South Island Model: development and calibration

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ABSTRACT

This paper reports on the development of a regional transport model for New Zealand's South Island in AIMSUN traffic simulation software. The model will be useful for road controlling authorities, planners and decision-makers to test different contingency scenarios in case of natural disaster such as earthquake, wildfire, flooding, tsunami, etc. The road network and other land use features were imported into AIMSUN from Open Street Map. The South Island was divided into 541 unit areas with centroids based on 2013 census data. An O-D matrix was created for light vehicles (commuting and tourism trips) and heavy vehicles (freight trips) based on 2013 census data, land use GIS shapefiles, Regional Tourism Organisation (RTO) data, and Ministry of Transport (MOT) data. The model was first calibrated macroscopically by adjusting the O-D matrix separately for light vehicles and heavy vehicles using the "Frank and Wolfe" static assignment method and based on detector loop traffic count data that were extracted from the NZTA website for the base year 2013. Then the model was calibrated at the mesoscopic level using the C-Logit Stochastic Route Choice method. Further publications will describe the validation of the model using data from the 2016 Kaikoura earthquake, as well as, outputs from the model when the Alpine Fault magnitude 8 (AF8) scenario is applied.

Keywords: Travel Demand Modelling, Transportation Modelling, Static OD Adjustment, Calibration.

1. INTRODUCTION

New Zealand is an island nation with a land area of 268,107km^2 and a population of 4,509,700 (NZIP, 2015). Earthquakes, volcanoes, storms, and glaciers have shaped the landscape of New Zealand over millions of years (ODESC, 2007). It consists of two main islands, namely the South Island (150,437km^2) and North Island (113,729km^2). The South Island is the larger island, dominated by the Southern Alps (ODESC, 2007), with a population of 1,004,400 (2013 census) and contains seven regions (Canterbury, Otago, Southland, West Coast, Malborough, Nelson, and Tasman). The role of infrastructure networks, especially the transportation network, in keeping industries connected to other regions and other parts of the world is undeniable. The transport network (road, rail, sea, and air) in New Zealand is a well-developed and well-connected infrastructure containing: 11,000km of State highways; 80,000km of local roads; Seven international airports; 28 regional airports with scheduled services; 4,000km of rail track; and 14 exporting seaports (MOT, 2017). The road network, in particular, plays a vital role in the transportation system. Around 70% of freight tonne-kilometres and more than 100 million bus trips are undertaken on the road network each year (MOT, 2017). The road network is also the main corridor connecting airports and seaports, and provides accessibility for most export and import goods. Although state highways cover just 12% of all roads in NZ, they carry around 50% of all flow (MOT, 2017). The South Island State Highways are long, narrow routes with little redundancy in case of emergency; in particular, just three corridors (SH7, SH73, and SH8) connect the east and west coast (Robinson et al., 2015).

New Zealand has experienced several natural disasters in recent decades. Among those, earthquakes have caused the highest number of causalities (184 deaths) and economic loss (US$28.5 billion) (EM-DAT, 2017). Three major earthquakes have hit New Zealand in recent years, all located in the South Island, including the Canterbury Earthquakes in 2010 and 2011, and the Kaikoura Earthquake in 2016. The Alpine Fault in the South Island is of significant concern in the region as a potential earthquake location in the future, and could be of higher magnitude than those experienced earlier (Berryman et al., 2014). Understanding the operational performance of the road network in the South Island in case of such an emergency is of vital importance for road authorities, managers and users.

This research is part of a National Science Challenge project - Resilience to Nature's Challenges - and aims to assess the resilience of the South Island road network to natural disasters. This paper outlines the first part of that research, the development and calibration of an inter-city travel demand model for the South Island. To that end, section two explains the methodology and section three determines the network creation process. Travel demand modelling is explained for light vehicle movements and heavy vehicle movements in section four and, finally, the calibration process in macroscopic and mesoscopic is expressed in section five.

2. METHODOLOGY

The overall methodology for the assessment of the resilience of the South Island road network to natural disasters is included in

Figure 1. This paper will discuss the process to establish the supply data and travel demand matrix in order to develop the base model, followed by the calibration procedure.

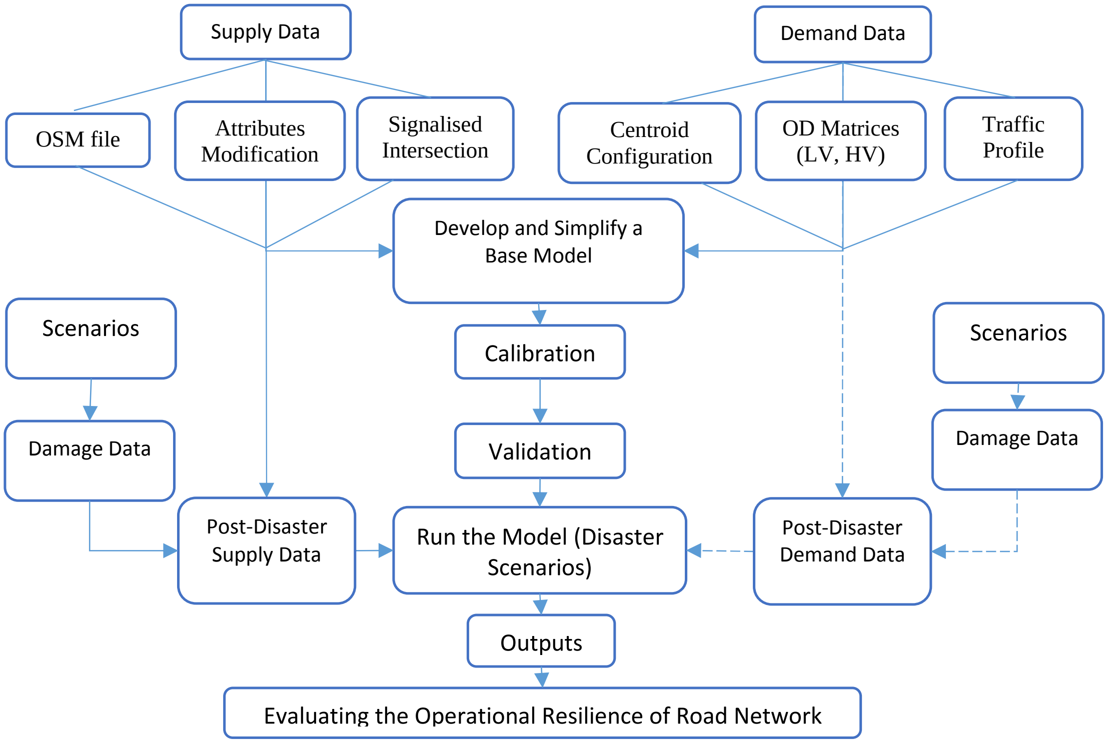


Figure 1: Methodology to assess the resilience of the road network to natural disasters

