Safety Assessment of Taxi Drivers in Singapore

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This paper presents a comprehensive safety assessment of taxi drivers in Singapore. Six years of accident records (2001 through 2006) maintained by traffic police were employed for three analyses: a trend analysis, a factor analysis, and a cause analysis. In the trend analysis, it was found that the taxi accident rates were consistently higher than the safety standard set by Singapore's Land Transport Authority, even though no evidence suggested an increasing trend in taxi accidents. In the factor analysis, 10 significant factors that have contributed to the taxi accidents were identified with two binomial logistic models. Accidents in which taxi drivers were responsible were compared with (*a*) those accidents in which the taxi drivers were not responsible, and (*b*) those accidents in which the drivers of private cars were responsible. Following the factor analysis, the seven most common accident causes were ranked. The relative accident propensities according to individual factors identified in the factor analysis were computed. These findings suggest that any behavior-modification training program to be developed must be unique for taxi drivers and must take into account the specific factors and causes highlighted in this study.

Taxi drivers are an important group of road users in the transport system as they play a key role in providing good-quality personalized transportation service to the general public. As occupational drivers, taxi drivers are associated with significant road safety problems. With the development of the taxi industry as a public transport mode, taxi accidents and accident-related injuries have increasingly attracted research attention. The relevant studies on taxi driver safety include fatigue problems, vision problems, legal obedience, risk taking and risk perception, and safety belt use (*1–7*).

However, most of these studies have focused on investigating physical or behavioral risk factors, and very little research has been done to systematically assess the safety status of taxi drivers at the city or country level (*8*). Furthermore, as far as could be ascertained, various road and environmental factors have never been investigated with differentiation between taxi driver behavior–related and taxi operation–related factors. This is largely because of inadequate and fragmented information on accident occurrence and accident causes. However, results from existing studies have implied that taxi drivers, as a unique occupational driver group, may be significantly different from typical nonprofessional drivers (*4–6, 9*). Without a driver behavioral–level understanding of specific risk factors and accident causes, any safety programs and campaigns designed to reduce taxi driver accidents may not be efficiently targeted and thus may not be cost-effective.

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In Singapore, taxi drivers as public transport service providers perform an important task that not only enhances the mobility of individuals but also supports the national economy. Over time, there have been significant improvements in the operational efficiency of taxi services. However, it appears that safety standards have not improved in tandem with these other areas. Under the Taxi Quality of Service (QoS) standards for accident rates, taxi companies are required to comply with the standard of not more than two accidents per 10 million km. Singapore's Land Transport Authority (LTA) has set this standard based on what the taxi companies were able to achieve in past years. However, performances of the taxi companies has not been satisfactory since the official monitoring of QoS standards commenced in September 2003.

To determine proper measures that can be used to improve taxi safety, this study attempts to conduct a comprehensive safety assessment of taxi drivers in Singapore. However, the results are relevant to any city with a similar mode of taxi operations—that is, a large proportion of taxis are hailed on-street, rather through advance bookings. This paper presents the method and major results arising from three specific analyses:

1. Trend analysis to examine whether the occurrence of taxi accidents in general have changed in comparison with all-vehicle accidents and private car accidents;
2. Factor analysis to identify the significant driver and road environmental factors that influence driver behavior in taxi operations and hence have an impact on road safety; and
3. Cause analysis to determine the specific causes that lead to involvement of those identified factors that have resulted in taxi driver safety problems.

TAXI ACCIDENTS IN SINGAPORE: TREND ANALYSIS

Singapore's Traffic Police department maintains a comprehensive accident database that records all vehicular accidents involving injuries, including those involving taxis. Six years of accident records (2001–2006) are used in the analysis. This section summarizes taxi accident frequency and overall accident rates in Singapore. To appreciate the accident trend regarding taxis, it is helpful to compare taxi accidents with accidents involving private cars. The private car is used as the control group because vehicle characteristics (e.g., size, make, and associated facilities) of both the private car and the taxi are similar. Taxi accidents are compared with all-vehicle accidents and private car accidents to reveal possible trends that occurred over those 6 years.

Taxi Accident Frequency

In studying taxi accident frequency, accidents were filtered into two types and compared with corresponding types of accidents involving private cars. The first category includes accidents involving at least a taxi, regardless of the responsible party (denoted as TA1), and the second category includes accidents in which the taxi driver was identified as the responsible party in the accident (denoted as TA2). Accidents involving at least a car are designated CA1, and accidents involving a car in which the car driver was found to be responsible are designated CA2.

Table 1 gives the statistics for taxi and private car accidents (i.e., TA1, TA2, CA1, and CA2), along with a summarized total of all vehicle accidents in Singapore from 2001 to 2006. During those 6 years, of a total of 41,465 injury accidents in Singapore, taxis were involved in 8,015 accidents (19.3%); of those, 5,010 were judged to have taxis as the responsible party (12.1%). These proportions can be considered high, given that the taxi population was only about 2.8% of the vehicle population in Singapore during the study period. However, because taxis, as public vehicles, are likely to be used more than other vehicles, these preliminary figures do not imply that taxi drivers are more prone to accidents than other drivers.

The severity index (i.e., the ratio of fatal and serious injuries to all injuries) among taxi accidents is 0.029 in the case of TA1 (see Table 1) and marginally higher at 0.033 for TA2. These numbers are slightly lower than those of private cars, which were 0.034 and 0.039 for CA1 and CA2, respectively. Furthermore, the severity indexes for both taxi accidents and private car accidents were lower than the severity index of 0.046 for total accidents. This finding implies that there are other types of vehicles (e.g., motorcycles) where victims are more likely to suffer serious or fatal injuries than taxis or private cars.

