNZ. This means that the 'benefits' of the outage for that sector last some time.

[14] All values are in 2015 dollar terms unless stated otherwise.

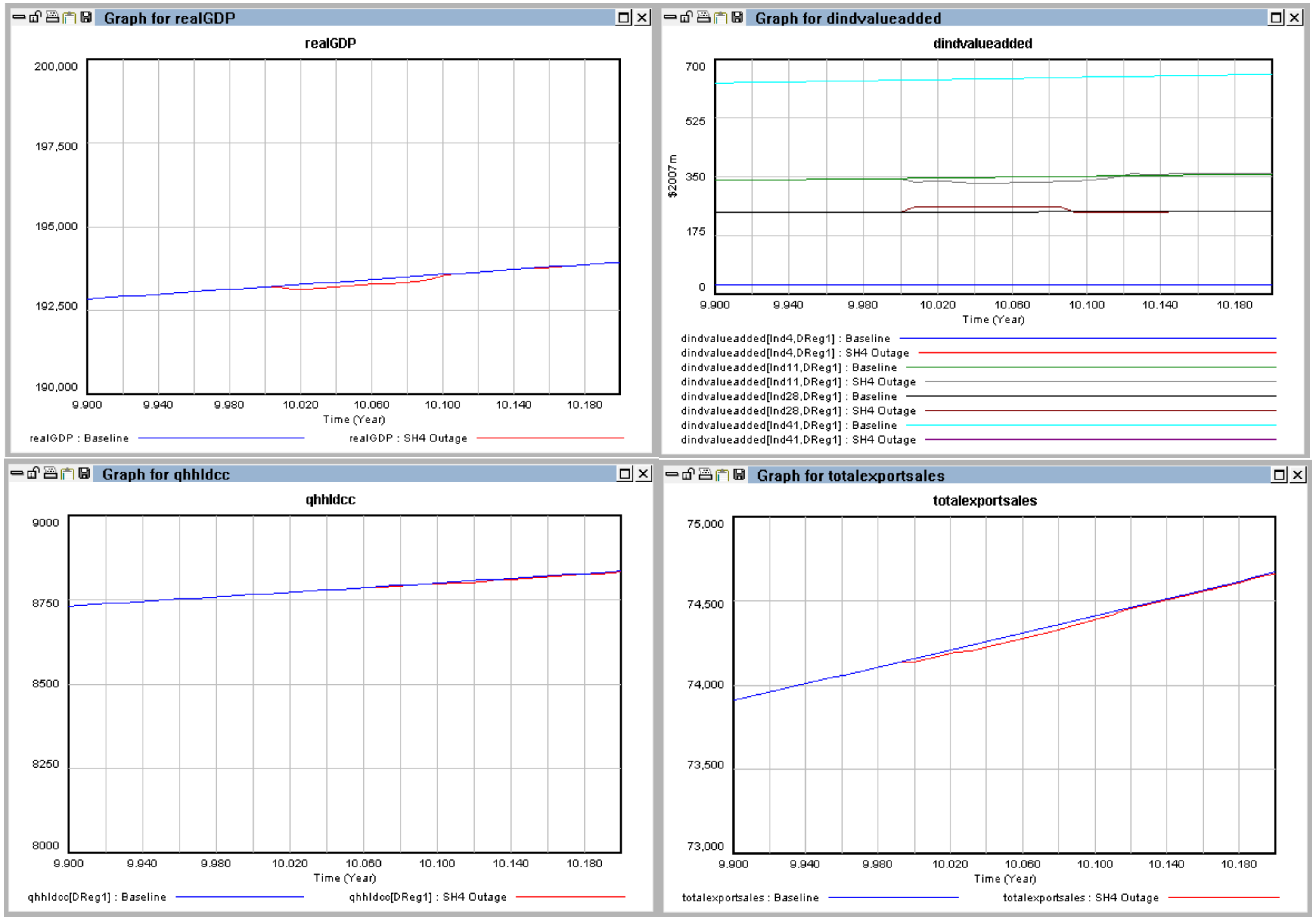

Figure 2 **A Selection of Indicators Produced by MERIT.** Clockwise from top left: (1) Real New Zealand GDP ($\$_{2007}$mil); (2) Real Industry Value Added ($\$_{2007}$mil). DReg1 = Manawatu-Wanganui region, Ind4 = Sheep and Cattle Farming, Ind11 = Dairy Product Manufacturing, Ind28 = Road Transport Services, Ind41 = Personal and Other Services; (3) Household Utility ($\$_{2007}$mil), Dreg1 = Manawatu-Wanganui region; (4) Total New Zealand Export Sales ($\$_{2007}$mil).

