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RESILIENCE FINDINGS

A Socio-spatial Analysis of Vulnerability to Increases in Motor Fuel Costs in Aotearoa NZ

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Findings

Increases in fuel prices can be driven by a range of factors such as supply chain disruption (e.g. COVID-19 and the 2026 Middle East conflict), general inflation, and changes to government policy settings (e.g climate related emissions reduction policies). Such increases have differential impacts and contribute to social inequity. We calculate a national level index of vulnerability to increases in motor fuel costs at the small area level for Aotearoa New Zealand, drawing on established methods. Those living in "accessible" rural areas near urban centres are more likely to be vulnerable.

1. Questions

Aotearoa New Zealand (NZ) is one of the most car dependent countries in the world; 96 percent of households have access to a car. Alongside this 91 percent of distance travelled, and 83 percent of all trips in New Zealand are made by car or van (Waka Kotahi NZ Transport Agency 2019).

When transport costs increase, the financial burden of car dependency increases. Those who cannot afford the increased costs spend less on other items, such as food, home heating or healthcare (Martiskainen et al. 2023; Sovacool et al. 2023) or travel less, restricting their ability to participate in out of home activities.

The impacts of fuel price increases are spatially uneven (Dodson and Sipe 2007; Mattioli et al. 2023; Mattioli and Fischer 2024; Mattioli et al. 2018). A previous study in Ōtautahi Christchurch concluded that most households could either maintain or adapt to fuel price increases, though some peri-urban areas were at risk (Rendall et al. 2014).

Our research questions are:

- What are the spatial patterns of vulnerability to motor fuel price increases in Aotearoa New Zealand?
- How is vulnerability distributed across different socio-demographic groups?

2. Methods

We draw on established methods to calculate and index fuel price vulnerability at the Statistical Area 2 (SA2)[1] level as a function of three factors: exposure, sensitivity, and income (Mattioli and Fischer 2024; Mattioli et al. 2018).

Exposure E

Exposure considers reliance on motor vehicle and therefore the level of susceptibility to fuel price changes, typically measured using metrics of car dependency, including household car ownership, proportion of travel by car and mode share or fuel expenditure (Mattioli et al. 2018). We use motorisation rate measured as the number of vehicles per 1000 population (Mattioli and Fischer 2024) (50%). A weighted proportion of work or education trips undertaken by car or van was also included in the exposure index (50%). These weights are defined as:

$$wTTWi = \frac{TTWi}{TTWi + TTEi}$$

$$wTTEi = \frac{TTEi}{TTWi + TTEi}$$

Where :

TTW = proportion of all trips to work that are made by car as driver or passenger

TTE – proportion of all trips to education that are made by car as driver or passenger

Exposure is expressed as:

$$Ei = 0.5Mi + 0.5(wTTWiTTWi + wTTEiTTEi)$$

Where:

M=motorisation rate

Sensitivity S

Sensitivity considers the extent to which the population is affected by price change, often measured using socio-economic disadvantage, household income or unemployment (Mattioli et al. 2018). We use median household income from Census 2023 adjusted with regional equivalised values and cost of living, to reflect considerable disparities in housing costs between regions.

1 SA2s are a statistical unit that aims to reflect communities that interact together socially and economically (Stats NZ 2023). https://www.stats.govt.nz/assets/Methods/Statistical-standard-for-geographic-areas-2023/Statistical-standard-for-geographic-areas-2023.pdf

We calculated the proportional difference between median household gross income and equivalised disposable income after deducting housing costs at the regional level and applied the difference to SA2 level median income (adjustments are in the Appendix)[2].

Adaptive capacity AC

Adaptive capacity refers to potential to reduce demand for fuel typically measured through access to public transport (Mattioli et al. 2018).

We calculated the number of public transport stops within an 800m (~10minute) walk of population weighted meshblock[3] centroids and then calculated the mean number of stops accessible from meshblocks within each SA2. We combine access to all stops (PT)with access to stops with a frequent service (PTF).

Given the lack of public transport outside of main urban centres, we propose that proximity to services, even where public transport does not exist, is an important component of adaptive capacity. More accessible services means that people face shorter car-based travel distances. Furthermore, where people are able to access destinations closer to home, they may be able to adapt by walking or cycling.

