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A cross-modal risk analysis of substance impairment

NZIER report to the Ministry of Transport
9 June 2014

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NZIER was established in 1958.

Authorship

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Key points

This report provides an assessment of the relative risk of fatalities across transport modes where alcohol and drug impairment are contributing factors in accidents.

Our approach

- The risk ranking of transport activities can change depending on which risk estimation approach is used, because the estimation of risk is based on different parameters –participation-based versus population-based accidents.
- Population-based assessments of the relative risk of fatalities across modes can be misleading, as these do not explicitly consider the risk exposure of individuals to activities.
- Taking a participation-based approach is data intensive; the analysis is sensitive to assumptions; but the overall result is a risk comparison based on transport use.

Results

- Road transport activities have the highest risk with a population-based approach. After applying a participation-based approach road transport moves to the middle of the risk ranking.
- After adjusting risk exposure based on estimates of participation we found that airline operations were about 25 times safer than road transport and more than 400 times safer than private aviation.
- The relative risk level of recreational maritime activities is almost half that of road transport. However, the result depends on assumptions made about participation and improved information is required to reach robust estimates.
- Commercial maritime activities have a risk level that is 2.6 times higher than road transport. This group covers a wide range of activities with varying levels of risk. The data required to disaggregate this group was not available during the investigation.

Sensitivity analysis

- Large scale events can affect the ranking of activities. Particularly in categories with lower participation levels than road or airline travel. The hot air balloon incident near Carterton on 7 January 2012 fell outside the timeframe of the analysis (2002-2011) by 7 days. If it had happened within the timeframe the relative ranking of the agricultural and other non-airline aviation category would be higher than the commercial helicopter category.

Improving estimates

- Further disaggregation of transport activities could potentially provide greater insight, but this would require more extensive statistics and primary research.
- The recent introduction of regulations for adventure tourism activities (e.g. rafting or jet-boating) could potentially lower the relative risk ranking of these activities in future. Thus, further insight could be gained if this analysis is updated in two or three years.

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1. Introduction

This report provides an assessment of the relative risk of fatalities across transport modes, where alcohol and drug impairment are contributing factors in accidents. The report is intended to assist the Ministry of Transport in its evaluation of the adequacy and consistency of impairment regulation across transport modes.

We briefly provide some context for our analysis below, reporting on the overall level of fatalities across transport modes. We then introduce the approach we use for calculating the relative risks of fatality for each transport mode.

1.1. Transport mode fatalities

We have aggregated the data for fatalities and time-spent by transport mode over 10 years (2002-2011) to minimise the impact of discontinuous and lumpy data. This is particularly important in transport modes that tend to a have a higher number of passengers and a single serious incident can involve many fatalities.

Table 1 Number of fatalities by transport mode 2002-2011

Transport mode	Fatalities
Road*	3929
Rail*	150
Commercial maritime **	64
Recreational maritime**	173
Aviation*	152

Source: Ministry of Transport* and Maritime New Zealand **[1]

As can be seen in Table 1 road deaths dominate transport fatalities. The total for non-road fatalities of 539 amounts to only 14% of the 3929 road fatalities over the period 2002-2011.

1.2. Approach

We have applied two methodologies to estimate the relative risk of a fatality across a range of transport activities.

1. A population-based approach - per million population
2. A participation-based approach - average annual time spent per person for each transport activity.

The advantages and disadvantages of these approaches are set out in Table 2. The population-based approach is commonly used because the information required is usually more readily available. The ranking of transport activities can change entirely depending on which approach is used, because the estimation of risk is based on different parameters – participation-based versus population-based accidents.

[1] The definition of maritime fatalities varies depending on how death at counted as maritime, medical incidents on the water or water safety incidents. Maritime provide NZIER with maritime fatalities of 237, while the Ministry of Transport reports fatalities of 227. To be conservative we have use the numbers provided by Maritime New Zealand

Table 2 Advantages and disadvantages of the approaches

Method	Advantages	Disadvantages
Population-based	The information required for the estimate is more readily available. International comparisons are published. Provides a very rough proxy of the relative risks of different modes of travel, in the absence of participation-based estimates that are not readily available.	As actual risk exposure is not considered, only a very rough approximation of risk is derived for travel mode. International comparisons do not include factors that could influence participation. For example, geography could influence participation in ocean-based marine activities.
Participation-based	Risk rankings are based on a measure of actual exposure to risk. As actual risk exposure is explicitly considered there is potential to build a more robust picture of the relative riskiness of difference travel modes. This is particularly useful for periodic evaluation of safety programmes and for assessing the need for any further regulatory interventions.	International comparisons are much less common. More detailed information is required, and the results heavily depend on assumptions made about actual exposure time in each travel mode.

