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SPECIAL CONTRIBUTION

Heavy Vehicle Crash Characteristics in Oman 2009–2011

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خصائص حوادث المركبات الثقيلة في عمان 2009-2011

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ABSTRACT: In recent years, Oman has seen a shift in the burden of diseases towards road accidents. The main objective of this paper, therefore, is to describe key characteristics of heavy vehicle crashes in Oman and identify the key driving behaviours that influence fatality risks. Crash data from January 2009 to December 2011 were examined and it was found that, of the 22,543 traffic accidents that occurred within this timeframe, 3,114 involved heavy vehicles. While the majority of these crashes were attributed to driver behaviours, a small proportion was attributed to other factors. The results of the study indicate that there is a need for a more thorough crash investigation process in Oman. Future research should explore the reporting processes used by the Royal Oman Police, cultural influences on heavy vehicle operations in Oman and improvements to the current licensing system.

Keywords: Traffic Accidents; Accident Prevention; Automobile Driving; Safety; Oman.

الملخص: في السنوات الأخيرة، شهدت عمان تغير في أعباء الأمراض نحو حوادث الطرق. الهدف من هذة الورقة هو وصف الخصائص الرئيسية لحوادث المركبات الثقيلة في عمان وتحديد سلوكيات القيادة التى تؤثر على مخاطر الوفاة. ثم فحص بيانات الحوادث من يناير 2009 إلى ديسمبر 2011 والتى أظهرت وقوع 22,543 حادثاً على الطرق في هذة الفترة الزمنية شمل منها 3,114 مركبات ثقيلة. على الرغم من أن معظم هذة الحوادث كانت بسبب سلوكيات القيادة، كانت هناك نسبة صغيرة بسبب عوامل أخرى. أظهرت نتائج هذة الدراسة إلى أنه هناك حاجة إلى تحقيق شامل للحوادث في عمان. البحوث المستقبلية يجب أن تفحص عمليات إعداد تقارير الحوادث المستخدمة من قبل شرطة عمان السلطانية، والتأثيرات الثقافية لعمل المركبات الثقيلة في عمان وتحسين نظام تراخيص المركبات الحالي.

مفتاح الكلمات: حوادث الطرق؛ الوقاية من الحوادث؛ قيادة المركبات؛ السلامة؛ عمان.

Oman, along with other Gulf Cooperation Council (GCC) countries—the United Arab Emirates (UAE), Saudi Arabia (KSA), Kuwait, Bahrain and Qatar—has experienced substantial social and economic development as a result of the discovery of oil. With targeted effort from governing bodies, this development has contributed to a reduction in the burden of many life-threatening infectious diseases. As a result, the burden of disease has now shifted towards non-communicable diseases.[1] In particular, the prevalence of road traffic injuries in Oman is very high; in 2007, road traffic injuries accounted for 73.3% of total hospital deaths due to external causes.[2] Moreover, a significant number of those who sustain injuries as a result of traffic accidents live with pervasive and debilitating physical, emotional and behavioural impairments.[3]

Within the Arab world, Oman has one of the highest rates of road traffic fatalities.[4] Between 1985 and 2009, 13,722 men, women and children lost their lives in car crashes in Oman and 165,757 were injured.[5,6] In 2011, more than 7,700 road traffic crashes were recorded in Oman, averaging close to one crash every hour and one fatality every 10 hours.[4] Definitions of fatalities resulting from traffic crashes vary from country to country. Internationally, the World Health Organization (WHO) defines a road traffic fatality as a death occurring within 30 days of involvement in a traffic crash.[7] However, in Oman, this definition is not applied as the Royal Oman Police (ROP) define road traffic fatalities as those in which death related to a crash occurs between the time of the crash and the closure of the case file in January of the next year;[6] thus, it is difficult to determine the accuracy of a direct comparison with other countries using the WHO definition.

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Recently, there has been a growing effort within Oman to reduce the impact of traffic incidents. A number of policy changes have been made, such as the introduction of seatbelt and mobile phone laws as well as fixed and mobile speed detection devices. However, significant effort is still required across a number of organisations, government departments and the wider population to stem the increasing number of road traffic accidents in Oman.

One area which may require specific attention is that of heavy vehicle safety. As countries, including Oman, witness economic development, the use of heavy vehicles becomes crucial for the transportation of goods and with increased use comes an increase in the number of heavily vehicle crashes. In 2010, heavy vehicles represented 12.5% of registered vehicles in Oman.[7] However, research from other countries suggests that mortality and morbidity as a result of heavy vehicle crashes are proportionally higher than their percentage of registrations.[8] In Finland, between 1990 and 1997, heavy vehicles represented approximately 6% of registered vehicles yet accounted for 16% of crashes.[8] Research to date has yet to explore heavy vehicle crashes within Oman. The purpose of the current research, therefore, was to analyse road traffic crash data pertaining to heavy vehicles in Oman in order to identify the key characteristics of these crashes and the factors that influence the likelihood of fatalities. This analysis will aid in identifying road traffic accident trends in order to enable future efforts to be directed towards improving heavy vehicle safety in Oman.

