Risk Matrix: Fatal and Serious Injury Rates for Different Travel Modes in Victoria, Australia

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Abstract: Absolute injury numbers, commonly used as a road safety indicator, overlook the likelihood of injury relative to travel exposure. Adjusting crash and injury rates for exposure offers a fuller picture of safety by linking travel activity to crash outcomes. In Victoria, Australia, fatal and serious injury (FSI) numbers across nine travel modes were scaled by exposure to calculate FSI rates. These were then visualised in a risk matrix, plotting FSI rates (likelihood of injury) against absolute FSI numbers for each mode to assess both injury frequency and risk by travel mode.

Background

Since the early 20th century, transportation has cantered on the motorcar, leading to significant congestion, emissions, and safety challenges(Köhler, 2013; Schafer, 1998). Societal pressures, notably climate change, are now driving a shift toward alternatives like motorcycles, bicycles, and public transport, influenced by cost, efficiency, and demand(Lipschutz, 2012). This modal shift raises a key question: how does it affect road safety? Globally, road crashes claim around 1.3 million lives and cause 20–50 million serious injuries annually (World Health Organization, 2019), a concern underscored by the United Nations' 2030 Agenda for Sustainable Development, which prioritises safety as a sustainability goal(UN General Assembly, 2015). In Australia, the Safe System approach, inspired by Sweden's Vision Zero, aims to eliminate fatal and serious injuries (FSI), yet crashes remain a persistent public health issue(Mooren, Grzebieta, & Job, 2011). Safety varies by travel mode, and while absolute injury numbers are often used as an indicator, they don't fully reflect risk without accounting for travel exposure(Lejeune et al., 2007). Research reveals that exposure-adjusted analysis highlights disparities, especially for vulnerable road users—pedestrians, cyclists, and motorcyclists—who face greater risks, emphasising the need for informed, exposure-based safety policies(Blaizot, Papon, Haddak, & Amoros, 2013).

Method

This study assessed annual average fatal and serious injury (FSI) rates in Victoria, Australia, across a four-year period, utilising travel exposure data from the Victorian Integrated Survey of Travel and Activity (VISTA) alongside injury data from VicRoads CrashStats and Transport Safety Victoria (TSV). VISTA supplied exposure metrics—number of stops, distance travelled, and travel time—scaled to population estimates(Department of Economic Development, 2017), while CrashStats (covering 2012–2016) provided road injury data involving registered vehicles, and TSV documented public transport incidents (e.g., falls) not included in CrashStats. FSI rates were computed for nine travel modes, including car driver, car passenger, motorcycle user, cyclist, pedestrian, bus passenger, tram passenger and train passenger by normalising injury counts with exposure measures. Following data filtering and matching, descriptive and relative risk analyses were conducted, and results were visualised on a risk matrix plotting FSI rates (injury likelihood) against total FSI numbers for each mode.

Results

Injury Frequency

Between 2012 and 2016, Victoria recorded an annual average of 224 fatalities and 4,597 serious injuries, totalling 4,821 fatal and serious injuries (FSI) across nine travel modes. Car occupants (drivers and passengers) accounted for the majority of FSI, followed by motorcyclists, pedestrians, cyclists and public transport users as shown in Table 1.

Table 1. Annual average FSI by mode, Victoria, Australia 2012–2016.

Travel Mode	Fatalities per Annum	% of Total Fatalities	Serious Injuries per Annum	% of Total Serious Injuries	FSI per Annum	% of Total FSI
Car driver	99	44.2%	1935	42.1%	2034	42.2%
Car passenger	40	17.9%	720	15.7%	760	15.8%
Taxi passenger	0	0.0%	11	0.2%	11	0.2%
Motorcycle rider	39	17.4%	914	19.9%	953	19.8%
Pedestrian	36	16.1%	529	11.5%	565	11.7%
Cyclist	8	3.6%	419	9.1%	427	8.9%
Bus passenger	1	0.4%	34	0.7%	35	0.7%
Tram passenger	0	0.0%	25	0.5%	25	0.5%
Train passenger	1	0.4%	10	0.2%	11	0.2%
Total	224	100.0%	4597	100.0%	4821	100.0%

