Al Aamri, A., Padmadas, S. S., Zhang, L.-C., & Al-Maniri, A. (2025). Improving the Efficiency and Quality of Road Crashes Data in the Sultanate of Oman: Evidence-Based Recommendations. *Journal of Road Safety*, *36*(2), 63–74.
https://doi.org/10.33492/JRS-D-25-1-2563701

Article Type 1: Peer-reviewed papers

Improving the Efficiency and Quality of Road Crashes Data in the Sultanate of Oman: Evidence-Based Recommendations

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Keywords: road traffic crash, road injuries, National Road Traffic Crash (NRTC) database, data quality, data linkage, Oman

https://doi.org/10.33492/JRS-D-25-1-2563701

Journal of Road Safety

Vol. 36, Issue 2, 2025

Abstract

Reliable Road Traffic Crash (RTC) data are essential for accurately identifying risk factors, establishing priority areas for policy interventions and evaluating intervention outcomes. In many countries, inadequate and inconsistent data pose challenges for developing evidence-based policies for reducing the RTC burden, while RTC continue to exert significant impact on national and family resources. We conducted a critical evaluation of the strengths and weaknesses of the National Road Traffic Crash (NRTC) database in Oman. This assessment was grounded in the development of a holistic, integrated framework to evaluate the causes and consequences of RTC. The integrated framework of RTC was developed, building on the behavioural, economic, social, technological, and environmental dimensions outlined in the Haddon Matrix and the C3-R3 systems model. We then critically assessed the NRTC database and proposed coherent strategies to enhance the recording, monitoring, and analysis of RTC data. Our evaluation highlighted the relevance of key variables necessary for understanding the dynamics and complexities of RTC, as well as the gaps and challenges present in the NRTC database. The paucity of relevant RTC data hindered our ability to accurately predict and validate the interactive effects of factors associated with RTC and related injury outcomes. The limitations of the NRTC database underscores the urgent need for structured modifications including multi-sectoral data integration. Our integrated framework can improve the quality of NRTC database, help policymakers to better understand the dynamics and complex interplay of RTC factors and enable the implementation of data-driven policies for effective road safety interventions.

Key findings

- The interactive effects of human-road-environment variables are key to predicting road crashes.
- Multi-sectoral data linking to road crash data can help design better road safety interventions.
- Haddon Matrix and C3-R3 systems model together offer better insights for predicting road crash incidents.
- Civil ID information can enable linkage of NRTC database with other relevant databases.

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Glossary

RTC Road Traffic Crashes
NRTC National Road Traffic Crash database
GCC Gulf Cooperation Council
ROP Royal Oman Police

Introduction

Reliable data from Road Traffic Crashes (RTC) are fundamental to accurately ascertaining the RTC risk factors, identifying priority areas for interventions, designing evidence-based policies, monitoring performance, and evaluating intervention outcomes (Memon, 2012; Peden et al., 2004; Sohail et al., 2023). Evidence from high-income countries suggest that RTC data informed by scientific research have substantially contributed to reducing RTC burden and associated injuries (Memon, 2012). Data completeness and accuracy are the two essential features of RTC databases to improve road safety and develop effective countermeasures (Imprialou & Quddus, 2019; Peden et al., 2004; Sohail et al., 2023).

The quality and reliability of any data are dependent on collection methods including who collects the data, tools and methods of collection and how the information is recorded and processed (Imprialou & Quddus, 2019; Peden et al., 2004). RTC are complex in nature and different institutions use data for different purposes (e.g., enforcement, trauma care etc.) (Imprialou & Quddus, 2019). A critical challenge, however, is to harmonise the data to enable RTC data to be linked with other relevant databases (Peden et al., 2004). Harmonisation and regularity of data collection could greatly improve the assessment of road safety indicators of any country (Grimm & Treibich, 2010) and simplify understanding of road crashes globally.

In this study, we posited the question: how can we improve the quality of existing data collection systems to better understand and measure road traffic crashes and associated injury outcomes? We answer this question with a focus on addressing the strengths and limitations of National Road Traffic Crash (NRTC) database in Oman.

The aims of this paper are three-fold: first, to present an integrated framework for understanding the behavioural, economic, social, technological, and environmental factors associated with RTC, incorporating the elements of Haddon Matrix and the C3-R3 systems approach. Second, to undertake a critical assessment of the existing data collection procedures and recording systems, reflecting on the strengths and weaknesses of National Road Traffic Crash (NRTC) database in Oman, and suggests coherent ways to record, monitor and analyse road crash data. Third, to provide policy recommendations aimed at improving the quality of data collection and processing of NRTC database in Oman.