Methods

Crash data were obtained from the ROP Directorate General of Traffic and included details on all ROP-attended heavy vehicle crashes occurring from January 2009 until December 2011, including all serious crashes but omitting minor crashes. In the ROP data, serious crashes were defined as those where there is either an injury, public property damage or an inability for the involved drivers to determine, among themselves, who was at fault. This definition is a result of the 2006 ROP policy which states that minor crashes (where the three aforementioned criteria do not apply) are to be resolved between drivers' insurance companies without police involvement.[6,9]

As the original ROP crash database is in Arabic, translation into English was performed according to the published bilingual statistical report of the ROP (for the purpose of this research). In some cases, translation was based on terms or definitions used by three Omani academics familiar with road safety literature.

The data collected were predominantly concerned with the at-fault vehicle and driver and in labelling crash causes; thus, the data were divided into three sub-datasets—crash, person and vehicle. For the purpose of this analysis, a new combined dataset was developed in order to enable characterisation of at-fault crashes, and to differentiate between fatal and non-fatal crashes in relation to characteristics of drivers, vehicles and crashes. Driver-related data included age, gender, nationality, seatbelt usage and licence status of the driver. Vehicle-related data included the type of vehicle. Crash-related data included the time, place, reason and severity of the crash, including whether a fatality occurred before file closure.

Internationally, there are several definitions related to heavy vehicles. However, within this dataset, the ROP's Traffic Safety Institute's definition was used. According to this definition, a heavy vehicle is a motor vehicle with a weight of >4,000 kg (4 tonnes) when unladen, as recorded by the ROP at the time of registration.[10]

The combined dataset was explored and analysed using the Statistical Package for the Social Sciences (SPSS), Version 16 (IBM, Corp., Chicago, Illinois, USA). The severity of the heavy vehicle crashes (fatal versus non-fatal) was explored and then linked to characteristics related to the driver, vehicle and crash. Due to the policy that minor crashes are to be handled by insurance companies, property damage-only crashes in the dataset represented only serious accidents. In light of this, it was decided to group injury and property damage crashes and compare them with fatal crashes to determine the factors most associated with loss of life. Due to the small number of crashes in some categories, Fisher's exact tests were conducted (using r) to identify whether the occurrence of a fatality was independent of certain factors. Further, the adjusted standardised residuals for each variable and the effect size (Cramér's V)were calculated.[11]

The factors that were significantly related to the likelihood of fatality were then included in a multiple logistic regression model to further indicate important predictors for fatalities within at-fault heavy vehicle crashes.

Results

Over the three-year sample period, there were 2,543 police-reported road traffic crashes in Oman. As a result of these crashes, 2,829 people were killed and a further 31,313 were injured. Close to 50% of the crashes were reported to involve more than one vehicle. Of the total number of crashes in Oman during this timeframe, 3,114 incidents involved heavy

vehicles (13.8%). Of these heavy vehicle crashes, 11.7% involved a fatality, 62.6% involved an injury and 25.7% resulted in no physical harm to those affected. The crashes resulted in 268 deaths and 2,134 individuals being injured. There were limited data available on heavy vehicle crashes in which the heavy vehicle driver was not at fault. Of the 3,114 heavy vehicle crashes, 59.7% (n = 1,859) were deemed the fault of the driver. The at-fault crashes were the focus of the remaining analysis.

As shown in Table 1, within at-fault heavy vehicle crashes, almost half of the drivers were aged 21–30 years (46.2%), the vast majority were male (99.3%) and over 40% were expatriates. The majority of drivers were reported to be wearing a seatbelt (97.7%) and approximately two-thirds of the drivers were unlicensed (65.2%). Of the unlicensed drivers, 94.4% held either an Omani light vehicle licence or one from another GCC country and 2.2% held no driving licence at all. In terms of crash characteristics, 70% of these crashes occurred during the daytime and around half involved other vehicles. With regards to the principal reason identified for the crash, the majority were the result of common unsafe driving behaviours such as speeding, incorrect vehicle manoeuvres, inattention and not keeping a safe distance from the preceding car.

Only a small number of heavy vehicle crashes were deemed to be the result of fatigue (0.5%) or alcohol (1.8%). Furthermore, the ROP attributed a small number of the crashes (8.8%) to factors other than driver behaviour, such as vehicle or road conditions or the climate [Table 1]. The majority of the heavy vehicles involved in these crashes were standard 'trucks', meaning they were rigid and articulated trucks not including tankers and heavy equipment vehicles.