We therefore use the access to service domain from the 2023 New Zealand Index of Multiple Deprivation (IMD). IMD measures the concentration of deprivation by small neighbourhood area and can be disaggregated into its component domains (Exeter et al. 2023). The access to services domain is an index of drive time-based accessibility to the nearest 3 of each of the following services: health, education, supermarket and service stations.

Adaptive capacity is:

$$ACi = 0.5Ai - 0.25PTi - 0.25PTFi$$

Where:

A = Access to services domain of the index of multiple deprivation

PT = Mean number of bus stops accessible within 800m from meshblock centroids within SA2

PTF = Mean number of bus stops with a frequent service accessible within 800m from meshblock centroids within SA2

The overall index (VI) can be expressed as:

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2 https://www.stats.govt.nz/information-releases/household-income-and-housing-cost-statistics-year-ended-june-2025/

3 A meshblock is a small geographical unit used by StatsNZ to collect, aggregate and analyse data https://datafinder.stats.govt.nz/layer/120980-meshblock-2025/

Table 1. Factors in the overall vulnerability index

Vulnerability factor	Component of factor	Weighting within factor	Overall index weighting
Exposure	Motorisation rate – number of vehicles per 1000 population (StatsNZ 2023a; 2023b)	50%	33.3%
	Proportion of travel to work trips by car as driver or passenger (StatsNZ 2023a).	50% - weighted by proportion of work and education trips that are -work trips -education trips	
	Proportion of travel to education trips by car as driver or passenger (StatsNZ 2023a).		
Sensitivity	Median household income (StatsNZ 2023a) adjusted for y region level disposable income after deducing housing costs – Household Income and Living Survey 2025 (StatsNZ 2026)** (see Appendix)	100%	33.3%
Adaptive capacity	Access to services domain of the NZ Indices of Multiple Deprivation (IMD) 2023 (Exeter et al. 2023; 2017)	50%	33.3%
	The mean number of public transport stops within 800m of each population weighted meshblock centroid in the SA2 (Waka Kotahi New Zealand Transport Agency 2023). **	25%	
	The mean number of public transport stops with a route with frequent departures[a] within 800m of each population weighted meshblock in the SA2 –(Waka Kotahi New Zealand Transport Agency 2023).**	25%	

[a]defined as a stop served by at least one route with a scheduled frequency of at least every 15 minutes 29 seconds, between 7am and 7pm, 7 days a week

** These items are inverted in the indicator calculation as they operate in the opposite direction to other items

$$VIi = \frac{Ei - Si + ACi}{3}$$

Table 1 details the components of the index and the sources of data.

We excluded SA2s with a usual resident population of less than 12 as they had missing data for other census variables. We also deleted SA2s with no IMD measure, typically oceanic or coastal inlet areas. The final dataset includes 2265 SA2s.

We analyse the index according to socio-demographic characteristics to understand how vulnerability is distributed across different groups. We consider the following socio-demographic characteristics: age, gender, ethnicity, disability (Census 2023) rurality (NZ Geographic Classification for Health (Whitehead et al. 2021), and area level socioeconomic deprivation based on the New Zealand Index of Deprivation (Atkinson et al. 2024).

3. Findings

Figure 1 shows the spatial distribution of the overall fuel vulnerability index, which can also be viewed as a web map. Rural and peri-urban areas are relatively more vulnerable to fuel price increases than main urban centres. 10.5% of the population in main urban areas are in the highest fuel vulnerability quintile (Table 2). Peri-urban or rural areas with high accessibility to urban centres are more likely to be in the highest risk quintile, with 38.8% of the population in these areas in VQ5 (Vulnerability Quintile 5). A smaller proportion of those in the most remote rural areas are in the

