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Department for Transport
Great Minster House
76 Marsham Street
London SW1P 4DR
Telephone 020 7944 8300
Web site www.dft.gov.uk

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Work-related road safety: age, length of service and changes in crash risk

Lisa Dorn and Helen Muncie
Department of Human Factors
Cranfield University
Cranfield
Bedfordshire MK43 0AL

Introduction

Age and experience are known to be major factors in road traffic collisions (Maycock *et al.*, 1996) and are commonly used as predictors of crash frequency (Evans and Courtney, 1985). But age and experience are difficult to separate when investigating crash risk (Brown, 1982; Ryan *et al.*, 1998; Mayhew and Simpson, 1990; Bierness, 1996). Experience is closely related to age but independently influences crash risk. For age, mileage-adjusted crash risk declines with age but then rises for drivers over 65 (Maycock *et al.*, 1991). This is thought to be due to physical and cognitive declines in older people and to increased risk-taking in younger drivers (Chipman *et al.*, 1992; Clarke *et al.*, 1998; McGwin and Brown, 1999). For experience, even limited driving experience has a major effect on road safety. For example, there is a disproportionately higher crash rate during the first year of driving, particularly in the first few months after licensure (Sagberg, 1998). For age and experience, Mayhew *et al.* (2003) found larger decreases in crash risk amongst younger novices compared with older novices during the first few months of driving. This was interpreted as due to greater initial risk-taking amongst younger novices, with on-road driving experience facilitating a more rapid learning rate compared with older novices. They suggest that this was an appropriate point at which to provide training intervention. There is reasonable literature on the effects of age and experience on accident involvement, but little is known about whether these effects can be generalised to professional drivers, especially since professional drivers differ substantially from the general population of drivers.

Crash risk is greater for drivers who drive for work, even when taking into account increased mileage (Broughton *et al.*, 2003). Bus drivers are a special group of professional drivers that differ markedly from the general population of car drivers in a way that is likely to affect their crash risk in many ways. Most bus drivers are already experienced drivers before gaining a Public Commercial Vehicle (PCV) Licence and may start work as a bus driver at any age. It is possible that being an older, experienced driver before learning to drive a bus may be beneficial, but currently there is no evidence to indicate that this is the case. There are several factors that may increase bus crash risk, however. Firstly, they have responsibility for passengers. Secondly, they drive a large heavy vehicle that is constantly pulling in and out of traffic, mostly in built-up areas. Thirdly, bus drivers have a higher annual mileage than private motorists. Finally, their collisions are work related and therefore organisational factors such as bus schedules are likely to exert a strong influence on their driving behaviour. They cannot easily adjust to task demands in the same way as private motorists can if it means running late.

To examine crash risk, many studies use official accident data (e.g. Abdel-Aty *et al.*, 1998; Evans and Courtney, 1985; McGwin and Brown, 1999; Ryan *et al.*, 1998). These databases have the advantage of being large and usually collected over a long time-period. Although official data are not often collected for research purposes and may lack relevant information. For example, culpability may not be recorded (e.g. Wählberg, 2002). Other studies are limited by small sample sizes (e.g. Hancock *et al.*, 1990). Within company databases, there may be additional problems. Crash data are often collected for insurance purposes, with culpability being recorded to support the commercial operation of the company. Such databases are concerned with policies, claims and claimants rather than accident and driver characteristics. Arriva is a major UK bus company and its incident database collects information not only for insurance claims purposes but also for risk management purposes, hence driver characteristics are available. Their database can help to determine the factors that may be influential in the increased crash risk of drivers driving for work. A further advantage is that all incidents are reported and attributed to a particular driver, no matter how minor. This is due to a strictly adhered to company policy that all vehicles are checked at the start and end of each shift.

There are many ways to assess the crash risk associated with different types of road user. Since conclusions on safety issues cannot be reliably drawn without exposure information (Evans, 1991), crash rates are usually normalised against some measure of exposure. Several researchers have suggested using induced exposure techniques to produce a relative risk ratio index. The calculation of crash risk used for the present study is a ratio of the proportion of all at fault drivers represented in each group divided by the proportion of non-responsible in each group (Cooper, 1990; Lyles *et al.*, 1991; Stamatiadis and Deacon, 1997). This method is based on the assumption that in two-vehicle crashes there is a driver who is responsible for the collision and that the second driver is selected randomly from the driving population (Haight, 1973).

Many organisations are concerned about the frequency with which their employees are involved in crashes, but there is little published data to guide company policy on what can be done to address their increased exposure to risk. As part of a Training Needs Analysis, this study aims to investigate the role of age and bus driving experience on crash risk.