3. BASE NETWORK

Generally, three sources of data are required in a successful traffic simulation model, first for building the model, second for calibrating the model, and third for validating the model (TRB, 2010). Data required to build the model contains supply data, demand data, and land use distribution data. To build the network, the Open Street Map (OSM) file was imported to AIMSUN directly. The OSM file contains all categories of the road network, railways, waterways, land use, natural resources, and some other extraneous data. In this research, the road network is only modelled, therefore other imported transportation networks such as railways and waterways, and other extraneous data such as buildings, land use, and natural resources, were removed. All road network, links, and nodes, were imported as a network to AIMSUN. To check the accuracy of the OSM imported road network, the New Zealand road centreline GIS shapefile (LGNZ, 2017) was added as a layer to the model.

Since the OSM file contains all categories of the road network, and the research aims to model the main corridors in the South Island, there are many links which are unnecessary to model, and they were removed to simplify the network. The NZTA One Network Road Classification (ONRC) provides a classification system for the road network in New Zealand based on volume. ONRC divides roads into high volume, national, regional, arterial, primary, secondary, access, and low volume. This was used to select the main roads and alternative links on the model. Residential roads, service roads, and living streets (category of road network on OSM file) were first checked by ONRC, and then by google earth and google maps, to explore their importance. A number of unclassified roads (one category of road in OSM) were kept in the network model to use as alternative routes in case of disasters, even though their volume in normal conditions is low. The network configuration was examined for any errors, such as unconnected links and centroids, floating sections, conflicting turning and movements, and other such errors. These were then amended.

Imported road features, such as speed and capacity, were modified based on the Auckland Road Network Model features (developed by the Auckland Forecasting Centre) (Figure 2) due to the availability of the data. However, for cities and urban areas, the speed was reduced to 50km/h. In Christchurch, the speed on the motorway and highways was reduced to 80km/h, and for the rest of road types, it was set to 50km/h. Further amendments are planned to better reflect the driving environment of the South Island.

The detectors were located on the network model based on their geographic coordination systems, their reliability, the scope of the project, and their relevance to the research project. A total of 620 detectors were located on the network at 310 locations providing excellent coverage of the main highways and corridors.

4. TRAVEL DEMAND MODELLING

There are two ways to import demand to the road network; traffic states and an Origin-Destination (OD) matrix (TSS, 2017). Traffic states can be operated when flows on the sections are known. The required data for traffic states are observed section flows and turning proportions at each intersection. The route choice model is not practical in this method (TSS, 2017). The OD matrix is based on the number of trips between centroids for each vehicle type, trip purpose and time period. The critical part is the process of creating the OD matrix based on the aim and scope of each particular project. The OD matrix is usually shaped by land use and demographic datasets. While more steps, data, and sophisticated analysis are usually required to create the OD matrix for the network, it provides more capability to investigate traveller activity (TSS, 2017).

The first step is to select the best centroid configuration regarding the scope of the network, availability of datasets, and trip purposes. As the latest census data in New Zealand is for 2013, all land use, demographic, business data, and GIS shapefiles for this year were extracted and utilised. The census data is available in four levels, mesh block, unit areas, districts, and region. Given the scope of this project, modelling inter-city trips on regional and main corridors, the unit areas were selected as the basis of centroid configuration. Therefore, 541 centroids were inserted representing each unit area. The next step is to collect data from relevant sources and create an OD matrix based on three different travel purposes, namely commuting, tourism, and freight. The first two cover light vehicle movements and the third one covers heavy vehicle movements.

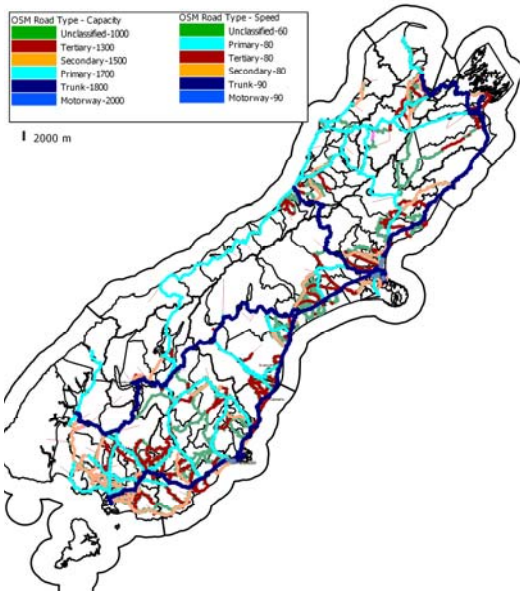


Figure 2: Road Network Hierarchy and Related Features

4.1. Commuter Trips

Commuter trips come from 2013 census data based on where people live and work. This data includes the number of commuter trips in and out of the unit area, the main means of travel, gender and employed population (StatsNZ, retrieved 2018). Respondents who were involved but did not state a workplace or stated a workplace address that could not be coded were assigned as 'New Zealand not further defined'; which is 8.5 percentage of respondents in the 2013 Census. Around 0.4 percent of respondents in the 2013 Census were coded to “no fixed address” as they stated multiple areas as a workplace, such as builders (StatsNZ, retrieved 2018).The dataset containing travel distances and the main means of travel between a unit area to the other unit areas was extracted and imported to an excel sheet. Then, all the trips were combined in one excel sheet, including all unit areas and the number of trips. Among all modes of travel, private car and company car trips were summed up and used in the OD matrix. Moreover, it indicates one-way trips to the workplace destination that is AM trips. Therefore, the created commuting matrix was transposed and considered as return trips or PM trips, assuming all return home. The total number of trips which has been generated as commuting or work trips is 323,484 trips.

4.2. Tourism Trips

The main source for tourism data is Statistics NZ (census data) and the tourism section of the MBIE website. There are two kinds of survey available for the tourism industry; the Domestic Travel Survey (DTS) and the International Visitor Survey (IVS). To determine the OD matrix for tourism trips, the tourism locations or hot spots, as a destination, and the origins, should be clarified. Two sets of information were utilised to find the OD matrix for domestic tourists; the number of trips (day, overnight and total) (StatsNZ, retrieved 2018) and trip distribution pattern based on bank transactions (MBIE, retrieved 2018). Unfortunately, availability of international tourist data was insufficient to create the international trips OD matrix. Consequently, it has been assumed international tourists exhibit similar behaviour to domestic tourists for the purpose of building the OD matrix.