Table 2 Net Change in Gross Domestic Product as a result of SH4 Road Outage ($\$_{2015}$ thousand)

Commodity Type	Lapsed time since event		
	1 Month	**2 Months**	**6 Months**
Manawatu-Wanganui			
Farm products	-50	-130	-320
Other primary products	-60	-220	-640
Manufactured food products	-1,150	-1,520	-1,330
Other manufactured products	-180	-290	-390
Wholesale and retail trade	-20	-80	-160
Other services	-280	-230	670
Rest of New Zealand			
Farm products	-350	-900	-1,670
Other primary products	-60	-180	-320
Manufactured food products	-270	-630	-630
Other manufactured products	-310	-920	-1,960
Wholesale and retail trade	350	1,480	5,540
Other services	-810	-2,630	-4,170

Table 3 Net Change in Gross Domestic Product as a result of SH4 Road Outage ($\$_{2015}$ thousand)

Component of GDP (expenditure measure)	Lapsed time since event		
	1 Month	2 Months	6 Months
Household Consumption			
Manawatu-Wanganui	-90	-510	-580
Rest of New Zealand	570	-380	2,880
Government Consumption			
Manawatu-Wanganui	-480	-180	-160
Rest of New Zealand	140	-1,580	-960
Net Exports			
Manawatu-Wanganui	-1,870	-2,610	-2,250
Rest of New Zealand	-380	-3,070	-6,590
Investment Consumption			
Total New Zealand	-6,110	-2,530	-3,040
Total GDP	-8,220	-10,870	-10,720

The total loss in Gross Domestic Product (GDP) over the 6 months beginning at the time of the road outage is estimated at $10.7 million (Table 3). Note that although the MERIT model runs extended over a timeframe longer than 6 months, the outcomes did not change significantly after the first 6 months and hence only this timeframe is selected for reporting. Table 3 also reports the breakdown of GDP loss into the separate components used to calculate GDP.[15] The majority of the total loss in GDP occurred in the first month and is associated particularly with changes in net exports for Manawatu-Wanganui region, and reductions in savings/investment consumption. In MERIT the quantities of investment consumption are influenced by levels of business/household/government income. Net losses of investment consumption are also caused by drawing down of inventories as occurs when demand switches to new types of sources of commodities (e.g. from suppliers in another region).

For the RoNZ a number of dynamics play out over time, causing some oscillation in the net difference in incomes for the region compared to the baseline scenario, and hence changes in household and government consumption. As explained above, some industries in the RoNZ benefit from an increase in market share during the six months studied, while other industries do not largely because of increased transportation costs. After around six months the oscillation largely subside with household and government expenditure returning largely to the same levels as the baseline scenario run.

[15] A variety of different methods are recognised for calculating GDP. Although in principle the different methods should lead to the same result, this does not always occur in practice. The components listed in Table 3 are for the expenditure method of calculation.

4 Further Considerations

The economic accounts currently available for input within MERIT are formulated according to the boundaries of NZ regional councils. This means that when running MERIT we currently report the study region (i.e. the locality in which the impact occurs) as a whole regional council boundary, for example Manawatu-Wanganui region in the case of this study. When an infrastructure outage affects a part of a region more intensely, there will clearly be some uneven distribution of impacts within the region. In the case of the SH4, it is anticipated that the impacts would be disproportionately high for Whanganui District. Reducing the extent of the study region would help to better discern some of these distributional impacts. Although the MERIT model is set up to receive economic accounts for varying spatial boundaries, it is important to note that the establishment of these accounts (SAMs) is a very laborious process.

As a final point it is worthwhile reiterating that this study has not considered the potential economic impacts stemming from loss of value of perishable products and tourism-related impacts. These are two categories of effects where we would like to extend our modelling. Although the MERIT model is well suited for including these types of impacts in an economic evaluation, some further work is required to help set appropriate model parameters. Ideally this would involve calibrating behaviour parameters against historic experiences.

5 References

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