Method

Crash data

There are 121 Arriva depots in the UK and analysis includes crashes that occurred throughout these depots from December 2000 to June 2003. Only crashes that met the following criteria were included: drivers were between 18 and 64 years, had 0–35 years service history with Arriva, and details about the crash and culpability were complete. This left a total of 15,100 incidents that were suitable for inclusion in the analysis. The crash database also includes passenger falls inside the bus, but they have not been included in the following analysis.

Participants

There were 12,244 bus drivers included in the analysis. Drivers were aged between 18–64 years (mean = 42.8 years, SD = 10.8). Information about a driver's sex was not available, but almost all Arriva bus drivers are male. Years in service ranged from one month to 35 years (mean = 6.1, SD = 7.6). Length of service (LOS) was the operational definition of bus driving experience. LOS was categorised into three groups, with equal proportions of drivers in each category: LOS1 (0 to 1 years); LOS2 (1 year and 1 month to 5 years); and LOS3 (over 5 years).

Crash risk ratio and culpability

The analysis presented is based on the frequency of collisions, so that any one driver may appear in the data more than once if they have been involved in multiple collisions between the time periods of interest. For culpability, at fault, part fault and not at fault categories are assigned to every crash based on a claims investigation that may include police statements, witness reports, photographic evidence and driver self-reported details of the circumstances surrounding the crash.

Two measures of crash risk are calculated from crash frequency data. Firstly, those 'Solely Responsible' for a crash, defined as the risk of being the sole cause of a crash. This was calculated by dividing the frequency of at-fault crashes with the frequency of not at-fault crashes. Secondly, those 'Partly Responsible' for a crash, defined as the risk of contributing to the cause of the crash and is calculated by adding the frequencies of at-fault and part-fault crashes and then dividing by the frequency of not at-fault crashes. A ratio of 1 means that if drivers are involved in a crash the likelihood of them being responsible for causing the crash and the likelihood of them not being found at-fault is the same. A ratio of less than 1 means that the driver is not likely to be the cause of the crash and a ratio of more than 1 means that the driver is likely to be the cause of the crash (Haight, 1973). Crashes were grouped according to culpability so that separate analyses were performed for at-fault ($n = 6,230$), not at-fault ($n = 7,448$) and part-fault crashes ($n = 1,422$).

Results

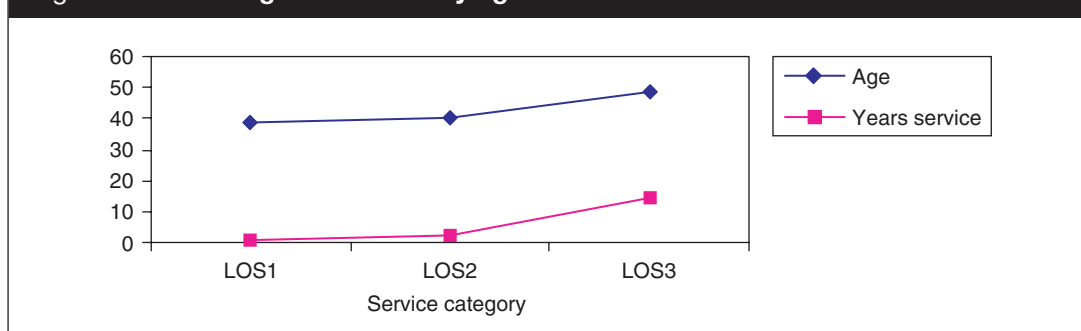
LOS categories

One-way ANOVA (ANalysis Of VAriance between groups) showed a significant difference in mean age for each LOS category ($F(2,15097) = 1453.62, p < 0.0001$). Post hoc tests show that all three LOS categories are significantly different from each other ($p < 0.0001$). LOS1 had the youngest bus drivers and LOS3 had the oldest bus drivers. The mean years in service for each LOS category was also significantly different ($F(2,15097) = 12885.56, p < 0.0001$) again post hoc tests showed significant differences between LOS1, LOS2 and LOS3 ($p < 0.0001$). Table 1 and Figure 1 show the descriptive statistics for age and LOS.

Table 1 Age and years of service by LOS

	LOS1		LOS2		LOS3	
	Age	Years service	Age	Years service	Age	Years service
Mean	38.5	0.43	40.5	2.6	48.7	14.2
Std deviation	10.5	.27	10.3	1.1	9.2	7.7
Minimum	18	.01	19	1.01	24	5.01
Maximum	64	1.0	64	5.0	64	35

Figure 1 Mean length of service by age and LOS



Location and manoeuvre at time of crash

Table 2 and Figure 2 shows the proportion of crashes taking place at different locations by LOS.