The recommendations drawn from the present study are relevant in Oman and elsewhere in the Gulf Cooperation Council (GCC) region with similar institutional structure and road incident monitoring systems.

Framework for understanding the dynamics of RTC

The Haddon Matrix provides a useful framework for road safety analysis as it contains a temporal sequence that identifies risk factors in three phases of traffic crash: the pre-crash; the crash; and the post-crash stage (Mohan, 2006; Zein & Navin, 2003). Each phase can be analysed through the four factors of the Haddon Matrix: human; vehicle; road and social environment factors (Mohan, 2006; Zein & Navin, 2003). The Haddon Matrix combines these factors in a logical order (Table 1).

The three elements of the temporal sequences represent the rows of the matrix, and the four elements of the traffic system represent the columns so that the matrix will end-up with twelve cells (Zein & Navin, 2003). Once the inter-related factors associated with a crash are specified, a range of potential risk factors can be identified, and the interventions and countermeasures can be developed and implemented over both short- and long-time periods (Mohan, 2006; Runyan, 2003).

In the pre-crash phase, countermeasures should aim to prevent the crash and injuries or if a crash does occur reduce injury severity. Post-crash countermeasures should aim to reduce the adverse outcome (Mohan, 2006). Although this matrix is used as a comprehensive detection tool in identifying road safety problems and enabling successful safety interventions, there are some limitations (Runyan & Yonas, 2008; Thomas et al., 2013). It does not facilitate the interaction between the four elements of traffic system, nor does it incorporate the effect of exposure to crash risk such as distance travelled and level of traffic volume (Thomas et al., 2013).

The C3-R3 systems approach expands on the Haddon Matrix by integrating the temporal and spatial inter-relationship between underlying factors which influence the road user, vehicle and road environment performance (Zein & Navin, 2003) and provides a more dynamic analysis of failure phases and countermeasures. The fundamental blocks of C3-R3 are illustrated in Figure 1 and include the road users, the vehicle, and the road environment (entities) and the pre-crash and post-crash timeline phases.

Source: Zein and Navin (2003, p. 22)

According to Zein and Navin (2003), the pre-crash timeline consists of three phases (the three “Cs”): creation, cultivation and conduct phases. The creation phase starts when an entity, a road user, the vehicle or the road environment, and their characteristics are identified. The cultivation phase represents the development and the maturity stage of the entity so that its operational characteristics are set. The conduct phase represents the actions and the condition of the entity immediately before the occurrence of the crash.

The post-crash timeline consists of three “Rs” phases: response, recovery and reflection. The response phase represents the immediate response action of the entity to the

Table 1. The Haddon Matrix

Phase		Factors			
		Human	Vehicle and equipment	Road environment	Social environment
Pre-crash	Crash prevention	Information Attitudes Impairment Police enforcement	Roadworthiness Lighting Braking Handling Speed management	Road design and road layout Speed limits Pedestrian facilities	Enforcement activities Cultural norms permitting speeding and red light running
Crash	Injury prevention during the crash	Use of restraints Impairment	Occupant restraints Other safety devices Crash protective design	Crash-protective roadside objects	Laws concerning use of safety equipment
Post-crash	Life sustaining	First-aid skill Access to medics	Ease of access Fire risk	Rescue facilities Congestion	Health insurance Access to EMS trauma systems, rehabilitation services Family and social support

Adapted from Mohan (2006, p. 24)