Figure 1 illustrates the changes in taxi and private car accident frequencies from 2001 to 2006. Assuming a linear time trend, the fitted trend lines show that for the 6 years of analysis, private car accidents have dipped slightly, whereas taxi accidents have increased slightly. But the statistical test on the difference in slopes for taxi accidents and private car accidents shows no statistical significance ($p = .7$). Hence, there is no evidence to suggest that the number of taxi accidents has increased or that changes in the number of taxi accidents are systemically different from those of private car accidents. Nevertheless, although the overall increase may not be significant, it is premature to conclude that this is true for all types of taxi accidents. Moreover, the variations in exposure, such as vehicle mileage, may be a reason to explain the variations in accident frequencies. A more detailed analysis on accident rates will throw more light on this issue.

Taxi Accident Rate

Based on the taxi population and mileage estimates of LTA and the taxi accident data from the Traffic Police, the taxi accident rates per 100 taxi drivers and accidents per 10 million vehicle km traveled were computed. As shown in Table 2, the average taxi accident rates from 2001 to 2006 are 6.49 accidents per 100 taxi drivers and 4.28 accidents

TABLE 1 Accidents for All Vehicles, Taxis, and Private Cars (2001–2006)

	2001	2002	2003	2004	2005	2006	Total
All Vehicle Accidents							
Number	7,091	6,878	6,446	6,845	6,706	7,499	41,465
Severity index[a]	0.069	0.049	0.049	0.037	0.036	0.037	0.046
Taxi Accidents (TA)							
Number of TA1[b]	1,268	1,419	1,289	1,354	1,266	1,419	8,015
Severity index of TA1	0.045	0.029	0.033	0.026	0.024	0.020	0.029
% of TA1 in all vehicle accidents	17.9	20.6	20.0	19.8	18.9	18.9	19.3
Count of taxi driver involvements (TA1)	1,378	1,530	1,420	1,466	1,401	1,596	8,791
Number of TA2[c]	768	862	839	851	745	945	5,010
Severity index of TA2	0.047	0.035	0.035	0.033	0.032	0.020	0.033
% of TA2 in TA1	60.6	60.7	65.1	62.9	58.8	66.6	62.5
% of TA2 in all vehicle accidents	10.8	12.5	13.0	12.4	11.1	12.6	12.1
Count of taxi driver involvements (TA2)	786	879	863	870	759	966	5,123
Private Car Accidents (CA)							
Number of CA1[d]	3,134	3,002	2,772	2,844	2,756	3,215	17,723
Severity index of CA1	0.056	0.038	0.034	0.026	0.022	0.026	0.034
Number of CA2[e]	2,231	2,183	2,056	2,062	1,756	2,293	12,581
Severity index of CA2	0.062	0.043	0.041	0.029	0.024	0.030	0.039
% of CA2 in CA1	71.2	72.7	74.2	72.5	63.7	71.3	71.0

[a]Severity index = ratio of fatal and serious injury to all injury accidents.
[b]TA1: accidents involving at least a taxi, regardless of the responsible party.
[c]TA2: accidents in which the taxi driver is identified as the responsible party.
[d]CA1: accidents involving at least a private car, regardless of the responsible party.
[e]CA2: accidents in which the private car driver is identified as the responsible party.

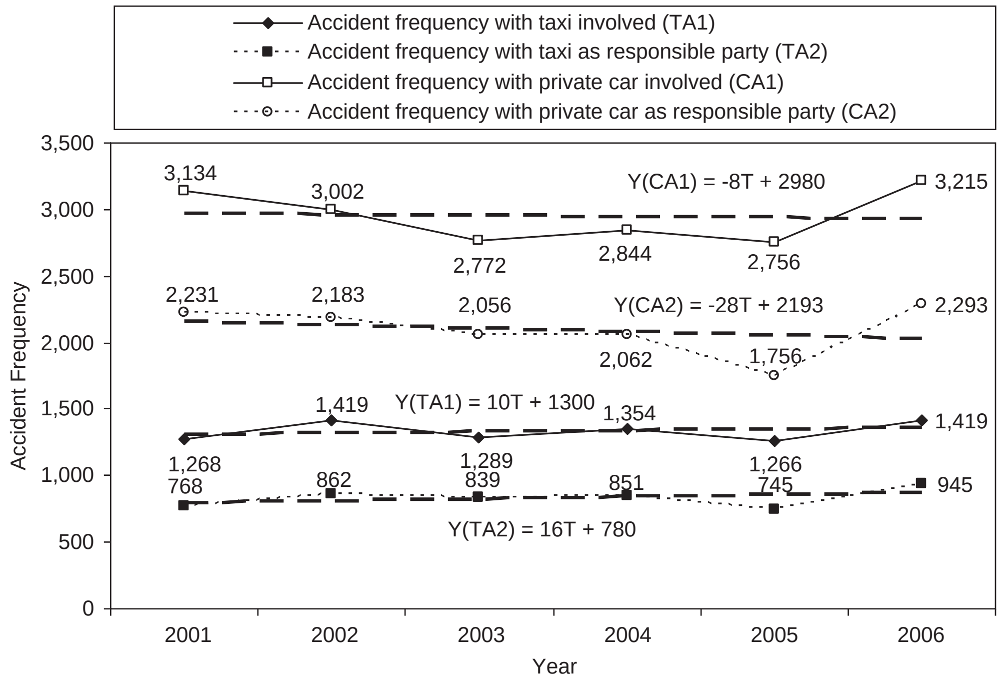

FIGURE 1 Comparison of taxi accidents and private car accidents.

per 10 million veh km traveled for TA1 accidents. The corresponding values for TA2 accidents are 4.09 accidents per 100 taxi drivers and 2.67 accidents per 10 million vehicle km traveled. The accident rates per million vehicle km traveled, even in the case of responsible taxi drivers (i.e., TA2), are higher than the QoS standard of two accidents per million veh km traveled, as set by LTA.