Source: NZIER

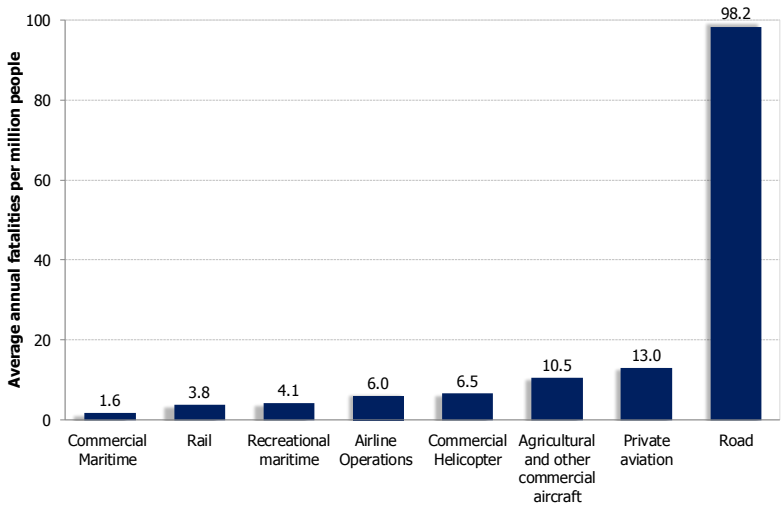
The participation-based approach requires much richer information to estimate a common measure of participation across a diverse range of modes and activities. We use this approach and the assumptions applied to estimate annual average participation are described in Appendix A.

2. Comparison of modes on a population basis

On a population basis, the risk of a fatality in road transport could be perceived to be ten times higher than all the other non-road transport activities compared in Figure 1. But this comparison offers no sense of the frequency that people participate in these transport activities and in doing so expose themselves to some level of risk. For example, the majority of employees commute to and from work in a car on a daily basis. Those commuters are far less likely to be participating in recreational boating at the same level of frequency. The description of the types of activities included in each category is in Table 3.

Figure 1 Transport mode fatalities per 1 million people in New Zealand

Annual average 2002-2011



Source: NZIER based on Ministry of Transport fatality statistics

Table 3 Description of categories

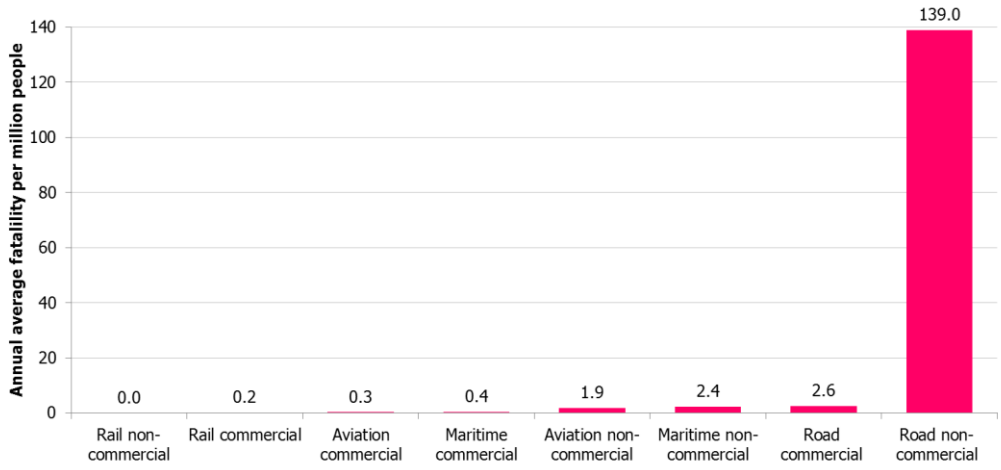
Category	Types of activity
Road	Road vehicle activities. Cyclist and pedestrian fatalities are excluded.
Commercial maritime	Sea freight, commercial fishing, charter fishing, jet boating for hire, ferries.
Rail	Passenger and freight rail.
Recreational maritime	Yachting, recreational fishing, kayaking, and private jet boating.
Airline operations	Commercial passenger and freight airline activities.
Commercial helicopter	Helicopter services for hire.
Agricultural and other commercial aircraft	Topdressing, sightseeing activities that are for hire.
Private aviation	Recreational and private aviation journeys that are not for hire.