The number of domestic trips was collected from the Domestic Travel Survey (DTS) which has been conducted by the Ministry of Tourism from 1983 to 2012, although there was no survey undertaken from 1991 to 1998 (MOT, 2008). The DTS defines a day trip as “a trip made within one day, outside the area in which the respondent usually lives or works day to day, involving travel of at least 40km one way from home, or travel by aeroplane or ferry service.” (MBIE, retrieved 2018). Day trip data have been collected based on the last seven days of the respondents return date. The overnight trip is as “a trip made in New Zealand, but outside the area in which the respondent usually lives or works day-to-day, which involves a minimum of one night away from home.” (MBIE, retrieved 2018). The overnight trips data have been collected for the last four weeks of the respondents return date. The applied total trips are the sum of the day and overnight trips. In this research, the total number of domestic trips were utilised to establish the source OD tourism matrix.

The trip distribution pattern between seven regions, as origins, and fourteen RTOs, as destinations, were developed based on bank transactions for the accommodation industry. First, the total number of bank transactions between fourteen RTOs as destinations and seven regions as origins were extracted for 2012. These data are sourced from BNZ, cover almost 20% of the New Zealand card market and is “geographically distributed broadly in line with the New Zealand population.” (MBIE, retrieved 2018). It was extracted for 2012 due to the availability of the total number of trips for this year. The address of the cardholders was used as the origin of trips, summarised to the seven regions in the South Island. Then, the number of accommodation transactions were utilised, due to their application as a tourism attraction criteria, to calculate the amount of accommodation transactions between RTOs and regions. The next step was to estimate the number of trips in this matrix. The total number of trips for each RTO was applied to calculate the annual and daily number of trips for RTOs and Regions. The issue is that the source of total trips is different from bank transactions which causes inconsistency in the Canterbury region. For the trips data, the Canterbury Region is divided into Hurunui, Mackenzie, Central South Island, and

Canterbury. However, for the bank transactions, it is divided into three different categories: Christchurch, South Canterbury, and North Canterbury. Therefore, the total number of trips for all the Canterbury Region were split into the three aforementioned transaction catgories based on their transaction weight. Then the annual and daily number of trips between each region to the RTOs was calculated.

The next step was to find the main attraction location in each RTO and the number of accommodation outlets. Each location corresponds to a unit area, therefore the centroid of the unit area is used as a destination, and the number of accommodation outlets determine the weight of that unit area. The destination of each RTO and the number of accommodation outlets was extracted from the Regional Tourism New Zealand website (RTO, retrieved 2018). For the origin of tourism trips, the total number of trips for each destination is split up to all unit areas in each region based on the population weight. Finally, the OD matrix of the tourism trips was created based on the accommodation transactions, number of accommodation outlets, population weight, and total number of tourism trips.

4.3. Heavy Vehicles Trips

Heavy vehicle travel demand is divided into two parts: freight demand and tourism demand. The freight travel demand is created based on a study by the Ministry of Transport (MOT) known as the “National Freight Demand Study (NFDS)”. NFDS, first undertaken in 2008, is one of the most comprehensive studies available to help forecast the future national and international activity in freight movements (NFDS, 2014). Data, from 2012, for 19 different commodities for the South Island were extracted containing movements between different regions, reported in million tonnes. Tasman, Nelson, and Marlborough are regarded as one region in this set of data. Therefore, TNM, West Coast, Canterbury, Otago, and South Island are the regions. This set of data is for all modes of transportation including road, railway, and coastal shipping. Total movements, in million tonnes, were then converted to the number of road trips based on the percent of road movements and the average payload of 10 tonnes per heavy vehicle (NFDS, 2014). Finally, the daily trips were calculated for each commodity between the five regions. Three different movements are reported in the NFDS program, namely exports, imports, and domestic. Movement of wool, steel and aluminium, and other minerals were ignored due to negligible movements. Horticulture and other agriculture products were combined, as well as manufacturing and general freight. The data used to distribute movements between centroids is shown in Table 1.

4.3.1. Liquid Milk movements

Liquid milk movements account for approximately 9% of the total freight movements in 2012 (NFDS, 2014). The main movements of liquid milk are from farms to dairy processors and factories. The NFDS data has been obtained from five main processors including Fonterra, Westland Milk, Open Country, Mirika, and Tatua. The SI produces more than a third of the total liquid milk, and Canterbury and Southland are the leading producers in the SI. South Island key dairy factories were extracted from the websites of each processors. These factories and related centroids are a destination for liquid milk movements. The origin is the farmlands area, which was extracted from the GIS shapefile labelled grassland (Table 1). To clarify the accuracy of farmland data, the number of employees “A014 Sheep, Beef Cattle and Grain Farming” were added to the Unit Areas (centroids) data. In this case, if there was an employee on that unit area, then the farmland area was considered for the next step, otherwise, it was regarded as zero. The weight of origin centroids was calculated using Equation(1).

$$\text{DistributionWeight}_{Commodity_i} = \frac{W_{C_i R_j}}{\sum_{i=1}^{n} W_{C_i R_j}} \qquad (1)$$

Where the commodity is liquid milk, $W_{C_i R_j}$ indicates the weight of centroid in the given region, C_i indicates the centroids, and R_j indicates specific region such as Tasman, Nelson, Marlborough

(TNM), Canterbury, Otago, Southland, and West Coast. Therefore, based on origin weight and destination, the trips were distributed.