Figures 2 and 3 show that two taxi accident rates have slightly decreased for both TA1 and TA2 accidents. It is found that there was an average annual decrease in the TA1 accident rate of 0.25 per 100 taxi drivers ($p = .07$) or 0.27 per 10 million vehicle km traveled ($p = .09$). The corresponding decrease for the TA2 accident rate is 0.11 ($p = .29$) and 0.14 ($p = .19$). However, judged by the p-values, it cannot be concluded with a 95% confidence level that the taxi accident rates are significantly decreasing.

A comparison of the taxi accident rate (TA1 accidents) was made with the overall accident rates in Singapore. As reported by Ho, the fatality rate in 2006 is 0.09 fatalities per 10 million vehicle km traveled (*10*). This figure was estimated based on the statistics of road traffic accidents and vehicle mileage recorded by the Singapore Traffic Police and LTA. In the absence of the all-vehicle mileage, this fatality rate was used combined with the available fatalities in 2006 to estimate the all-vehicle mileage and, thus, to calculate the overall accident rate in 2006, which was about 3.55 accidents per 10 million km. The comparison indicates that the taxi accident rate of 4.28 accidents per 10 million km was 20.6% greater than the overall accident rate in 2006.

In summary, although there is no evidence to suggest an overall increase in the taxi accident rate, the higher rate than the target means that there is still a need to identify the causes of taxi accidents in a more detailed manner. This can only be achieved through an in-depth study identifying the factors influencing the taxi accidents and the causes associated with responsible taxi drivers. The assessment

TABLE 2 Taxi Accident Rate by Year

			Accidents with Taxi Involved (TA1)			Accidents with Taxi as Responsible Party (TA2)		
Year	Taxi Population	Total Distance (million km)	Number	Rate (per 100 taxi drivers)	Rate (per 10 million km)	Number	Rate (per 100 taxi drivers)	Rate (per 10 million km)
2001	18,798	2,871	1,268	6.75	4.42	768	4.09	2.68
2002	19,106	2,605	1,419	7.43	5.45	862	4.51	3.31
2003	19,384	2,732	1,289	6.65	4.72	839	4.33	3.07
2004	20,407	3,140	1,354	6.63	4.31	851	4.17	2.71
2005	22,383	3,611	1,266	5.66	3.51	745	3.33	2.06
2006	23,334	3,777	1,419	6.08	3.76	945	4.05	2.50
Average	20,569	3,123	1,336	6.49	4.28	835	4.06	2.67

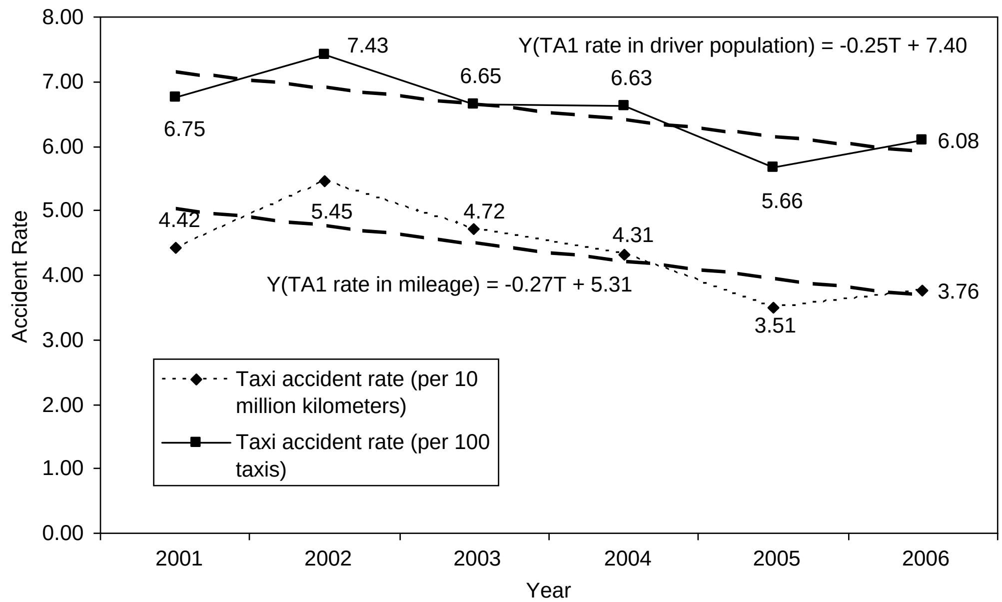

FIGURE 2 Accident rate in accidents with taxi involved (TA1).

methodology and analysis results of the in-depth study are presented in the following section.

TAXI ACCIDENT ANALYSIS OF FACTORS AND CAUSES

To develop appropriate safety programs or countermeasures to reduce the accident rates, it is necessary to determine whether there are specific factors that contribute to taxi accident occurrence and, if so, what the specific causes are that give rise to these accidents. This section provides a detailed analysis to address these issues. The analysis is divided into two phases: (*a*) a factor analysis, and (*b*) a cause analysis.