For all LOS categories, most crashes occur at bus stops, junctions, traffic lights and in bus lanes.

Table 2 Percentage of all crashes by location and LOS

Service length	Bus stop	Junction	Traffic lights	Bus lane	Roundabout	Pothole	Road works	Pedestrian crossing
LOS1	27.8	33.0	12.0	9.9	7.2	6	2.6	1.5
LOS2	26.5	31.4	13.5	10.6	7.2	5.6	3.1	2.2
LOS3	26.9	28	13.1	9.6	8.4	6.4	2.7	2

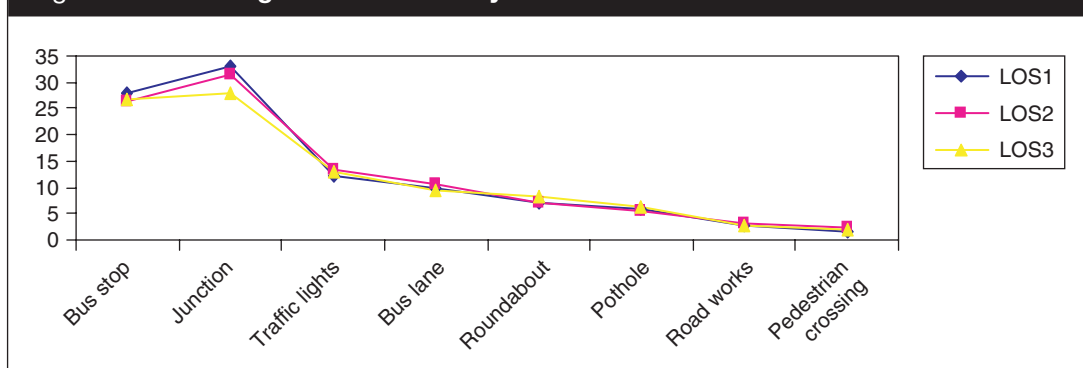
Figure 2 Percentage of all crashes by location and LOS

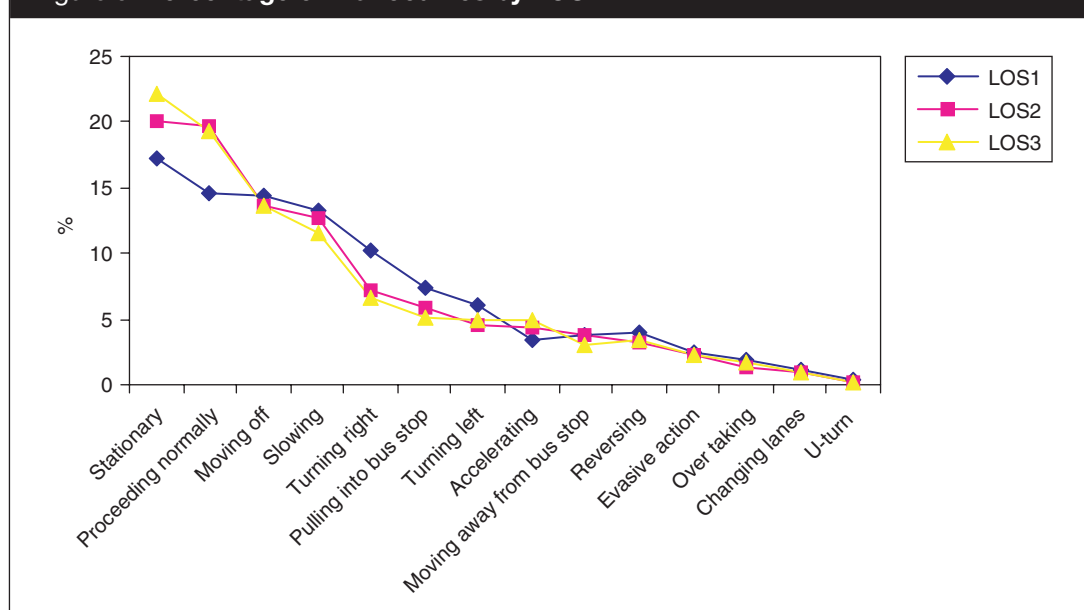
Table 3 shows the kinds of manoeuvres performed at the time of the crash in the order of their proportion relative to all other kinds of manoeuvres performed.

