

Trouble in paradise: a systems analysis of beach driving fatalities on Fraser Island (K'gari)

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Abstract

Beach driving remains a necessary form of transport in Australia, however it is not without incident. Between 2002 and 2015 there were over 160 reported 4WD crashes, including 4 fatalities on Fraser Island (K'gari), off the Queensland coast, Australia. Although beach driving provides a unique driving environment, there is little research investigating the causal nature of such crashes. The paper first reviews the cornerstone areas of the National Road Safety Strategy, in light of this unique driving environment. It also considers the guiding principles of the associated Safe System approach, before describing the results of applying two sociotechnical systems analysis approaches to this complex driving environment and a fatal crash. First, Cognitive Work Analysis was used to describe the K'gari beach driving 'system' along with constraints impacting driver behaviour. Second, Accimap was used to describe the contributory factors involved in a fatal 4WD beach driving accident that occurred in April 2009. The findings show that beaches present as complex roadway environments with a range of often conflicting priorities. Further, the analyses show that beach driving collisions likely involve a larger range of systemic failures than previously identified. In conclusion, the paper discusses the possibilities of Safe Systems interventions in light of the outlined sociotechnical systems approach. The details of current beach driving research are provided, while an overview of the ongoing research agenda is articulated. This agenda seeks to enhance our understanding of cultural, economic, environmental and social implications of off-road and beach driving to improve safety and stakeholder coordination.

Introduction

Fraser Island or K'gari (paradise) in the language of the local Butchulla aboriginal people, is world heritage listed and is the largest sand island in the world. It is located off the southern Queensland coast, Australia and is 120 kilometres in length and approximately 24 kilometres at its widest point (Figure 1). It has a residential population of less than 200, yet it receives more than 390,000 annual visitors in the form of daytrips and short term stays. It is a popular destination for local, national and international tourists, with more than 80% of visitors camping in designated areas along the eastern beach. Access to the island is by barge while access and travel on the island is afforded by the use of 4WD vehicles traversing the eastern beach and sandy inland tracks.

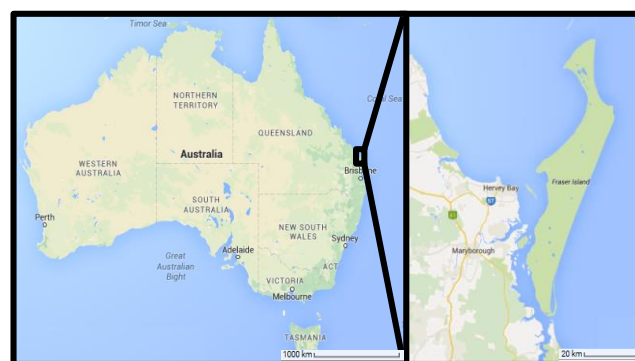


Figure 1. Fraser Island (K'gari) geographic context (Source: Google Maps).

The beaches of K'gari, like any Queensland beach on which vehicles are permitted to drive, are considered gazetted roads under state government legislation. That is, all road rules and regulations that pertain to state government constructed and managed roadways, also apply to the beaches. While this allows for greater regulation, enforcement and prosecution, it is not without issue.

When considering the cornerstone areas of the 'safe systems' National Road Safety Strategy – Safe Roads; Safe Speeds; Safe Vehicles; Safe People (ATC 2011) – it becomes apparent how unique the beach driving environment is. Moreover, the need for a focussed strategy is highlighted. As a gazetted roadway each of these safety approaches should remain and be prioritised, however the nature of the four pillars appears distinct to the beach driving environment. *Safe Roads* seeks to ensure the driving surface is designed and maintained to reduce risk, however the beach as a road is maintained and influenced simply by wave action and seasonal variation. In fact, there is very little physical intervention to the beach driving surface by the authorities in line with its National Parks and World Heritage status.