Source: NZIER

The significant difference in risk between road transport and non-road transport, looking through a population-based lens, is not unique to New Zealand. Savage (2013) compared the annual average risk of a fatality per million people in the United States for the period 2000 to 2009 (Figure 2). Savage found that even this seemly parsimonious approach can involve complexities such as suicides and terrorist incidents that can sometimes be counted as part of transport safety statistics if a transport activity is involved.

Figure 2 Transport mode fatalities per 1 million people in the United States

Annual average 2000-2009



Source: Savage (2013)

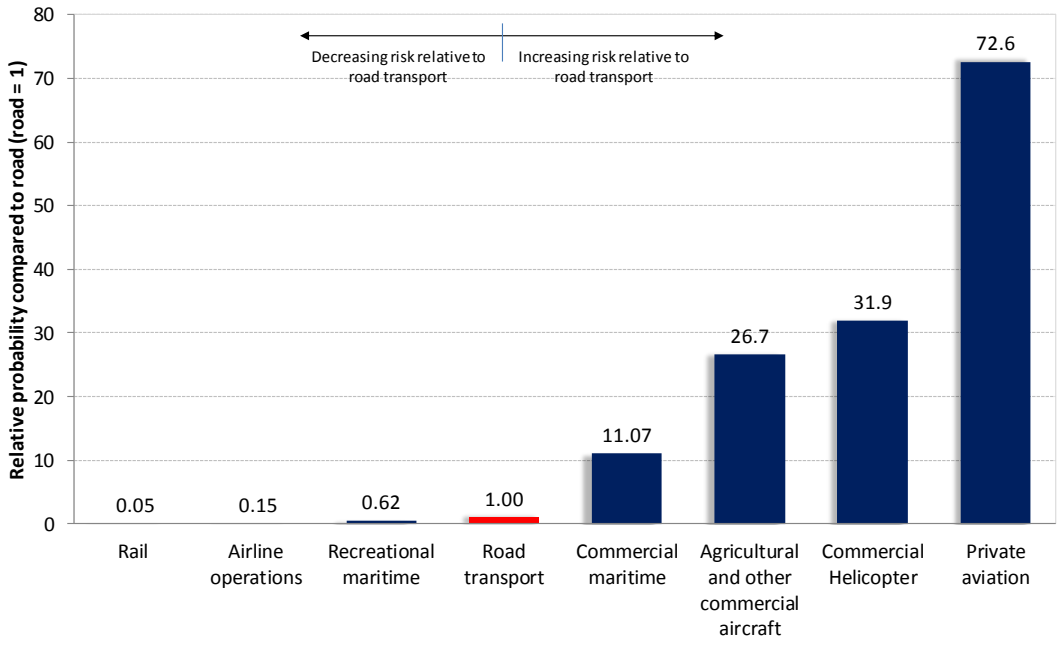
The pattern of cross-modal risk based on population is similar to New Zealand. The risk level in comparative modes appears higher in New Zealand on a population basis, but this maybe because of the much smaller population base in New Zealand and the sometimes lumpy nature of accidents.

3. Comparison of modes on a participation basis

To provide insight into the risk based on actual participation we estimated the average time people spent in each of the activities (the person-hours). Figure 3 shows the relative risk of a fatal injury based on injury statistics published by the Ministry of Transport and our estimates of the person hours spent in each transport activity. The implication of this relative risk ranking is the risk of a fatality varies substantially across transport activities in general; before adjusting for contributing factors such as substance-impairment. Therefore, the implementation of a common safety rationale across the spectrum is likely to need interventions that are specifically tailored to the needs and nuances of each activity.

