Factors affecting the safety performance of bus companies—The experience of Taiwan bus deregulation

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Abstract

This study was undertaken to explore the factors affecting the safety performance of bus companies in Taiwan. A conceptual framework was developed based on the theory of organizational accidents. Environmental and organizational factors were assumed to determine the safety performance of bus companies. Since the deregulation of intercity passenger transportation in 1995 the bus transportation industry in Taiwan has been restructured, and this provides an opportunity to gain insight into the factors that influence the safety performance of bus companies. The study results show that the bus companies on joining intercity bus services in Taiwan did experience higher risks of being involved in major injury and minor injury accidents. The study results provide convincing evidence that organizational factors, including driver-specific, vehicle-specific and general management factors, have significant effects on the safety performance of bus companies. Therefore, if the economic deregulation was implemented with some safety regulation policies, we might have the opportunity to pursue a better safety performance by the bus transport industry as a whole, rather than just prevent the deterioration of the existing safety performance. Furthermore, the limited resources available to monitor the safety performance of bus companies are suggested to focus on those companies that run intercity services as well as those companies of small size, having older fleets, and a higher traffic conviction rate.
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1. Introduction

No deterioration of safety performance was found after deregulation of the bus and coach industries in Britain (Evans, 1994; White et al., 1995; White, 1995). The same results were evident in the deregulation of the trucking and airline industries in the United States (Chow, 1987; Capelle and Beilock, 1987; Jerome, 1985). However, some studies indicated that the deregulation of the trucking industry was found to change the behavior of the carriers, and influence their safety performance (Chow, 1989; Corsi and Fanara, 1989; Jovanis, 1989).

Organizational factors, which include firm size, fleet age, fleet size, operational mileage, type of cargo, and compliance with safety regulations, have been found to significantly affect the carriers' safety performance in the trucking industry (Corsi and Fanara, 1989; Moses and Savage, 1992, 1994; Mejza, 1998; Arnold and Hartley, 2001). The associations between safety performance and company characteristics, including the type of operation and the size of fleet, were also explored recently for passenger motor carriers (Corsi et al., 2002). Hence, there is a possibility that deregulation of the transport industry will change the organizational and operational characteristics of individual carriers, and restructure the companies within the industry. Deregulation is then expected to impact in different ways, positive or negative, upon the safety performance of carriers with different characteristics, and have an overall impact on the industry as a whole. If this assumption is true, we might be able to shed some light on the reasons for the inconsistent conclusions regarding the impacts of deregulation on the safety performance of individual carriers and the transport industry as a whole.

Intercity bus transportation, which handles more than 60% of the intercity passenger trips in recent years, is the primary mode for long distance travel in Taiwan (MOTC, 2002). In Taiwan, under the pressure of rapid market expansion and worldwide enterprise privatization, the entry barrier to the intercity bus market was removed in 1995. Many new companies have joined the existing bus companies in this deregulated market. Deregulation has resulted in some positive effects on intercity transportation service, such as lower fares, more frequent service and new vehicles with luxurious entertainment facilities. However, deregulation has also brought the pressure of competition to bus companies. This could force bus companies to reduce resources previously allocated to safety management, and thereby posing a threat to their safety performance. Moreover, with deregulation, less experienced companies and drivers have entered the industry. A serious question that has arisen from deregulation is: will the higher accident risk associated with the lack of experience of these novice companies will be offset by the implementation of new safety management concepts and new vehicles?

Deregulation of the intercity bus market in Taiwan has provided the opportunity to study the relationship between safety performance and organizational as well as

operational characteristics of individual carriers, and to review the actual effect of deregulation on safety performance. Thus, this paper proposes a conceptual framework based on the theory of organizational accidents that relate both the environmental and organizational factors to the safety performance of bus companies. Poisson regression models are then employed to formulate the accident risk of bus companies according to their organizational and environmental characteristics. Forty-two bus companies or about two thirds of the total bus companies in Taiwan, including those established before and after deregulation in 1995, were interviewed for empirical study purposes. The numbers of fatal and injury accidents that occurred in 2001 for each bus company interviewed were collected. This study explores the environmental and organizational factors that affect the accident risk of bus companies, and provides valuable information to help both regulators and bus companies to make the right decisions concerning safety management programs.

