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# Driving for Work Crashes: A Systems Analysis

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### Abstract

Work-related road safety is a government priority. A Safe System analysis of 300 driving for work (DFW) crashes was carried out, along with an exploratory socio-technical analysis of one significant case to better understand the context around DFW crashes. The Safe System analysis showed three distinct crash types: 1) multiple vehicle crashes often involving work vans, utes, and SUVs in side impact crashes; 2) vulnerable road users often involving professional drivers; and 3) single vehicle crashes involving people driving vans or light trucks for work losing control on rural roads with fatigue, non-seat belt use, and speed often implicated. There was a range of unique characteristics of DFW crashes, in particular, injuries to others who were implicated in DFW crashes but not those DFW themselves. Socio-technical systems analyses show promise for understanding the context around DFW crashes, but arrangements for better data access, coordination, and use are needed.

### Key Findings

- The characteristics of driving for work (DFW) crashes differed from non-work related crashes, suggesting the influence of different systems factors
- DFW crashes were most often linked to multiple failures across the Safe System
- A Safe System analysis identified three distinct crash types across the DFW crashes
- Socio-technical systems analysis is a promising approach for understanding the full context around DFW crashes

## Introduction

In New Zealand, road traffic fatalities make up around 30 percent of all worker fatalities (McNoe et al., 2005) and between 22-36 percent of the national road fatalities including workers, bystanders, and commuters (Lilley et al., 2019). Although not reported, it may be that similar patterns exist for serious injury and minor injury crashes. As a result, work-related road safety is a strategic priority in New Zealand's road safety strategy, Road to Zero (Ministry of Transport, 2019). Also, safety when working in and around vehicles is a priority for the national health and safety regulator, WorkSafe.

Beyond analyses of driving for work (DFW) crash prevalence and specific crash characteristics, there remains a

knowledge gap in terms of understanding the context within which work-related motor vehicle traffic crashes occur. This understanding is essential to the development and implementation of effective, evidence-based safety initiatives.

One method for better understanding the context of, and factors involved in, crashes is to analyse crash records from a Safe System perspective. Safe System analysis frameworks have proven useful in determining factors associated with casualties and crashes (Hirsch et al., 2017, 2018; Mackie et al., 2017; Thorne et al., 2020).

In road transport, Safe System factors are generally grouped into four areas: speed, roads and roadsides, vehicles, and road users. The approach encourages a broader examination of the immediate crash context, particularly

consideration of factors other than driver error. It enables patterns of factors associated with specific types of crashes to be identified. For example, Safe System studies have shown that higher severity crashes are more likely to involve multiple system failures, and fatal crashes were more likely to involve extreme behaviours compared to serious injury crashes (Hirsch et al., 2017).

There are, however, limitations in focusing exclusively on serious and fatal crashes, as is often the case with Safe System approaches. These crashes represent a small percentage of the overall crashes, conflicts, and interactions that happen daily on our roads. Although they are of strategic importance, they do not tell the whole story (Hydén, 1987). Extending examinations to less severe crashes and more common conflict scenarios could potentially provide useful insights into DFW crashes.

Additionally, there is increasing interest amongst safety practitioners and researchers in examining the broader social and organisational context within which all types of crashes occur. Broadening the focus from the immediate road environment and crash circumstances can enable consideration of ‘upstream’ factors that contribute to, or lay the foundations for, crashes. To support building this more contextualised view, systems methods for analysing safety incidents are moving towards ‘socio-technical’ system approaches (Mackie et al., 2017; Salmon, 2020; Salmon & Lenné, 2015; Stanton, 2019).

Although socio-technical systems theory was originally developed in the 1950s, it has only more recently become prominent in mainstream risk management (Stanton, 2019). Socio-technical methods aim to dig deeper, beyond immediately identifiable crash factors, to understand the technical and social context that contributes to incidents. For example, while a Safe System analysis can help to identify that fatigue is frequently suspected in particular kinds of fatal work crashes or under certain road conditions, a socio-technical systems analysis can obtain more information about the context that led to the driver being fatigued. This can include data on what planning, funding, or maintenance actions may have contributed, thereby helping to pinpoint organisational actions that can ultimately lead to the prevention of fatigue crashes.

There are, however, challenges with socio-technical analyses that must be resolved if the approach is to be broadly applied to the problem of road safety, and to work-related road safety in particular. The availability and quality of appropriate data (Hirsch et al., 2018; Mackie et al., 2017) and gaining acceptance of Systems approaches within the road safety eco-system are key to obtaining value from this approach.