Figure 3 Relative probability of a fatality compared to road transport 2002-2011

After adjusting for the esitmates time spent in each transport activity



Source: NZIER

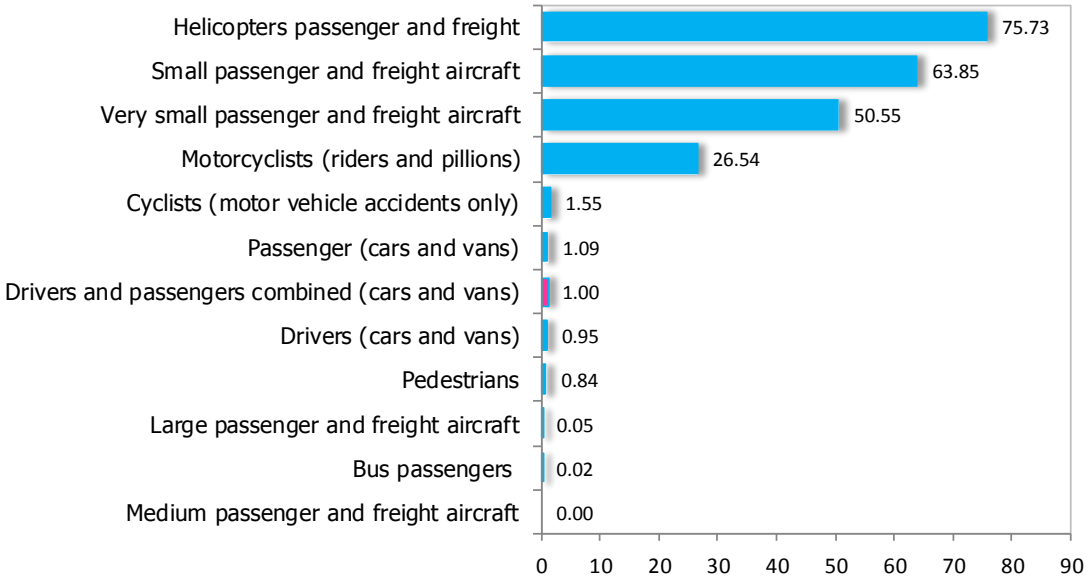
The relative ranking in Figure 3 is broadly comparable to a similar analysis by the CAA for the period between 2000 and 2003 (shown in Figure 4). The CAA did not include maritime or rail transport activities. There are some differences in the relative risk levels which could be due to the different time periods and the assumptions. The time period can be a key source of variation for two reasons. Firstly the timeframe used by CAA is quite short which means the results are more sensitive to single accident events. This sensitivity can manifest as higher risk when compared to a longer assessment period. Secondly safety outcomes can

generally improve over time[2] as a result of the cumulative effects of safety improvements and technological advances.

The relative risk profiles in Figure 3 and Figure 4 both implicitly reflect variations in the risk associated with different activities, institutional structures, and commercial incentives. A more comprehensive study is required to obtain insight into the effect of such variations on the ranking. This kind of in-depth study was outside the scope of the project. Exploring the effect of these variations is an opportunity to gain further insight.

Figure 4 CAA's analysis of the relative probability of fatality per person hour

2000-2003



Source: Campbell (2004). Travel safety comparisons: land and air; New Zealand and Australia.

Using a participation-based approach the ranking of transport activities can change depending on the measure of "participation" used. Table 4 shows the change in ranking of modes in the EU when different measures are applied. Air travel is ranked higher on a time basis than on a distance basis. Using a distance measure makes air travel appear safer than ferry travel, whereas the use of the time measure results in ferry travel being twice as safe as air travel. This is due to the large difference in relative distances of these two travel modes. We have chosen to use a time-based approach for comparing risk across modes. This overcomes the bias created by a distance-based approach.

[2] See Savage (2013), Winston (2013) and USCG (2012).

Table 4 Cross-modal risk ranking under different approaches

Cross-modal fatalities risk in the EU in 2001/02			
Fatalities per 100 million person kilometre travelled		Fatalities per 100 million person hours travelled	
Road (all road transport)	0.95	Road (all road transport)	28
Ferry	0.25	Air	16
Air	0.035	Ferry	8
Rail	0.035	Rail	2

Source: European Transport Safety Council, 2003.