In the factor analysis, two binomial logistic models are employed to identify the significant factors in taxi accidents. This is done by comparing the accidents in which the taxi drivers were responsible with (*a*) those accidents in which the taxi drivers were not responsible and (*b*) those accidents in which the drivers of private cars were responsible. The significant factors are identified when their odds

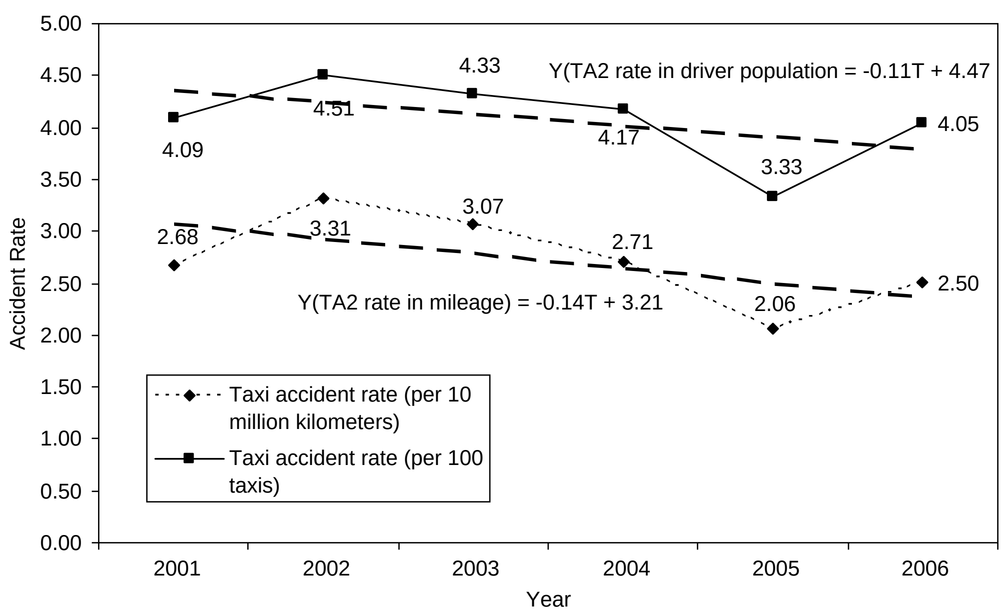

FIGURE 3 Accident rate in accidents with taxi as responsible party (TA2).

ratios are significantly greater than 1.0 when compared with the reference lowest risk group. Following the factor analysis in which the significant factors have been identified, a cause analysis is conducted to determine the causes that lead to involvement of these factors. The cause analysis is undertaken to obtain the disaggregate relative accident propensity.

Factor Analysis

Table 3 shows the candidate factors shortlisted for analysis. They are divided into two categories: driver factors and environmental factors. These are chosen based on the availability of the police-reported accident data from 2001 to 2006. The dependent variables chosen for each of the binomial logistic model are also given in Table 3, along with the reference factor for comparison.

From the two binomial logistic models, two sets of factors are to be identified. The first set, arising from a comparison of taxi accidents between responsible drivers and nonresponsible drivers (abbreviated as the "responsibility" model), represents factors that suggest taxi drivers are more likely to be causing the accidents. Factors identified in this model are related to problems associated with taxi driver behavior. Crash-reporting officers categorized each driver involved in accidents as either responsible or nonresponsible. The responsibility model assumes that this Traffic Police attribution of responsibility is reliable. The second set, arising from a comparison of all accidents of responsible drivers between taxi drivers and car drivers (abbreviated as the "comparison" model), represents factors suggesting that taxi drivers are more prone to accidents than other drivers. Factors identified in this model are related to problems associated with the operation of taxis, either as a distinct class of vehicles or as a specific nature of business operation. The resulting sets of factors are to be combined, as a factor appearing in any set will imply that it is more than likely to associate with, if not contribute to, taxi accident causation.

Results of the significant factors from the two models are given in Table 4, including the estimated odds ratio (OR), *p*-value, and 95% Wald confidence interval (95% CI). In the responsibility model, seven categories of factors are found to be significant. Two age groups and three speed-limit groups are included in the list of significant factors. These factors are largely influenced by taxi driver behavior. The comparison model also identifies seven categories of significant factors, with three factors not found in the first model. Hazards associated with these factors are related to the way taxis operate on the road. Discussions of the results from the two models are presented as follows.

TABLE 3 Factors Considered in the Analysis

	Category
Dependent Variable	
Model 1. Driver responsibility	Responsible (1) Nonresponsible (0)
Model 2. Accident type	Taxi accident (TA2) (1) Private car accident (CA2) (0)
Independent Variable	
Driver factors	
Age	<20, 20–29, 30–39 (reference), 40–49, 50–59, >59 (dummy variable)
Gender	Female (1), male (0)
Environmental factor	
Year	From 2001 to 2006 (linear)
Day of week	Weekend (1), weekday (0)
Time of day	Daytime: 10 a.m.–5 p.m. (reference) Peak time: 7 a.m.–10 a.m. and 5 p.m.–8 p.m. Nighttime: 8 p.m.–7 a.m. (dummy variable)
Directional element	One-way traffic (1), otherwise (0)
Road section	Intersection (1), otherwise (0)
Roadway type	Expressway (1), otherwise (0)
Horizontal element	Bend (1), otherwise (0)
Roadside element	Shoulder (1), otherwise (0)
Grade separation	Flyover (1), otherwise (0)
Tunnel effect	Tunnel (1), otherwise (0)
Car park effect	Car park (1), otherwise (0)
Speed limit	<40, 40, 50, 60, 70, 80, 90 (km/h) (dummy variable)
Presence of surveillance camera	Camera site (1), noncamera site (0)
Road surface condition	Wet surface (1), dry surface (0)
Collision type	Single-vehicle accident (1), otherwise (0)
Vehicle occupancy	With passenger (1), without passenger (0)