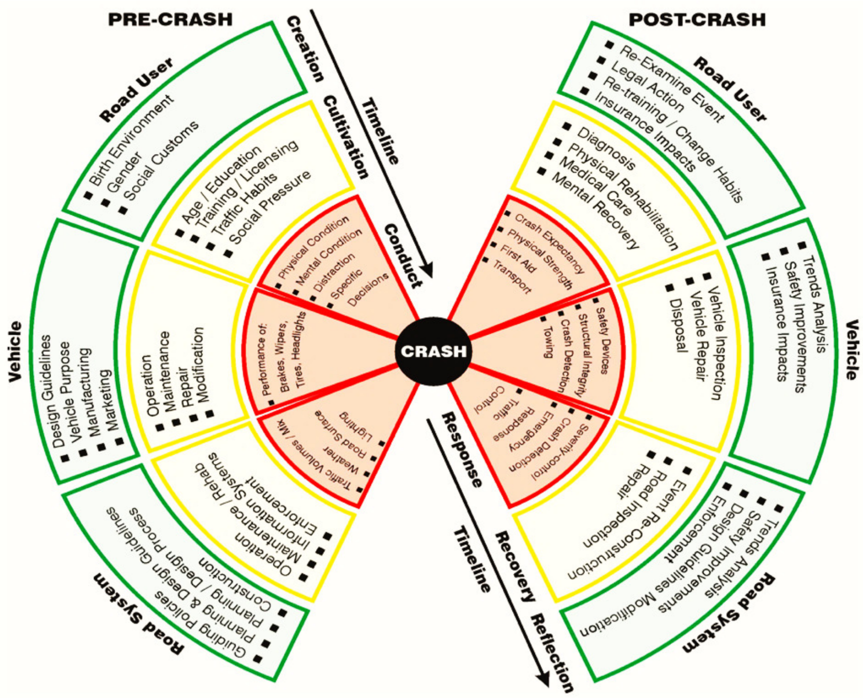


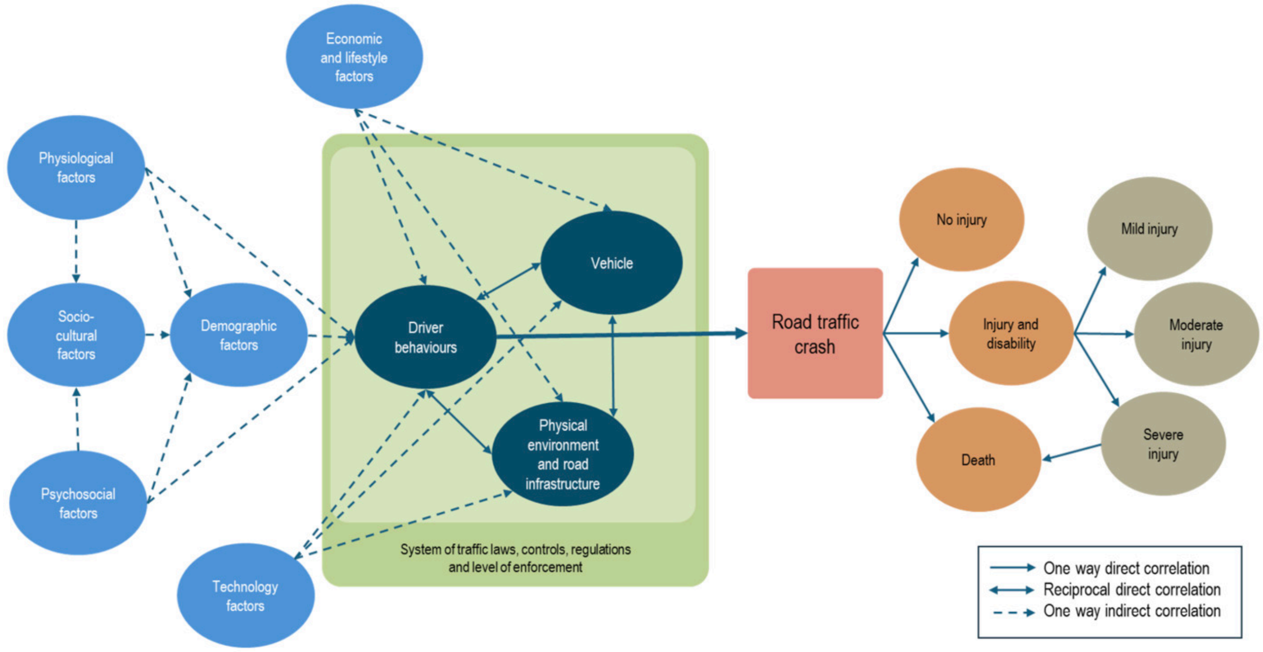
Figure 1. The C3-R3 systems approach

Source: Zein and Navin (2003, p. 22)

crash once it occurred. The recovery phase represents the action taken by the entity following the crash. The reflection phase represents the reflection of the entity on the events of the crash to prevent the reoccurrence of the crash in the future.

