Economic Impacts of the State Highway 1 Brynderwyn Hills Closure

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m.e research

Economic Impacts of the State Highway 1 Brynderwyn Hills Closure

Prepared for

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www.me.co.nz

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1 Introduction

Northland Inc is participating in a programme of work with transport planning officials in Northland (Waka Kotahi, Northland Transport Alliance etc.) on a resilience response package for the roading network in Northland post Cyclone Gabrielle, Government Ministers have asked Northland to develop the package of appropriate responses. As a part of this group, Northland Inc is being requested to provide advice on the effect on our economy from the State Highway 1 Brynderwyn Hills closure (for the 58 or so days it was closed).

Northland Inc are wanting to be able to accurately identify the effect on both our and NZ's economy of this piece of roading infrastructure being closed – the Brynderwyn section in question is essentially (coming from south to north) the entire piece from just after the Maungatarouto intersection through to the bottom of the hill on the northern side before Waipu Gorge Road.

Market Economics (M.E, www.me.co.nz), in conjunction with GNS Science (www.gns.cri.nz) and Resilient Organisations (www.resorgs.co.nz), under the Ministry of Business, Innovation and Employment (MBIE) funded Economics of Resilient Infrastructure (ERI) project, have previously created a tool known as MERIT (Measuring the Economic Resilience of Infrastructure Tool) – refer to www.merit.org.nz for further information. MERIT may be used to assess the economic impacts associated with infrastructure outages, including transport related outages. Subsequently, an online version of the tool, known as Transport MERIT, was developed by M.E and Abley (www.abley.com) through funding provided by Waka Kotahi. In this report we use Transport MERIT to assess the economic impacts of the State Highway 1 Brynderwyn Hills closure.

2 Method

2.1 Overview

MERIT is a dynamic, multi-regional and multi-sectoral economic model that contains all 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 approximately 4 years of full-time development. Furthermore, it is important to note that MERIT is only one step in a series of 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 described in the remainder of this section.