Following this introduction, a conceptual framework for the safety performance of bus companies, based on the organizational accident theory is first developed in Section 2. The deregulation of intercity bus service in Taiwan is introduced in Section 3, and the measurement of the variables for model formulation is prepared in Section 4. The data collected for this study are presented in Section 5. Model estimation results are presented in Section 6. The interpretations and discussions for the study results are presented in Section 7 and our concluding remarks are made in Section 8.

2. A conceptual framework for the safety performance of bus companies

Research concerning the safety of commercial vehicles has followed a conventional causal paradigm, which states that human factors, vehicle factors, road factors, and environmental factors determine the accident risk (Chow, 1989; Jovanis, 1989). Human error is commonly recognized as the major factor contributing to commercial vehicle accidents, so that most studies and management strategies relating to the safety problems of the transport industry have had a driver focus (Chatterjee et al., 1994; Zegeer et al., 1994; Dionne et al., 1995; Hamed et al., 1998; Arnold and Hartley, 2001).

Professional drivers operate their commercial vehicles under pressure, directly or indirectly, from their organization (Chatterjee et al., 1994). Such pressure might force the drivers to work unsafely, or under unsafe conditions. Hence, driver failure should be viewed as the consequence of organizational factors rather than as the principal cause of a commercial vehicle-related accident (Reason, 1997; Arnold and Hartley, 2001). Reason (1997) proposed a causal process of organizational accidents, and provided an effective tool to investigate the root of these accidents. He proposed that organizational factors influence workplace factors, which in turn result in unsafe acts and these unsafe acts might eventually lead to an accident. Besides this causal chain, organizational factors and workplace factors can also be the direct cause of an accident. In other words, the accident risk of an organization can be
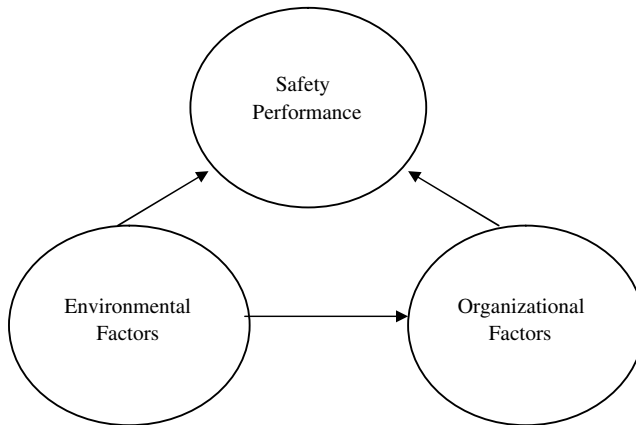
Fig. 1. A conceptual framework for the safety performance of bus companies.

determined by organizational factors, workplace factors and unsafe acts. Therefore, by taking the organizational and workplace factors into consideration, it is expected to provide more insight into the safety performance of transportation companies than by only considering the factors influencing driver failure.

Based on Reason's causal process of organizational accidents, a conceptual framework for the safety performance of bus companies was then established as shown in Fig. 1. Two factors, organizational and environmental, were assumed to affect the safety performance of bus companies. Most of the organizational factors deal with managerial decisions regarding company operations, some of which involve driver polices, vehicle policies, or general company operations. Therefore, the organizational factors affecting safety performance can be divided into three sub-categories: driver-specific factors, vehicle-specific factors and general management factors. Recent studies of motor carrier safety have found some evidence of this relationship in the trucking industry (Moses and Savage, 1992, 1994; Mejza, 1998; Arnold and Hartley, 2001).

The environmental factors refer to those influences that are beyond the control of bus companies. Changes in government policy, improvements in highway engineering, implementation of traffic safety policies and so on, are environmental factors affecting the safety performance of bus companies. Furthermore, some environmental factors, especially changes in government policy such as deregulation, are expected to significantly impact upon the bus companies and influence their safety performance.

3. Deregulation of the intercity passenger transportation service in Taiwan

Bus transportation in Taiwan can be divided into two sub-categories, local bus companies and intercity bus companies. The local bus companies provide

bus services within a metropolitan area, including bus services within an urban area and connections between the main city and its satellite cities, and are not allowed to run their services by way of freeways. The intercity bus companies offer bus services between major cities, and most of their services are run using the freeways.