Source	Organisation	Details	Description
Land Use and Carbon Analysis System (LUCAS) Land Use Map (LUM)	Ministry of Environment	Natural forest	Areas since 1 January 1990
		Pre-1990 planted forest	Areas on 1 January 1990
		Post-1989 forest	Includes post-1989 planted forest
		Grassland – high producing	grassland with high-quality pasture species
		Cropland – perennial	all orchards and vineyards
		Cropland – annual	• all annual crops • all cultivated bare ground
Business Demography Tables	NZ Stat	A014 Sheep, Beef Cattle and Grain Farming	Liquid milk movements
		A03 Forestry and Logging	Log movements
		C141 timber dressing	Timber Movements
		C149 Other Wood Products	Timber Movements
		C111 Meat and Meat Product Manufacturing	Meat and Meat Product movements
		C114 Fruit and Vegetable Processing	Horticulture and other agriculture
		A020 Aquaculture	Fish Movements
		C112 Seafood Processing	Fish Movements
		C203 Cement, Lime, Plaster and Concrete Product Manufacturing	Limestone, cement and fertiliser movements
Land Information New Zealand (LINZ)	LINZ	NZ Topo50 land cover data	NZ Landfill Polygons (Topo, 1:50k)
			NZ Mine Polygons (Topo, 1:50k)
			NZ Quarry Polygons (Topo, 1:50k)
National Freight Demand Study	MOT	19 different commodities	Movements in million tonnes between regions
Livestock Movements	MOT	Number of movements of livestock between territorial local authorities (TLAs)	

Table 1: Utilised Sources to Distribute Movements between Centroids

4.3.2. Milk and Dairy Products: Manufactured Dairy Products Movements

Two kinds of movements were considered for dairy products, domestic and export, the majority of which are for domestic trips. The movements mostly occur between the factories or processors either for distributing purposes or process completion storage purposes (NFDS, 2014). The export movements happen between factories and ports, both of which are known. For domestic movements the destination is not clear. Therefore, the population of unit areas were regarded as a distribution parameter. Based on Equation(1), the weight of destination centroids was calculated for this commodity. Finally, two OD matrices are created for dairy products.

4.3.3. Log, Timber and Wood Products Movements

Almost 15% of the total freight task in tonnage is attributed to forestry and forest products, and around 30% of the total harvested-prone forest area is in the South Island (NFDS, 2014). The two main movements for this commodity are logs and timber products, and these include export and domestic trips. Two kinds of data clarify the origin of logs; forest areas and number of employees “A03 Forestry and Logging” category (Table 1). Therefore, if there was an employee on a unit area, the forest area was considered as a weight, otherwise as a zero weight. The destination was extracted from a NZFOA (2012) report, forest owners, and their location was found from their websites. For the timber movements, the origin was taken from the number of employees in “C141 timber dressing”, and the destination was taken from employees in “C149 Other Wood Production”. The trips for timber export happens between timber dressing companies (C141) and ports.

4.3.4. Livestock Movements

Livestock farming is one the most important users of the road network in New Zealand. Most of the movements are originated from farms to other farms and meat works or sale yards. The total number of daily trips between territorial local authorities (TLAs) was taken from the MOT website. The grassland area (Table 1) were utilised to the centroids as a weight of distribution. Therefore, the movements from farms to farms were created. Due to lack of information, other movements were not considered.

4.3.5. Meat and Meat Products Movements

Among export, import and domestic movements for meat and meat products, the export movements were just considered and the rest of the movements were ignored due to the low number of trips. Geographic units of meat and meat products manufacturing (Table 1) were taken as the weight for the origins. Then, the OD matrix was created between meat processors and ports.

4.3.6. Horticulture and other agriculture Movements

Export and domestic trips were considered for the horticulture movements. Cropland data (Table 1) were utilised at the centroids as a weight of generated trips for exports and domestic trips. The number of horticulture processors in each unit area were taken from the “fruit and vegetable processing” dataset (Table 1) and were regarded as a destination weight for domestic trips.

4.3.7. Fish Movements

Most of the fish movement trips occur between ports and processing plants. Distribution of landed fish to the processors is performed by road network (NFDS, 2014). Both export and domestic trips are considered. The aquaculture employee numbers (Table 1) were applied as a generation weight and seafood processing employee numbers (Table 1) as an attraction weight.

4.3.8. Coal Movements

Due to the lack of information for domestic and import trips, only export movements of coal were considered. Therefore, the mine GIS shapefile was used to find the location and number of mines in each unit area, which was then used as the destination weight.

4.3.9. Movements of Aggregate

Internal movements of aggregates were created based on quarry locations and numbers (Table 1) as a generation weight and population as a destination weight. It was assumed that a more populated area would result in more aggregate consumption and more trips to that area.

4.3.10. Movements of Limestone, Cement, Fertiliser

Two sets of OD matrices were created for this commodity, one for imports and one for domestic. The trips were distributed based on number of employees of cement, lime, plaster and concrete product manufacturing (Table 1) as a generation factor and ports or population as an attraction factor. It was assumed more populated areas consume more of these products.

4.3.11. Waste Movements

It was assumed that waste movements start from each unit area to the landfill locations. The landfill locations were taken from a GIS shapefile (Table 1). Therefore, trip distribution was implemented based on population weight of each unit area and landfill locations.

4.3.12. Total Manufacturing and Retail Movements

This type of movement contains general movements of goods between unit areas and to or from the ports, main proportion of HV trips on the network. The weight of distribution for each unit area was calculated based on the following equations:

$$\mathrm{WeightOfPopulation(WoP)} = \frac{\mathrm{PW}_{\mathrm{C_iR_j}}}{\sum \mathrm{PW}_{\mathrm{C_iR_j}}} \tag{2}$$

$$\mathrm{WeightOfBusinessUnits(WoBU)} = \frac{\mathrm{BUW}_{\mathrm{C_iR_j}}}{\sum \mathrm{BUW}_{\mathrm{C_iR_j}}} \tag{3}$$

$$\mathrm{DistributionWeight}_{\mathrm{GeneralMovements}} = \frac{\mathrm{WoP} + \mathrm{WoBU}}{2} * 100 \tag{4}$$

Therefore, the average weight of population and business units were utilised as a weight of generation and attraction for general internal movements.

4.3.13. Tourism Heavy Vehicle Movements

For the tourism demand, there is no need to create a new matrix, as the OD matrix formed for light vehicles was used. The number of trips used for tourism, heavy vehicle movements, is assumed to be 1% of light vehicles movements.

4.3.14. Overall Source OD Matrix

Finally, all created OD matrices for HVs movements were summed up in one OD matrix, ready to import to the network. Therefore, three different matrices were applied to the network, commuter trips and tourism trips corresponding to light vehicles, and freight trips representing heavy vehicle trips. These are source OD matrices for three different purposes. All of these matrices indicated the trip distributions for the whole period of simulation, which is 24 hours. Hourly traffic release profile for each region, as well as for the whole South Island, were calculated based on available Average Weekday Hourly Traffic (AWHT) for 42 sites on the whole network, including 12 in Canterbury, 14 in Otago, 6 in TNM, 4 in West Coast, and 5 in Southland. There was not a significant difference between traffic profiles of each region, consequently, the traffic profile for the whole SI was applied to the matrices to generate hourly trip distribution matrices.