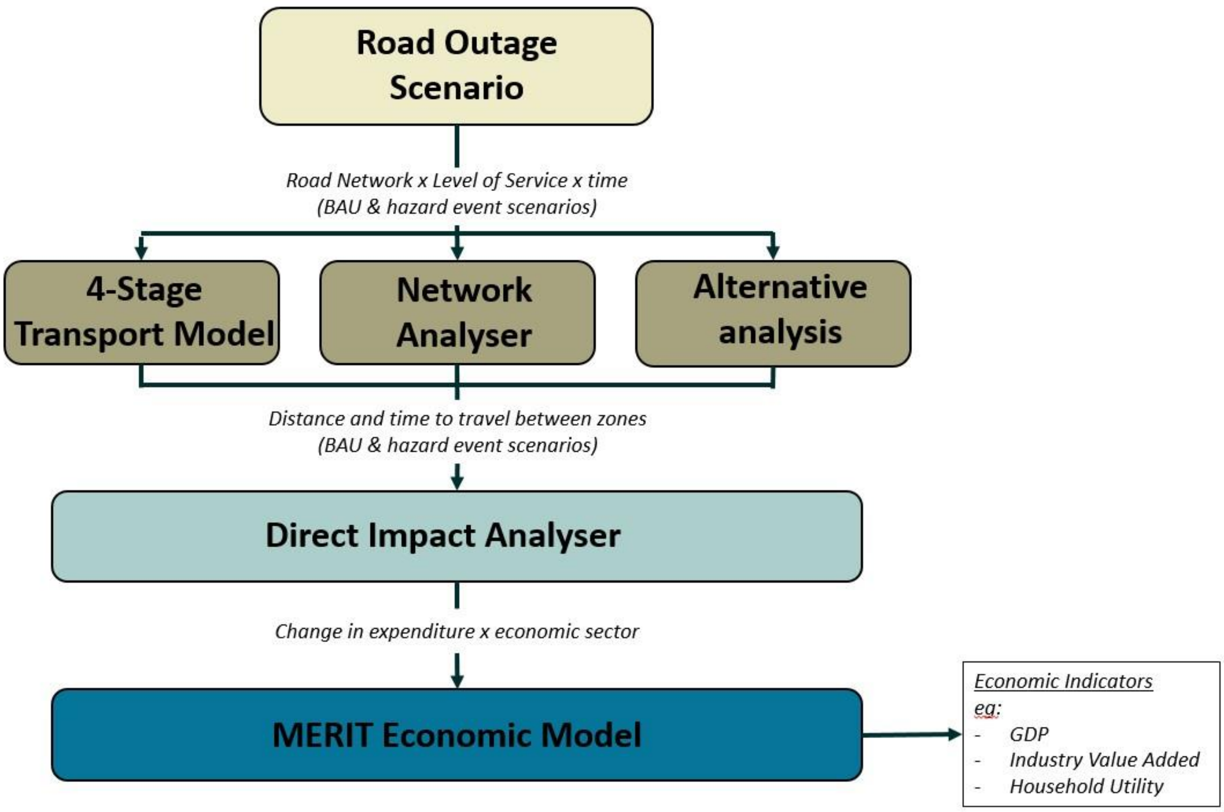

Figure 1 Modelling Road Outages using Transport MERIT

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). Typically, the outage is described by 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 returns. 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 because of the road outage scenario. There are several 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. 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 consider road capacities when estimating the likely redistribution of trips following a change in the road network. An appropriately formulated 4-step transport model will also consider 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 'GIS-based Network Analyser' (developed as a collaboration between M.E and Abley) to estimate the changes in transport routes between geographic units for the 2015 year. This model uses discrete mathematics (graph theory)[2] to assess alternatives routes based on a contiguous 2013 LINZ-produced road network layer for New Zealand[3]. 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

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

[2] A Floyd-Warshall path algorithm is used to trace all routes between Census Area Units across all 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.

will not be captured.[4] Furthermore, and as noted above, travel demand may also have changed in response to the outage – this also is not 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, a key next step is the translation of 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). 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).

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 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.

2.2 Calculating Direct Impacts

As explained above, MERIT was originally developed under the ERI research programme. It is however being continuously refreshed and updated through other projects. Table 1 provides a snapshot of the types of impacts that are likely to occur because of a road outage and whether they are included in the Direct Impact Analyser. 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.

[4] Congestion on neighbouring roads may also be impact – this also is not accounted for.

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	
	Included	Method Identified		Non-market	Outside scope
Freight					
Time costs	X				
Vehicle operating costs	X				
Emission costs				X	
Perishable 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	
Reduced supply of labour		X			
Vehicle operating costs	X				
Emission costs				X	
Shopping					
Time costs				X	
Vehicle operating costs		X			
Emission costs				X	
Recovery and Rebuild					
Increased construction		X			
Opportunity costs of capital		X			

In terms of the Brynderwyn Hills 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 because of needing to transport goods via longer routes. Although loss and degradation of perishable products are additional freight-related impacts resulting from the outage, these types of impacts have not been incorporated in this study.

Although the increased costs of travel to work (but not work-related travel during the day) are included, these are small given the nature of the road outage. The 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 the Brynderwyn Hills, as this is considered outside the scope of the study.

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) – this step has however not been undertaken 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.

Step 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). 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[5]. 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 because of import/export trade.

Step 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.[6,7]

Step 3: Calculate freight routes

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[5] Not we use Census Area Units, rather than the newer Statistical Areas, here as the underpinning data for the current version of Transport MERIT is based on the 2013 rather than 2018 Census of Population and Dwellings.

[6] As a hypothetical example, imagine that the forestry industry in Territorial Authority 1 sells $1 million 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.

[7] 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.

As noted above, M.E in collaboration with Abley have constructed a GIS-based Network Analyser to determine 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. 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).