We describe in Appendix A the assumptions behind the estimate of person hours for each transport activity. If significant changes are made to these assumptions the relative risk ranking of each mode could change. For example, we have assumed an average speed of 50 km per hour for road transport to estimate time spent in this activity. If this speed was doubled then recreational maritime activity would swap places with road transport in the risk ranking in Figure 3.

Further disaggregation of the transport activities could lead to additional insights, particularly for the commercial maritime group. The group includes a wide range of activities such as commuter ferries, interisland ferries, jet boating, rafting, domestic cargo shipment and domestic fishing operations. Disaggregation of commercial maritime would require fatality and participation data for individual sub-sectors. Participation information was not available at a sufficient level of detail during this investigation. We have however reported fatalities in the maritime sector further by activity in Appendix B. This provides information for the first step of any future analysis should participation data become available.

4. Cross-modal risk analysis of substance impairment

4.1. Substance impairment as a contributing factor

We outline below the evidence and assumptions that we make for each mode.

Aviation

International estimates of the extent of the role of drugs and alcohol vary. Newman (2006) reviewed aviation incidents between 1975 and 2006 in Australia and concluded that only 0.4% of all accidents were related to drugs and alcohol. But because Newman did not make any adjustment for under-reporting it is possible Newman's estimate is an under-estimate. Li and Baker (2007) reported that the presence of alcohol in general aviation crashes in the United States has fallen from 30% in the early 1960s to 8% in the mid-2000s. The analysis did not look at the presence by different types of aviation activity or the type of pilot licence.

The Australian Transport Safety Bureau (2005) reported that 23%[3] of surveyed respondents indicated that alcohol, drugs or prescribed medication effected flight safety at least once in the last 12 months.

Further investigation is required to confirm the full extent of the role of substance impairment in aviation accidents in New Zealand. We have assumed that substance impairment is a contributing factor in 8% of aviation fatalities. The assumption is based on the result of Li and Baker (2007) in the U.S.

The sensitivity of results related to this assumption is discussed in section 4.3. In particular, we investigate the impact of lower evidence of potential substance impairment in the commercial aviation sector than private aviation of the relative risk ranking.

Road

According to the Ministry of Transport (2012), substance impairment was a contributing factor in 34% of fatal crashes between 2009 and 2011. We have applied this estimate to the period from 2002 to 2011.

Maritime

O'Connor and O'Connor (2005) found that drugs and/or alcohol were a contributing factor in 28% of boating fatalities in Australia. This is similar to the share in road fatalities in 2001 (26%). This may indicate the risk of a fatal boating accident while impaired by drug and or alcohol is similar to the risk of driving a vehicle while impaired.

The US Department of Homeland Security et al. (2012) found that alcohol was the leading contributing factor (16%) in recreational boating fatalities in 2011 for the United States. Maritime NZ (2008) note the alcohol was consumed in 18% of boating fatalities based on post mortem testing investigations. This percentage is considered to be a conservative

[3] Of the 1196 that responded.

estimate due to the legislative limits on testing. For the purpose of our analysis we have assumed that substance impairment is a contributing factor in 25% of recreational maritime fatalities.

There is an absence of any estimates of the role of drugs and/or alcohol as a contributing factor in fatalities in commercial maritime activities. We have assumed commercial incentives and health and safety regulation reduce the incidence of substance impairment. Therefore, we have assumed that substance impairment is a contributing factor in 8% in commercial maritime fatalities.