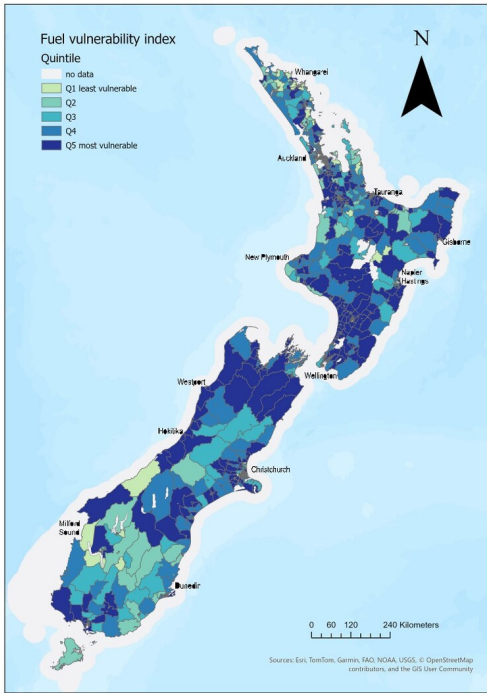

Figure 1. Overall fuel vulnerability index

most vulnerable quintile (16.8%), although over half of the population in remote rural areas are in the two most vulnerable quintiles. In absolute terms, there is a considerable number of people in the highest risk vulnerability index living in urban areas. Of 883,848 people in the most vulnerable quintile, 92% are in urban or peri-urban areas.

Those living in the most socioeconomically deprived areas are less likely to live in an area vulnerable to fuel price changes according to this index (Figure 3), as a result of proximity to services, including public transport, and slightly lower motorisation rates. Nevertheless, there are almost 200,000 people living in the most socioeconomically deprived areas (NZDep Deciles 9 and 10) who also live in areas most vulnerable to fuel price increases (VQ4 and VQ5).

Table 2 shows the distribution of fuel vulnerability quintiles by age, gender, ethnicity, rurality and disability.

Both younger (<15 years) and older (≥ 65 years) age groups are more likely to live in areas more vulnerable to fuel price increases. However, the median age increases across vulnerability quintiles, indicating that fuel price vulnerability may have a particularly large impact on older New Zealanders. Both European and Māori ethnic groups are substantially more likely to live in more areas with high vulnerability to fuel prices than other ethnic groups[4],

4 The "Other" ethnic group is also more likely to live in areas vulnerable to fuel price increases. A large proportion of this ethnic group reports "New Zealander" and are likely European New Zealanders.