Each cell in the C3-R3 systems approach is a combination of an entity and a timeline phase, representing the individual elements that traffic safety professionals need to understand to reduce the crash risks. The C3-R3 systems approach focuses mainly on the interrelationship between the components of the transport system and the timeline of crash stages, so that effective road safety countermeasures can be identified by linking all these elements of transport system (Hermans et al., 2008). For example, the elements in the pre-crash C3 phases aim to reduce the number of RTC, while the R3 phases are post-crash and aim to reduce injury severity.

While both these frameworks provide valuable insights into the factors contributing to road traffic crashes, a more



Factor	Detail
Demographic	Age, sex, nationality
Socio-cultural	Religious beliefs, customs, values, traditions
Psychosocial	Thoughts, feelings and other cognitive characteristics that affect the attitudes
Physiological	Body growth and sex hormones, sleep and wakefulness
Economic and lifestyle	Income, employment, urbanisation
Technology	Mobile phones, Speed cameras, Music system, GPS systems
Physical environment and road infrastructure	Weather condition, road design, speed limit, traffic lights

Figure 2. Integrated framework on the causes and consequences of road traffic crashes

comprehensive framework is required to account for the complex interplay of multiple variables.

We propose an integrated conceptual framework, building on the Haddon Matrix and C3-R3 systems approach, to offer a holistic understanding of the complexities underlying the causes and consequences of road traffic crashes (Figure 2).

RTC involve a multiplicity of interacting factors (Al-Aamri et al., 2017). The primary factors can be considered in three categories: road user behaviour, vehicle and road environment. In most RTC, two or more of these factors interact, for example, driver behaviour may be influenced by road characteristics (e.g., speed limits, road design) or vehicle features (e.g., large SUV sport cars), just as vehicle performance may be impacted by the quality of the road or driver behaviours. However, in addition to these three factors, the framework also needs to consider the interactive effects of other factors such as traffic policy, rules and regulations, physiological, psychosocial and cultural, technological, family, economic and lifestyle factors.

The green box in the middle part of Figure 2 highlights the prominence of road safety policies, regulations, interventions and level of enforcement, which have influence on the road infrastructure, vehicle characteristics and driver behaviours. For example, the inclusion of road safety education within curriculum at schools could improve the road crossing and driving behaviours among children and young drivers.

Similarly, economic and lifestyle factors such as level of income, employment rate and urbanisation have an impact in determining the preferred mode of travel and the characteristics of road infrastructure. For instance, in Oman, economic growth has resulted in rapid urbanisation, improved road infrastructure and a steady increase in number of registered motor vehicles in the country (Al-Reesi et al., 2013), economic and lifestyle factors that have impacted driver behaviours (Arslan & Ozkan, 2024). Likewise, technology factors such the use of smartphones and entertainment systems inside the vehicle have emerged as sources of distraction for the drivers that can divert the driver's attention and lead to risky behaviours (e.g., speeding, reckless driving) (Arslan & Ozkan, 2024; NHTSA, 2022a).

The psychosocial factors such as thoughts, feelings, and other cognitive characteristics affect the attitudes towards the driving behaviours, particularly young drivers. Likewise, the physiological factors influence the driving behaviour especially for drivers aged below 25 years as the prefrontal cortex of their brains is still at its development stage (Shope, 2006), which could affect the decision-making in unexpected circumstances. Additionally, the circadian and sleep systems can change at different stages of age, which suggest a direct association between chronological age and fatigue related crashes (Di Milia et al., 2011).

Young drivers' perceptions of driving risk may be also influenced by the culture of the community or nation where they belong (Shope, 2006). From their community, young drivers can learn and repeat at risk behaviours associated with driving that increases the likelihood of violating road safety rules, of being involved in a crash that may injure or kill (Shope, 2006). The driving culture in Oman creates social norms that result in an increased risk of men involved in a road traffic crash. Men are more likely to be the breadwinner for their families (Al-Aamri et al., 2017) and usually spend long hours at work resulting in men driving when they are fatigued. More generally, RTC is an outcome of the interaction of a multiplicity of factors although some factors may not appear directly associated with the occurrence of road traffic crashes (Mohan, 2006).

NRTC database: Strengths and limitations

NRTC database is maintained and published by the Directorate of Road Traffic of the Royal Oman Police (ROP) and it is the only source of RTC data in the Sultanate. The database has basic information of RTC such as crash date, time, severity level, gender, age and nationality of drivers and injury outcomes, number of causalities, number of fatalities, type and number of vehicles involved, cause of crash, type of collision, location, type of road, weather conditions and crash description. Due to copyright and data protection reasons, we could not include a sample of the NRTC reporting form. The following sections summarise a few limitations of the NRTC database.