Safe Speeds is intended to complement the road environment and seek road user compliance to limits. However, the beach as a roadway is predominately an 80km/hr driving environment that experiences rapid changes, unstable surfaces, pedestrian priority, and distraction – with limited signage, instruction or road infrastructure. It is questionable whether applying conventional road speed limits in the beach environment is appropriate. Further as a gazetted roadway it permits any person with regular on-road or international licensing to drive in this complex environment.

Safe Vehicles has the strategic intent of lessening the likelihood of crashes and simplifying the driving task through the design of the vehicle. In the beach environment not only is it a roadway context of vast unfamiliarity for many drivers, it is further compounded by the necessity of the use of 4WD vehicles which have high rollover risks for inexperienced drivers (Keall and Newstead 2007). Moreover, there is a lack of control on which vehicles can be used when driving on the beach.

Safe People seeks to 'encourage safe, consistent and compliant behaviour through well informed and well educated road users' (ATC 2011 p 41). As a gazetted roadway it is possible for the authorities to regulate and enforce specific behaviours on the beach. However, there are limited requirements for specific education when using the beach as a road. Only those drivers who seek organised tours are required to view specific safety information about beach driving. What is recognised in this paper is that these strategic cornerstone areas of road safety, are not well supported in the beach driving environment.

Unsurprisingly then, crashes occur. K'gari has seen numerous incidents and most significantly 4 fatalities from 3 separate accidents since 2009. Three of the deaths resulted from two motor vehicle accidents that occurred in 2009. These fatalities were passengers in 4WD hire vehicles being driven by a fellow tourist, who they had only recently met, driving on sand for the first time. The fourth fatality in October 2014 was the driver of the vehicle and was killed when her vehicle overturned on an inland sand road.

At the time of the 2009 accidents international tourists were permitted to undertake self-drive tours of the island. Since 2011 these tourist groups are required to be part of 'tag-a-long' tours. While they still self-drive, they are part of a convoy of up to 6 vehicles that is led by an experienced 4WD operator from the tour company. The most recent fatality occurred while the tourist in question was participating in this type of monitored 4WD excursion. Prior to departure the designated tourist drivers of the 4WD vehicles are required, by law, to view a 30 minute instructional video, undertake a vehicle inspection and complete a 30 minute test drive of their designated vehicle. This instruction is provided by the tour company.

There is no doubt that beach driving crashes represent a significant problem. As a result, standard road safety interventions are being applied, particularly when visitor numbers are high. These include the use of speed cameras and random alcohol and drug testing. Whilst this is encouraging, the program of research from which this paper derives argues that the unique context in which beach driving occurs raises questions regarding a standard road safety approach. This research seeks to take a socio-technical systems view of this road safety issues (see Salmon and Lenne, 2015), as such it is useful here to acknowledge the differences between this approach and that of the current 'Safe System' approach adopted through National Road Safety Action Plans (ATC 2011).

While the safe systems approaches do contain elements of systems thinking, it has been pointed out they are not underpinned by socio technical systems (STS) thinking models or methods. Salmon and Lenne (2015), however, point out that whilst there is confusion about 'systems' approaches, some of the key principles of STS are present in current road safety thinking. For instance, the acknowledgement of human fallibility; the understanding that the principles of road safety are a shared responsibility across stakeholders; and the consideration of factors beyond road users, such as roadway design and vehicles. Such parallels are aligned with STS thinking approaches such as Rasmussen's (1997), yet the differences are also significant. Consider, for example, the current road safety strategies focus on behavioural failures as 'error' (ibid); and conversely that STS thinking views the overall system as the appropriate unit of analysis. Further, STS considers that interactions, not components, are of most interest when seeking to understand behaviour, and largely moves away from the approach which typically focusses on road users themselves (Salmon and Lenne 2015).

Indeed, through an STS approach this research anticipates that the unique nature of beach driving environments may provide an opportunity to implement new context driven interventions. A first step in determining this requires that the beach driving context be described and understood, along with the systemic factors that contribute to beach crashes. In particular, the extent to which the environment and associated crashes are different to standard road environments and crashes needs exploration. In addition, the stakeholders who share responsibility for beach driving crashes should be identified. This paper is a response to this, exploring the beach driving environment and also highlights the contributory factors involved in the April 2009 incident which resulted in 2 fatalities.