TABLE 4 Model Results in Factor Analysis

Parameter	Odds Ratio	*p*-Value	95% Wald Confidence Interval
Responsibility Model (Model 1)			
Driver age			
50–59 years	1.14	.006	1.04–1.25
>59 years	1.44	<.001	1.26–1.66
Day of week			
Weekday	1.14	.007	1.03–1.25
Time of day			
Nighttime	1.18	<.001	1.08–1.29
Road section			
Intersection	1.30	<.001	1.16–1.45
Roadway type			
Nonexpressway	1.47	<.001	1.19–1.62
Speed limit			
40 km/h	1.25	.024	1.14–1.36
70 km/h	1.13	<.001	1.02–1.30
90 km/h	1.19	.030	1.04–1.29
Vehicle occupancy			
Without passenger	1.23	<.001	1.08–1.39
Comparison Model (Model 2)			
Day of week: weekday	1.12	.006	1.05–1.20
Time of day: nighttime	1.40	<.001	1.28–1.53
Road section: intersection	1.39	<.001	1.15–1.78
Roadway type: nonexpressway	1.20	.002	1.11–1.32
Horizontal element: straight road	1.39	.010	1.18–1.49
Road surface condition: wet surface	1.29	<.001	1.16–1.44
Collision type: multivehicle accident	2.00	<.001	1.82–2.13

Driver Age

As shown in Table 4, the driver age groups that are significantly at a higher probability of being the responsible party in accidents are those in the 50–59 category (OR = 1.14, 95% CI = 1.04–1.25) and those above 59 (OR = 1.44, 95% CI = 1.26–1.66). These represent the older drivers. Those above 59 are 44% more at risk of being responsible for accidents than those aged 30 to 39, whereas for those from 50 to 59, the risk is 14% higher. This is not surprising, as driver age is generally found to increase accident risk (*11*, *12*). This is usually attributed to poorer physical and perception abilities resulting from possibly poorer eyesight, weaker muscle strength, and reduced alertness.

Day of Week

The result shows that taxi drivers have a 14% higher chance of being responsible in accidents on weekdays than on weekends (OR = 1.14, 95% CI = 1.03–1.25). However, taxi drivers are 12% more likely to be involved in weekday accidents than car drivers (OR = 1.12, 95% CI = 1.05–1.20). There are several reasons why weekday driving results in higher risks. Weekday driving is more stressful because of the higher volume of traffic. The driver workload is higher because of increased interaction with traffic in a wide variety of maneuvers. Drivers are also more likely to be engaged in more interruptive movements because of traffic controls. Furthermore, a number of control schemes are operative only during the weekdays in Singapore—such as the Electronic Road Pricing (ERP) system and the exclusive bus lane system. The presence of such systems increases the level of driver workload in vehicle control and navigation. Clearly, if the work hours remain the same between weekdays and weekends, the workload and, hence, stress will be higher for weekday driving. Driver education will be the primary measure to address the risk in weekday driving.

Time of Day

Nighttime driving is found to result in an 18% higher risk of being responsible for accidents (OR = 1.18, 95% CI = 1.08–1.29) than daytime driving. It is consistent with the finding by Lam that taxi driving was found to have a 59% higher risk at late night of being involved in injury accidents (*8*). Although traffic flow may be lower during the night hours, visibility is generally reduced, and travel speeds may be higher. Previous studies have found that poor vision acuity and visual problems are associated with an increased risk of motor vehicle accidents among taxi drivers (*3*). Furthermore, compared with general car drivers, taxi drivers are at 40% higher risk at night than in the day (OR = 1.40, 95% CI = 1.28–1.53). This increase in risk compared with general car drivers may be due to the compounded effect of taxi drivers having the greater need to seek locations, spot potential passengers, stop for boarding and alighting under poorer night vision conditions. Fatigue may also cause an increase in the risk to taxi drivers compared with general car drivers, as taxi drivers generally work long shifts at night.

Road Section

That the section of road is a significant factor in both models implies that both driver behavior and the nature of taxi operations contribute to higher risks at intersections. As expected, there is a higher risk at intersections than at other sections of the road network. The risk of being responsible for an accident is 30% higher at intersections than elsewhere (OR = 1.30, 95% CI = 1.16–1.45). This is consistent with all-traffic safety analyses, as traffic intersections are more hazardous because of increased interactions between various traffic movements (*13*). The variation of speeds at intersections caused by signal controls or other junction controls also increases the likelihood of accidents. Taxi drivers are more prone to wrong judgments at intersections. Compared with general car drivers, the risk for taxi drivers is 39% higher at intersections than elsewhere (OR = 1.39, 95% CI = 1.15–1.78). This higher value reflects the fact that taxi drivers, by virtue of the taxi operations, are at greater risk at intersections. They experience a higher driver workload at intersections than do other drivers, including unfamiliarity in route and turns and the need to pick up or drop off passengers near intersections (*8*). The increase in driver workload at intersections may be further exacerbated by longer driving hours and fatigue issues associated more with taxi driving than with other forms of driving (*1*).

Roadway Type

Between expressways and other roadway types, expressways are safer. As the factor is significant in both models, the problem associated with nonexpressway travel is influenced by both taxi driver behavior and taxi operations. Comparing responsible and nonresponsible cases, taxi drivers face a 47% higher risk on nonexpressway roads than on expressways (OR = 1.47, 95% CI = 1.19–1.62). However, compared with general car drivers, the increased risk is only 20% (OR = 1.20, 95% CI = 1.11–1.32). Naturally, taxi operations are more stressful in nonexpressway conditions, as there are increased requirements related to stopping to pick up or drop off passengers, seek potential customers, and make quick navigational decisions. The results also indicate that poorer driver behavior makes street driving even more hazardous. This may result from indiscriminate lane changing, turning, stopping, and possible lack of concentration (these will be explored further under the cause analysis).