Travel Frequency

Table 2 shows the travel exposure distribution by travel mode. Overall, Victorians spent 109 billion minutes travelling per annum, covered 47.2 billion kilometres and made 5.9 billion stops (across all modes under study). By distance, most travel occurred by car, followed by public transport and as a pedestrian. By time, most travel again occurred by car, followed by as a pedestrian and then by public transport. It should be noted that slower travel modes may be subject to higher exposure in terms of time and the number of stops, whereas faster modes may be subject to higher exposure by travel distance.

Table 2. Average annual travel exposure by mode, Victoria, Australia 2012–2016. Source: VISTA.

Travel Mode	Travel Time per Annum		Distance per Annum		Stops per Annum	
	Minutes × 100 Million	% of Total	Km × 100 Million	% of Total	Stops × 100 Million	% of Total
Car driver	517.6	47.6%	265.7	56.3%	24.5	41.6%
Car passenger	255.4	23.5%	134.0	28.4%	13.3	22.6%
Taxi passenger	4.1	0.4%	1.7	0.4%	0.2	0.3%
Motorcycle rider	3.0	0.3%	1.6	0.3%	0.1	0.2%
Pedestrian	177.0	16.3%	12.7	2.7%	15.1	25.7%
Cyclist	23.5	2.2%	4.4	0.9%	1.0	1.6%
Bus passenger	24.0	2.2%	9.2	1.9%	1.2	2.1%
Tram passenger	16.6	1.5%	3.4	0.7%	1.0	1.8%
Train passenger	65.7	6.0%	39.2	8.3%	2.4	4.1%
Total	1086.9	100.0%	472.0	100.0%	58.8	100.0%

Injury Risk Rates

Table 3 presents FSI rates for each travel mode across three exposure measures. Examining the FSI rate per 100 million minutes reveals a shift from absolute FSI numbers: while cars top the injury count, adjusting for exposure highlights motorcycle riders and cyclists as having higher relative risk compared to car drivers and passengers. This table enables a quantitative comparison of risk across modes,

factoring in both FSI and travel exposure. Public transport proved safest overall, with train passengers at the lowest risk, followed by bus and tram passengers.

Table 3. Annual FSI risk rates across nine travel modes, Victoria, Australia 2012–2016

Travel Mode	FSI Rate per 100 Million Minutes		FSI Rate per 100 Million Km		FSI Rate per 100 Million Stops	
	FSI Rate	95% CI	FSI Rate	95% CI	FSI Rate	95% CI
Car driver	3.93	3.76–4.10	7.65	7.33–7.99	83.13	79.58–86.81
Car passenger	2.98	2.77–3.19	5.67	5.28–6.09	57.19	53.23–61.36
Taxi passenger	2.67	1.42–4.63	6.42	3.41–11.11	59.93	31.80–103.73
Motorcycle rider	319.62	299.81–340.40	602.09	564.77–641.24	8176.83	7670.01–8708.50
Pedestrian	3.19	2.94–3.46	44.39	40.84–48.16	37.35	34.36–40.52
Cyclist	18.20	16.53–19.99	97.77	88.82–107.38	449.28	408.17–493.43
Bus passenger	1.46	1.03–2.00	3.82	2.70–5.25	28.94	20.50–39.77
Tram passenger	1.50	1.00–2.19	7.34	4.87–10.66	24.29	16.10–35.28
Train passenger	0.17	0.09–0.29	0.28	0.15–0.49	4.62	2.45–7.99
Total	4.44	4.31–4.56	10.21	9.93–1051	82.05	79.76–84.39