Rail

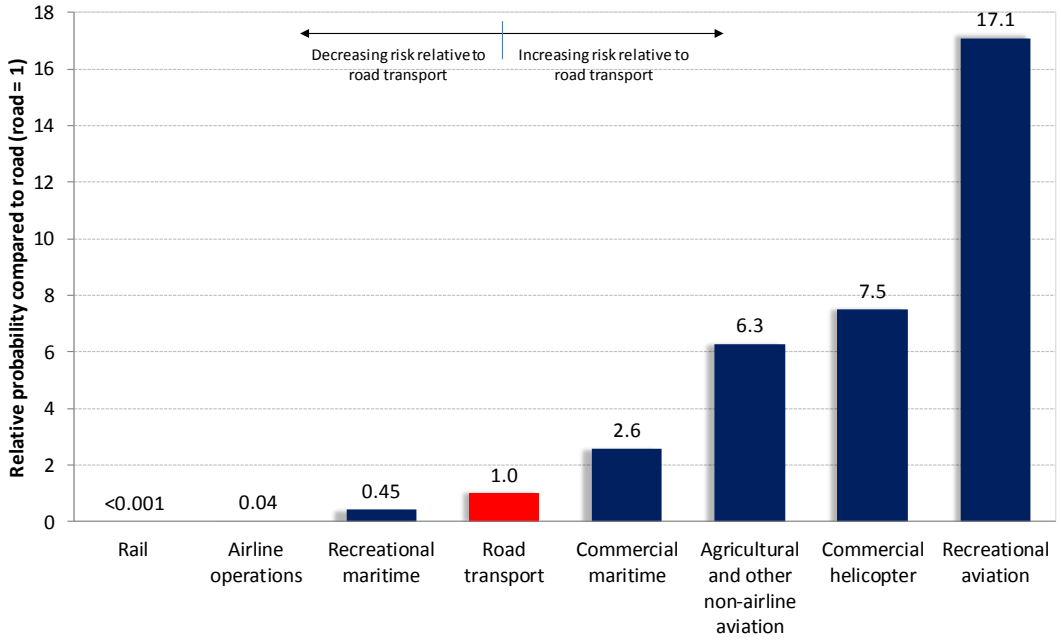
There was only one fatality where substance impairment was identified as a contributing factor between 2002 and 2011.

4.2. Adjusting the risk profile for substance impairment

The risk profile is indicative of the relative risk of substance impairment leading to a fatality across a wide range of transport activities. Further investigation would be required to establish a comprehensive assessment of the level of risk of a specific activity.

The results of our analysis indicate that rail transport and airline operations have the lowest risk of substance impairment leading to a fatality (Figure 5.) The relative risk of airline operation is 25 times lower than road and more than 400 times lower than private aviation.

Figure 5 The probability of substance impairment contributing to a fatality across modes based on participation in transport activities relative to road transport



Source: NZIER

Commercial maritime has an estimated relative risk that is 2.6 times higher than road transport. The full effects of the recently introduced safety management plans, adventure tourism operator certification and safety audits are not reflected in the risk profile.

Further disaggregation of commercial maritime was not possible because of insufficient data. Further research could reveal more insights into the relative risk of sub-sectors such as fishing and adventure tourism.

Agricultural and other aviation had an estimated relative risk that is six time higher than road transport.

Private aviation has the highest relative risk. This is primarily because private aviation has a high rate of fatalities and lower flight hours than any kind of commercial aviation. So, the fatality risk is generally higher before adjusting for the contribution of drug and or alcohol impairment.

The relative risk of recreational maritime is almost half that of road transport. Given that this type of transport activity has the lowest level of institutional structures or regulation capable of dealing with substance impairment; it is probably the area where stronger regulatory signals could improve safety.

4.3. Sensitivity analysis

Developing the relative risk ranking required making assumptions about the percentage of fatalities which involved substance impairment as a contributing factor in fatal incidents. In this section we the test the sensitivity of the relative risk to changes in the assumptions about impairment rates in fatal incidents. The rate of substance impairment for road transport is held constant throughout the sensitivity analysis to enable any changes in the risk ranking readily comparable. The assessment of substance impairment contribution to road fatalities is the most reliable across any of the categories.

The Ministry of Transport also asked NZIER to assess the sensitivity of the results to a large scale infrequent event such as the hot air balloon incident near Carterton on 7 January 2012.

The complexity of attributing causation with multiple contributing factors

The causes of accidents are typically complex. There can be a wide range of contributing factors in any given situation. Broadly the contributing factors fall into three categories:

- human factors – driver/pilot impairment, inattention, behaviour
- vehicle factors – mechanical failure, loss of control
- environmental factors – severe weather, slippery road surface, rouge waves, lightning strikes, and bird strikes.