FATAL AND NON-FATAL CRASHES

Univariate Analysis

A number of factors were significantly associated with fatalities [Table 1]. These included the age and nationality of the driver, whether the driver was wearing a seatbelt, their licence status, the type of crash that occurred and the reasons for the crash.

There was a small effect (V = 0.10) of age on the likelihood of a fatality, with crashes involving drivers aged 21–30 years less likely, and crashes with drivers aged 41–50 years more likely to result in a fatality. Nationality also had a small effect (V = 0.06) on the likelihood of a fatality with crashes involving non-Omani drivers more likely to lead to a fatality. Increased reported use of seatbelts also had a small effect (V = 0.18) in lessening the likelihood of fatality. Surprisingly, licenced drivers were slightly more likely to be involved in a fatal crash (V = 0.09).

With regards to the type of crash, there was again a small effect (V = 0.21), with fatalities less likely in overturns and collisions with fixed objects and more likely when a person or animal was run over. In addition, when the reasons for the crash were attributed to driver fatigue (increased risk), overtaking (increased risk) and incorrect vehicle manoeuvres (decreased risk), there was a small effect (V = 0.20) on the likelihood of a fatality occurring.

Multivariate Analysis

The results were further examined through a multivariate logistic regression model including only the significant univariate predictors (age, nationality, seatbelt, licence status, crash type and reason) [Table 2]. The Hosmer-Lemeshow test (5.741; P = 0.676) indicated a good level of fit and the model explained 20.8% of the variance in occurrence of fatal crashes (Nagelkerke's R^2 = 0.208).[11] For each predictor, the most numerous category was selected as the referent group to calculate the odds ratios (OR). The results of the logistic regression are shown in Table 2.

Age group was a significant predictor for fatal crashes, with drivers aged 41–50 years being 2.09 times as likely to have a fatal crash than those aged 21–30 years (P <0.01). No other age groups significantly differed from the referent category. Not wearing a seatbelt increased the likelihood of fatality by 6.58 (P <0.01). Licence status was also found to be associated significantly with the likelihood of a fatality, with licenced drivers 1.64 times more likely to be involved in fatal crashes compared to drivers who were not licenced (P = 0.01).

Both crash type and the reason for the crashes were significantly associated with the likelihood of a fatality occurring. Compared to vehicle collisions, crashes involving a person or animal being run-over were 2.38 times more likely to lead to a fatality (P <0.01), while overturned vehicles (P <0.01) and fixed-object collisions (P <0.01) were 0.26 and 0.30 times as likely, respectively. When compared to crashes caused by speeding, fatigue (OR = 10.65; P <0.01), overtaking (OR = 2.77; P <0.01) and vehicle defect-related crashes (OR = 3.06; P <0.01) were at an increased likelihood of fatality, while failure to keep a safe distance (OR = 0.27; P = 0.01) and incorrect vehicle manoeuvres (OR = 0.42; P <0.01) decreased the likelihood of fatality.

Discussion

The purpose of the current study was to analyse crash data pertaining to heavy vehicle accidents in Oman in order to identify trends and enable future efforts to