Risk Matrix

This section evaluates and visualises the combined impact of FSI numbers (casualty magnitude) and FSI rates per 100 million minutes (risk or likelihood) across all studied travel modes, using a risk matrix (Figure 1) that plots FSI rates against absolute FSI on logarithmic scales due to significant variation. The matrix categorises modes into four groups: (i) low risk, low casualties, (ii) low risk, high casualties, (iii) high risk, low casualties, and (iv) high risk, high casualties. Among the nine modes, motorcyclists exhibit the highest risk and rank second in FSI after car drivers, who, despite having the most injuries, show a much lower risk per time. Cyclists similarly face a higher risk than car passengers and pedestrians but contribute fewer FSI. Public transport users consistently fall into the low risk, low injuries

category.

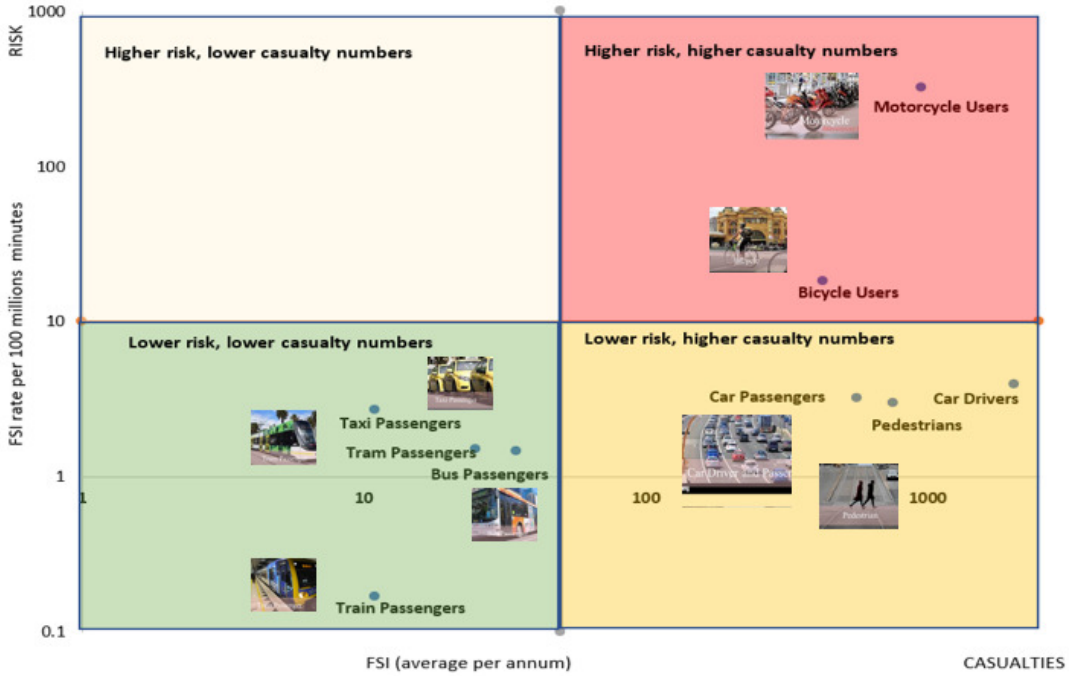

Figure 1. Risk–injury plot for road user groups between FSI and FSI rate per 100 million minutes on a base-10 log scale.

Conclusions

Absolute counts of fatalities and serious injuries (FSI) are common road safety indicators, but they reflect only injury magnitude, not risk, which requires factoring in exposure (i.e., likelihood of injury across different contexts). In transportation, assessing injury risk against varied exposure measures offers deeper insight into the comparative safety of travel modes. These findings can explain road safety implications of modal shifts, guiding investments toward pressing safety priorities. Emphasising measures that enhance safety, health, and environmental outcomes fosters greater synergy, supporting a sustainable system that balances social, economic, and environmental goals. Additionally, the simplified risk matrix provides an effective, multidimensional visualisation in a single, accessible graph, ideal for executive discussions.

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