Speed Limit

As shown in Table 4, speed limit is identified as a significant factor influencing taxi accidents among responsible drivers. The greater distinction between responsible and nonresponsible drivers rather than between taxi drivers and general car drivers implies that the hazards associated with speeds may be influenced more by driver negligence than by taxi operations. The U-shape hazard effect in speed limit is unusual. On low-speed roads of 40 km/h, taxi drivers are 25% more likely to be the responsible party in accidents than the reference category of 50 km/h (OR = 1.25, 95% CI = 1.14–1.36). Accidents on low-speed roads are associated with passenger activities, particularly those of seeking, stopping, or waiting. Under these conditions, taxi drivers take on additional workload above the driving workload to search for passengers and navigate while communicating with passengers. There is also a possibility that taxi drivers may not appreciate the road environment as well on low-speed roads, thereby being more reckless. On 70-km/h roads that are typically semiexpressway routes, the increased probability of accident responsibility (13%) associated with taxi drivers is highly significant (OR = 1.13, 95% CI = 1.02–1.30). On these roads, driver errors are associated with navigation at high speed rather than with passenger activities. There is, therefore, scope to improve driver behavior on semiexpressways. Surprisingly, at a 90-km/h speed limit, taxi drivers are 19% more likely to be the responsible party of an accident (OR = 1.19, 95% CI = 1.04–1.29), in contrast with the earlier finding that expressways have lower risks than other roads. This finding may be associated with some high risk-taking behavior of taxi drivers such as speeding, which may indicate that taxi drivers are more likely to be at fault in such situations (*6*). As this factor is not significant in the second model, the implication is that the speed limit effect is more associated with driver behavior than with taxi operations. It shows that improvement in safety can be achieved with driver education. Further investigation into causes in the next section will give insight into this.

Vehicle Occupancy

The presence of a passenger on board reduces the taxi accident propensity by 23% (OR = 1.23, 95% CI = 1.08–1.39). This is consistent with the finding by Lam, in which a 20% higher risk of injury accident involvement was found for taxis carrying passengers (*8*). This is clearly a behavioral issue rather than an operational one. It is intuitively reasonable to expect that taxi drivers would drive more carefully with a passenger on board. Furthermore, the driver of an occupied taxi has no need to seek potential passengers on the roadside, although the possibility of needing to seek the destination remains. Considering the offsetting nature induced by the presence of passengers, it may be inferred that the hazards associated with seeking a potential customer or responding to a street call may be higher than searching for the final destination. This will have a serious implication for the training needs of taxi drivers.

Horizontal Element

Compared with private cars, taxis are more prone to accidents on straight roads than on bends (OR = 1.39, 95% CI = 1.18–1.49). This factor is significant not as a behavioral problem of taxi drivers but more because of the way taxis operate. There are more passenger-related activities on straight roads, such as boarding and alighting of passengers. At such locations, there is a clear distinction between taxi and car operations. Besides the need for more stops, the possibility of stopping at places on roads where private cars do not stop, stopping longer at such places than private cars would, and potential last-minute changes in movements at the request of either onboard or on-street passengers makes driving more hazardous, even at sites with good sight distances. Further analysis into causes in the next section will provide insight into this problem.

Road Surface

Wet road surfaces have a negative effect on safety, and this effect is found to be associated more strongly with taxi operations than with driver behavior. The odds of a taxi driver being at fault are 29% higher on wet road surfaces than on dry road surfaces (OR = 1.29, 95% CI = 1.16–1.44). Poor visibility during raining periods increases the workload and stress on taxi driving. Decreased performance level is more serious among taxi drivers who have to endure the entire period of rain. Furthermore, besides poor visibility and an increased possibility of making incorrect navigational judgments, making erratic changes in movements on wet pavement surfaces will exacerbate hazards.

Collision Type

Compared with general car drivers, taxi drivers are twice as likely to be involved in multivehicle collisions than in single-vehicle collisions (OR = 2.00, 95% CI = 1.82–2.13). This is an interesting finding, especially when this factor is not significantly related to driver behavior but rather to taxi operations. The explanation for the higher likelihood of taxis having more multivehicle collisions seems likely to involve their being rear-ended by another vehicle while frequently stopping to pick up or drop off passengers, even if the stopping maneuver was not dangerous or illegal.

In summary, the factor analysis has identified 10 significant factors that influence taxi accidents. Risk mitigation can be achieved by introducing proper driver training to better prepare drivers to manage the situations associated with these factors. Indeed, the significant difference revealed between car drivers and taxi drivers in these factors may strongly indicate that driver training and education designed along the same pattern for the typical car driver may be inadequate to prepare taxi drivers to operate safely on the roads.

Cause Analysis

Having identified the factors that influence taxi accidents, the next important task is to determine the specific causes of accidents associated with each of these factors. This is accomplished by conducting a cause analysis. A cursory investigation of the causes of accidents can be done by collating accidents by the recorded cause of accidents in those cases in which the taxi driver is responsible.

Because of the change in the reporting format of accident causes in 2003, and to obtain a consistent result on accident causes, only the latest 4 years of data (2003–2006) were used. On the basis of accident records, seven leading causes of accidents are identified and ranked, as shown in Table 5. Most of these accidents were caused by careless or reckless driving on the part of the taxi drivers, such as failing to observe the movement or intention of other drivers or ignoring basic road controls.

To understand the causes of accidents associated with the specific factors identified in the factor analysis, the relative accident propensities for each factor were computed. This was done by computing the ratio of accident propensity of each category of factors to the average accident propensity for a specific accident cause. Table 6 shows the results of relative accident propensities applied to the seven leading causes previously identified (see Table 5). Those ratios of at least 1.05 are highlighted and considered to be significantly above the average occurrence. These may be candidates for driver training. A detailed discussion of the causes for each factor is given in the following section.