The goals of this study were to 1) determine the Safe System factors associated with fatal, serious injury, and minor injury crashes that occurred involving light and some service vehicles while driving for work in New Zealand, and 2) to explore the potential of socio-technical methods for analysing driving for work crashes or crash clusters.

## Method

The work was carried out in three phases:

1. Scan of work-related causality studies
2. Safe System analysis of 300 DFW crashes
3. Case study of socio-technical AcciMaps approach within DFW context

### Scan of causality studies

Literature related to DFW crashes was reviewed with the goals of identifying innovative methodological approaches, key themes in the DFW literature, and to position the project.

Key word searches were conducted in Science Direct and Google Scholar using search terms “driving for work”, “crash”, “work-related”, “fatality”, “occupational”, “injury”, “contributing factors”, and “system influences”. The majority of the initial literature found was related to heavy trucks, which were not the focus of this study, so “light vehicle” became a key area of focus as the search progressed. Given the existing focus on heavy vehicles, the focus of this study was on driving for work in lighter vehicles in a range of contexts, but also including specific service vehicles. Literature was selected where it included methodologies relevant to the project scope and findings that revealed common characteristics of DFW crashes. Fifty-one relevant papers were identified and reviewed, including peer-reviewed publications, technical reports, and conference presentations.

Research methods were reviewed and summarised. The project team used this information to identify methodological approaches and coding protocols based on variables found to be relevant in other studies. A summary of the literature was also produced that highlighted key themes and findings.

### Safe System analysis method

A Safe System analysis of 300 DFW crashes was undertaken to explore the characteristics of DFW crashes and differences in minor, serious, and fatal crash trends. The sample included 100 fatal crashes, 100 serious injury crashes, and 100 minor injury crashes. Consultation with industry experts indicated that this sample size would be sufficient to gain a broad understanding of factors involved in DFW crashes, noting that the aim was not to gather a fully representative sample of DFW crashes.

Waka Kotahi’s (NZ Transport Agency) Crash Analysis System (national crash database) was used as the primary case identification tool. Crash Analysis System data are available to approved users, are de-identified and do not require ethics approval. Crash classification (fatal, serious, minor) was provided within the Crash Analysis System data and followed Waka Kotahi’s classification system whereby serious is classified as injuries requiring medical treatment or removal to and retention in hospital, and minor is classified as injuries requiring first aid, or which cause discomfort or pain to the person injured. These data were sup-

plemented by publicly available, de-identified work-related fatalities data from WorkSafe to identify additional work-related fatal driving crashes. Fatalities involving a worker driving from the WorkSafe dataset were matched with fatalities in the Crash Analysis System (confirmed by worker age, work industry, month and year of crash). The case identification process was completed in stages so that more recent DFW crashes were prioritised and to enable random sampling where possible.

Crashes occurring from 2019 onwards were prioritised due to the introduction of the 'Vehicle Usage' attribute in the Crash Analysis System, which assisted in confirming the crash occurred while someone was using their vehicle for work-related purposes. All minor and serious crashes were identified using Crash Analysis System data alone and occurred between 2019-2020. However, due to the infrequency of fatal crashes, it was necessary to sample back to 2011 and utilise WorkSafe data to identify 100 fatal crashes, with the most recent crashes in this dataset being selected for analysis.

The crashes included were limited to light vehicles able to be driven on a Class 1 driver licence (cars/wagons, SUVs, utes, vans, and light trucks). However, some service vehicles, (e.g., buses, 9-seater and above, and rubbish trucks) were included because the literature review indicated that they have not typically been examined in studies looking at trucks/heavy freight driving for work.

Cases were restricted to people driving in the course of their work. Therefore, commuting to or from a fixed location of work was not included, but travelling to and from non-fixed locations of work was. Additionally, crashes in which someone was engaged in work activities that involved driving for work, but not actively driving their work vehicle at the time of the crash, were included, e.g., they were involved in a traffic crash while working after exiting their vehicle.

The 300 crash cases identified were then coded using a Safe System analysis coding framework. The coding framework was a modified version of coding frameworks used in previous Safe System analyses, in particular the Serious Injury Crashes study previously undertaken by several members of the research team (Hirsch et al., 2017, 2018; Mackie et al., 2017; Thorne et al., 2020). The most substantial modification to the framework entailed splitting the User pillar into two sub-pillars, DFW Users, and Other Users, in order to differentiate crash factors related to the primary driver for work from those of Other Users involved in the crashes (i.e., to explore 'exposure' factors as well as those directly relating to driver).