Table 1: Heavy vehicle crashes by fatality in 2009–2011

Variable	Total n (%)	Fatal n (%)	Non-fatal n (%)	% Fatal
Age group in years*				
≤20	118 (6.3)	13 (6.0)	105 (6.4)	11.0
21–30	859 (46.2)	78 (35.8)	**781 (47.6)**	9.1
31–40	523 (28.1)	64 (29.4)	459 (28.0)	12.2
41–50	231 (12.4)	**45 (20.6)**	186 (11.3)	19.5
≥51	128 (6.9)	18 (8.3)	110 (6.7)	14.1
Gender				
Male	1,846 (99.3)	218 (100.0)	1,628 (99.2)	11.8
Female	13 (0.7)	0 (0.0)	13 (0.8)	0.0
Nationality*				
Omani	1,071 (57.6)	106 (48.6)	**965 (58.8)**	9.9)
Non-Omani	788 (42.4)	**112 (51.4)**	676 (41.2)	14.2
Seat belt use*				
Yes	1,817 (97.7)	197 (90.4)	**1,620 (98.7)**	10.8
No	42 (2.3)	**21 (9.6)**	21 (1.3)	50.0
Licence status*				
Licensed	647 (34.8)	**101 (46.3)**	546 (33.3)	15.6
Unlicensed	1,212 (65.2)	117 (53.7)	**1,095 (66.7)**	9.7
Crash time†				
Early morning	175 (9.4)	22 (10.1)	153 (9.3)	12.6
Morning	733 (39.4)	82 (37.6)	651 (39.7)	11.2
Evening	543 (29.2)	59 (27.1)	484 (29.5)	10.9
Night	408 (21.9)	55 (25.2)	353 (21.5)	13.5
Crash type*				
Vehicle collision	874 (47.0)	106 (48.6)	768 (46.8)	12.1
Person or animal run over	176 (9.5)	**54 (24.8)**	122 (7.4)	30.7
Overturned vehicle	402 (21.6)	28 (12.8)	**374 (22.8)**	7.0
Fixed-object collision	393 (21.1)	26 (11.9)	**367 (22.4)**	6.6
Motorcycle/ bicycle	14 (0.8)	4 (1.8)	10 (0.6)	28.6
Reasons for crash*‡				
Speed	835 (44.9)	90 (41.3)	745 (45.4)	10.8
Inattention	182 (9.8)	28 (12.8)	154 (9.4)	15.4
Fatigue	9 (0.5)	**4 (1.8)**	5 (0.3)	44.4
Alcohol	33 (1.8)	2 (0.9)	31 (1.9)	6.1
Overtaking	83 (4.5)	**27 (12.4)**	56 (3.4)	32.5
Climatic conditions	20 (1.1)	4 (1.8)	16 (1.0)	20.0
Sudden stopping	19 (1.0)	0 (0.0)	19 (1.2)	0.0
Lack of safe distance	100 (5.4)	4 (1.8)	96 (5.9)	4.0
Incorrect manoeuvre	434 (23.4)	31 (14.2)	**403 (24.6)**	7.1
Vehicle failure	108 (5.8)	21 (9.6)	87 (5.3)	19.4
Road conditions	35 (1.9)	7 (3.2)	28 (1.7)	20.0
Heavy vehicle type				
Truck	1,618 (87.0)	183 (83.9)	1,435 (87.4)	11.3
Heavy equipment	63 (3.4)	10 (1.5)	53 (4.4)	15.9
Water tanker	164 (8.8)	22 (3.4)	142 (11.7)	13.4
Sewage tanker	12 (0.6)	3 (0.5)	9 (0.7)	25.0
Oil tanker	2 (0.1)	0 (0.0)	2 (0.2)	0.0

**Significant (P <0.01) difference between licensed and unlicensed crashes. Bold = Figures with adjusted standardised residuals greater than +2.58 (P <0.01). †Crash times were classified as early morning (1:00 am to 5:59 am), morning (6:00 am to 12:59 pm), evening (1:00 pm to 5:59 pm) or night (6:00 pm to12:59 am). ‡Total dataset for crash reasons was 1,858 due to one missing data point.*

improve heavy vehicle safety. Prior to discussing the findings of this analysis, it is important to recognise the limitations inherent to the nature of the data source. While the data should only include serious crashes, due to the potential for confusion as to the nature of minor or serious crashes, there is still a possibility that minor crashes have been recorded incorrectly as serious crashes by the police. Furthermore, crashes are investigated by police officers at the scene, who then complete a crash report and send it later to the

Table 2: Logistic model estimation and odds ratios for significant independent variables for heavy vehicle fatal crashes in 2009–2011

Variable	B	SE	Significance	Odds ratio	95% CI	
Age group in years						
≤20	0.120	0.350	0.732	1.127	0.568	2.237
21–30	-	-	-	1.000	-	-
31–40	0.131	0.204	0.520	1.140	0.764	1.702
41–50	0.739	0.234	0.002	2.094	1.324	3.314
≥51	0.322	0.308	0.295	1.380	0.755	2.523
Nationality						
Omani	-	-	-	1.000	-	-
Non-Omani	0.145	0.202	0.474	1.156	0.777	1.718
Seat belt use						
Yes	-	-	-	1.000	-	-
No	1.884	0.378	0.000	6.579	3.135	13.803
Licence status						
Licensed	0.495	0.194	0.011	1.641	1.123	2.399
Unlicensed	-	-	-	1.000	-	-
Crash type						
Vehicle collision	-	-	-	1.000	-	-
Person or animal run over	0.868	0.240	0.000	2.382	1.488	3.814
Overturned vehicle	-1.358	0.269	0.000	0.257	0.152	0.436
Fixed-object collision	-1.217	0.266	0.000	0.296	0.176	0.499
Motorcycle/bicycle	0.690	0.682	0.312	1.993	0.524	7.588
Reasons						
Speeding	-	-	-	1.000	-	-
Inattention	-0.202	0.263	0.441	0.817	0.488	1.367
Fatigue	2.366	0.735	0.001	10.652	2.524	44.955
Drink driving	-1.252	0.814	0.124	0.286	0.058	1.410
Overtaking	1.019	0.300	0.001	2.771	1.538	4.992
Climatic conditions	0.722	0.614	0.240	2.058	0.618	6.855
Sudden stopping	-19.370	8,962.844	0.998	0.000	0.000	0.000
Lack of safe distance	-1.329	0.542	0.014	0.265	0.091	0.766
Incorrect manoeuvre	-0.857	0.256	0.001	0.424	0.257	0.701
Vehicle failure	1.119	0.298	0.000	3.063	1.707	5.496
Road conditions	0.791	0.507	0.119	2.205	0.816	5.958

SE = standard error; CI = confidence interval.