Table 3 Percentage of manoeuvres by LOS

Manoeuvre	LOS1	LOS2	LOS3
Stationary	17.2	20.1	22.1
Proceeding normally	14.6	19.7	19.3
Moving off	14.4	13.7	13.7
Slowing	13.2	12.6	11.6
Turning right	10.3	7.2	6.6
Pulling into bus stop	7.3	5.9	5.1
Turning left	6	4.6	5.0
Accelerating	3.5	4.4	5.0
Moving away from bus stop	3.8	3.7	3.1
Reversing	3.9	3.2	3.4
Evasive action	2.4	2.2	2.2
Overtaking	1.8	1.4	1.7
Changing lanes	1.2	0.9	0.9
U-turn	0.4	0.2	0.2

Bus drivers in all service categories reported that they were most often stationary, proceeding normally, moving off from a stationary position or slowing down at the time of the incident. To a lesser extent turning right and pulling into bus stops posed a problem as did turning left for novice bus drivers. Accelerating and pulling away from bus stops, reversing, taking evasive action, overtaking, changing lanes and making U-turns were reported less often at the time of the incident. The pattern is similar across LOS categories, with the possible exception of being stationary at the

Figure 3 Percentage of manoeuvres by LOS

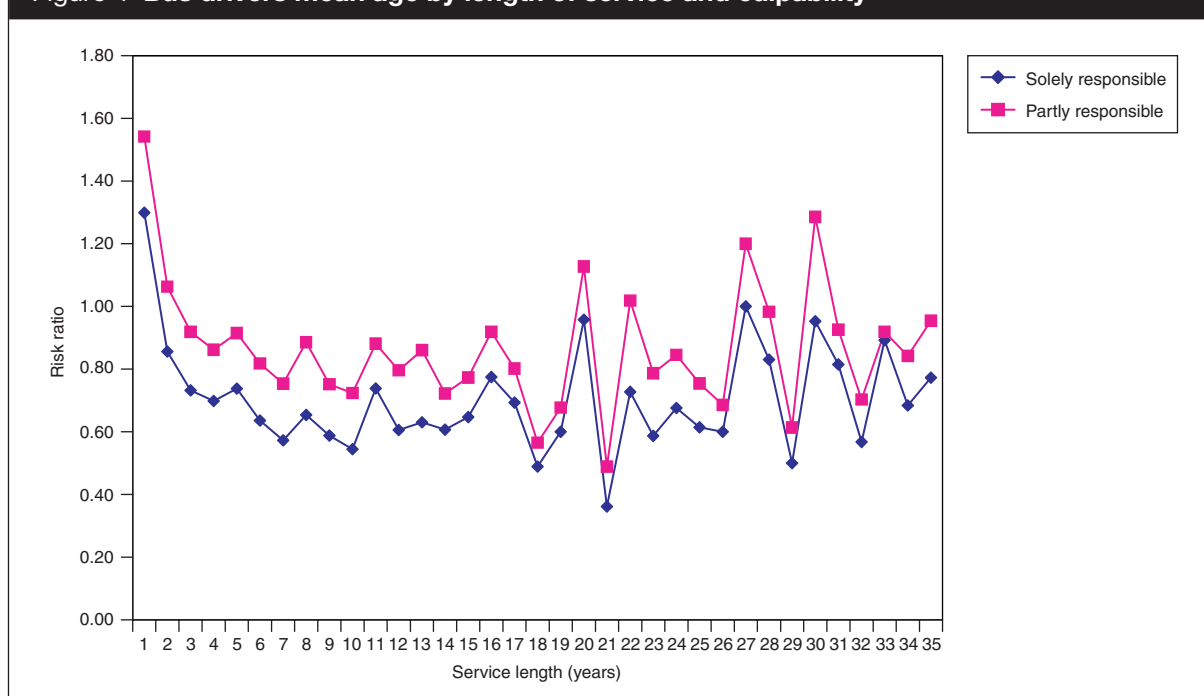


time of the crash and proceeding normally for which less experienced bus drivers appear to be under-represented compared with more experienced drivers.

LOS and culpability

Figure 4 provides information relating to the risk ratios for every year of service according to whether the driver was classified as solely or partly to blame for a crash. The results show that risk ratios decline after the first two years of driving but crash risk ratios exceed 1.0 three times after 20 years of service for part-blame crashes, whereas for sole-blame crashes it exceeds 1.0 for the first year only. Given

Figure 4 Bus drivers mean age by length of service and culpability



these findings, a more focused analysis of the first three years of service was conducted.

First three years of service

Table 4 shows the frequency of at-fault, not at-fault and part-fault crashes and the total number of crashes for the first three years of service.