Until deregulation in 1995, only two intercity bus companies, one publicly owned and the other one privately owned, had been chartered to operate the intercity bus service in Taiwan. Although the government-operated bus company had a very illustrious history, it had been suffering from enormous financial burden. While its scale of operations had been decreasing, the intercity passenger market had been expanding rapidly. The scale of operations of the other (privately owned) bus company could not meet the market demand under the regulations imposed at that time. Consequently, the intercity bus market was substantially deregulated by administrative rulings beginning in 1995. By lowering the entry and exit thresholds, and by relaxing the regulation on fares, many new bus companies as well as existing local bus companies were enticed to join this new open market. The publicly owned intercity bus company was finally privatized in July 2001.

However, local bus services are still, operating under strict regulations in Taiwan. The deregulation of the intercity bus service has dramatically restructured the bus industry in Taiwan over the last seven years. After deregulation of the intercity bus service, bus companies can be categorized into four groups. They are the newly established intercity bus companies, the existing local bus companies that have joined the intercity bus service, the existing local bus companies that have not joined the intercity bus service, and the private intercity bus company that had been established prior to deregulation.

According to the official statistics (MOTC, 2002), the fatal accident rates were 0.079 and 6.334 per million vehicle kilometers for buses and cars in 2001, respectively. Though the bus transportation is one of safe means of transport in Taiwan, however, its safety performance is still not so good as those in most developed countries, such as Great Britain. About half of the bus companies who had operated local bus services prior to deregulation, joined the intercity bus service, and are therefore operating under a mix of regulated and unregulated conditions. However, all the new bus companies in the intercity service are running in a deregulated environment. Despite the fact that many well-established as well as new bus companies compete in this deregulated market, no new or additional safety regulations have been established to prevent the potential increase in accidents. Therefore, the safety performance of individual intercity bus companies is used to explore the effect of deregulation on the safety performance of bus companies. Those existing bus companies that have not joined into the deregulated market (intercity service) are used for comparison purpose. Two important questions are expected to determine the impact brought about by deregulation on the safety performance of individual bus companies:

(1) Have the new entrants experienced a higher safety risk than the existing local bus companies on joining the new intercity service?

(2) Have the existing bus companies, on joining the new intercity service, experienced a higher safety risk than other existing bus companies that did not join the intercity service?

4. Measurement of the variables in model formulation

Based on the conceptual framework developed in this study, the safety performance of individual bus companies is determined by both environmental and organizational factors. A causal factor analysis model relating safety performance to environmental and organizational factors was established in order to identify the significance of this assumed relationship. The measurements of safety performance, environmental factors, and organizational factors are presented as follows.

4.1. Measurement of safety performance

The degree of physical risk to life or property in a specific time period is widely used to represent or define safety performance (Mejza, 1998). The degree of physical risk in transportation safety literature is always referred to as the probability of causing fatal, injury, or property damage only accidents (Moses and Savage, 1992, 1994; Mejza, 1998; Chang and Yeh, 2003, 2004). Thus, the number of bus-related accidents occurring in one year is used as an indicator for the safety performance of the individual bus companies.

Fatal accidents occurring in a given time period are usually selected to represent the safety performance in road safety literature due to the availability and accuracy of their data. However, fatal accidents are few and as such cannot completely represent the safety performance of an individual bus company. Therefore, other types of accidents and their related severity are included in this study. The two additional indicators included are major injury accidents and minor injury accidents. A fatal accident is defined as having at least one person that died within 24 h in a bus-related accident. A major injury implies that at least one injured person in a bus-related accident would have a hospital stay of more than three days or died after 24 h in a bus-related accident. A minor injury means that all injured persons in a bus-related accident would have a hospital stay of less than three days.

Another indicator, property-damage-only (PDO) accidents in one year, was also considered as an important measurement for safety performance in data collection design stage of this study. According to the official definition, a PDO accident refers to a traffic accident involving property damage of more than $NT 5000 (approx. $US 150). However, during the interview with the bus companies, we found the numbers of PDO accidents for interviewed bus companies might be seriously underreported for the following reasons. First, some bus companies had their own repairing workshops, and failed to precisely estimate the real expense induced by each bus-related collision. Second, bus drivers might be unwilling to report PDO accidents to their companies for fear of being punished. Third, there is no mandatory reporting system

for bus related PDO accidents. It might make the bus companies to underreport their PDO accidents to prevent themselves from being imposed by additional regulations on their operation. Therefore, the number of PDO accidents was not finally considered as an indicator of safety performance in this study due to its inconsistency and unreliability.