Step 4: Calculate net change in transport margins

The actual information used to 'shock' MERIT for the purposes of the road outage scenario is a set of ratios that describe the *net change* in transport margins, per $ of commodity purchased, for each study region (i.e., both the Northland region and rest of New Zealand (RoNZ)), and by different commodity types. 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 generalized 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 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 GIS-based Network Analyser, combined with information from StatsNZ on workplace 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]

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[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.

[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

2.3 The MERIT Model

The MERIT model is 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).
- 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.

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.

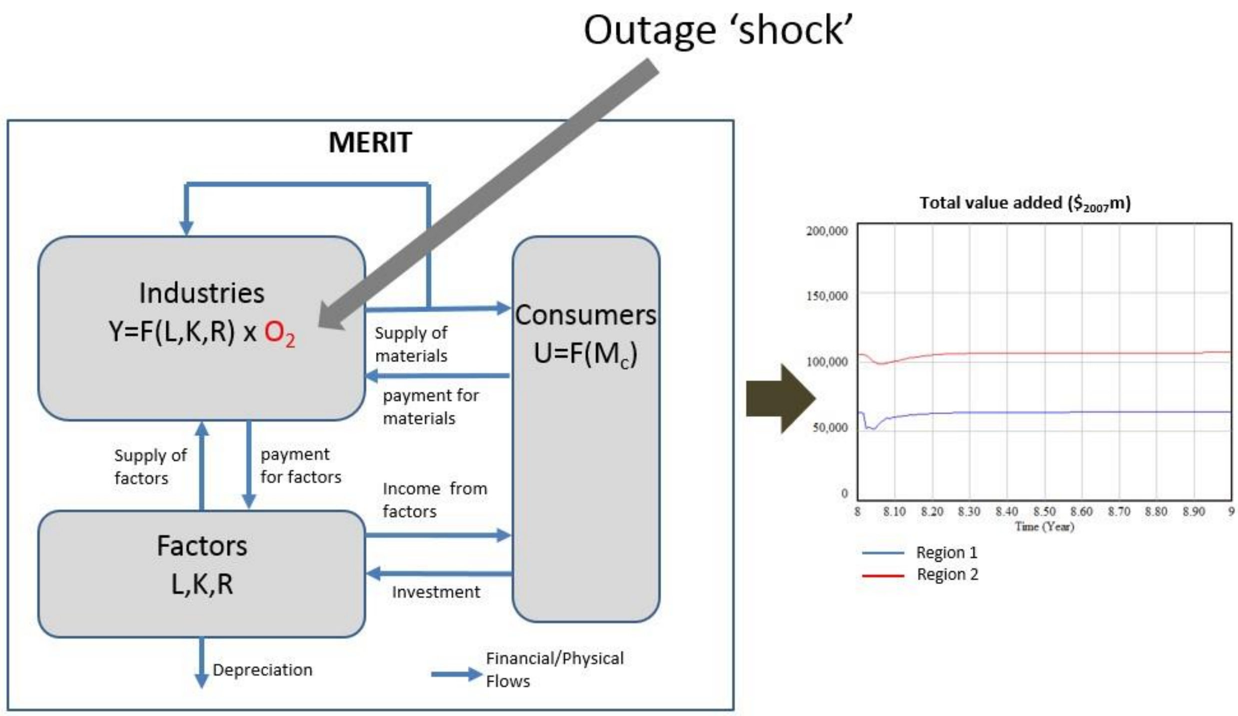


Figure 2 Measuring the Economic Resilience of Infrastructure Tool (MERIT). Note: Y = output, L = labour, K = capital, R = natural resources, U = Utility and Mc = materials/commodities. The 'F' represents is a function of.