1. Manual reporting system

The manual recording system of crash data is one of the main limitations of the NRTC database in Oman and in the Arab region in general (Abounoas et al., 2020). Unlike automated systems, manual reporting systems require more time to generate written reports, have a higher risk of errors (e.g., data input, duplication) and are difficult to update when corrections or changes are required. To reduce these errors, existing data collection protocols and guidelines could be improved using digital data collection systems (Tiam et al., 2022). This needs to be supported by routine in-service training programs and periodic (online) assessments and supportive supervision to ensure police officers understand and follow the correct protocols for reporting RTC.

2. Challenges with the definition and classification of RTC related deaths

The definition of RTC deaths varies across countries (Peden et al., 2004), making it difficult to determine the extent of accuracy, especially when comparing key indicators (Al-Bulushi et al., 2015). For instance, while some countries define RTC deaths as having occurred within 30 days of the crash, different post-crash timeframes are also used (e.g., within 24 hours, 7 days, more than 30 days), contributing to discrepancies in reported crash death rates (WHO, 2018).

Additionally, there is a lack of documentation of severe injuries that eventually lead to death. Fatal outcomes occurring during hospitalisation or post-discharge may be missed in police records, resulting in underreporting of RTC-related deaths (Peden et al., 2004). Another challenge is related to reporting the cause of death. For example, if a person involved in a crash dies at the hospital following a medical event (e.g., haemorrhage, myocardial infraction), then the medical event may be recorded as the cause of death rather than the crash (Bachani et al., 2012).

To improve data accuracy, integrating civil identification numbers across multiple databases, such as police, hospital, and civil registration records, can help identify the health outcomes of people involved in crashes including death or for non-fatal crashes, subsequent conditions that may have been a direct result of the crash (e.g., chronic pain, hypertension, cardiac problems, diabetes etc.). Therefore, post-crash follow-ups, especially for people transferred to hospital, are required to properly understand and enable audits of RTC and related injury/crash outcomes.

3. Challenges with recorded data

Driver at fault and co-passengers

Data on the demographics and injury outcomes of passengers, including in the counterpart vehicle, are often not recorded. In contrast, a range of data related to drivers at fault are recorded including driving experience, licence status, history of previous crashes, traffic offences and other personal risk factors. These data should be available for research to help analyse and understand the types of injury outcomes of passengers. Ideally, a case file with a comprehensive documentation of the incident, damages, and human/animal injury outcomes would be created and then be available for analysis for crash prevention and legal use if required.

Other road users

Although the details of other road users involved in the crash are not directly associated with the cause of RTC, they are critically important for road safety analysis especially for those belonging to vulnerable groups such as children and elderly (Imprialou & Quddus, 2019). Royal Oman Police (ROP) need to record characteristics of all users involved in crash event including passengers and pedestrians, at least retrospectively if not at the time of incident.

Data related to features of the involved motor vehicles

Motor vehicle features can present a risk to the driver as well as other drivers and non-motorised road users (e.g., pedestrians, cyclists, etc) (Wenzel & Ross, 2005). The existing NRTC database is limited as it only contains information related to the driver at fault. More detailed information that is required to investigate crash events is not recorded (e.g., motor vehicle age, design, mass, braking system, lighting system, safety technology, Antilock Braking System (ABS)). Integration with other sources such as the database of vehicle registration unit at ROP, vehicle services history, linkage to the database of insurance companies and dashboard camera data can help unravel the complexities associated with RTC outcomes (Brach et al., 2022; Imprialou & Quddus, 2019).

Geocoded locations of RTC

Geocoded locations of RTC are fundamental for spatial analysis to identify high-risk areas, where RTC are more frequent. This is crucial for the enforcement authorities to take effective measures to reduce the risk of RTC (Benedek et al., 2016; Beto et al., 2021; Yu et al., 2014). Unfortunately, these data are not available in the NRTC database. A key step to improving the RTC database is to develop an official base-map storing all road-related attributes including road geometric feature, road networks and traffic volume. To ensure accurate and direct linkage with RTC database, common indexes between these data sources are required. This can be achieved by using GPS-based applications integrated with GIS system in reporting crash locations (Beto et al., 2021; Brown et al., 2015; Imprialou & Quddus, 2017). The distance to the nearest speed camera facility or important road signs prior to the incident might be useful in improving the accuracy of the RTC locations as well understanding the behavioural aspects of drivers.