Description of the 18th April 2009 crash.

On the morning of 17th April 2009, a group of 11 foreign tourists hired a 4WD from a vehicle rental company in Hervey Bay, Queensland. The designated drivers of the group were shown a 10 minute safety induction video, whilst some shopped for groceries, and others packed the luggage on the 4WD vehicle. The vehicle itself was an 11 seater 8 cylinder diesel 4WD with a seat configuration of 3 across the front and 8 passengers on 2 bench seats facing each other in the cabin. The group signed rental agreements, were further briefed on engaging the vehicle in 4WD and the benefit of reduced tyre pressures if stuck in soft sand. They were provided with maps and itineraries and they departed. The groups journey to, and on K'gari that day were uneventful and they rendezvoused with other groups at a designated campsite for the evening.

The group departed early on the second day (18th April), heading north on the eastern beach for a destination known as Champagne Pools. After a short time one of the individuals who had packed the luggage at the hire company and was not a designated driver asked if he could drive, a request which was granted. After travelling for perhaps 10km, one of the designated drivers noticed that they were getting close to the water's edge. The driver subsequently swerved sharply to the left to avoid a wave, losing control of the vehicle which rolled 3 $\frac{3}{4}$ times. Two individuals were thrown from the vehicle and killed, while 5 others were seriously injured.

The response to the incident is also noteworthy. A Queensland Parks Services Wildlife Ranger was the first on the scene, shortly followed by two others leaving one to summon emergency assistance. The lack of communication facilities made the access to medical assistance very slow. The crash occurred at around 7.30am, Police and Ambulance Services were notified at 7.55am and 7.56am, not arriving at the scene until 8.40am and 8.45am respectively. The two helicopters required to evacuate patients did not arrive on scene until 9.18am.

Method

There is a growing body of research involving the application of so-called systems thinking theories and methods to road safety issues (see Salmon and Lenne, 2015). These approaches have been prominent for the last two decades in the area of accident analysis generally (e.g. Leveson, 2004; Rasmussen, 1997) and have also enjoyed significant attention in the areas of systems analysis and design (Karsh et al., 2014; McIlroy and Stanton, 2011; Salmon et al., 2012). The philosophy is that accidents, and indeed safety, are emergent properties that arise from non-linear interactions between components across complex sociotechnical systems (e.g. Leveson, 2004). In short, accidents are underpinned by a network of interacting, contributory factors covering a range of actors and artefacts and are not simply the product of one bad decision or action alone. In a driving context, this suggests that, even in crashes that have direct driver-related causes, there are a range of other contributory factors worthy of investigation.

Two systems approaches were used to investigate the beach driving environment and beach driving fatalities on K'gari. Cognitive Work Analysis (CWA, Vicente, 1999) is a framework used to identify constraints on activities and then support the design of new systems (Vicente, 1999). To better understand the beach as a roadway environment this study developed an abstraction hierarchy from the first stage of CWA - Work Domain Analysis. Accimap is an analysis framework (Rasmussen, 1997) which is used here to represent the causal network underpinning the fatal incident of 18th April 2009 across six organisational levels: 1. government policy and budgeting; 2. regulatory bodies and associations; 3. local area government planning & budgeting (including company management); 4. technical and operational management; 5. physical processes and actor activities; and 6. equipment and surroundings.

Results

Work Domain Analysis

Key inputs for the WDA Abstraction Hierarchy (AH) were identified from three sets of resources: 1. The regulation of the 'beach as a road' defined by Queensland government transport related legislation and policy; 2. The road safety literature and departmental guidance concerning beach driving; and 3. The observation and inspection of the beach driving environment on K'gari.

The AH is presented in Figure 2. Due to space constraints the top three levels are represented in full while the bottom two have been summarised only. While there is much that can be drawn from this representation, this paper will only outline some key insights.