Table 4 Crash frequency by service length				
Service length	All crashes (frequency)	At-fault crashes (frequency)	Not at-fault crashes (frequency)	Part-fault crashes (frequency)
Year 1	4,166	2,129	1,639	398
Year 2	2,106	874	1,021	211
Year 3	1,541	588	803	150

Table 5 shows the ratios for a driver being solely responsible and partly responsible for the cause of the crash for the first three years of service. The asterisk indicates whether the driver is more likely to be involved in the cause of the crash.

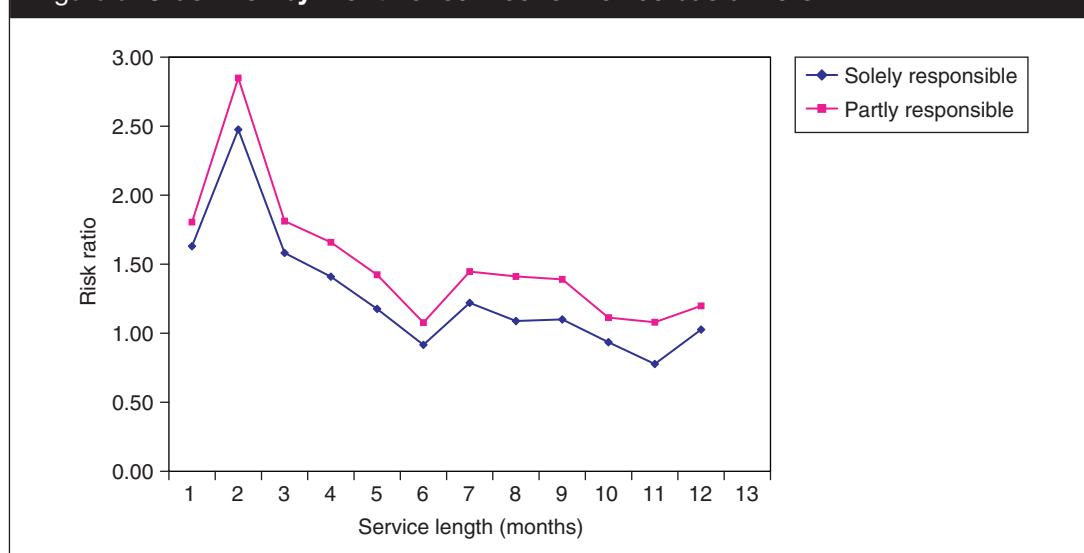
Table 5 Risk ratios for first three years of service by culpability		
Service length	Solely responsible	Partly responsible
Year 1	1.30*	1.54*
Year 2	0.86	1.06*
Year 3	0.73	0.92

Given that the first year of service carries the greatest risk of being both solely and partly responsible for a crash, a more detailed analysis of the first year of service was conducted.

Month by month crash risk

The same data cleaning procedures were also conducted on drivers in their first year of service only, which left a total of 4,166 crashes that were suitable for inclusion in the analysis. Length of service was then categorised into 12 groups in increments of one month each. The data were then divided according to culpability for at-fault ($n = 2,129$), not at-fault ($n = 1,639$) and part-fault crashes ($n = 398$), and crash risk ratios were calculated as previously described.

Figure 5 shows a sharp decline in crash risk for both sole- and part-blame crashes during the first year of service.

Figure 5 Crash risk by month of service for novice bus drivers

To investigate crash risk according to age and first year of service, an analysis of older and younger novice drivers was then conducted. The results are shown in Figure 6 for part-blame crashes and in Figure 7 for sole-blame crashes.

To determine the relative contribution of age and bus driving experience, the crash risk for novices who were similar in experience but different in age is shown in Figures 6 and 7.

Figures 6 and 7 shows that younger novice bus drivers have generally higher risk ratios for the first few months of driving a bus compared with older novice bus drivers for both part- and sole-blame crashes. Older novices show a steeper decline in crash risk compared with younger novices. An effect of experience is also in evidence with an overall decline in crash risk over the first year of driving.