5. CALIBRATION PROCESS

The most critical and difficult steps of simulation are calibration and validation. Calibration can be performed based on one parameter or a set of parameters. The geographical scale of the network, the objective of the research, and the type of the network should be considered in selecting the appropriate parameter(s). However, the proposed calibration process for AIMSUN by Casas et al. (2010) considers two types of parameters (behavioural model or dynamic traffic assignment model) and their nature (global and local parameters). The summarised general process is (Casas et al., 2010):

1. Calibration of behavioural models using global parameters (all vehicle type parameters, such as reaction time, reaction time at the stop, speed acceptance, etc.)
2. Calibration of behavioural models using local parameters (all section and node parameters that have an influence on the vehicle behaviour, such as local reaction time variation, jam density,

lane-changing zonification of the section)

3. Calibration of dynamic traffic assignment using global parameters (number of different alternatives to consider, the time interval, the default cost functions parameters, etc.)
4. Calibration of dynamic traffic assignment using local parameters (scale factor per OD pair, cost function for an individual section, etc.).

The calibration was performed based on a comparison of real count data and the model assigned count data for selected detectors on the network. At the macroscopic level, XY scatter plots and R square were used. The equation of the line of best fit indicates how well the assigned and real data are matched (NZTA, 2014). The R square value is another measurement to check the model performance. The R squared and line of best-fit criteria for the model category of “A: Regional” should be more than 85% and y=0.9x-1.1X, respectively. At the mesoscopic level, an hourly GEH of less than 5 and 10 are used in addition to XY scatter plots and R squared. The GEH determines the tolerance of relative and absolute errors on the network using the following Equation, where m is the modelled count and o is the observed count (NZTA, 2014).

$$\mathrm{GEH} = \sqrt{\frac{2(m-o)^2}{(m+o)}} \tag{5}$$

The GEH statistic considers “the larger percentage differences on lower counts and larger absolute differencies on higher counts”. The related hourly GEH count criteria based on model type A should be less than 60% for GEH<5 and less than 90% for GEH<10 (NZTA, 2014).

5.1. Static Assignment for 2013

The real count data (NZTA, 2017) were assigned to the detectors on the modelled network in an hourly base for comparative purposes. As mentioned previously, in this study 622 detectors, located at 311 different geographically well spread sites, are applied in the calibration process. The demand source matrix for light vehicle and heavy vehicle movements were produced as described in the previous section. The total number of generated commuter trips, tourism trips, and freight trips were 323,484, 68,097 and 16,778, respectively. Hourly traffic demand for the three purposes over 24 hours were utilised and assigned to the network macroscopically based on the “Frank and Wolfe” method. The result returned an R squared of 60.5% for the primary created OD matrix for all purposes (Figure 3). The overall GEH<5 is 53.14% (330 sites) and GEH<10 is 83.25% (517 sites).

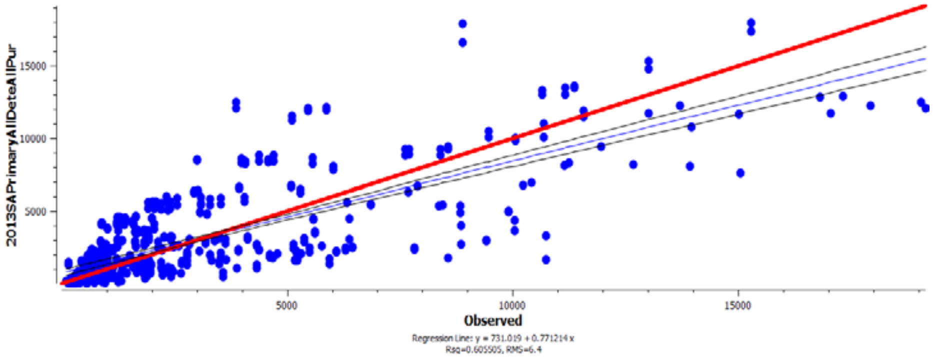


Figure 3: XY Scatter plot for Static Assignment of Primary 2013 OD matrix

This result is for all detectors on the network regardless of their locations and counts. Given that this study is for inter-city movements, detectors near cities, mostly with high flows, can alter the results. This is because of the lack of other city trip purposes, such as shopping, education, and other daily trips in the model. To eliminate these impacts, real data set locations were limited to the highways. Therefore, the number of detectors were reduced to 250 (125 sites), all in the main corridors away from cities. The result illustrated some improvement in the R squared, around a 13% increase (R squared is 68.3%) (Figure 4). The overall GEH<5 is 60.96% (153 sites) and

GEH<10 is 86.85% (218 sites) which indicates a 14.7% increase in GEH<5 and 4.3% increase in GEH<10. These results do not meet the NZTA criteria, and needed to be altered to match with the count data. Therefore, the next step was to use the "Static OD Adjustment" process to adjust the primary created OD matrix using real count data on each detector. The applied algorithm "is based on a bi-level model solved heuristically by a gradient algorithm, and includes an assignment at each iteration" (TSS, 2017). This process was first used to adjust the light vehicle movements and then heavy vehicle movements, separately. The result of the static assignment of source LV OD matrices shows an R squared value of 59.6% (Figure 5a). Using the static OD adjustment process, the total number of commuting trips were increased from 323,484 to 516,217 (59.6% increase) trips and the total number of tourism trips were decreased from 68,097 to 65,081 trips (4.4% decrease). The R squared increased to 99.2% (Figure 5b).