Directorate General of Traffic to be entered into the database.[6,9] Thus, all crash data is manually handled, leading to the potential for errors while transcribing crash reports to the database or to investigator bias.

With these limitations in mind, this paper focused on the characteristics of at-fault serious heavy vehicle crashes; these findings therefore may not reflect prevalence within Oman's general heavy vehicle driving population. As there was a lack of previous research on the prevalence of various risk factors, for example

regarding speeding, the analysis also could not indicate the relative risk of crashes for the identified factors. The factors analysed do, however, represent important areas of focus for future interventions. Importantly, these factors also pose a high risk for road crashes.

At a general level, heavy vehicle crashes accounted for 13.8% of all crashes that occurred in the three-year study period. This appeared to be representative of the 12.5% of registered vehicles in Oman that are heavy vehicles. Given that the present data explored crashes serious enough to be reported by police, it is surprising that heavy vehicles were not over-represented. Specifically, the mass of a heavy vehicle should increase the average crash severity, leading to a higher level of reporting. It is also worth noting, however, that this comparison may not take into account heavy vehicles not registered in Oman that are engaged in cross-border transport. Furthermore, heavy vehicles typically conduct a greater amount of travel than other vehicles and the number of km travelled is often used to estimate levels of exposure to traffic hazards. Unfortunately, there is no record of km travelled in Oman for specific vehicle types. Thus, it is not possible to draw conclusions regarding the overall representative level of heavy vehicle involvement in crashes, nor draw accurate comparisons to other countries.

Of all heavy vehicle crashes, 59.7% were the fault of the driver. This is reasonably low when compared with findings from Australia. Recent reports for the main insurer of heavy vehicles in Australia, the National Transport Insurance Company, have indicated that truck drivers were at fault in multivehicle crashes in 46.3% and 70% of cases during 2007 and 2011, respectively.[12,13] Given that multivehicle crashes accounted for 24.1–24.6% of crashes, truck drivers therefore were at fault in 86.8–92.8% of all crashes. However, it should be noted that differences in reporting practices between countries and the different sources of data (insurance company versus police data) may partially account for this difference in fault rates, particularly considering multivehicle crashes accounted for close to half of the crashes in the current report.

Just over half of the drivers involved in heavy vehicle crashes in Oman were under the age of 30 years. This aligns with similar trends in road safety research internationally, yet contradicts a recent report of serious Australian heavy vehicle crashes which revealed a greater trend towards older drivers.[13] It is, however, important to note that the Australian heavy vehicle industry is often considered an ageing industry which is struggling to renew its workforce and most companies refuse to hire drivers below 25 years of age due to increased insurance costs. Furthermore, census data from Oman has shown that a significant proportion of the population of Oman are young, with 44.7% of the population under the age of 20 years.[14] The high proportion of drivers under the age of 30 years in the current sample suggests the need for targeted safety initiatives for younger heavy vehicle drivers, such as those included in graduated licensing systems.

The high number of expatriate heavy vehicle drivers is not surprising given that 29.4% of Oman's population in 2010 were expatriate.[15] Heavy vehicle drivers in Oman also may be transporting goods to or from the UAE, KSA or Yemen, which conduct trade with Oman. Anecdotally, it is also commonly suggested that the majority of heavy vehicle drivers are expatriate. While it is difficult to tell how representative the proportion of Omanis and expatriates is in the current sample, it does highlight the need for a safety initiative that would account for cultural differences. In the context of traffic safety, the influence of culture has recently gained increased attention, even forming the topic of a recent special edition of a traffic-related journal.[16] When such a high proportion of truck drivers are from other nations, it would be an error to assume that standardised approaches known to be effective for one culture would necessarily have a sufficient impact on the industry as a whole. Thus, it is important for future research to examine the influence of culture on safety in the heavy vehicle industry of Oman and identify safety initiatives which either operate effectively across cultural barriers or provide education targeted to specific subcultural groups in the industry.