The final framework contained 134 qualitative variables with predefined categories (Figure 1). For each pillar of the Safe System, relevant variables (crash factors) were coded. The values of the variables in each pillar then determined whether that pillar was 'triggered' in each crash, i.e., implicated in either the occurrence or the severity of the crash. In addition, some Road User pillar variables were used to determine whether 'reckless' or 'extreme' behaviour was a key factor in the crash, as opposed to a relatively equitable contribution by multiple system factors. This approach was

based on the Wundersitz and Baldock (2014) methodology adapted in a Serious Injury Crashes study (Mackie et al., 2017) with some further modifications.

The data used to code each variable included: traffic crash reports; Safer Journeys risk assessment tool (Mega Maps); vehicle safety rating tools (e.g., Rightcar); WorkSafe fatality data, and Google Street View. During coding, cases with insufficient crash detail, or where it became clear the study criteria were not met, were removed and replaced with a new crash case.

The inter-rater reliability between multiple coders was calculated using kappa score – a measure of the rating reliability between two or more raters for qualitative variables corrected for the likelihood that raters may agree by chance. A free-marginal kappa score was used as there were no restrictions on how many cases could be assigned to each category. Of the 134 variables coded, 100 had perfect agreement between raters, scoring 1.0. For the remaining 34 variables, kappa scores ranged from -0.55 to 0.77. The overall average for all variables was 0.81. Following inter-rater assessment, discrepancies in coding were reviewed and discussed, a consistent approach was agreed, and re-coding was undertaken as required.

Once coding was completed, a brief analysis was conducted to identify any impacts of COVID-19-related restrictions on DFW crashes. This involved separating the data into 'pre-COVID-19' and 'post-COVID-19' time periods – the latter including crashes from 21 March 2020 onwards. Relevant crash factors were then compared between the two periods.

Following the review of the data to assess COVID-19's impact, descriptive analyses were completed for each variable coded, using total crashes at each severity as the denominator. This enabled comparisons across crashes regardless of the number of crash parties or road users involved or the number of people injured in the crash.

A Multiple Correspondence Analysis (MCA) of the final coded dataset was then undertaken to identify and define 'clusters' of crash factors (variables) that tended to occur together. The aim was to summarise and visualise the data and to identify groups of individuals with similar profiles in their attributes. Statistical analyses were performed using software R (version 4.0.3). In addition, statistical packages 'FactoMineR' and 'factoextra' were utilised.

MCA is a technique that looks for underlying structures and relationships within datasets with multiple cases of the same factors (i.e., vehicle type). It finds these relationships by reducing the dataset to dimensions, which can be thought of as relationships within the dataset. These relationships are not clusters, but in fact often variations within the data that show a pattern (i.e., size of vehicle, or number of vehicles involved). Each dimension explains a percentage of the variation within the dataset, and dimensions are ranked so that those which show the most variation are first. In this analysis, missing data were neither discarded nor imputed, instead, a missing category was created for each of the variables with missing values. As the dataset contained a range of crash types, it meant that some variables were missing by nature. For example, for