4. Bias and misclassification

Crash severity level and associated factors

Crash severity is determined based on the maximum injury severity of all people involved in a crash (Al-Bulushi et al., 2015; WHO, 2010). The ROP officers at the crash site are required to make rapid assessment and report the cause of crash and other relevant attributes in a limited timeframe, especially when one or more people are seriously or fatally injured. However, due to the complexity of certain crash scenarios along with time constraints, these assessments may be restricted to preliminary observations rather than in-depth investigations. Therefore, data on RTC based on police judgment might be subject to bias and misclassification (Orsini et al., 2021), even though these records are usually cross-verified or validated by the legal and insurance systems, and other sources including the reports from vehicle damage experts.

The crash preventive measures are mainly developed based on data related to crash causation factors. The cause of crash in the NRTC database is determined based on subjective assessments conducted by the police officer at the crash site. The form used by ROP has a fixed list of the potential factors contributing to the crash including factors related to driver-fault, vehicle defects, road-related factors and weather conditions. There is lack of data relating to the secondary contributing factors associated with RTC, which restricts our understanding of the influence of multiple risk factors and related outcomes.

In-depth crash investigation is one of the effective approaches used in many countries to improve the quality of data determining the crash contributory factors. A team of transport experts visit the crash site, independently of police inquiries, to ascertain the potential contributory factors (Beanland et al., 2013; Flannagan et al., 2018; Imprialou & Quddus, 2017). Police reports usually focus on driver-related factors while specialist team reports give more attention to the interaction between the vehicle and road-related factors.

The police often use their own criteria to specify the severity of crash outcome based on their experience and judgment, which could lead to potential misclassification compared to hospital records (Mandacaru et al., 2017; Watson et al., 2015; Yannis et al., 2014). Linking police database and health records can help overcome the problems related to misclassification (Mandacaru et al., 2017; Weijermars et al., 2018).

Time of the crash

Time of the day is a critical factor influencing the level of alertness and wakefulness of drivers. Accurate reporting of crash time is crucial for identifying the effect of factors such as driver attention, fatigue, traffic volume and risk behaviours such as driving under the influence of alcohol and speeding.

The reported crash time in the NRTC database does not contain precise time information at the minute-level, it has only the hour-level which means that the time is rounded, which can mislead potential effects of traffic volume on predicting the real-time of crash occurrence (Beto et al., 2021; Golob & Recker, 2003; Imprialou & Quddus, 2017). The accuracy of reporting time of the crash can be improved by automatically calling the nearest police unit using in-vehicle systems (this method is currently used in the European Union) or alternatively recording the time when the police receive the call about the crash (Altwaijri, 2013; Imprialou & Quddus, 2019).

Use of mobile/smart phones and entertainment systems

In-vehicle technology, dashboard entertainment systems and smartphones are significant sources of distraction to a driver's attention, increasing the likelihood of collision or near collision by 23 times compared to driving without distraction (Beanland et al., 2013; Public Health Ontario, 2014; Tucker et al., 2015). Despite this fact, mobile phone use is rarely reported as a contributing factor in RTC due to the difficulty in verifying it at the time of the incident (WHO, 2015).

Al-Aamri et al. (2017) analysed the NRTC database between 2010-2014 and identified that only 6 of 35,785 reported crashes were attributed to the use of mobile phone while driving, suggesting significant underreporting. Oviedo-Trespalacios et al. (2017) has reported that traditional methods (e.g., police reports, driver self-reporting), are often unreliable in identifying mobile phone use immediately before or during a crash. Moreover, observational studies at sites of RTC often lack the accuracy needed to judge whether mobile phone use directly contributed to the crash (Sagberg et al., 2015). To bridge this gap, researchers have suggested the integration between the telecommunication network records and crash investigations (Beanland et al., 2013). Countries such as the UK and Australia applied this integration to determine whether drivers were actively using their mobile prior to the crash (Sullman, 2012). Such integration, combined with legal frameworks to protect privacy, can improve the accuracy of RTC databases in identifying mobile phone-related distractions.

Additionally, researchers have proposed the use of in-vehicle event data recorders (EDRs) and automated vehicle monitoring systems as tools to capture real-time data on driver behaviours, including usage of mobile phone (Doecke et al., 2021). Incorporating these advanced data collection methods into RTC investigations could considerably enhance the reliability and accuracy of information regarding driver distractions and help policymakers to develop more effective interventions to reduce mobile-phone-related crashes.