Underpinning these three categories is a large number of contributing factors that could be considered in an incident analysis. The implication of this complexity is that the presence of alcohol or other substance by no means guarantees whether impairment was a contributing factor among other factors or indeed that substance impairment was the *primary cause* of a fatal incident. For example, if a recreational boatie falls overboard without a lifejacket on and subsequent tests show the presence of a substance that could have impaired balance or decision-making, a judgement is required to determine whether the primary cause of drowning should be attributed to the impairing substance or the lack of a lifejacket and the capacity to self-rescue.

Our results are not very sensitive to large changes in the assumptions about substance impairment as a contributing factor. For example the ranking of transport activities does not change if the assumption about substance impairment in aviation is reduced by 50%. If the aviation assumption is reduced by two-thirds then the commercial helicopter operations category and the agricultural and other non-airline aviation category move below commercial maritime in the ranking.

The sensitivity of results to large scale events

At any given point time there is a low probability of a large scale fatality incident occurring. For example, aviation incidents involve passenger aircraft occur far less often than private aviation incidents. The hot air balloon incident near Carterton 2012 is an example of a large scale event occurring relative to the number of fatalities in agricultural and other non-airline category. This incident fell outside the scope of analysis timeframe by 7 days. If it had occurred within the timeframe, the relative risk of the category increased from 6.3 to 7.8. Which means this category would be higher than the commercial helicopter operator category by 0.3.

This is not surprising because the 11 fatalities in the balloon incident is a 25% increase in the total fatalities in the category over a 10 year period and the associated increase in participation time is very small (less than 0.01%) relative to activities in this category. However, the probability of such an event in this aviation category is less than 5% and it is therefore a statistical outlier, assuming the frequency of events can be approximated by a normal distribution.

Commercial accountability incentives compared to private incentives

Commercial incentives and regulatory frameworks tend to support greater incentives for safety checks and internal accountability than in the case of private individual. Cranfield et al. 2011 reported the presence of alcohol in pilot fatalities varies by pilot medical certificate class in the U.S. in 2004-2008.

Table 5 Variation in toxicology results by activity type.

Medical certificate category	Type of aviation activity	% of pilot fatalities positive for alcohol
First class	Commercial passenger services	6%
Second class	Commercial air freight and non-passenger aviation	6%
Third class	Private aviation	8%

Source: Based on Cranfield et al. 2011

Reducing the assumption about substance impairment from 8% to 6% for the three aviation sub-categories naturally reduces the materiality of the level of relative risk. This is a direct result from reducing the attribution assumption. However, this change does not affect the relative ranking of the transport categories.

5. Improving estimates

This report provides the Ministry of Transport with information on the relative risks of impairment fatalities to enable an assessment of the adequacy and consistency of impairment regulation across modes.

The analysis of the significance of substance impairment and the relative risk of harm related to substance impairment could be improved by:

- obtaining more detailed information of participation and risk exposure – particularly in recreational maritime
- disaggregating the transport activities further. For example by breaking road transport into categories like motorcycle, private car and van, commercial, and public transport
- expanding the scope of the risk analysis to include serious and minor injuries
- in-depth consideration of the effect of institutional structures and commercial incentives on the relative risk across modes and sub-modes.

The recent introduction of regulations for adventure tourism activities (e.g. rafting or jet-boating) could potentially lower the relative risk ranking of these activities in future. However, the impact of these changes will not be captured in the time series investigated in this report. Thus, further insight could be gained if this analysis is updated in two or three years.

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Appendix A Assumptions

Aviation

The calculation was based on fatality statistics and seat hours offered by the type of aviation activities as published on the Ministry of Transport website.

Road transport

Private light vehicle occupancy is based on results from the travel survey published by the Ministry of Transport.

Average speed is assumed to be 50 kilometres per hour. Increasing this speed would proportionally decrease participation time and therefore proportionally increase the relative risk estimated for road transport.

Commercial vehicles and motorcycles passengers are assumed to have a single passenger. Increasing the average number of passengers for these activities would proportionally increase participation and decrease the relative risk estimate for road transport.

Commercial maritime

Commuter ferry trips and travel time is based on the travel survey published by the Ministry of Transport.