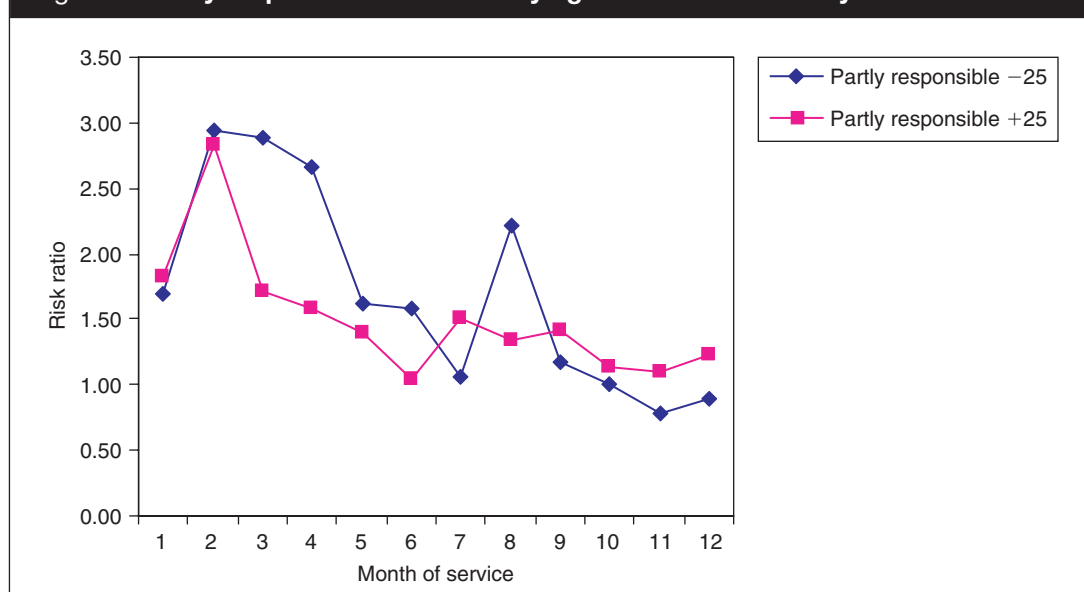
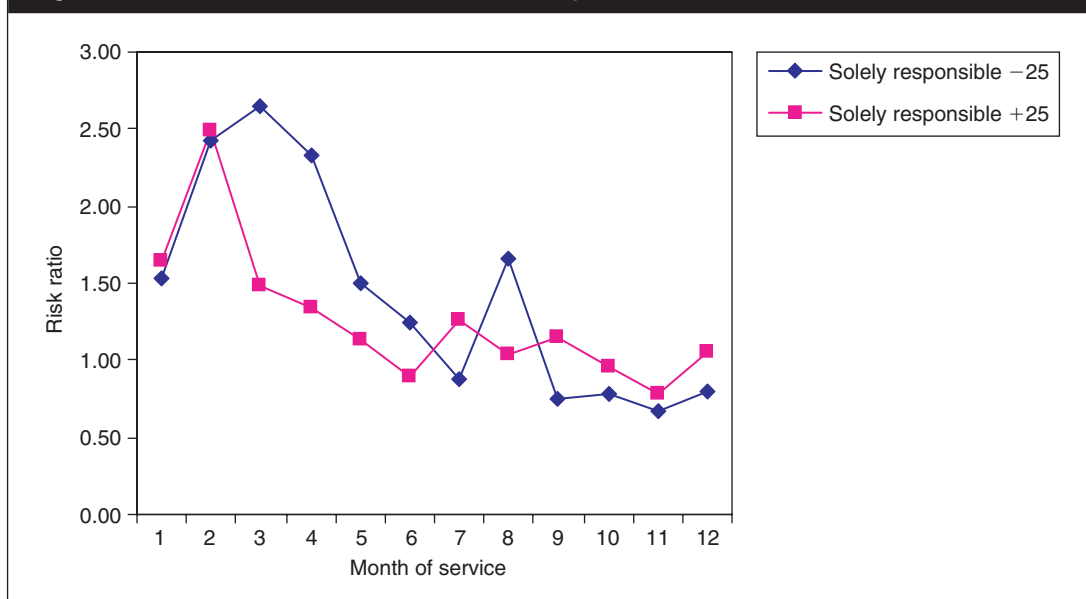
Figure 6 Partly responsible crash risk by age and month of first year of service

Figure 7 Solely responsible crash risk by age and month of first year of service

Prediction equations: age, length of service and culpability

A multiple regression analysis was used to evaluate the relative contributions of age and LOS on crash frequency. Crash frequency was divided into three types, at-fault, not at-fault and part-fault crashes, and a regression analysis was conducted to evaluate the relative contributions of age and LOS on crash frequency. In particular, age and LOS were used to predict three criterion measures of crash frequency: at-fault, not at-fault and part-fault crashes.