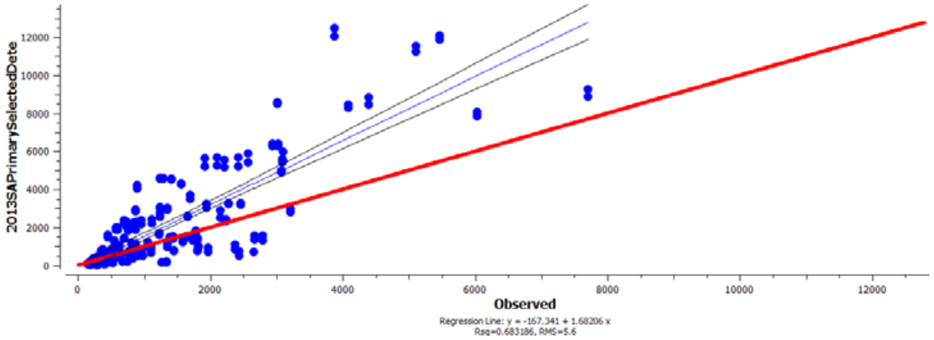
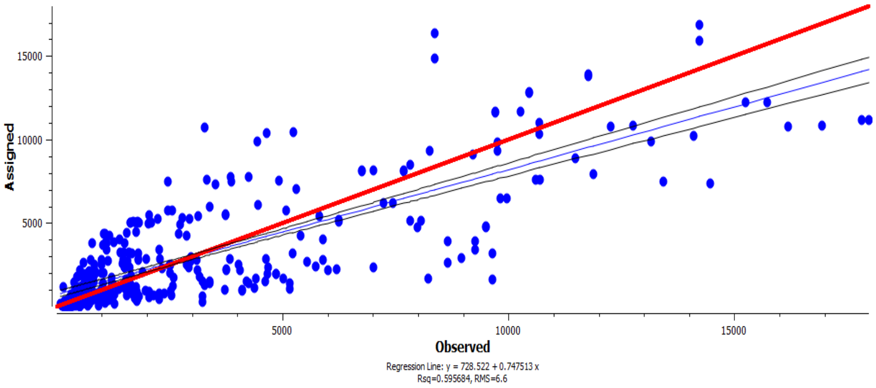
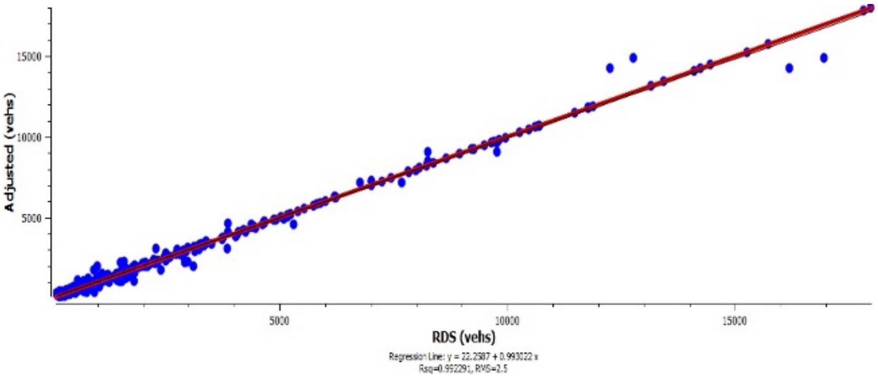


Figure 4: XY Scatterplot for Static Assignment of Primary 2013 OD matrix (for Selected Detectors)



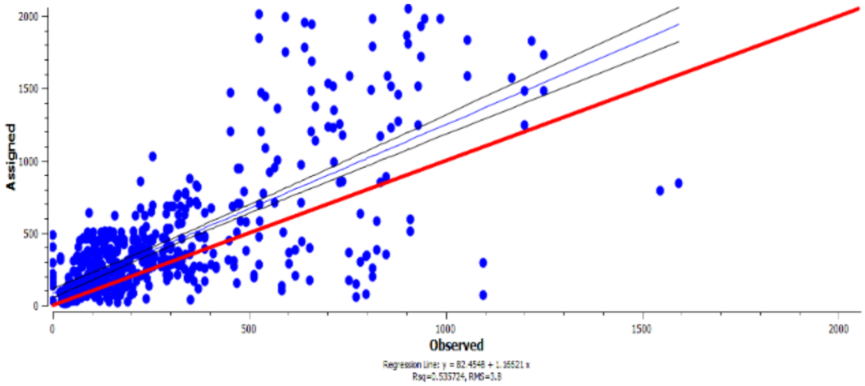
a) Before calibration



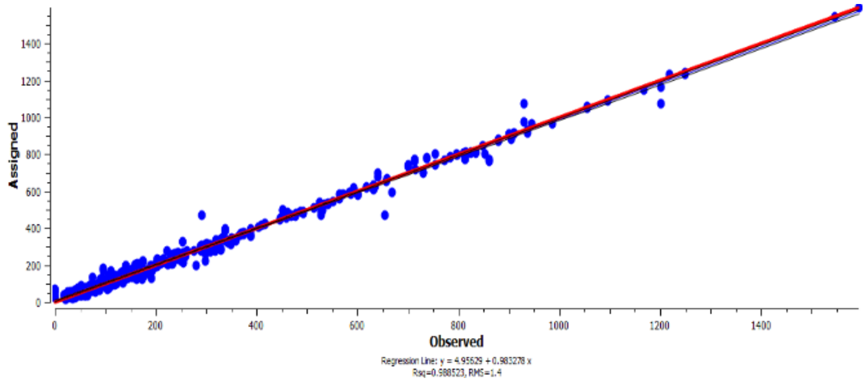
b) After calibration

Figure 5: XY Scatter plot for Adjusted Light Vehicle 2013 OD matrix

Static assignment of heavy vehicle movements on the network returned an R squared of 53.6% for the source OD matrix assignment, and with OD adjustment it increased to 98.8% (Figure 6a and Figure 6b). The total number of trips also increased from 16,778 trips to 25,790 trips. This indicates a 53.7% increase in comparison to the source matrix, which is considerable, but when compared to the total number of trips in the network, it has only been altered by 2.2% of total trips.



a) Before calibration



b) After calibration

Figure 6: XY Scatter plot for Static Assignment of Primary Heavy Vehicle 2013 OD

Finally, a static assignment scenario was run based on all purpose adjusted matrices and an R squared of 99.2% was obtained. The summary of static OD adjustment is shown in Table 2.

Purpose	Source Trips	Adjusted Trips	R2 Source	R2 Adjusted	Explanation	
Commuting	323,484	516,217	59.6	99.2	59.6%	47.2%
Tourism	68,097	65,082			-4.4%	-0.7%
Freight	16,779	25,790	53.6	98.8	53.7%	2.2%
Total	408,360	607,089	-	-	48.7%	48.7%
R2	60.5	99.2	NA	NA	622 Detector	
R2	68.3	NA	NA	NA	250 Detector	

Table 2: Summary of Static OD Adjustment Process

As can be seen, the total number of trips increased by 48.7%, with commuting trips accounting for 47.2% of all adjustments. This indicates that most adjusted trips happened on commuting trips, due to the lack of other trip purposes in cities being considered. For instance, Figure 7 illustrates the numerical differences of LV movements between districts as an origin (X-axis) and Ashburton centroids (legend). The districts have been arranged based on distance to Ashburton District, travelling north or south. Most of the alterations occurred among Ashburton centroids. This indicates that the adjusted trips occurred near urban areas to match the modelled count trips to the observed count data. Analysis of other districts also displays the same trend, with most of the adjusted trips occurring in adjacent centroids in the same district areas. For HV adjustment process, it happens in different patterns depending on the movements and number of trips between centroids (Figure 8). However, most of the adjustments occurred among neighbour districts and some major districts. For instance, lots of movements was adjusted between Christchurch city, as the main city, and Ashburton District. Timaru and Selwyn Districts are also two adjacent districts in the north and south of Ashburton with significant trips adjustment. Similar to LV, the majority of movement changes happened among Ashburton centroids.