Jet boating passengers estimates were based on TAIC (2012) "Jet boating accidents: historical impact review".

Hours worked per week by the crew of various vessel categories were based on marine vessel operational hour surveys (Maritime NZ, 2007).

Commercial maritime operate 50 weeks per year (Maritime NZ, 2008).

There are 3,831 commercial vessels in NZ (provide by Maritime NZ).

Recreational maritime

Participation rates per vessel were based on US Coastguard Recreational Boating study 2011. The results of the study were:

- each vessel spends an average of 17 days in the water per year
- 4.9 hours per day in the water
- there were an average of 2.4 people on board.

There are approximately 400,000 recreational vessels in New Zealand based on Maritime NZ, 2008.

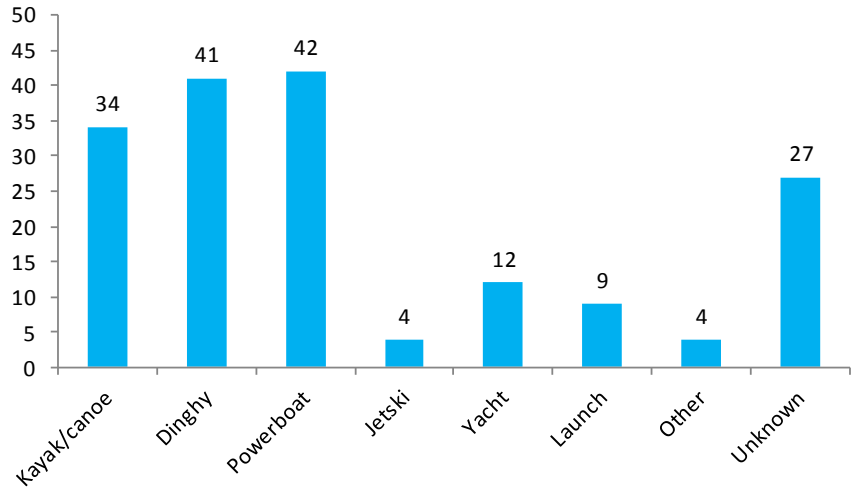
Rail

An average trip of 20 minutes.

Appendix B Maritime activities.

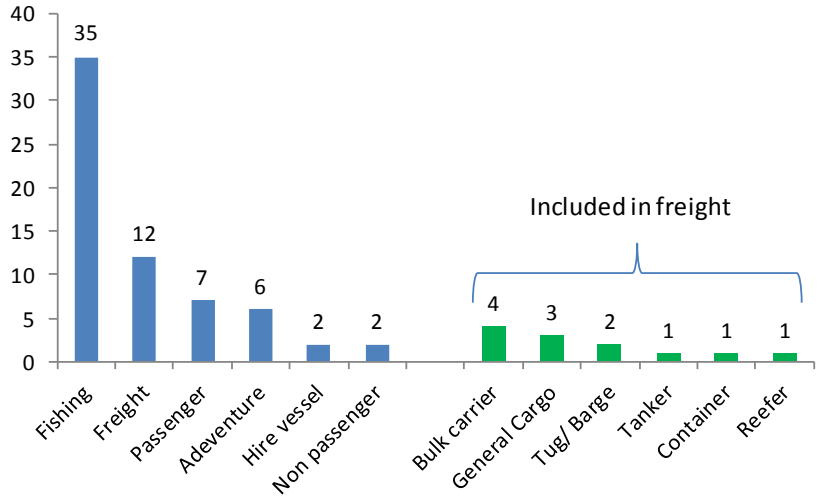
Maritime activities cover a wide range of heterogeneous activities and pastimes that have inherently different risk profiles. Figure 6 and Figure 7 show the number fatalities for recreational and commercial maritime activities respectively. The purpose of the figures is to provide a sense of the distribution of total fatalities by types of activity. Greater information on the level of participation for the range of activities is required to include this level of disaggregation in the participation based analysis in our report.

Figure 6 Recreational maritime fatalities by vessel type 2002-2011



Source: NZIER based on statistics provided by Maritime New Zealand

Figure 7 Commercial maritime fatalites by vessel type 2002-2011



Source: NZIER based on statistics provided by Maritime New Zealand