4.2. Measurement of environmental factors

According to the conceptual framework developed in Section 2, deregulation would not only influence the safety performance of bus companies directly, but also impact their safety performance indirectly through changes in their organizational circumstances. Bus companies established in the post-deregulation era might develop a more profit-oriented culture than the older companies established in the era of regulation. Hence, those that entered the industry after deregulation tend to have less experience in bus service operation, have a more profit-oriented culture, and a more competitive approach regarding company operation within an unregulated market, and therefore are expected to have higher accident risks than those companies established prior to deregulation.

The intercity bus service is a new business for almost all the bus companies involved, and higher accident risks are expected for these novice companies. However, even though the existing bus companies as well as the new entrants are novice operators when it comes to intercity bus service, the experience of the existing local bus companies in local bus services may be beneficial to their intercity bus service operation. Hence, the existing local bus companies that joined intercity services are expected to experience less accident risk than the new participants.

Two dummy variables are then designed to grasp the impact of deregulation on the safety performance of bus companies. The first one is used to distinguish whether the bus company was established after deregulation ($E1$), and the second is used to identify whether the bus company is providing intercity bus service ($E2$).

The third environmental factor is used to represent the impact of the primary traffic environment in which a bus company operates. The more a bus company operates in the urban area, the higher an accident risk it will have. This is because the traffic characteristics in urban areas are usually more complicated than those in other areas (Moses and Savage, 1992; Hamed et al., 1998). The proportion of operation mileage conducted within the urban area is thought to be an appropriate measure to reflect the working environment of individual bus companies. For lack of availability and accuracy of this information, the proportion of drivers working for bus services in the urban area ($E3$) is used as a proxy variable to capture the impact of physical environment in this study.

4.3. Measurement of organizational factors

All the organizational factors seem to deal with managerial decisions regarding company operations. Some factors involve driver polices, some involve vehicle

policies, and some involve general company operations. Thus, driver-specific factors, vehicle-specific factors and general management factors are considered in this study to represent the organizational factors that affect the safety performance of bus companies.

4.3.1. The driver-specific factors

The only one driver-specific factor used in this study is the average number of total traffic convictions while driving buses, excluding parking violations, per driver in one year ($D1$). This variable is employed to reflect the average driving record of each bus company. Parking violations are excluded due to their negligible influence on the occurrence of accidents. The research conducted by Lantz and Blevins (2002) showed that the traffic convictions of commercial vehicle drivers could be employed to identify high safety risk motor carriers. It is obvious that the more convictions per driver a bus company has, the higher an accident risk it will have.

4.3.2. The vehicle-specific factors

Vehicles and relevant equipment are considered the technical factors affecting the safety performance of bus companies. Although the technical factors make only a minor contribution to road traffic accident risk, vehicles and equipment should not be neglected when studying safety. Two vehicle-specific measurements, fleet age and fleet performance, are considered in this study.

Fleet age affects accident risk in several ways. First, new vehicles incorporate new technologies that improve safety. Second, new vehicles tend to have fewer failures in operation. Thus, the index variable ($V1$) measuring the proportion of vehicles aged less than five years is designed to reflect the fleet age. Vehicles aged less than five years are viewed as new vehicles by relevant traffic laws in Taiwan. The higher the proportion of new vehicles a bus company has, the less accident risk it will experience. The other vehicle-specific factor is fleet performance, which is defined as the number of mechanical failures during operation per million of kilometers traveled in one year ($V2$). This variable represents the quality of a bus company's vehicle maintenance. Thus, the more mechanical failures a bus company experiences, the higher their accident risk will be.

4.3.3. General management factors

The first general management factor considered is the ratio of driver to non-driver staff, which represents the depth of support for a bus company ($M1$). This variable is designed to capture the effect of the organizational structure on the safety performance of bus companies. A higher ratio means each non-driver staff member must support more drivers. A bus company with higher supporting ratio implies that its organizational structure is flat, and is expected to have a higher level of accident risk. Furthermore, the firm size, which is measured by the capital of a company, is another general management factor ($M2$). The bus company with more capital is expected to have a lower accident risk considering the economy of scale.