The highest level of the abstraction hierarchy describes the functional purpose of the 'beach as a road' system. Two overall purposes were identified, the first is 'safe vehicle access to (coastal) destinations'; while the second is to 'limit the need for roadway infrastructure'. What is immediately recognisable is that these two functional purposes are likely in conflict – it is questionable whether it is possible to prioritise safety whilst at the same time limiting roadway infrastructure.

The next level details and links the measures or values that enable progress towards the functional purposes to be understood. While six values were identified, only three connect to both functional purposes. Maximise compliance; safe passage/movement of vehicles; and maximise conformity with relevant standards and regulations are important to both purposes. The system described here considers that minimise environmental damage is not a measure for 'safe vehicle access to (coastal) destinations' indicating a probable conflict between the world heritage status of K'gari and the prioritisation of unrestricted visitor access. Again this conflict is noteworthy, as interventions designed to improve safety will have to have only minimal impact on the environment.

The purpose related functions within the middle of the AH represent the functions required for the system to fulfil its purpose. Within this system ten purpose related functions were identified. A useful way to conceive these functions is through means-ends relationships. For example if the generalised function of 'driver training' represents the question '**what**', then 'minimise trauma and collisions'; 'maximise compliance'; 'minimise environmental damage' and 'maximise conformity with standards and regulations' is '**why**'; and then object related processes of 'provides rules about behaviour'; 'inform / educate road users'; 'impacts vehicle operation'; and 'provides information about speed' is '**how**' the generalised function of 'driver training' is achieved. What is interesting is that while driver training is explicitly required as a function in the 'beach as a road' system, it is seemingly not being adequately met.

At the bottom of the hierarchy are the physical objects that are found in the 'beach as a road' system. The inspection of the beach revealed a number of unique physical objects for a roadway, including the ocean and waves, shipwreck, aeroplane, creeks and wash outs, rocks, logs and wildlife. This system also contains a number of expected roadway elements including speed signage and information signage. Importantly it also include those objects which while physically located away from the beach environment, are of significant influence on its use as road, for example road rules, finances, legalisation, and maintenance guidelines.

The level above the physical objects represents the 'affordance' or the functional capacities of the physical objects. For example consider the affordance of 'surface for mobility' as an object related process of hard sand. What is interesting is that affordances may be linked to multiple objects, and from a system perspective here is where opportunities and constraints may be recognised. For example the object related process of 'depict path' is an affordance of 'hard sand'; 'soft sand'; 'puddles'; 'creeks & wash outs'; 'tyre tracks'; 'undulations'; 'vehicles'; and uniquely on the beach as a road 'aeroplanes'.