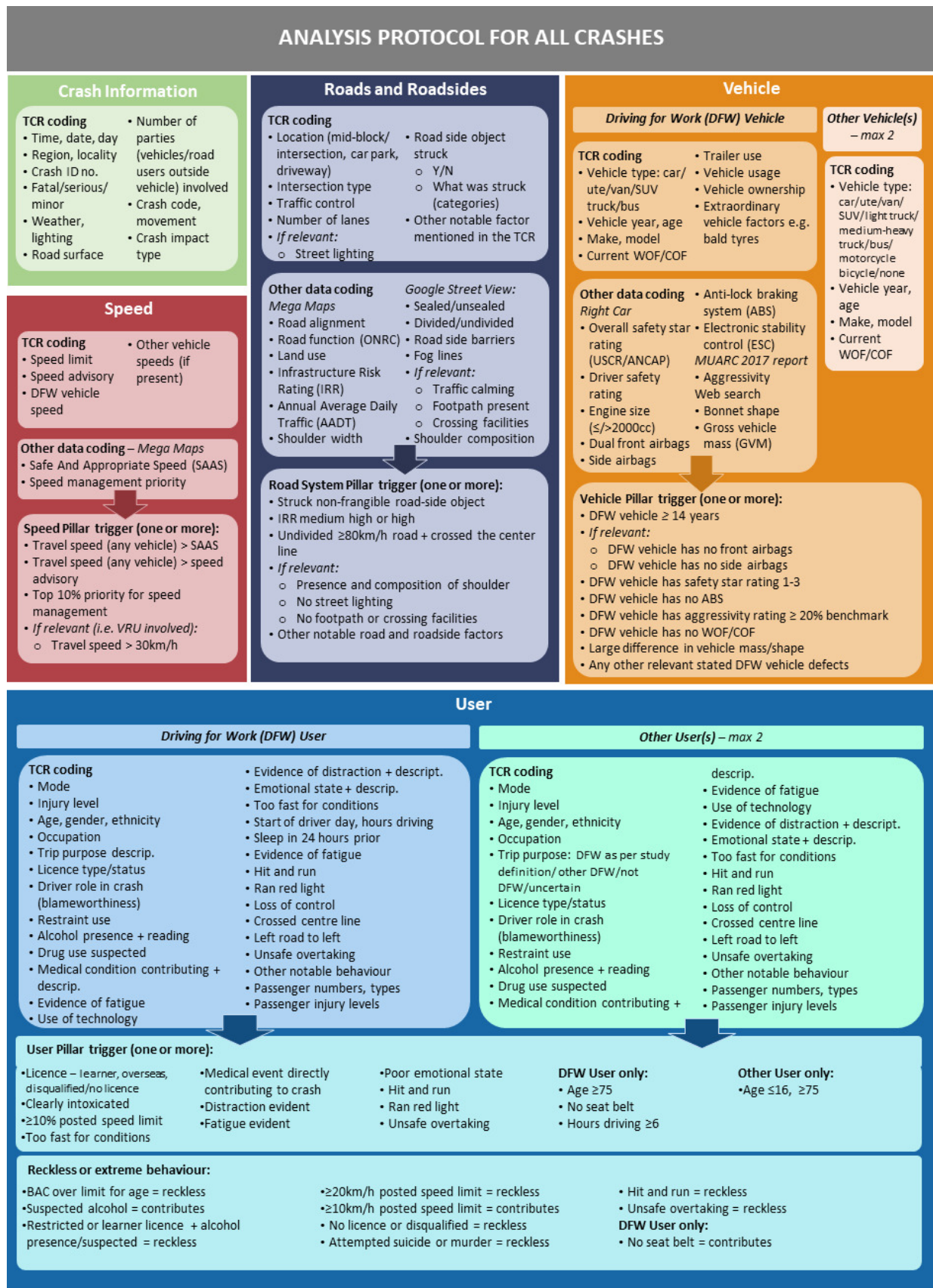


Figure 1. Safe System DFW Analysis Coding Framework

single car crashes, other party mode would, by default, be missing. Imputation does not make sense for cases like this. All variables included in the MCA analysis were treated as nominal variables, and having a missing level retained as much information as possible and did not change the variable's type.

In order to identify crash characteristics that often occurred together, cluster analysis was performed using the axes from the MCA. To achieve the best clustering outcomes, a Hierarchical Clustering on Principle Components (HCPC) approach was employed. This approach conducts a clustering algorithm based on the MCA results and allows for consolidation between hierarchical clustering and partitioning clustering. More specifically, partitioning clustering uses k-means algorithm to split the data into groups.

### Socio-technical AcciMaps case study

Following the literature review of socio-technical analytical methods in a DFW and broader road safety context, the AcciMap methodology (Rasmussen, 1997) was chosen. Creating an AcciMap involves the construction of a multi-layered diagram in which various causes of an incident are arranged according to their causal remoteness to the incident (Branford et al., 2009). The approach is theoretically driven and provides a structured methodology for analysing incidents. Additionally, in New Zealand, AcciMaps has been successfully used in a study of cyclist fatalities which provided some assurance that appropriate data were accessible (Mackie et al., 2016).

To create an AcciMap for DFW crashes, WorkSafe provided the research team with a list of 20 work-related road fatalities occurring between 2013 to 2020. Each case was reviewed to determine its suitability and the list was narrowed to four possible cases. Traffic Crash Reports (TCR) were sourced for three of the four cases. Applications were also made for Coroner's reports of which three of the four were publicly available. Information provided by the Coroner's Office included Police reports, expert analyses, witness statements, medical information (with sensitive information redacted in the original file), and other supporting information used to make conclusions on the case. The final case was selected based on the availability of suitable data.

The data for the selected case were reviewed, and an initial list of causal factors was created and fitted to an AcciMaps model. Where possible, factors were triangulated by cross checking information across the various documents. The suitability of the prescribed AcciMap levels was also reviewed to ensure that they adequately reflected the context of the case under consideration. Certain elements of the case that could potentially be identifying were changed for the AcciMaps and reporting, while ensuring that the relevant system factors remained to provide an adequate example of that nature of a driving for work crash.