Wearing of seatbelt

Wearing a seatbelt is critical to reducing the injury severity of RTC. Although the national seat belt law in Oman stated that both the front and rear seats occupants are required to wear a seatbelt, enforcement of seat belt for the rear seat passengers is questionable. There could be possible overreporting of seatbelt compliance by drivers at fault for avoiding legal actions and penalties.

5. Lack of linkage with other relevant data sources

The high burden of mortality and disability resulting from RTC has considerable economic, social and health care implications for the families, as most people injured in RTC are the primary income earner of their family (Al Mazrui et al., 2015; Kamruzzaman et al., 2013; Majdan et al., 2012; WHO, 2015). Follow-up data on the outcomes and impact for people involved in RTC and is important and needs to be addressed in future research.

Currently, data collected by insurance companies, hospitals and support agencies are important sources to determine the economic cost of the crashes and enabling decision makers to designing suitable remedial measures and effective interventions. In addition, health and wellbeing related data are not only important for quantifying short and long-term consequences of RTC, but these data could be also used to explore the association between the drivers' health conditions and RTC. However, integrating these sources into a unified database could strengthen analytical capabilities and aid decision maker to better comprehend the data and policy gaps. Many countries have integrated road crash data collection system that Oman could learn from including:

- The US Fatality Analysis Reporting Systems (FARS): This database links police crash reports with medical, toxicology, and insurance records with the aim to assess risk factors and consequences of RTC (NHTSA, 2022b).
- Sweden's Traffic Accident Data Acquisition (STRADA) system: This database combines hospital records with police crash report to provide a comprehensive picture of assessing crash severity and outcomes (Swedish Transport Agency, 2021).

Rabbani et al. (2022) conducted a comparative study to explore the differences between developed and developing countries in RTC data collection systems. The authors highlighted that developed countries often employ advanced data collection tools for RTC data collection, leading to more reliable and comprehensive datasets.

In addition, there is a lack of data related to risk to exposure (e.g., traffic volume and average annual daily distance travelled). Linkage to these data can help assess the effects of different types of exposure on the crash involvement rate.

With an attempt to improve the NRTC database in Oman, the ROP piloted the Integrated Microcomputer Accident Analysis Package (iMAAP) in 2015, a second-generation of crash data management system developed by the UK Transport Research Laboratory (TRL). iMAAP is an advanced version of the Microcomputer Accident Analysis Package (MAAP) and MAAPcloud, both of which have been used in the UK and worldwide including Saudi Arabia and United Arab Emirates to improve RTC data collection and analysis (TRL, 2017). iMAAP is a flexible web-based system and has the capability of handling a number of database platforms and GIS-based systems along with enhancing IT and security standards (TRL, 2017). A connection to the internet is required to record the crash details and automatically save the records in the main server (TRL, 2017). However, in the event of weak or no network connectivity, data can be saved in the tablet device used at the crash site and can be transferred over to the main server when connecting the tablet to any computer within which the iMAAP has been installed.

6. Reflection on the strengths and weaknesses of iMAAP System

In 2015, ROP used iMAAP in documenting a sample of RTC in two areas in Muscat namely: Al-Khoudh and Othaiba. Figure 3 and Figure 4 show the prototype of screenshots adapted from iMAAP crash recording system. There are five different windows: crash-related, vehicle-related, casualty-related, Ministry of Health (MoH)-related, and Emergency Medical Service (EMS)-related data. iMAAP is a GIS based system which record crash locations accurately. It also has the capability to import and export data to other software format. It has details from a range of data sources including data related to drivers, passengers, pedestrians, vehicle features, road features and detailed information of casualty health conditions. It depends on the end-users to decide on the number of variables and type of data they need.

Figure 3. Screenshots of prototype iMAAP crash recording system, Police-reporting task

However, road traffic related data are missed in this system, and it is not clear if iMAAP users are able to add new fields to include traffic data or if changes require major system redevelopment. It is also unclear whether iMAAP has the capability of automatically sketching the crash scene and to produce user-defined reports and queries. Linkage to other data sources such as insurance companies and post-crash support agencies is therefore important for determining the economic cost of the crashes.

Recommendations for improving NRTC database

The limitations of the NRTC database underscore the urgent need for structured improvements, including multi-sectoral data integration. Our integrated framework can assist data administrators and policymakers in better understanding the dynamics and complex interplay of RTC factors, enabling the implementation of data-driven policies and effective road safety interventions.