5. Data collection, analysis and model specification

5.1. Data collection

In order to collect the required data for this study, a survey was conducted in the summer of 2002 to gather the characteristics and safety performance of individual bus companies. A questionnaire was developed, and all the bus companies in Taiwan were asked to provide the relevant information for the year of 2001. Although some managers were not willing to reply to this questionnaire citing commercial sensitivity, 42 bus companies, or about two thirds of the total bus companies in Taiwan, had the questionnaires completed, either by their general managers or their representatives. Among the companies that replied, seven were new bus companies entering the intercity service, thirteen were existing bus companies joining the new intercity service, and one was the intercity bus company that was in existence before deregulation, and twenty-one were existing bus companies that had not joined the new intercity service.

The means and standard deviations of the variables of interest collected from the 42 bus companies are summarized in Table 1. Table 1 indicates that the average amount of capital for all the companies that replied was six hundred million New Taiwan dollars (about eighteen million US dollars). Their average number of years in business was 37.9 years. The averages number of total employees and drivers per company was 410 and 291, respectively. The average number of traffic violations, excluding illegal parking, per driver, per bus company was 0.317 in 2001. The ratio of driver to non-driver staff was 3.4, which implied that each member of the non-driver staff supported 3.4 drivers in operation. On average, each company traveled 17.9 million bus vehicle kilometers and experienced 4.120 mechanical failures per million bus vehicle kilometers during operation, in 2001. The proportion of vehicles aged less than five years was 0.422 on average.

In this study three types of transportation accidents occurring in 2001 were collected for each individual bus company. They were, fatal accidents, major injury accidents, and minor injury accidents. The results reported in Table 1 show that on an average the bus companies that replied experienced 0.762 fatal accidents, 1.786 major injury accidents, and 5.000 minor injury accidents. The average accident rates of the bus companies that replied experienced 0.080 fatal accidents, 0.103 major injury accidents, and 0.359 minor injury accidents per million bus vehicle kilometers.

5.2. Data analysis

In order to have an insight into the relationship between the accident risks and the characteristics of the bus company, all the companies that replied were further divided into four categories. Type I includes the new bus companies which were established after deregulation, and which provided intercity service only. Type II refers to the existing local bus companies that joined the intercity bus service after deregulation. Type III companies are the existing local bus companies that had not joined the intercity service after deregulation, and type IV was the one and only intercity bus

Table 1
The means and standard deviations for the characteristics of different types of bus companies (standard deviations in parentheses)

Variables	Type of bus company			
	Type I, new bus companies entering intercity service	Type II, existing bus companies joining new intercity service	Type III, existing bus companies not joining new intercity service	All bus companies
Total employees	272 (400)	429 (317)	388 (425)	410 (426)
Total drivers	234 (380)	327 (240)	256 (285)	291 (300)
Age of company (years)	2.5 (1.9)	46.5 (24.9)	45.6 (18.1)	37.9 (25.0)
($E3$) The proportion of drivers working for a bus service in urban areas	0[a]	0.32 (0.40)	0.47 (0.45)	0.23 (0.75)
($D1$) The average number of traffic convictions, excluding parking violations, per driver in 2001	0.453 (0.410)	0.222 (0.430)	0.351 (0.722)	0.317 (0.591)
($V1$) The proportion of vehicles less than 5 years old	0.689 (0.412)	0.462 (0.300)	0.297 (0.215)	0.422 (0.285)
($V2$) Mechanical failures during operation per 10^6 bus vehicle-km in 2001	1.502 (3.406)	0.753 (1.083)	7.152 (10.102)	4.120 (7.836)
($M1$) The ratio of driver to non-driver staff	5.6 (6.7)	3.9 (4.5)	2.4 (2.8)	3.4 (4.2)
($M2$) Capital (NT\$ 10^6)[b]	150 (124)	290 (393)	900 (2605)	600 (189)
Travel mileage (10^6 bus vehicle-km)	13.5 (19.2)	18.1 (13.0)	11.8 (9.4)	17.9 (27.5)
No. of fatal accidents	0.429 (0.787)	1.000 (1.225)	0.712 (0.092)	0.762 (0.983)
No. of major injury accidents	1.143 (1.676)	3.000 (3.916)	1.143 (2.081)	1.786 (2.807)
No. of minor injury accidents	3.143 (4.914)	5.692 (5.879)	4.619 (9.651)	5.000 (7.963)
Fatal accidents per 10^6 bus vehicle-km	0.190 (0.495)	0.060 (0.100)	0.058 (0.074)	0.080 (0.210)
Major injury accidents per 10^6 bus vehicle-km	0.166 (0.338)	0.129 (0.127)	0.070 (0.129)	0.103 (0.176)
Minor injury accidents per 10^6 bus vehicle-km	0.672 (1.018)	0.302 (0.245)	0.303 (0.670)	0.359 (0.640)
The sample size	7	13	21	42[c]