Driver Age

For the two age groups that have been identified, one significant cause is found for the 50 to 59 group and four causes for the >59 group. Interestingly, the relative propensities for the >59 group are generally higher than those for the 50 to 59 group, with the exception

TABLE 5 Major Taxi Accident Causes by Year

Accident Cause	Number of Taxi Accidents 2003	2004	2005	2006	Total
1. Failing to keep a proper lookout	430	388	331	274	1,423
2. Failing to give way	147	154	150	216	667
3. Disobeying traffic signs and signals	90	87	70	84	331
4. Changing lane without due care	40	53	44	130	267
5. Failing to have proper control	60	61	59	54	234
6. Turning without due care	38	51	54	51	194
7. Following car too closely	3	14	14	99	130

of disobeying traffic signs and signals. Very clearly, the older group has more difficulty in making good judgments associated with traffic conditions, even though these older drivers have a higher tendency to obey traffic rules. Failing to give way is a common problem among older drivers, indicating a serious problem of misjudging situations that demand discernment on who has the right-of-way. This problem is more seriously manifested in changing lanes without due care, affecting the most senior group. This implies that the ability to judge gaps in traffic streams may deteriorate with age. Failing to have proper control and turning without due care are also significant causes for the most senior group, indicating that the ability to negotiate the vehicle while having to make decisions associated with interactions with other vehicles may also deteriorate with age. The fact that some of these problems may be caused by poorer eyesight does not imply that those with sufficiently good eyesight will be able to make good driver judgment in interacting situations. Therefore, to qualify older taxi drivers, the eyesight test is inadequate; tests on psychomotor abilities may also be needed.

Day of Week

Although weekday conditions have been identified to be significantly more hazardous than weekend conditions, the cause analysis indicates that no single cause is more dominant than others. This is not surprising and is perhaps rather revealing. Weekday conditions generally require a higher level of mental alertness in taxi drivers, and this tends to affect driving abilities generally.

TABLE 6 Relative Accident Propensity

Significant Factor	Accident Cause[a] 1	2	3	4	5	6	7
Driver age							
50–59 years	0.97	1.07[b]	1.04	1.01	1.02	0.92	0.95
>59 years	0.97	1.08[b]	0.72	1.20[b]	1.07[b]	1.07[b]	0.97
Day of week							
Weekday	1.00	1.03	0.98	0.99	1.00	0.93	1.01
Time of day							
Night time	0.95	1.02	1.24[b]	0.98	1.04	0.98	0.84
Road section							
Intersection	0.65	1.74[b]	2.22[b]	0.17	0.28	1.37[b]	0.38
Roadway type							
Nonexpressway	0.93	1.17[b]	1.17[b]	1.01	0.77	1.17[b]	0.64
Speed limit							
40 km/h	0.90	1.39[b]	0.00	1.29[b]	1.02	2.38[b]	0.89
70 km/h	0.85	0.44	0.75	0.93	1.78	0.64	2.46
90 km/h	1.47	0.03	0.14	1.13	1.84	0.05	2.75
Horizontal element							
Straight road	0.98	0.97	0.94	1.02	1.01	0.97	1.02
Vehicle occupancy							
Without passenger	0.99	1.05	0.94	1.13[b]	0.86	1.11[b]	0.77
Road surface condition							
Wet road surface	1.32[b]	0.95	0.87	1.04	1.23[b]	1.03	0.98
Collision type							
Multivehicle accident	0.92	1.06[b]	0.92	1.08[b]	0.92	1.02	1.01

[a]Accident cause: 1. Failing to keep a proper lookout; 2. Failing to give way; 3. Disobeying traffic signs and signals; 4. Changing lane without due care; 5. Failing to have proper control; 6. Turning without due care; and 7. Following car too closely.
[b]Accident causes with relative accident propensity >1.05.

Time of Day

Taxi drivers are at a higher risk under nighttime conditions than daytime conditions. The dominant, and highly significant, cause is disobeying traffic signs and signals; the propensity is 24% higher than the mean. The lower ability to see well at night, particularly in reading traffic signs and interpreting traffic signals, may explain the high propensity. This may be more acute when taxi drivers are operating in less familiar territory, are affected by fatigue, or are distracted by passenger demands or requests (*8*). As driver training is seldom conducted or required under nighttime conditions, this finding indicates that perhaps there should be more attention given to night driving, particularly in correctly reading road conditions.

Road Section

Intersections are the most hazardous location on roads. The results in Table 6 show that the significant causes are disobeying traffic signs and signals, failing to give way, and turning without due care. These causes are common mistakes of drivers at intersections. Given that poor driver behavior as well as taxi operations are associated with this factor, the three causes identified may be affected by both reckless driver actions as well as careless actions resulting from high workload. Training and behavior modification of taxi drivers should take into account the intersection effect on driving.

Roadway Type

In taxi operations, nonexpressway conditions are more hazardous. The relative propensities are higher for causes like failing to give way, disobeying traffic signs and signals, and turning without due care. These are associated with reading and maneuver problems. The need to seek passengers increases the tendency of taxi drivers to make errors of judgment and actions associated with these causes. When confronted with decisions to pick up on-street passengers, taxi drivers sometimes may be unaware of the street operating and traffic conditions, leading them to commit unintentional and possibly intentional violations or to take higher maneuver risks. Driver training should also address this aspect of need.