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 equals demand for all commodities and factors, and income equals expenditure for all economic agents). For an 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 exhibit out-of-equilibrium behaviour e.g., including industries operating at a loss. MERIT is a *simulation* model that shows a *transition pathway* towards equilibrium. It is not necessary that an equilibrium is 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 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 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 because of production supply chains (i.e., 'indirect' effects) and changes in consumer spending because 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 can produce a variety of indicators to help us evaluate the impacts of an infrastructure outage, including GDP, regional value-added (like 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.
- 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 separate analyses for different benefits and costs), applications of MERIT are less-likely to result in the overestimation of impacts through double-counting,[11] 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).

[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 rich 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.

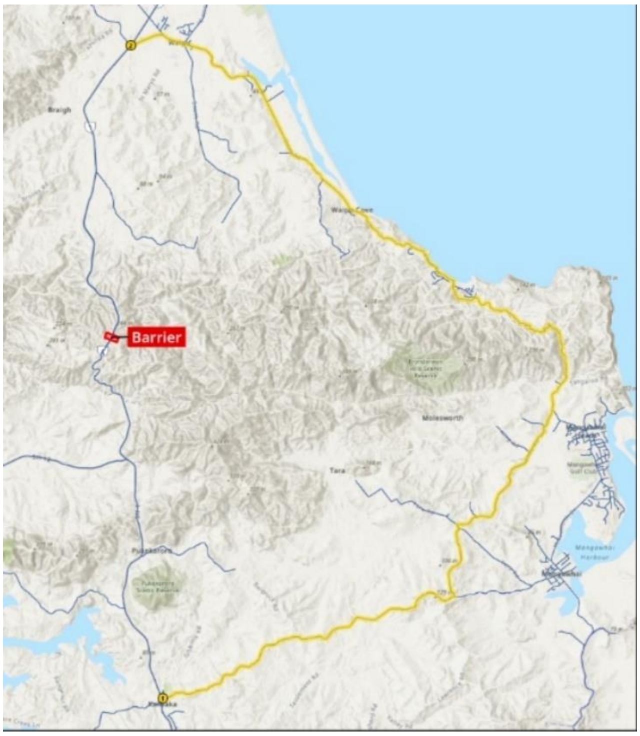
[11] When undertaking a welfare or cost-benefit analysis of a road outage it would, for example, be easy to double count the costs of additional travel to work, both as a loss of leisure time and reduction in labour.

3 Results

3.1 Specification of the outage

As above the outage was assumed to occur for 58 days. To simulate the rerouting associated with the outage a 'barrier' was put in place as per Figure 3 below. This barrier induces the rerouting behaviour; with the primary detour following the agreed Waka Kotahi detour route for the segment (via Mangawhai).

Figure 3: Closure barrier position (in red and named) and primary detour route (in yellow)



3.2 Economic Impacts

Although the outage is for a 58-day period, the impacts simulated by MERIT extend over a 1-year period. Transport margins are estimated to increase by $62 million[12], and household vehicle operating costs by $9.94 million. Furthermore, household consumption (a measure of welfare) increases by $40.86 million. 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 because the model incorporates some lag time for changes in firm production decisions. Table 2 shows the accumulated changes in value added over the 1-year period. Total value-added losses equate to

[12] All values are in $\$NZ_{2023}Q1$ millions unless otherwise stated.

$54.50m. Most heavily impacted are the wood and paper manufacturing ($28.44m), food manufacturing ($19.50m), and forestry and logging ($15.28m) industries.

Table 2: Accumulated Change in Value Added ($\$NZ_{2023}Q1m$)

	Total Impacts
Sheep, beef & grain farming	-1.37
Dairy cattle farming	-1.24
Forestry & logging	-15.28
Other agriculture	-2.11
Mining	-0.25
Food manuf	-19.50
Wood & paper manuf	-28.44
Chemical & mineral manuf	-5.22
Other manuf	-0.62
Utilities & construction	-3.73
Trade & hospitality	-2.24
Road transport	37.88
Other transport & storage	-7.95
Other services	-4.35
TOTAL	-54.40