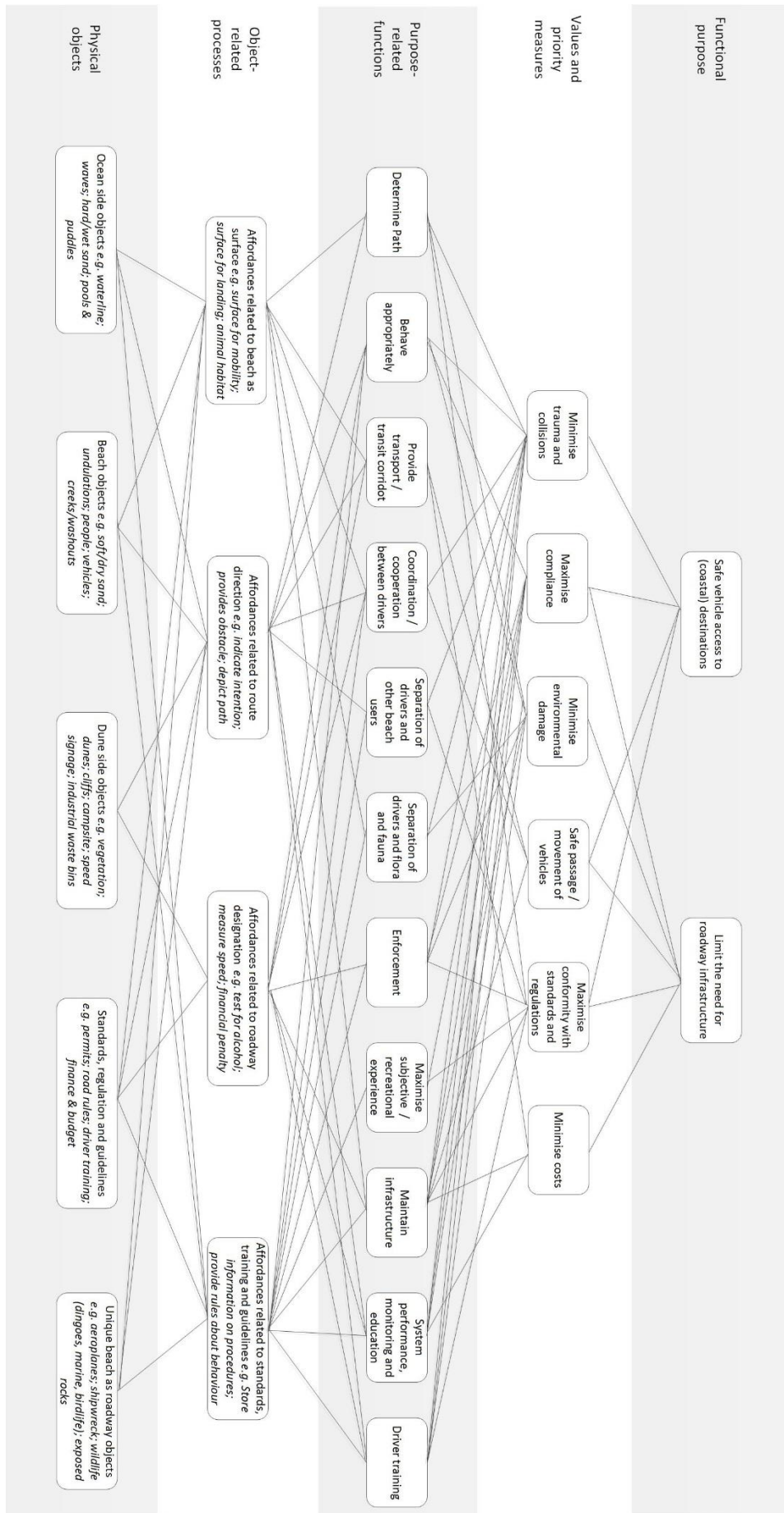


Figure 2. Beach as a road - Work Domain Analysis, Abstraction Hierarchy

Accimap

The data for the development of the Accimap was obtained from the Coroner's report on the driving fatalities that occurred on K'gari (Queensland Courts 2010). This details the circumstances of two independent fatal motor vehicle incidents in 2009. The report outlines the evidence in both incidents and importantly it describes the circumstances surrounding the hiring of the vehicles; driver training, the vehicles specifications; the crashes themselves and the emergency response. This paper presents an analysis from one of those which resulted in the deaths of two foreign tourists in April 2009.

The Accimap is presented in Figure 3. At the top level, government policy and budgeting, sits a report commissioned by the Queensland State Government in 2005 which made a number of recommendations for the safety of the use and hire of 4WD vehicles on K'gari. Rather than influence behaviour, this is included as these recommendations were only implemented following the fatal incidents of 2009.

The Coroner's Report makes no references regarding contributory factors that may be included within either the 'regulatory bodies and associations'; nor the 'local area government planning & budgeting' levels. What is known, however, is that a range of important stakeholders reside at these levels, including Queensland government departments related to the administration and management of emergency services and the environment; the relevant local government; and also management associations for environmental protection and accommodation on K'gari (Stevens and Salmon 2015). It is likely that further analysis of this incident would also identify contributing factors at this level.