With regards to the types of crashes, 52.4% did not involve any other vehicle, which is substantially higher than reports on serious major highway crashes in the USA, where approximately 34% of accidents involve just a single vehicle.[17] However, this finding is higher than serious crash insurance statistics from Australia, where approximately 75% involved a single vehicle.[12,13] It is important, however, to recognise that the current statistics do not include non-fault crashes due to the data collection focus of the ROP. If it is assumed that the remainder of crashes in which the heavy vehicle driver was not at fault all involved another vehicle, single vehicle crashes would represent 31.6% of crashes, which would be comparable to rates in the USA.

Similar to other reports published in the literature, the majority of heavy crashes in the current study were caused by common driver behaviours such as speeding, incorrect manoeuvres and inattention.[18–21] Worth noting, however, is the fact that fatigue was a factor in very few of the serious heavy vehicle crashes in the dataset (n = 9). This is quite different to statistics from Australia where fatigue accounted for 11.9% of serious

crashes; however, similar statistics from the USA with fatigue accounting for approximately 0.7% of serious crashes.[13,17] It should be recognised that Oman is a geographically smaller nation than Australia and the USA, and that therefore there may be less long-distance driving resulting in reduced likelihood of road fatigue. However, there may be alternative explanations for this finding. Research has shown fatigue to be a major contributor to heavy vehicle crashes, while driving long hours has been associated with falling asleep at the wheel and increased injury severity in the case of a crash.[8,17,22–25] However, fatigue is commonly under-represented in crash statistics.[26,27] Whenever a driver is fatally injured, it is impossible to enquire directly regarding fatigue; thus, it can be difficult to determine fatigue as the crash cause within police investigations. In the literature, a number of factors have been used to determine the involvement of fatigue in crashes, including single-vehicle crashes during high risk fatigue times (e.g. 12:00–6:00 am and 2:00–4:00 pm), head-on collisions while overtaking, the absence of evidence of evasive actions and the location of the crash being clearly visible for several seconds prior to the crash.[6,28] The ROP do not have a formal inspection process by which fatigue is determined. In Oman, a crash is classified as being caused by fatigue according to the findings and view of the ROP investigator or by a direct confession from the driver. Additionally, the crash database does not indicate all factors contributing to crashes, but only the single predominant cause. Thus, fatigue-related crashes could be primarily identified as being caused by incorrect manoeuvres or other behaviours. By introducing a more thorough approach to determining fatigue as well as enabling the use of multiple causal factors, it may be possible to increase the accuracy of investigation reports and gain better insight into the impact of fatigue on the drivers of heavy vehicles in Oman.

An important category of crash causes, is the influence of external factors, including those related to the vehicle, road and climate. As previously stated, this analysis reviewed at-fault serious crashes. The fact that 8.8% of heavy vehicle driver at-fault crashes were attributed to factors not directly under the driver's control again brings into question the classification of crash causes on ROP reports. In such cases, it is anticipated that some driver behaviours were unsuitable for the conditions at the time of the crash and this further highlights the need for changes to the ROP crash investigation processes.

FACTORS ASSOCIATED WITH FATAL CRASHES

With regards specifically to fatal crashes, it is important to note the differences between statistical significance and real-world applicability. Factors which were found to be associated with the likelihood of a fatality did not always represent those which account for the greatest number of fatalities. In both the univariate and multivariate analyses, drivers aged 41–50 years were at higher risk of fatalities. The fact that this statistic remained significant in the multivariate model suggests that other factors do not account for this variance. While it could be argued that older drivers are more susceptible to a greater severity of injuries in crashes, drivers over the age of 50 years were not at a higher risk. The sample size of these older drivers may have been insufficient to reveal trends; however, there is a need for further research to examine the risks associated with drivers over the age of 41 years. Nonetheless, drivers aged 21–30 years (35.8%) and 31–40 years (29.4%) showed a higher proportion of crashes in comparison to drivers aged 41–50 years (20.9%). Thus, while older drivers may need specific attention in order to address the reasons for their increased likelihood of fatal crashes, younger drivers represent the highest proportion of drivers in Oman and should be targeted to reduce the total number of fatalities.

Nationality was significant in the univariate analysis, with expatriates at a higher risk of fatalities due to the over-representation of Omanis in non-fatal crashes. However, this significance did not hold in the multivariate analysis. This suggests that the difference in fatality rates may be accounted for by other predictors, such as the cause of crashes. Additionally, it should be noted that the overall differences in the proportions of fatal and non-fatal crashes may highlight differences in the reporting of crashes. Given that expatriate drivers may be on visas which could be lost if they are found to have broken any laws, less severe crashes may therefore not be reported. Furthermore, differing employment conditions have been shown, internationally, to have an impact on heavy vehicle safety. For example, subcontractors, owner-operators and informal employees have higher rates of crash involvement and associated injuries.[29–31] Regardless of the reasons for these differences, the loss of significance when accounting for other variables suggests differences of behaviour or other crash factors which should be explored to better understand how nationality and/or culture influences heavy vehicle crashes.