[a] The new entrants operate the intercity services, so there are no drivers working for bus services in urban areas.
[b] NT\$ means New Taiwan dollar.
[c] Including the only privately-owned intercity bus company established before deregulation.

company that was in existence before deregulation. Because only one company could not be used for statistical comparison, only the first three types of bus companies are included into the following comparisons. The means and standard deviations for the characteristics of these three types of bus companies are compared and summarized in Table 1.

The Type I bus companies had the lowest values for total number of employees, total number of drivers, company age, and capital among the three types of bus companies (see Table 1). Those characteristics indicated that Type I bus companies were smaller and had less experience in providing passenger transportation service than the other types of bus companies. The Type I bus companies had the highest proportion of new vehicles and the lowest proportion of urban area service, both of which are expected to have positive effects on safety performance. However, on the other hand, Type I bus companies also had the highest values of traffic convictions per driver and driver to non-driver staff ratio, and the lowest capital among the three types of bus companies, which are expected to have negative impacts on their safety performance.

Type II bus companies operated both urban and intercity passenger services and had, on average, the highest values for number of employees, number of drivers, company age, and traveling mileage among the three types of companies. Type II bus companies had the lowest value for traffic convictions per driver as well as the lowest mechanical failure rate during operation among the three types of bus companies, all of which are expected to reduce their risk for being involved in traffic accidents.

Type III bus companies had on average almost the same seniority as the Type II bus companies. They had the highest values for the proportion of urban bus service as well as mechanical failure rate during operation, and the lowest value for the proportion of new vehicles among the three types of bus companies, all of which are expected to have negative effects on transportation safety. However, on the other hand, Type III bus companies had the highest capital and the lowest drivers to non-drivers ratio among the three types of bus companies, both of which are expected to have positive effects on their safety performance.

Three different accident numbers for all three types of bus companies are presented in Table 1. The data shown in Table 1 seems to indicate that Type II bus companies have experienced higher accident numbers than other types of bus companies. However, the number of accidents without the exposure is not a good indicator to represent the accident risk of the bus companies. The exposure-based accident rates are employed to determine the accident risk of bus companies. Thus, three different exposure-based accident rates for all three types of bus companies are computed and shown in Table 1. The results reported in Table 1 indicate that Type I bus companies seemed to experience higher accident rates than the other types of bus companies. However, the results of the analysis of variance (ANOVA) show that all three different exposure-based accident rates are not significantly different among the three types of bus companies. Furthermore, the paired t-tests were also employed to test whether the accident rates between Type I and Type II, Type I and Type III, as well as Type II and Type III, are significantly different. Again we failed to find a

significant difference between any pair types of bus companies for any kind of accident rate.

Following the implementation of deregulation, dramatic changes in the operation characteristics of bus companies have appeared. Some changes may bring positive effects to the safety performance of bus companies, but some may have negative outcomes. Different types of bus companies have different characteristics that may affect their safety performance either positively or negatively. The average accident rates for the three types of bus companies are the aggregate safety performance as the result of the effects of individual influencing factors. Hence, there is no clear-cut information to determine which type of bus companies will have higher accident rates among the different types of bus companies. Therefore, a causal factor analysis technique is required in order to differentiate the effect of each influencing factor on safety performance of individual bus companies from those of other influencing factors.