Completing the AcciMap was an iterative process: levels were refined, causal factors grouped, and further information sought from new sources to help fill in upper levels. The final map was reviewed internally by the research team and by project stakeholders. It was also recommended that

a stakeholder group of experts in the field be brought together to discuss the map, the causes, and in particular the causal pathways between each cause. However, this consultation could not be completed within the timeframe of the project.

## Results

This section provides findings from the Safe System analysis and the Socio-Technical AcciMap analysis. The Safe Systems analysis was conducted for 300 DFW crashes (100 of each of minor, serious, and fatal), and included both a descriptive analysis of the crashes and a statistical cluster analysis. The Socio-Technical AcciMap analysis was conducted for one fatal crash.

### Safe System analysis

The descriptive component of the DFW Safe System crash analysis, similarly to more general crash analyses, showed that DFW injury crashes are often linked to multiple system failures across the Roads and Roadside, Speed, Vehicle, and User components of the Safe System. However, in multi-party crashes, DFW drivers were given a primary role in the crash in 42 percent of cases and DFW drivers were less likely to have primary responsibility in fatal crashes than non-DFW crashes.

When minor injury crashes were included, a strong relationship between the number of system pillars implicated and the severity of the crash was found. This suggests that concentrations of minor injury crashes may be a useful indicator of the potential for more severe crashes to occur, but also, that the addition of other system failures to minor crashes, may cause them to become serious injury or fatal cases.

In common with other areas of road safety, DFW crashes were frequently linked to rural roads, a lack of traffic diversion, seat belt non-use, low star-rated vehicles, and user distraction/inattention and fatigue. The following factors were found to be prominent or relatively unique to DFW crashes:

1. Crashes were disproportionately more likely to involve males but had a more even age distribution than non-DFW crashes (young male drivers (aged 21-40 years) made up a slightly larger number of overall crashes, but the proportion of crashes resulting in fatality increased from age 51 years).
2. Large vehicles (e.g., buses, vans, utes, and light trucks) were frequently involved in DFW crashes.
3. There was a notable involvement of vulnerable road users (motorcyclists, cyclists, and pedestrians, including people using scooters or motorised mobility devices) in urban DFW crashes, with buses often involved.
4. Injuries tended to be sustained by another party rather than the individual driving for work.
5. There was some indication that unpredictable manoeuvres were a more common factor in DFW crashes, in particular, when DFW drivers were trav-

elling at lower speeds and engaging in manoeuvres such as pulling into and out of traffic.

6. DFW crashes involved a high proportion of vehicles with no available star rating (39% of DFW vehicles in the sample), perhaps as more common cars were less likely to be work vehicles. There was little observed effect of vehicle age.

When compared to non-DFW road crashes, DFW crashes in general, were less likely to involve:

1. Both speed and alcohol, although very low speeds by heavy vehicles were often implicated in high severity injuries and speed was found to be a factor for single vehicle rural road crashes.
2. Extreme and/or reckless user behaviours.

Given the timeframe included in the datasets for this analysis, a comparison of crashes that occurred before COVID-19 lockdown restrictions were implemented (on 21 March 2020) to those which occurred after this date was undertaken. While restrictions were not continuous from March 2020, they were in place for several months and Auckland experienced a second lockdown later in the year. It should also be noted that COVID-19 impacts can extend beyond immediate restrictions. Therefore, data were split into a simple pre- and post-analysis to assess whether COVID-19 and associated restrictions impacted on DFW crashes.

Overall, analyses did not point to considerable differences in the types of crashes that occurred during, and post-COVID-19 restrictions compared to pre-COVID-19. The main differences in the dataset post-COVID-19 were fewer professional drivers being involved in crashes relative to other occupations (e.g., Labourers, and Technicians and trades workers), slightly more crashes occurring in strip shopping and rural residential areas, and a slight exacerbation of trends of driving too fast for the conditions among Labourer occupation types. These findings would seem to be consistent with the changes in daily patterns that COVID-19 lockdowns and subsequent periods have caused.

Analyses of the interactions between the different factors implicated in DFW crashes from the Safe System analysis (HCPC analysis) yielded three data clusters, each containing 188, 72, and 40 crash cases respectively. [Figure 2](#) shows a graphical picture of the clusters. The graph has the first dimension of the MCA on the x axis, and the second dimension on the y axis. Together, these dimensions explained 11 percent of the variation in the dataset. Each crash has a score in each of the dimensions, which is denoted by its location on the graph. The clusters the algorithm detected have been highlighted in red, green, and blue.