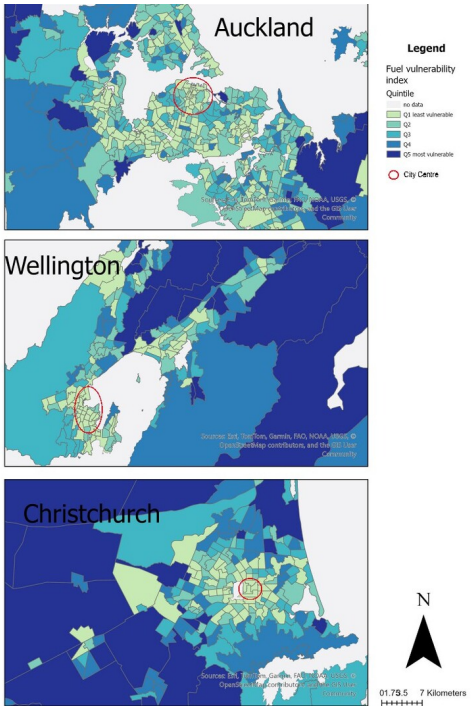

Figure 2. Fuel vulnerability index in three main cities

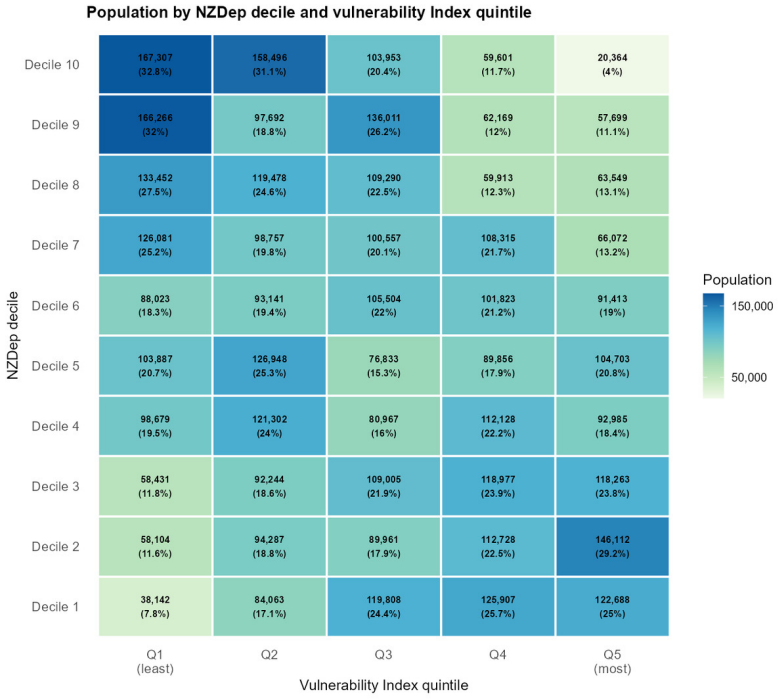

Figure 3. Population by NZDep decile and fuel vulnerability index quintile (Decile 10 = most deprived).

likely reflecting the urban social geography. There are no notable differences in spatial vulnerability between disabled and non-disabled populations or by gender.

While the most urban (U1) areas of NZ had the highest proportion of residents living in areas of low fuel price vulnerability (VQ1), a high proportion of residents in Urban 2 (U2, provincial centres), Rural 1, and

Table 2. Vulnerability Index Distribution by Socio-demographic groups

Variable	Q1 (least vulnerable)	Q2	Q3	Q4	Q5 (most vulnerable)
Total SA2s (n) (Census, 2023)	453 (20%)	453 (20%)	453 (20%)	453 (20%)	453 (20%)
Usual resident population (n) (Census, 2023)	1,038,372 (20.8%)	1,086,408 (21.8%)	1,031,922 (20.7%)	951,417 (19.1%)	883,848 (17.7%)
Households in occupied private dwellings (Census, 2023)	371,670 (20.9%)	380,250 (21.4%)	364,857 (20.5%)	339,438 (19.1%)	323,742 (18.2%)
Age group (Census, 2023)					
<15 years	176496 (18.9%)	207519 (22.2%)	200010 (21.4%)	184131 (19.7%)	167922 (17.9%)
15-29	254,424 (26.3%)	216,810 (22.4%)	195,636 (20.2%)	161,874 (16.7%)	139,167 (14.4%)
30-64	463,500 (20.5%)	492,225 (21.8%)	465,594 (20.6%)	433,194 (19.2%)	405,264 (17.9%)
≥65	143,958 (17.4%)	169,842 (20.5%)	170,673 (20.6%)	172,239 (20.8%)	171,498 (20.7%)
Median age (Census, 2023)					
Mean (SD)	37 (-7.7)	38.9 (-6.9)	40 (-7)	41.6 (-6.7)	43.5 (-5.6)
Gender (Census, 2023)					
Male / Tāne	509,436 (20.7%)	533,499 (21.7%)	507,285 (20.6%)	469,461 (19.1%)	439,836 (17.9%)
Female / Wahine	522,831 (20.8%)	548,400 (21.8%)	520,620 (20.7%)	478,908 (19.1%)	441,234 (17.6%)
Ethnicity (total response) (Census, 2023)					
European	591,741 (17.5%)	667,389 (19.7%)	701,172 (20.7%)	698,991 (20.7%)	723,354 (21.4%)
Māori	172,644 (19.5%)	193,287 (21.8%)	189,513 (21.4%)	170,409 (19.2%)	160,974 (18.2%)
Pacific Peoples	127,635 (28.8%)	119,067 (26.9%)	101,253 (22.9%)	63,852 (14.4%)	30,696 (6.9%)
Asian	260,715 (30.3%)	231,828 (26.9%)	166,599 (19.3%)	129,897 (15.1%)	72,186 (8.4%)
Middle Eastern, Latin American and African	28,758 (31%)	24,063 (25.9%)	18,036 (19.4%)	13,572 (14.6%)	8,310 (9%)
Other ethnicity	18,585 (16.5%)	22,737 (20.2%)	23,055 (20.5%)	23,373 (20.8%)	24,741 (22%)
Geographic Classification for health (Whitehead et al. 2021)					
Urban 1 (U1, Most Urban)	888,672 (27.8%)	803,676 (25.2%)	654,900 (20.5%)	511,014 (16%)	335,607 (10.5%)
Urban 2	87,228 (9.7%)	173,529 (19.4%)	201,774 (22.5%)	191,193 (21.4%)	241,062 (26.9%)
Rural 1 (R1)	30,450 (4.9%)	65,058 (10.6%)	116,919 (19%)	164,400 (26.7%)	239,115 (38.8%)
Rural 2 (R2)	27,612 (11.3%)	37,611 (15.4%)	53,322 (21.8%)	65,154 (26.6%)	60,861 (24.9%)
Rural 3 (R3, Most Rural)	4,410 (10.3%)	6,534 (15.3%)	5,007 (11.7%)	19,656 (45.9%)	7,203 (16.8%)
Disability status (Census, 2023)					
Not disabled	763,350 (20.7%)	800,139 (21.7%)	758,235 (20.5%)	708,825 (19.2%)	664,092 (18%)
Disabled	64,236 (21.5%)	64,632 (21.6%)	61,887 (20.7%)	56,118 (18.8%)	51,957 (17.4%)