5.3. Application of poisson regression models

The fact that a number of accidents occurring in a given period follows a Poisson distribution is widely recognized (Moses and Savage, 1992; Miaou, 1994; Dionne et al., 1995; Agresti, 1996; Chang and Yeh, 2003, 2004). If the number of accidents, y_i, occurring in a given period for an individual bus operator i, is independently Poisson-distributed with the mean μ_i, then its probability can be represented by the following equation:

$$P(y_i) = \mathrm{e}^{-\mu_i}\mu_i^{y_i}/y_i!, \quad i = 1, 2, 3, \ldots, n \tag{1}$$

The expectation μ_i must be positive, thus the exponential function $\mu_i = \exp(X_i, \beta)$ is commonly used in statistical and safety literature to ensure non-negative value (Moses and Savage, 1992; Miaou, 1994; Dionne et al., 1995; Agresti, 1996; Chang and Yeh, 2003, 2004), where X_i is a vector of explanatory variables representing the organizational and environmental factors of the bus operator i, and β is a vector of parameters that can be estimated by the maximum likelihood estimation method.

The amount of exposure to risk is another important factor in formulating the expected accident frequency for individual bus companies. Hence, the yearly travel mileage N_i (million bus vehicle kilometer) for the bus company i is then incorporated into the model as the exposure to the risk of being involved in an accident. That is, the expected number of accidents occurring in one year for the bus company i is assumed to be proportional to the yearly mileage N_i, and can be represented as

$$\mu_i = N_i \left(\mathrm{e}^{\alpha_0 + \sum_{j=1}^{k} \beta_j x_j} \right), \quad i = 1, 2, 3, \ldots, n \tag{2}$$

The variable x_j is the jth element of the explanatory variable vector X_i, and α_0 and β_j's are the parameters to be estimated in the model.
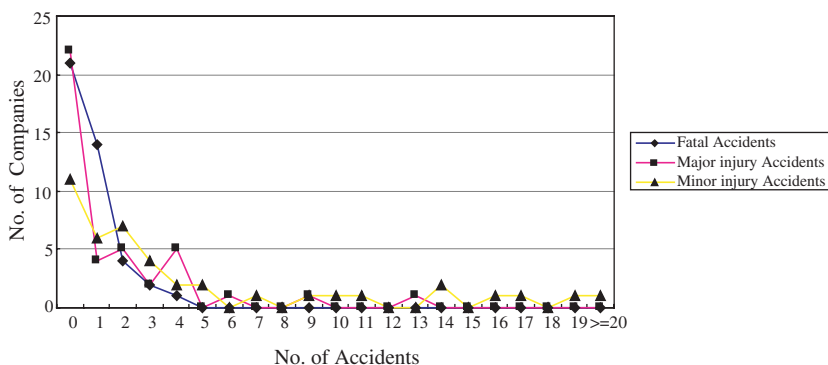
Fig. 2. The numbers of companies vs. the numbers of three types of accidents.

The distributions drawn in Fig. 2 indicated the relationships between the numbers of companies and the frequencies of fatal, major injury, and minor injury accidents occurred in 2001 in Taiwan. The distributions shown in Fig. 2 seemed to follow Poisson-like distributions. The results of dispersion tests for three types of accidents indicated that the dispersions are insignificant. Thus, the distributions are following the Poisson distribution.

6. Model estimation results

In order to differentiate the effect of each influencing factor on safety performance from those of other influencing factors, a correlation analysis between selected explanatory variables was conducted to detect whether the multi-collinearity exists before model specification. The results summarized in Table 2 show that the values of correlation coefficients between $E1$ and $E2$ (0.447), $E1$ and $E3$ (−0.342), $E2$ and $E3$ (−0.310), $E2$ and $V2$ (−0.393), as well as $E3$ and $D1$ (0.312) are significantly different from zero. However, the correlation coefficient values for all those significant pairs of variables are less than 0.5 and would not result in a problem of multi-collinearity. Hence, all the three environmental variables and five organizational variables were incorporated into the model specifications and estimations. The estimation results of the Poisson regression models for the number of fatal accidents, the number of major injury accidents, and the number of minor injury accidents are summarized in Table 3 and discussed, respectively, as follows.