The crash factors that most strongly defined the clusters included: number of crash parties/vehicles involved; other user vehicle type; mode/activity; other user injury level; other user alcohol or drug use; other user distraction inattention, and crash impact type. In summary, the clusters can be characterised as follows:

- Multiple vehicle crashes (n=188), often involving work vans, utes, and SUVs in side impact crashes, occurring across all land use types, and typically resulting in injury to non-driving for work drivers.
- Vulnerable road user crashes (n=72), often involving professional drivers in vans or buses colliding head on with a pedestrian in an urban or commercial shopping area.
- Single vehicle crashes (n=40) involving people driving vans or light trucks for work losing control on rural roads and hitting an object or rolling, with fatigue, non-seat belt use, and speed often implicated, and resulting in high worker injury rates.

## Socio-Technical AcciMap Analysis

The purpose of the AcciMap component of this work was to pilot the methodology with crash data available for DFW crash cases in New Zealand to assess its suitability for further roll out. One crash was chosen for analysis, the results of which are presented in [Figure 3](#). Aspects of the crash were de-identified for privacy reasons while retaining data relevant to the socio-technical analysis.

In summary, the fatality crash case study involved a taxi driver driving a 2009 Mitsubishi van with a current Warrant of Fitness (a document ensuring that the vehicle meets required safety standards). The driver was contacted late at night and requested to make a pick up at 5:00 am the following morning. The driver got lost and arrived visibly stressed. At roughly 5:25 am the driver failed to follow a right bend in the road, drove onto soft gravel on the left side of the road, and overcorrected, causing the van to roll and rotate around. The driver was not wearing a seatbelt and was ejected from the vehicle and died at the scene. Environmental factors were also involved: the road was undivided with a speed limit of 100 km/h. The shoulder was narrow, unsealed and running into a ditch.

The Coroner's report identified the driver had medical issues and was taking medication which came with a recommendation against driving. Communication regarding driving while taking the medication may have been insufficient. The Coroner's report deemed the advice provided by the prescribing General Practitioner contradictory because in some places the driver was advised against driving and in other places it was suggested that the driver should be careful driving. In addition, it is unclear whether advice against driving was reinforced by the pharmacist who provided the medication or the drivers' employer. The driver remained available to work according to employer records. The day before the fatal crash, the driver slept in his van, an unusual event due to a family emergency.

The AcciMap developed for this case study crash successfully demonstrated the range of factors that contributed to the fatality. These included decisions, actions, policies, and ways of working contributed to the crash, from societal norms around driving while fatigued and organisational pressures to accept jobs, to medication side effects and non-seat belt use. Of note, was conflicting medical advice to the driver around whether they were fit to drive, and the lack of fatigue management on the part of the employer.



**Figure 2. Cluster result achieved using the Hierarchical Clustering on Principal Components algorithm – consolidated with K means**

Overall, the analysis showed multiple factors were involved, and multiple points at which better policies or intervening actions could have prevented the crash from occurring or mitigated its severity.

It is acknowledged that data of this nature contains sensitive information and respect needs to be given to individuals involved. However, if crashes while driving for work are to be reduced, then broader systemic trends must be identified via methods such as AcciMaps. The benefits of using AcciMaps are particularly evident when maps are based on clusters of similar cases, allowing trends to emerge. Interventions can then be designed to address causes at higher system levels.

## Discussion

This study has utilised two different system methods to examine the characteristics of DFW crashes. The analyses have highlighted some key trends and provided useful insights into what would be needed to undertake broader systemic analyses using methods such as AcciMaps.

The Safe System analysis showed that in DFW crashes, failure across a greater number of Safe System components is associated with higher crash severity. Moreover, the burden of injury from these crashes is largely borne by other road users, including vulnerable road users. Statistical analyses yielded three distinct clusters of DFW crashes. These clusters provide useful opportunities for targeted

DFW safety interventions. Although further analysis is required before interventions are developed.

The completion of the AcciMap mapping exercise yielded useful insights into the suitability of this methodology. The AcciMap was developed to a point but, given project constraints, could not be fully pursued to include a deeper understanding of contextual factors. Using this method at scale would require easier access to relevant data sources. It would also require the creation of data sets that more easily allow for the identification of ‘upstream’ contributing factors to crashes. It was challenging to obtain the information required for this one case.

In reality, greater availability of data would benefit both Safe System and AcciMap type approaches. For the Safe System analysis, variations and limitations in CAS data were identified, possibly relating to the associated Serious Crash Unit (SCU) report for any case. However, SCU reports are generally unavailable for analysis purposes despite the rich array of contextual information they likely contain. Likewise, for both analyses, ACC and WorkSafe data (beyond publicly available data for supplementary purposes) was deemed too difficult to obtain within the parameters of this study, and yet these combined data sets may be valuable in understanding work related road safety trends and cases.