Speed Limit

The speed groups with higher risks are the 40-km/h roads, 70-km/h roads, and 90-km/h roads. Interestingly, the causes associated with the different categories of roads are not the same. On low-speed roads, the significant causes are failing to give way, changing lanes without due care, and turning without due care. These are associated with maneuvering problems and are likely to be affected by passenger-related activities such as last-minute actions of stopping, turning, and changing of lanes. On semiexpressways, the causes are failing to have proper control and following a car too closely. The first cause may be related to speeding or distracted attention. The latter cause, which is also present in expressway driving, is highly significant. The reason for following too closely is not clear, but that this has a rather high propensity indicates that significant attention must be given to training taxi drivers to maintain an appropriate following distance. Several other causes are dominant in expressway driving. These are failing to keep a proper lookout, changing lanes without due care, and failing to have proper control. These represent poorer driving skills associated with expressway driving. It is interesting to cross-reference these findings with those associated with road sections, as expressways are considered the safer conditions under that factor. Although expressways are a safer environment compared with urban streets, the cause analysis here indicates that there are still specific risk associations with expressway driving. As speed limit is not one of the significant factors associated with taxi operations, these specific risks in expressway driving are clearly related to poor driver behavior. Hence, there are gaps in expressway driving skills among taxi drivers.

Horizontal Element

The factor analysis reveals that straight roadways pose a higher risk to taxi drivers, and this is more associated with taxi operations than with driver behavior. From the cause analysis, there is no dominant cause identified, indicating that the risks are rather distributed.

Vehicle Occupancy

In the factor analysis, taxis without passengers are found to be more involved in accidents. This is related to problems of driver behavior. In the absence of passengers onboard, taxi drivers are either seeking on-street customers or traveling to answer booking calls. Both conditions may put the taxi drivers under stress. It is not surprising that the major causes associated with occupancy are changing lanes without due care and turning without due care. Clearly, recklessness is implied. In driver education, there is a need to address the issue of how to respond to passenger calls in a safe and responsible manner.

Road Surface

On wet road surfaces, which pose a more hazardous condition than dry road surfaces, two causes are found to have higher propensity. They are failing to keep a proper lookout and failing to have proper control. Although both are related to driver recklessness, the factor analysis has identified this as more related to taxi operations. Therefore, it may be inappropriate to conclude that taxi drivers are more reckless under wet surface conditions. Rather, because of the nature of taxi operations, taxi drivers may have to endure longer periods of stress under raining conditions, which compromises their abilities, thereby resulting in a higher likelihood of errors of judgment. This aspect of driver behavior needs to be properly addressed in driver training.

Collision Type

Taxis are more frequently involved in multivehicle collisions. Under this factor, the significant causes are failing to give way and changing lanes without proper care. Naturally, these causes involve vehicle interactions and seem to imply driver recklessness. However, it should be noted that the increased risk in this factor is due to taxi operations rather than the drivers themselves. Hence, the primary cause is likely drivers making errors of judgment or action when responding to passenger calls rather than poor driving skills.

With the factor analysis and cause analysis, specific causes of accidents have been identified on the basis of risk and driver propensity.

Further, by carefully considering these causes, better driving training programs could be designed. The study indicates that while driving skills may be improved, the problem of taxi accidents may be related to the nature of taxi operations and not merely driver behavior. Consequently, it is necessary to design an education program to ensure that taxi drivers can be better prepared to conduct their business with due consideration of the safety of other road users.

CONCLUSION

In this study, general taxi accident trends in Singapore were analyzed using 6 years of police-reported accident data. The trend analysis indicated that between 2001 and 2006, there was no evidence to suggest an increasing trend in taxi accidents. There was also no indication that the changes in the number of taxi accidents were systemically different from those of private car accidents.

For a more meaningful interpretation of the taxi accidents, exposures such as vehicle mileage need to be taken into consideration. This gives the taxi accident rates. Examination of taxi accident rates also shows that there is no evidence to suggest an overall increase in taxi accident rates from 2001 to 2006. However, the taxi accident rates are higher than the standard of two accidents per million vehicle kilometers set by LTA. Hence, there is a need to identify the causes of taxi accidents so that specific areas of training can be implemented to achieve an overall decrease in taxi accidents.

Following the trend analysis, a factor analysis was used to identify the factors that have contributed to accident occurrence. From the binomial logistic models, a total of 10 significant factors were identified: driver age, day of week, time of day, road section, roadway type, speed limit, vehicle occupancy, horizontal element, road surface, and collision type. Of the 10 significant factors, the factor analysis shows that taxi drivers tend to be the responsible party in cases of increasing age, driving without a passenger, and driving on 40-, 70-, and 90-km/h roads. The analysis also indicates that there are factors related to operation that need to be improved, including driving on straight roads, driving on wet road surfaces, and multivehicle collisions. The factors that are found to be associated with both driver behavior and taxi operations are driving on weekdays, driving at night, operating at intersections, and nonexpressway situations.

The analysis also shows that there is significant difference between car drivers and taxi drivers in the 10 factors. This strongly suggests that driver training and education designed to target the specific areas for taxi drivers is necessary to better prepare taxi drivers to operate safely on the roads. It also suggests that the typical car driver training programs are not sufficient for taxi drivers. Furthermore, there might be room for reform of the operation style of the taxi industry. An obvious example would be a reduction in on-street searching for customers and an increase in the proportion of customers who book taxis by phone or using the Internet.

For the purpose of cause analysis, seven leading causes of accidents have been identified: failing to keep a proper lookout, failing to give way, disobeying traffic signs and signals, changing lanes without due care, failing to have proper control, turning without due care, and following cars too closely.

Based on the study on risk and driver propensity, the seven causes were ranked according to the 10 individual factors identified in the factor analysis. It was found that older taxi drivers are at a higher risk of being involved in accidents involving the maneuvering of the vehicle. The nature of the taxi operations, such as seeking customers or responding to passenger requests, thus increasing the driver workload, appears to have an impact on the safety performance of taxi drivers. The analysis also suggests areas of carelessness by taxi drivers, especially on straight roads, high-speed roads, and wet surfaces.

With these causes of accidents taken into consideration, a targeted driving training program could be designed. It is also necessary to equip taxi drivers with knowledge about the nature of taxi operations so that they can conduct their business with due consideration for the safety of other road users.

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