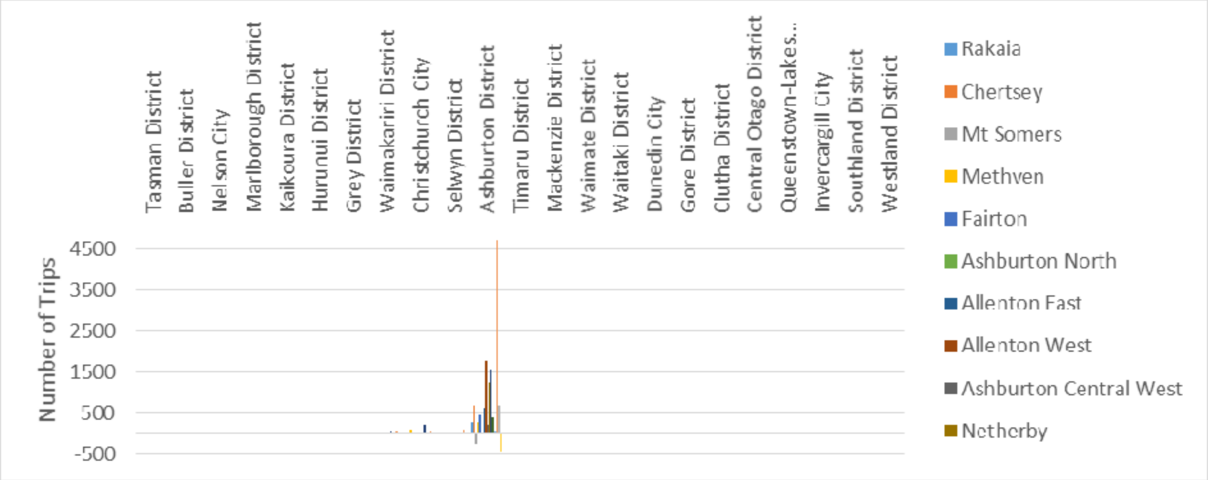


Figure 7: Variation of Primary and Adjusted OD matrix for Ashburton District on LV Movements

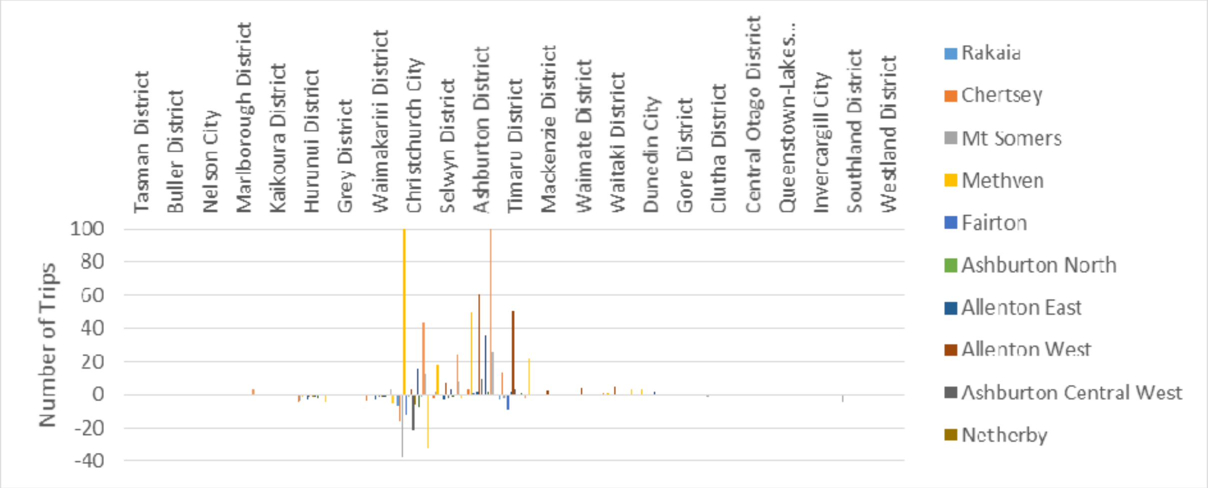


Figure 8: Variation of Primary and Adjusted OD matrix for Ashburton District on HV Movements

5.2. Dynamic Assignment (Mesoscopic Scenario) for 2013

The static assignment provides a travel demand matrix and a path assignment for the next step, dynamic assignment. The dynamic mesoscopic calibration process was in two parts. The first part of calibration was performed based on light vehicle (LV) movements, due to the long process of creating OD matrices for heavy vehicle (HV) movements. LV movements were created earlier than HV movements and account for almost 90% of all movements on the network. After 19 different runs, altering a variety of parameters including warm-up time, path assignment, assignment model, number of shortest path, scale, attractiveness weight, and control plan it was found that the Stochastic Route Choice, C-Logit model with a scale of 3 and K-shortest path (K-SP) of 2 are the most effective parameters to calibrate the network for LV movements using 2013 data. These parameters, were then applied to the scenario with the LV and HV trips. The general attributes of the mesoscopic scenario are:

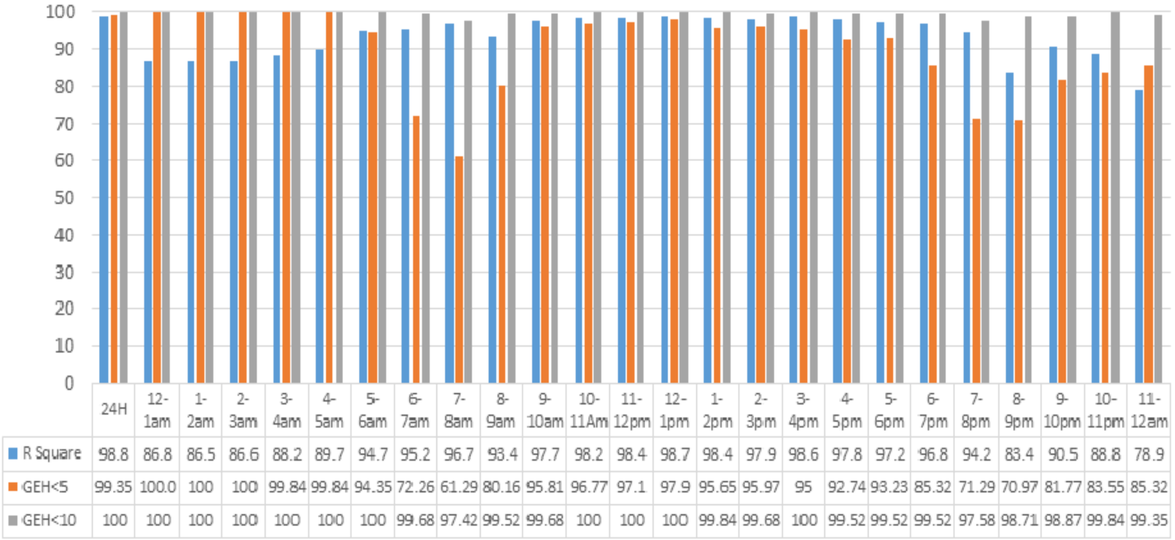
- Warm-up for 2 Hours,
- Use general traffic profile to create hourly OD matrix for each vehicle type
- Path assignment of static assignment
- Master Control Plan of "Actuated volume-base"
- One hour costs cycle
- Arrival: Exponential

Table 3 indicates four different runs to gain the best result for the mesoscopic scenario based on previous experience of the LV calibration process. On the last scenario (Run4), the main path of the static assignment without any sub-paths were applied on the dynamic assignment. In case of virtual queues, it asks the model to reassign the vehicles to the new route if they are in the virtual queue.

Run	Assig. Appr.	Model	Scale	K-SP	Beta	Saved Path Assig.	Enroute After Virtual Queue	Waiting Veh.	R2
1	SRC	C-Logit	3	2	0.15	Yes	No	4208	98.2
2	SRC	C-Logit	3	2	0.15	Yes	Yes	5158	98.2
3	SRC	C-Logit	3	2	0.15	No	Yes	0	96.4
4	SRC	C-Logit	3	2	0.15	No Sub-Path	Yes	0	98.8

Table 3: Used Parameters to Calibrate the Network

In the mesoscopic level, GEH should be examined against acceptable requirements rather than just the R squared value. As the type of this project is "Regional", the acceptable value for GEH<5 should be greater than 60% and GEH<10 should be greater than 90%. From Figure 9 it can be noted that the worst GEH<5 occurred at 7-8AM which is greater than the NZTA acceptable level of 60%. It is apparent from this figure that the R squared value and GEH<10 are acceptable in the AM and PM peak hours. Surprisingly, the GEH<5 suddenly dropped during AM peak hours which are likely to be related to the lack of directionality in the network. Contrary to expectations, there is also a relative lack of fit at the end of the day in the off-peak hours, although all are at an acceptable level. A possible explanation for this might be the higher modelled flow on the network during off-peak hours. However, it shows the network does not perform as well during off-peak hours after 7pm.



	24H	12-1am	1-2am	2-3am	3-4am	4-5am	5-6am	6-7am	7-8am	8-9am	9-10am	10-11Am	11-12pm	12-1pm	1-2pm	2-3pm	3-4pm	4-5pm	5-6pm	6-7pm	7-8pm	8-9pm	9-10pm	10-11pm	11-12am
R Square	98.8	86.8	86.5	86.6	88.2	89.7	94.7	95.2	96.7	93.4	97.7	98.2	98.4	98.7	98.4	97.9	98.6	97.8	97.2	96.8	94.2	83.4	90.5	88.8	78.9
GEH<5	99.35	100.0	100	100	99.84	99.84	94.35	72.26	61.29	80.16	95.81	96.77	97.1	97.9	95.65	95.97	95	92.74	93.23	85.32	71.29	70.97	81.77	83.55	85.32
GEH<10	100	100	100	100	100	100	100	99.68	97.42	99.52	99.68	100	100	100	99.84	99.68	100	99.52	99.52	99.52	97.58	98.71	98.87	99.84	99.35

Figure 9: Hourly GEH for 2013 Mesoscopic Scenarios

6. CONCLUSION

This research is part of a National Science Challenge – Resilience to Nature's Challenges project that aims to assess the resilience of the South Island road network to natural disasters. This paper outlined the first part of that research, the development and calibration of an inter-city travel demand base model for the South Island. The road network, including supply and demand data were initially created. The OSM file was operated as the base of supply data with modifications on default features. To simplify the network, unnecessary links were removed using ONRC, Goggle map and NZ road centreline GIS shapefile. The detectors were located on the network model based on their geographic coordination systems, their reliability, the scope of the project, and their relevance to the research project. The demand data for the whole South Island were created based on the unit areas centroid configuration and three main travel purposes, namely commuting, tourism, and freight. The required data were obtained from 2013 census data, land use GIS shapefiles, Regional Tourism Organisation (RTO) website, and Ministry of Transport (MOT) data.

The static assignment of primary created OD matrices returned a 60% R squared value, which did not meet the NZTA criteria for this type of project. Static OD adjustment was undertaken to alter the created OD matrix according to the real count data on the network, resulting in a much-improved R squared value of 98.8%, thereby meeting the NZTA criteria. Most of the OD alterations occurred in commuting trips and in adjacent centroids due to the lack of other city trip purposes included in the model. Then, the model was run in the dynamic mesoscopic level with the adjusted OD matrix. The R squared and hourly GEH results met the NZTA criteria.

A considerable amount of effort has been expended to create the source matrix for three different purposes and among 541 unit areas. There were some limitations, including lack of data for other urban trip purposes, inconsistency among agencies and organisations to provide source data, lack of road features data such as speed and capacity, and lack of detailed data for heavy vehicle movements. These limitations, especially the first one, caused considerable differences between source and final OD matrix around cities. However, the created source matrix and final adjusted matrix, based on 2013 census data, provide an excellent platform for future research. Further research will attempt to validate the model using data from the 2016 Kaikoura earthquake and, then, the Alpine Fault magnitude 8 (AF8) scenario will be applied to assess the resilience of the network.

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