Risk of at-fault crashes

The linear combination of age and experience was significantly related to at-fault crash frequency ($F(2,15097) = 46.46, p < 0.001$). The sample multiple correlation coefficient was 0.078, indicating that approximately 6% of the variance in at-fault crash frequency could be accounted for by age and LOS. Table 6 represents indices to show the relative strength of the individual predictors. All correlations were statistically significant. Age was positively correlated with at-fault crashes, experience was negatively correlated with at-fault crashes.

Table 6 Correlation coefficients for at-fault crash frequency, age and LOS

Predictor	Correlation between predictor and crash frequency	Correlation between predictor and crash frequency controlling for other predictor
Age	0.03*	0.037*
LOS	-0.069*	-0.078*

* = $p < 0.0001$

The prediction equation for the standardised variables is given below to understand better the relative importance of the predictors on crash frequency:

$$Z \text{ Risk (at-fault crash)} = 0.041 Z \text{ age} - 0.087 Z \text{ LOS}$$

This indicates that LOS is relatively more important than age in predicting at-fault crash frequency.

Risk of part-fault crashes

The linear combination of age and LOS was not significantly related to part-fault crash frequency ($F(2,15097) = 2.51, p < 0.05$). The sample multiple correlation coefficient was 0.018, indicating that only 0.03% of the variance in part-fault crash frequency could be accounted for by age and LOS.

Table 7 represents indices to show the relative strength of the individual predictors. The correlation between experience and crash frequency was statistically significant, however age was not significantly correlated with part-fault crash frequency.

Table 7 Correlation coefficients for part-fault crash frequency, age and LOS		
Predictor	Correlation between predictor and crash frequency	Correlation between predictor and crash frequency controlling for other predictor
Age	-0.011	0.003
LOS	-0.018*	-0.015*

* = $p < 0.10$

The prediction equation for the standardised variables is given below to understand better the relative importance of the predictors on crash frequency:

$$Z \text{ Risk (part-fault crash)} = -0.003 Z \text{ age} - 0.016 Z \text{ LOS}$$

This indicates that LOS is relatively more important than age in predicting part-fault crash frequency.

Risk of not at-fault crashes

The linear combination of age and LOS was significantly related to not at-fault crash frequency ($F(2,15097) = 55.82, p < 0.001$). The sample multiple correlation coefficient was 0.086, indicating that approximately 7% of the variance in not at-fault crash frequency could be accounted for by age and LOS.

Table 8 represents indices to show the relative strength of the individual predictors. All correlations were statistically significant.

The prediction equation for the standardised variables is given below:

$$Z \text{ Risk (not at-fault crash)} = 0.095 Z \text{ LOS} - 0.038 Z \text{ age}$$

Table 8 Correlation coefficients for part-fault crash frequency, age and LOS

Predictor	Correlation between predictor and crash frequency	Correlation between predictor and crash frequency controlling for other predictor
Age	0.003*	-0.035*
LOS	0.078*	0.086*

* = $p < 0.0001$

This indicates that experience is relatively more important than age in predicting risk of involvement in not at-fault crashes.

High bus crash frequency cannot be attributed to driver immaturity. It appears that lack of experience of driving a bus is more influential than youth in its contribution to crash risk for at-fault and not at-fault crashes.

Discussion

Generally, bus drivers are not to blame for most crashes, rather it is the behaviour of other road users that seem to be culpable. However, bus drivers in their first year are more likely to be responsible for crashes. Bus driving has a positive influence on both older and younger novices, so that by the end of the first 12 months of driving, their risk of being involved and not involved in a blameworthy and part-fault crash is about the same. Consistent with previous research (Sagberg, 1998; Mayhew *et al.*, 2003) this study shows that crash risk is attributable to age-related factors, with younger novices having a higher crash frequency than older novices with the same amount of bus driving experience. However, contrary to previous research, older novices show a more dramatic reduction in crash risk for at-fault and part-fault crashes compared with younger novices. Older novices appear to learn more quickly from their on-road experiences and develop the skills to avoid bus crashes. Crash risk increases in the second month of driving, this may be due to over-confidence after skills training. There is a suggestion here that perhaps professional driver training should include training in how human factors might impact on their crash risk.

There is now a body of evidence that some skills training may not be beneficial for road safety. Even specific skills training, such as skid control and braking techniques, have failed to find measurable improvements in accident rates (Lynam and Twisk, 1995; Gregersen, 1991). For example, in skid pad training, Katila *et al.* (1996) found that young drivers failed to comprehend that the purpose of training was to avoid a skid rather than be able to control it. This is particularly important given that an overestimation of driving skill may lead to *increased* accident risk (Gregersen, 1994).