In both the univariate and multivariate analyses, the lack of seatbelt use increased the likelihood of fatalities. Given the nature of seatbelts, the difference in the likelihood of fatalities may directly relate to the potential loss of life for truck drivers; however, further

research is needed to confirm whether this is the case or whether individuals who do not wear seatbelts are also more likely to engage in other high-risk behaviours. It should be noted that the frequency of seatbelt use in the reported dataset was very high. In the current dataset, almost all of drivers were reported to be wearing a seatbelt at the time of the crash. Although seatbelt use is mandatory for truck drivers in both Australia and Oman, one study found that seatbelt use was very low among Australian heavy vehicle drivers, with many seeing seatbelt use as unrelated to safety.[32] Given the reliance on police investigation data in the current dataset, it is thought that seatbelt use can only be confidently ascertained from crashes in which the truck driver died in other crashes there may be a high level of over-reported seatbelt use by drivers who do not want to admit to breaking the law in front of a police officer. An investigation into the prevalence of seatbelt use in the heavy vehicle industry of Oman is needed to better understand usage rates and associated behaviours. Furthermore, to see the direct benefits of seatbelt use, a more detailed analysis of crashes in which the heavy vehicle driver was injured or killed is required.

Licence status was found to be associated significantly with the severity of the crashes in both the univariate and multivariate analyses. Interestingly, drivers holding valid heavy vehicle licences contributed more to the occurrence of fatal crashes compared to those not licensed to drive heavy vehicle. Research on driving in the general population has shown that unlicensed drivers are over-represented in serious crashes and are more likely to engage in higher-risk behaviours.[33] It is unclear why unlicensed drivers would not be more frequently involved in fatal crashes given their representation in the total sample. It is important to recognise that, in this analysis, the classification of "unlicensed" included drivers with the wrong class of licence as well as those with no licence. It is important to note, however, that there is no current licence demerit point system in Oman, meaning that unlicensed drivers in the current sample represent those who have never received the appropriate type of licence for heavy vehicle driving. The finding that holding a licence increases the likelihood of a fatality could be explained predominantly by the much higher prevalence of unlicensed drivers in non-fatal crashes, perhaps indicating a higher proportion of minor error-related crashes from lack of driving skills and experience. Nonetheless, it is clear that the proportion of drivers without a licence in the current sample demonstrates a need to increase appropriate licensing in Oman. Moreover, the unexpected trend of crash severity related to licence status may highlight a need to improve the current licensing standards.

Crash type was also significantly predictive of the likelihood of fatalities. It is to be expected that when a heavy vehicle crash is classified as involving an animal or person being run over, those involving humans would have a much higher fatality rate. Unfortunately, it was not possible to distinguish in the database which crashes involved an animal and which involved a human being run over; thus, gaining a further understanding of the exact likelihood of these types of crashes influencing fatality rates was not possible. For example, it may be the case that 100% of crashes which involved a human being run over were fatal. Single-vehicle crashes (overturned and fixed vehicles-object collisions) were less likely to result in a fatality. Given the mass of heavy vehicles, and the relative protection given to truck drivers inside the vehicle, it is not surprising that crashes involving other vehicles would result in a higher risk of fatalities than single-vehicle crashes. Nonetheless, it should be noted that recent reports from Australia have shown that fatalities resulting from multivehicle crashes are typically the fault of the other vehicle's driver.[13] When a single-vehicle crash occurs, it is more likely to lead to a truck driver's death. Thus, it is an unusual finding that, within at-fault heavy vehicle crashes in Oman, single-vehicle crashes were at lower risk of resulting in fatalities. Without further examination to separate truck driver fatalities from other road user fatalities, and to better understand factors related to the non-fault vehicles, it is difficult to understand the implication of this finding.

The final category of factors which contributed to the likelihood of fatalities was the reason for a crash. While there were only three crash reasons that were significant in the univariate analysis, the use of speeding as a reference category revealed five significant predictors within this category. Specifically, crashes caused by fatigue, overtaking and vehicle defects were all more likely to result in fatalities than crashes predominantly attributed to speeding. While the issues associated with detecting fatigue in crashes were discussed above, it is worth noting that despite the significant finding in the current analysis, the very small number of fatigue-related crashes, most likely due to under-reporting, prevents any meaningful interpretation of the associated likelihood of fatalities. Overtaking may be viewed internationally as an unusual predictor of crashes; however, it should be noted that, within Oman, heavy vehicles are not permitted to overtake. For this reason, there may be other dangerous behaviours that occur while overtaking, as drivers may be in a rush to complete the manoeuvre. Further investigation is required to understand the association between overtaking and

fatalities in heavy vehicle crashes.