The quality of NRTC database was evaluated by reflecting on the strengths and limitations of the existing data recording and processing for research use. We present the following recommendations to improve the recording, monitoring and analysis of NRTC data recording and processing system.

Figure 4. Screenshots of prototype iMAAP crash recording system, Hospital-reporting task

1. NRTC database should be improved for ensuring accuracy and reliability of recording and updating RTC. Linkage to other relevant sources is also important to enhance the accuracy, and monitor, and update the crash records. The reporting form used by ROP should collect full details of the incident. For example, demographic data of all persons involved including drivers and passengers, including counterpart vehicles as well as non-motorised road users are pertinent for designing effective road safety interventions. In addition, there should be accurate recording of the vehicle condition (age, extent of damage, year of manufacture, safety measures), road (type of road, distance between the crash spot and vehicle) and weather conditions. Where appropriate, pre-designed diagrams to aid completion of the incident details need to be included.
2. Revisit the crash spot recording mechanisms and ensure that at least one of the assigned police officers is responsible for recording all on-spot crash related details. If circumstances are critical, then back-up system should be arranged to ensure that on-spot data are properly recorded.
3. Ensure logical flow and consistency of details recorded using built-in filter or skip questions. Electronic web-based software systems are an effective way to record crash data (Montella et al., 2019) on mobile apps and tablets, with essential back-up and online data transmission services.

4. Provide a customised classification table to record injuries, in consultation with the emergency ambulance services at the spot or during follow-up. In the absence of emergency ambulance services, record the injuries using the customised form. For example, the classification table could consider either pre-written statements or images of injuries that are common in RTC. It has to be noted that the police do not have formal training or skills to determine the type of injuries and therefore they may misinterpret and misclassify certain injuries. The police investigating the crash site are not experts of conducting assessments on injuries. However, the information they collect as part of the investigation can be cross verified with the hospital case records, and can be further researched to assess the factors associated with visible and invisible RTC injuries.
5. Ensure follow-up of injured or deceased victims, where appropriate in hospitals or home through preferably face-to-face interaction or online/postal post-incident details form.
6. Ensure proper supervision for recording crash data, validation and subsequent editing of data collected from the crash spot and cross-verify personal details of affected persons using unique identifiers linking the civil ID registration systems. Strengthen multisectoral coordination to ensure that the data collected are linked to Civil IDs and cross-validated.
7. Provide access to RTC data to researchers and experts in anonymous format. Engage researchers in the analysis and interpretation of RTC data, and in the design of road safety policies and interventions.

Conclusion

Improving the quality of RTC data is the first step to develop effective countermeasures and enhance road safety measures in any country. We evaluated the quality of existing data collection procedures and recording systems, reflecting on the strengths and weaknesses of both NRTC and iMAAP databases. The paper concludes with a set of recommendations aimed at improving data recording and processing for research and policy use.

Key messages

1. The crash reporting form should include full details of the incident, demographic data of all persons and other involved, vehicle condition, road and weather conditions.
2. Proper linkage of RTC data using civil identification numbers to other relevant sources (e.g., Ministry of Health, Ministry of Transportation and Telecommunications, database of vehicle registration unit at ROP, and Insurance companies) is important to enhance the accuracy, and monitor, and update the crash records.
3. Electronic systems (mobile apps/tablets) with essential back-up services (e.g., online data transmission facility) are recommended to record crash data.

Acknowledgements

We are grateful to The Royal Oman Police for providing us with access to the national road traffic accident database.

Author contributions

Amira Al Aamri (AAA) and Sabu S. Padmadas (SSP) designed the study and prepared the initial draft. AAA conducted the literature review and developed the integrated framework with support and supervision from Li-Chun Zhang (LCZ), Abdullah Al Maniri (AAM) and SSP. Abdullah Al Maniri (AAM) contributed to the discussion. AAA, SSP and LCZ conducted the final review and revised the manuscript for submission. All authors read and approved the final version of the article before submission.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Human Research Ethics Review

The study protocols for this study were reviewed and approved by the University of Southampton Ethics and Research Governance on 31 December 2018 (Submission 19019).

Data availability statement

The authors declare that no data nor protocols were used. We obtained the screenshots of iMAAP crash recording system.

Conflicts of interest

The authors declare there are no conflicts of interest.

Submitted: October 28, 2024 AEST. Accepted: February 21, 2025 AEST. Published: May 28, 2025 AEST.

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