At the technical and operational level, miscommunication and ambiguity about the driver's roles can be found. This led to the provision of inadequate driver training at the physical processes level prior to the incident.

The physical processes and actor activities level describes the activities leading up the crash itself. This level is focussed on the driver, the relationships between driver training and experience, and their ability to respond to the beach driving environment. Here the driver had no previous experience of driving on sand, had received only limited driver training, and was apparently exceeding the speed limit (Queensland Courts, 2010). The Accimap shows the consequent sharp turn, together with the sand surface, top loaded luggage, and the nature of the 4WD configuration all contributed to the rollover. However, following the rollover there are other contributory factors that determine the extent of injuries and the fatalities, including the failure of passengers to wear seatbelts, the lap belt nature of the restraints, and the delayed emergency response.

The equipment and surroundings level shows the beach environment and vehicle factors that contributed to the incident. The waves (and the vehicles proximity to them) initially caused the driver to swerve, and the nature of the sandy surface in conjunction with the vehicles speed and luggage load were deemed to have caused the vehicle to roll over. Following this aspects of the vehicle are important. The seat configuration in the vehicle and use of lap belts ostensibly contributed to the injuries incurred. Finally, the poor mobile phone network was a major factor in the delayed emergency response.

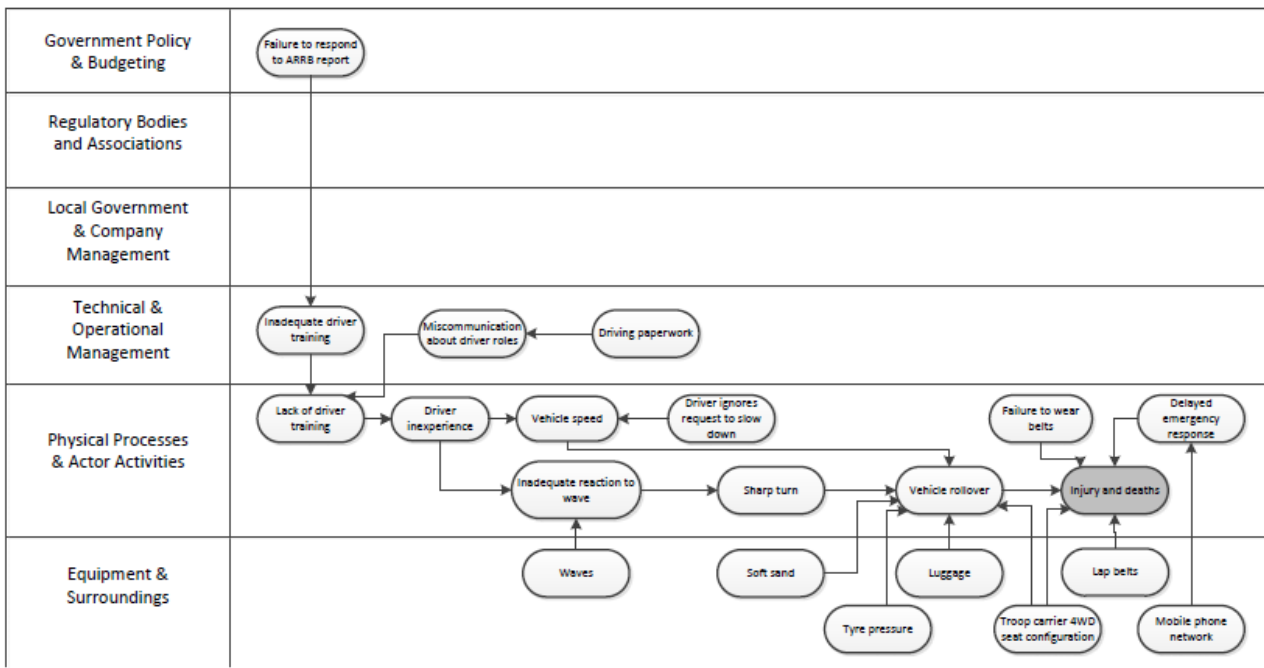


Figure 3. Accimap Analysis – Accident trajectory of 18th April 2009

It is highly likely that there are additional factors outside of those expressed in the Coroner’s report, that a systems investigation and approach to the incident may be expected to reveal. Perhaps from both the Regulatory and Company Management organisational levels there are necessary links to the provision of driver training.