Rural 2 areas lived in VQ5 areas of highest fuel price vulnerability. This likely reflects higher levels of motor vehicle reliance, lower levels of income, and the lack of available public transportation in rural and regional NZ, as well as longer travel times to services. Interestingly, the most remote communities (R3) had a relatively low proportion of people living in VQ5 areas of high fuel price vulnerability. This may reflect the strong relationship between socioeconomic deprivation and remoteness in NZ (Whitehead et al., 2024), and potentially lower rates of motor vehicle ownership in areas of high socioeconomic deprivation. Figure 3 suggests an inverse relationship between socioeconomic deprivation and the Fuel Vulnerability Index, potentially because car ownership is component of NZDep. In NZDep low car ownership is associated with higher levels of socio-economic deprivation, whereas in our index, households relying on car use are more vulnerable. This relationship could be further explored in future research.

Further, the indicator is an area-based measure of vulnerability to *change* in fuel prices in terms of the affordability of car use. Some populations in "less vulnerable" areas are likely to already have suppressed travel because of low motorisation and affordability difficulties – but may be in areas of high socio-economic disadvantage. Although we presented the distribution of the vulnerability index across different socio-demographic groups it is important to note that distributional analyses do not account for pre-existing injustices. Just because a particular group is less vulnerable to change, potentially because of reduced car reliance, does not mean that they are not transport deprived already because of limited car use.

As an area-based index, we present area level vulnerability but note that does not necessarily apply equally to individuals within those areas. For example, Adaptive capacity is based on spatial access to destinations or the public transport network, not on individuals' capacity to adapt based on socio-demographic circumstances. While the results show that disabled people are no more likely to live in *areas* that are most vulnerable to fuel price changes, the index does not account for social variations in adaptive capacity, and some disabled people may find it harder to use public transport.

Also important to note is that this is a *relative* index, showing areas that are most at risk. Being least vulnerable does not mean people living in those areas are not impacted by fuel price increases, but that relative to other areas, they may be less likely to experience the worst effects. However, as already noted, New Zealand is highly car dependent, meaning most people are likely to face some impacts.

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Appendix

Region	Income adjustment
Northland	-59%
Auckland	-68%
Waikato	-64%
Bay of Plenty	-61%
Gisborne / Hawke's Bay	-60%
Taranaki	-61%
Manawatū–Whanganui	-61%
Wellington	-65%
Tasman / Nelson / Marlborough / West Coast	-59%
Canterbury	-62%
Otago	-62%
Southland	-57%
All regions average	-64%

Income adjustments

Mean household income at the SA2 level is adjusted on a regional basis using the figures below. These adjustments are calculated at the regional level based on the difference between median household gross income and equivalised disposable income after deducting housing costs. Source: https://www.stats.govt.nz/information-releases/household-income-and-housing-cost-statistics-year-ended-june-2025/

SUPPLEMENTARY MATERIALS

Data

Download: https://findingspress.org/article/164147-a-socio-spatial-analysis-of-vulnerability-to-increases-in-motor-fuel-costs-in-aotearoa-nz/attachment/351440.csv