Vehicle defects have been commonly associated with the likelihood of crashes; however, tyre defects have specifically been associated with increased crash severity.[17] While it is not possible to determine what type of vehicle defects were associated with crash severity in the current dataset, anecdotally, a high number of trucks have bald tyres in Oman. Additionally, the fines that exist for bald tyres in Oman are insufficient when compared to the cost of replacing tyres. In fact, when considering only the financial implications, it is cheaper to receive a high number of fines than to replace a single tyre. While further research is needed to explain the variation in fatalities associated with vehicle defects, tyre defects may play a significant role in these crashes.

The final two crash causes that were significantly less likely to produce fatalities than speeding were failure to keep a safe distance behind the preceding vehicle and incorrect manoeuvres. Failing to keep a safe distance typically results in rear-end crashes which could be expected to produce lower fatality rates. Unfortunately, an incorrect manoeuvre is a somewhat vague category that is not easily interpretable.

FUTURE DIRECTIONS

During the analysis of the findings, a number of key directions for future research emerged. Due to the nature of the data analysed and their inherent limitations, this analysis primarily highlighted specific areas requiring research in the Omani context. There is a need for an estimation of km travelled per vehicle in order to understand the relative risk presented by heavy vehicles. In the current data, heavy vehicles appeared representative of their registration numbers, which may actually indicate that these drivers are under-represented in the statistics, given that trucks usually travel further and more often than other vehicles. There is also a need for research to examine why drivers aged 41–50 years were at a higher risk of fatalities; to understand the impact of cultural differences between expatriate and Omani drivers so as to enable targeted initiatives; to differentiate between fatality risks for truck drivers and members of the general public in heavy vehicle crashes, and to better understand the role of overtaking in heavy vehicle crashes in Oman. Due to the high representation of younger drivers in the current dataset, it is clear that specific initiatives should be aimed at these drivers, perhaps by implementing a graduated driver licensing system, as well as investigating potential issues with the current licensing system of heavy vehicle drivers in Oman.

Finally, there is a need for a more thorough crash investigation process. The current investigation process may be sufficient for identifying culpability and resolving legal issues related to crashes, but the data do not seem sufficient for understanding road safety in Oman. Without more comprehensive data, it is difficult to determine the relative contributions of different factors and to determine paths forward for future initiatives. The main issues in the current investigation process and dataset include unclear methods to determine the impact of fatigue; a lack of information about the involved vehicles and drivers who were not deemed culpable; a lack of data regarding multiple crash causes and behaviour; unclear information about vehicle defects and incorrect manoeuvres, and the combination of crashes involving a pedestrian or animals being run over into a single category. If police data are to provide sufficient information about crashes to help direct future government and policing efforts, there is a need to address each of these issues and conduct an evaluation of the current investigation process to identify weaknesses.

Despite limitations in the data, a broad range of factors were found to be significantly related to fatal crashes, including factors associated with people, society and culture, behaviour, vehicles, roads and government policies and practices, including licensing. This highlights the need for a broad approach to address the issue of heavy vehicle safety in Oman. As can be seen by these data, road safety is a complex topic, requiring strategies which target the many groups that share responsibility for improving outcomes. This lends itself to a 'safe system' approach, in which all aspects of the road network are addressed and all associated parties are involved to produce a safer road network for all users. This approach is used in other countries, including Australia, to great effect.[34] Additionally, it is important to recognise that, unlike private road users, heavy vehicle drivers are performing a transportation service and typically do so under the employment of an organisation. There is a need for all parties associated with the transportation of goods and customers via roads to play a role in ensuring everyone's safety. Some countries, such as Australia, have implemented laws which require that all parties who have a role in heavy vehicle transport be accountable for safety. Within Oman, the inclusion of heavy vehicles as workplaces under health and safety legislation could increase employer involvement in ensuring safety. Furthermore, the introduction of supply chain laws which hold both customers and organisations accountable should further ensure that safety is sufficiently prioritise within the industry.

Conclusion

Increased development within Oman has also increased the need for heavy vehicles, thereby increasing the risk of traffic accidents involving these vehicles. Data analysis of police records revealed that there were 3,114 crashes in Oman involving heavy vehicles (between January 2009 and December 2011). While the majority of these crashes were attributed to driver behaviours, a small proportion were attributed to factors relating to the vehicle, road and climate. Fatalities were more likely for drivers aged 41–50 years, those not wearing seatbelts and those who had the correct licence. When compared to the most common crash cause (speeding), fatigue, overtaking and vehicle defect-related crashes were more likely to result in a fatality. This analysis highlighted the need for further research on crash investigation processes as well as an improvements to the current licensing system in Oman and methods to incorporate age- and culture-targeted road safety initiatives for heavy vehicle operators.

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