For both at-fault and part-fault crashes, LOS and crash frequency is negatively correlated showing that bus drivers have fewer crashes as their length of service increases. Novices are involved in more crashes and are likely to be responsible for the crashes they are involved in. On the other hand, not at-fault crashes are

negatively correlated with LOS showing that drivers with longer service length are involved in more crashes that are the fault of another road user. Age and crash frequency are positively correlated in at-fault and part-fault crashes, with older drivers being more likely to be to blame for a crash. The negative correlation between age and not at-fault crashes suggests that younger drivers have more crashes that are caused by another road user. The results indicate that, although both age and LOS are important, LOS is the greatest predictor of crash risk in at-fault, part-fault and not at-fault crashes.

One possible interpretation of the findings for LOS and manoeuvres as the time of the crash is that experienced drivers appear to be over-represented in passive crashes that they are not to blame for. They more often are involved in crashes when they are stationary or proceeding normally. When the driver is deemed to be at-fault, the definition of culpability here might assume that the driver has exhibited behaviour that is inappropriate for the prevailing traffic demands and/or the capabilities of the vehicle being driven. Given that there are schedules to maintain, bus driving is governed by factors outside the traffic system that may increase crash risk if a bus driver is running late and feels the need to take risks. Therefore, culpability is a questionable assumption, even if assigned correctly. This is especially true when there are multi-vehicle crashes. Analysis of culpability should always be regarded with some caution.

Whether they are responsible or not, it is clear that training needs to target the risks associated with driving a bus particularly at bus stops and junctions, especially for novices. The findings suggest that inexperienced drivers have a higher percentage of crashes at junctions. Generally, bus crashes occur primarily at junctions that are problematic locations for all road users (Clarke *et al.*, 1998). Other crashes are due to problems inherent in the bus driving environment, such as bus stops and bus lanes. Inexperience in the form of lack of knowledge about hazards and the appropriate vehicle handling skills to allow the driver to manoeuvre safely may result in the driver taking unnecessary risks in unknown situations (Bailey *et al.*, 2003; McKnight and McKnight, 2003; Underwood *et al.*, 2002; McKenna and Horswill, 1999). At present, the average new bus driver receives about two weeks' instruction in a driving school based on vehicle handling skills training, in common with many other professional driver training courses. Currently, professional driver training neglects to consider work-related factors that might impact on driver behaviour. For example, driver stress is associated with riskier driving behaviour amongst professional drivers (Dorn, 2005; Dorn and Brown, 2003) and crash-involved bus drivers score significantly lower on dimensions of driver stress and higher on ineffective coping strategies (Dorn and Garwood, 2005).

Driving simulators can differentiate between professional and non-professional drivers (Dorn and Barker, 2005) and may be a useful tool for higher order skills training. The Arriva Bus Simulator has been developed to provide repeated opportunities to assimilate familiar experiences and accommodate to unfamiliar ones (Muncie and Dorn, 2003; 2004). Future research will consider the transfer of training effectiveness of a training programme that includes both simulating the demands of driving a bus under time pressure and classroom-based sessions designed to manage the human factors associated with driving for work.

There are methodological limitations that need to be considered. It is reasonable to assume that many of the employees with greater crash involvement will tend to

either leave the company or be asked to leave. Perhaps the reduction in crash frequency over time is due to the natural selection of drivers who are still with the company because of their higher safety standards. To follow the same group of drivers over time in a longitudinal analysis would take this into account (Maycock *et al.*, 1996).

Conclusion

Experienced drivers who are newcomers to driving a bus seem to demonstrate similar changes in crash risk as has been observed amongst inexperienced non-professional drivers. This suggests that both groups of drivers learn to drive after gaining a licence, calling into question the usefulness of current approaches to driver training. For bus drivers in particular, there is a suggestion that the training they receive may not adequately prepare them for the job of driving a bus. Given the elevated crash risk of novice bus drivers, the findings suggest that training could be improved to improve road safety. Van Zelst (1954) found over 50 years ago that training reduces the initial accident frequency peak by a substantial amount, especially for younger novices. Most bus crashes take place at junctions and bus stops in the first year of driving. Novice bus drivers have an increased risk of being involved in bus crashes and the length of service rather than age contributes most to crash risk. In contrast to previous literature for private motorists, professional older novices show a steeper decline in crash risk in the first few months of driving compared with younger novices. Work-related crash risk then is governed by different factors to that of private motorists, not only in terms of driver characteristics and risk exposure, but also due to organisational pressures. Specific training to deal with these demands is required to improve work-related road safety.

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Dorn, Lisa; Muncie, Helen

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