If more system focussed analysis of road safety issues are deemed useful, then it is suggested that agreed pathways for data use and access are determined, so that approved re-

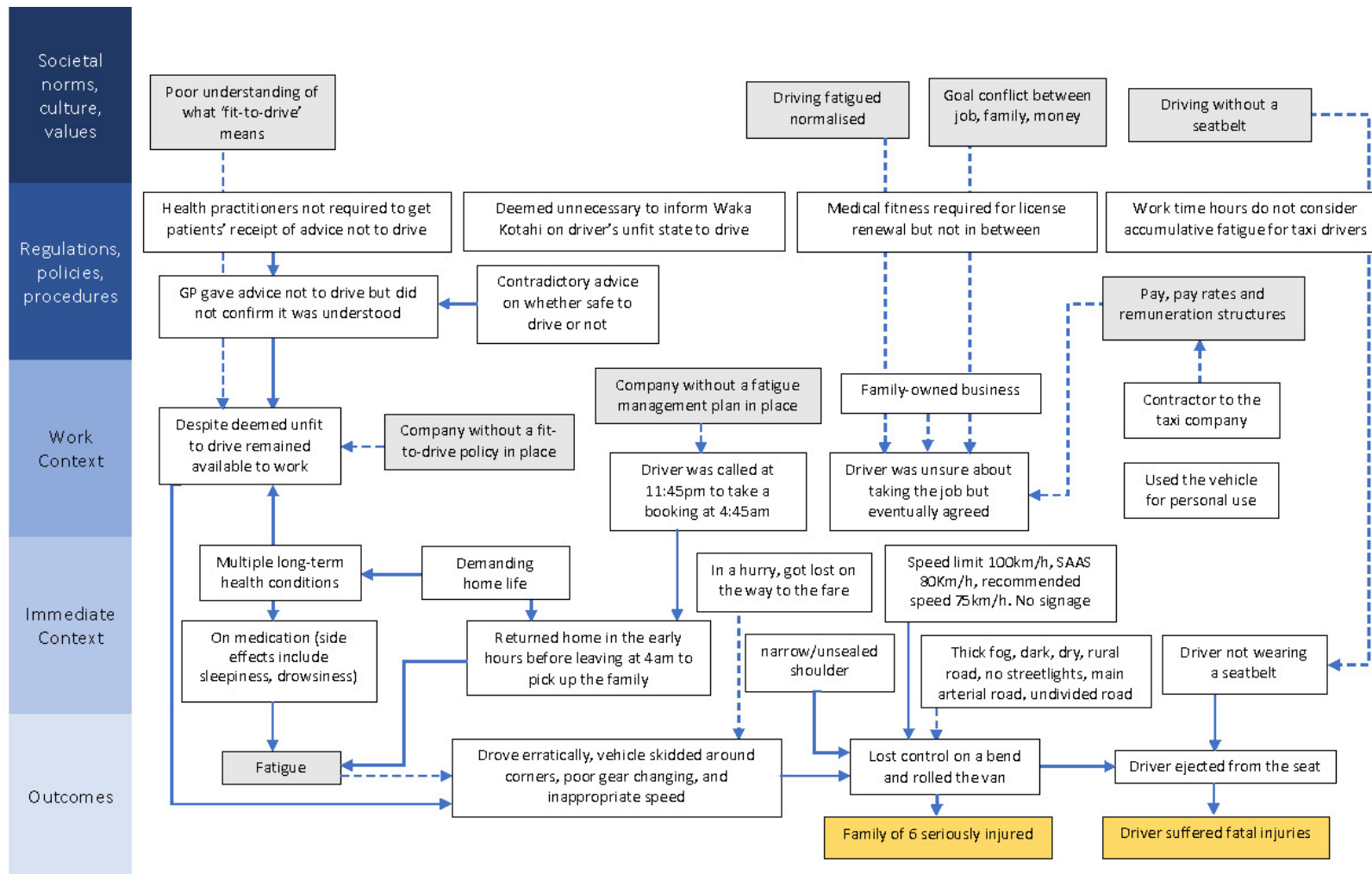


Figure 3. Pilot AcciMap of fatal crash case

searchers and/or studies can access necessary data without undue difficulty. Significant effort and resources are used to collect and store this data, and hence while there is an ethical obligation to ensure individual data is protected, we believe there is also an obligation to ensure the usefulness of the data is maximised.