Discussion

The exploratory analyses presented here confirm that beach driving systems are unique complex environments in which a systems thinking approach to accident analysis and prevention is warranted. Both the WDA abstraction hierarchy and the Accimap analyses provide a picture of a complex, high risk driving environment in which there are multiple factors influencing driving and indeed safety. A key conclusion from this case study is that standard road safety approaches to accident analysis and prevention in beach driving are not appropriate. Rather, it is these authors opinion that interventions need to be developed based on the unique nature of the driving environment and its constraints. When considering the key cornerstone areas of road safety intervention and the systems analysis overview presented here – the difficulties of implementation becomes evident. For example, there are very few opportunities for traditional safe roads design and management interventions. However when the pathways drivers take are determined largely by previous vehicles, is there a collective reinforcement of safe or indeed unsafe driving behaviour? When considering speed and human tolerance to impact forces on beach road surfaces – what kinds of speeds are in actual fact absolutely safe? Further research is therefore required in this context to develop approach beach driving safety strategies.

In the first instance the research agenda will focus on gathering data which will both inform a socio technical systems response to beach driving, but also value add the current strategic intent of the National Road Safety Strategy (ATC 2011). Key requirements to support this include understanding the physical and jurisdictional conflicts and opportunities for the design and maintenance of the beach as a road. Exploring the context of speed, and the posting of speed limits within a safety infrastructure constrained environment. While the use of vehicles is limited to 4WDs, there are lessons to be learned from the vehicle to vehicle and driver to driver awareness and conventions that occur in the beach driving system. Finally, what are the opportunities for well informed and

educated road users in this dynamic driving environment – what role and impact does current licensing, training, enforcement and regulation play in managing road safety on the beach? Principles tasks to support this will include new crash data collection and analysis systems, the exploration of context-driven safety interventions, and potentially a new approach to regulation.

In light of this further research exploring beach driving is required. This will reveal much more than simply a safety approach to beach driving. Through the lens of this particular off-road and infrastructure deficient environment there will also be applicable lessons to a range of national and international loose surface driving contexts. The significance and potential impact of this new knowledge cannot be understated, take for example in Australia where more than half of the 820,000km of roads are unsealed, and internationally, where in second and third world countries unsealed roadways may constitute more than 75% of the national roadway network (CIA 2014).

A research agenda has been established to seek to address the current research deficiencies and explore the potential for a range of safer driving environments. Initial research, currently underway seeks to further explore the beach driving systems from the driver perspective. The aim of this project is to develop an initial understanding of a driver's perceptions and reactions to driving on gazetted beach roadway environments. The objectives of this research are to: 1. Identify the range of physical and cognitive processes a driver undertakes in order to navigate the beach driving environment. 2. Identify the range of physical elements a driver encounters within the beach driving environment. The drivers will think aloud whilst driving, as a component of a data collection method called Verbal Protocol Analysis (VPA). They will also complete a survey at the conclusion of the driving task. The verbal protocol analysis approach has become popular as a way of assessing behaviour and cognitive in real world contexts with many recent applications in road safety studies (e.g. Salmon et al, 2013; Walker et al, 2011).

The broader program of ongoing research will seek to have two main aims; first it will undertake appropriate systems modelling of driving safety in beach and unsealed roadway environments, and, second, it will establish appropriate crash data systems to elucidate the full network of contributory factors involved in beach driving and unsealed roadway crashes. This will involve a series of targeted research activities, including development and testing of crash contributory factor classification schemes, the conduct of reliability and validity studies, prototype testing, and full scale trials over the next 36 months.

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