## Study limitations

There were several limitations in the Safe System analysis component of this work. These primarily related to the accuracy and representativeness of the traffic crash reports (TCRs) recorded in CAS. TCRs are generally completed at the scene of the crash (or shortly after) by the attending police officer. They provide a wide range of useful crash information, particularly around roads and roadsides, vehicles, and people involved, and they are relatively easily accessible. However, as noted in the literature, the accuracy and level of detail included in TCRs is variable and often relies on driver and witness statements, particularly for speed estimates and driver behaviours at the time of the crash. Information relating to work activities is also often absent or sparse, making both identification of driving for work crashes and coding of work-related crash factors difficult.

Of particular concern is the, on average, lower level of detail contained in serious injury and especially fatal crash TCRs. This is in part due to the difficulty/impossibility of obtaining witness statements from people who are seriously or fatally injured in a crash, but also because more severe crashes require SCU investigations to be completed, and the information from these appears to be rarely back-filled into the TCR. As a result, some crash factors, such as speed, driver behaviours, and work activities, are likely to be underreported and therefore may be underestimated in this study. In addition, the distinction between minor and serious injury crashes can be quite subtle, with the potential for overlap. This could lead to an underestimate of the extent to which the crash factors examined influence crash severity.

Another limitation of the research is that the results cannot be generalised to all injury crashes in which someone was driving a light vehicle or service vehicle for work. Due to the difficulties in identifying work activity in crash records, the sample is unlikely to capture the full range of these types of crashes, though we are confident that it includes a sufficiently useful range from which conclusions about common crash factors can be drawn. In addition, the sample is likely to include some crashes in which the identified Driving for Work User was not actually driving for work at the time of the crash. However, we expect this latter proportion to be small.

The COVID-19 impact analysis was a brief exercise and did not explore trends beyond 'pre' and 'post' COVID-19 restrictions being introduced. The 'post-COVID-19' dataset therefore includes periods during which no community spread was occurring, and no restrictions were in place. Furthermore, the post-COVID-19 dataset was much smaller than the pre-COVID-19 dataset, particularly for fatal crashes, and these smaller sample sizes mean the results should be interpreted with due caution.

Finally, with regard to the cluster analysis, the internal validity of the identified clusters is governed by the HCPC algorithm. However, we were unable to assess the external validity of those clusters, that is, the extent to which the current clustering results can be generalised to other crash events. Additional data on which external validity checks could be performed was not available.

## Conclusions

The aims of this work were to determine the Safe System factors associated with fatal, serious injury, and minor injury crashes that occurred in light vehicles, and some service vehicles, while driving for work in New Zealand, and to explore the potential of socio-technical methods for analysing driving for work crashes or crash clusters. A Safe System analysis of 300 DFW crashes was carried out, along with an exploratory socio-technical analysis of one significant case, to better understand the context around DFW crashes.

Results of the Safe System analysis identified a range of similarities and differences in crash characteristics between DFW and non-DFW crashes. Notably, DFW drivers were given a primary role in the crash in 42 percent of cases and were less likely to have primary responsibility in fatal crashes than non-DFW crashes.

Statistical analyses identified three distinct crash types: 1) multiple vehicle crashes often involving work vans, utes, and SUVs in side impact crashes; 2) vulnerable road users often involving professional drivers; and 3) single vehicle crashes involving people driving vans or light trucks for work losing control on rural roads with fatigue, non-seat belt use, and speed often implicated.

The Social-technical AcciMaps analysis approach showed promise. For the case study crash reviewed, the approach successfully demonstrated how decisions, actions, policies, and ways of working contributed to the crash – from societal norms around driving fatigued and organisational pressures to accept jobs, to medication side effects and non-seat belt use.

For Safe System and AcciMap type methods to be used more broadly to understand DFW crashes in New Zealand, easier, safe, and agreed access to relevant data sources would be required, as would new data sources that enable the identification of 'upstream' contributing factors to crashes. Waka Kotahi has recently added a 'driving for work' variable into their CAS reporting system which should improve the ease of identifying these types of crashes. However, identifying 'upstream' factors requires connections to be built between datasets held by Waka Kotahi, Ministry of Health NZ, Ministry of Justice NZ and other government agencies. Clearly identifying DFW crashes within linked datasets would provide a significant opportunity to better understand these crashes and develop well targeted interventions.

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## Author Contributions

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## Human Research Ethics Review

The data used in this study was publicly available de-identified data and as such, ethics approval was deemed as not required.

## Data Availability Statement

The AA Driving for Work report is available on request through the AA Research Foundation NZ.

## Conflicts of interest

The authors declare there are no conflicts of interest.

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