6.1. The fatal accident model

The proportion of vehicles aged less than 5 years ($V1$) and the capital of a bus company ($M2$) are the only two significant factors that affected the occurrence of fatal accidents, and their signs are the same as expected. The estimated results show that the higher proportion of new vehicles one bus company had, the fewer fatal

Table 2
The results of correlation analysis for the explanatory variables (p-values in parentheses)

	E1	E2	E3	D1	V1	V2	M1	M2
(E1) Was the bus company established after deregulation?		.447** (.003)	−.342** (.029)	.094 (.587)	.112 (.481)	−.173 (.329)	.242 (.127)	−.111 (.489)
(E2) Was the bus company running an intercity service?	.447** (.003)		−.310** (.048)	−.063 (.715)	.099 (.534)	−.393** (.022)	−.224 (.160)	−.164 (.306)
(E3) The proportion of drivers working for a bus service in the urban areas	−.342** (.029)	−.310** (.048)		.312* (.064)	−.025 (.875)	−.141 (.432)	.008 (.963)	.189 (.244)
(D1) The average number of traffic convictions, excluding parking violations, per driver in 2001	.094 (.587)	−.063 (.715)	.312* (.064)		−.143 (.407)	.008 (.965)	−.020 (.908)	.129 (.460)
(V1) The proportion of vehicles less than 5 years old	.112 (.481)	.099 (.534)	−.025 (.875)	−.143 (.407)		.067 (.705)	−.050 (.758)	−.249 (.117)
(V2) Mechanical failures during operation per 10^6 bus vehicle-km in 2001	−.173 (.329)	−.393** (.022)	−.141 (.432)	.008 (.965)	.067 (.705)		−.211 (.230)	−.050 (.780)
(M1) The ratio of driver to non-driver staff	.242 (.127)	−.224 (.160)	.008 (.963)	−.020 (.908)	−.050 (.758)	−.211 (.230)		.080 (.620)
(M2) Capital (NT\$ 10^6)	−.111 (.489)	−.164 (.306)	.189 (.244)	.129 (.460)	−.249 (.117)	−.050 (.780)	.080 (.620)	

* Significant level at $\alpha = 0.10$.
** Significant level at $\alpha = 0.05$.

Table 3
The estimated results of the Poisson regression models (*p*-values in parentheses)

Explanatory variable	Fatal accidents model	Major injury accidents model	Minor injury accidents model
Constant	-1.6731^{**} (0.0089)	-1.2124^{**} (0.0136)	-1.5800^{**} (0.0001)
(*E*1) Was the bus company established after deregulation?	-1.3073 (0.3303)	0.0042 (0.9940)	-0.3654 (0.3408)
(*E*2) Was the bus company running an intercity service?	-0.5534 (0.3093)	0.6870^{*} (0.0700)	1.1400^{**} (0.0002)
(*E*3) The proportion of drivers working for an urban bus service	0.1820 (0.7819)	1.2002^{**} (0.0026)	0.9112^{**} (0.0008)
(*D*1) The average number of traffic convictions, excluding parking violations, per driver in 2001	0.5407 (0.1169)	0.6833^{**} (0.0063)	1.3702^{**} (0.0001)
(*V*1) The proportion of vehicles less than 5 years old	-3.6823^{**} (0.0021)	-5.0701^{**} (0.0001)	-3.5740^{**} (0.0001)
(*V*2) Mechanical failures during operation per 10^6 bus vehicle-km in 2001	0.0090 (0.3333)	-0.0134 (0.4253)	0.0088 (0.1623)
(*M*1) The ratio of driver to non-driver staff	0.0164 (0.7795)	-0.0254 (0.4182)	0.0131 (0.5190)
(*M*2) Capital (NT\$ 10^6)	-0.0002^{**} (0.0366)	-0.0003^{**} (0.0001)	-0.0001^{**} (0.0021)
Log-likelihood	-30.618	-52.587	-70.241

[*] Significant level at $\alpha = 0.10$.
[**] Significant level at $\alpha = 0.05$.

accidents the bus company would experience. Furthermore, the more capital the bus company had, the less fatal accident risk it would experience.

The coefficient of the average number of traffic convictions, excluding parking violations, per driver is marginally significantly different from zero in the fatal accident model, and its sign is the same as per prior expectation. This implies that the worse the driving behavior is of a bus company's drivers, the more fatal accidents it would experience.

6.2. The major injury accident model

Two environmental and three organizational variables are shown to significantly affect the occurrence of major injury accidents, and their signs of coefficients are the same as per prior expectations. These five significant factors are: (1) whether the bus company was running an intercity bus service ($E2$); (2) the proportion of drivers working for an urban bus service ($E3$); (3) the average number of traffic convictions, excluding parking violations, per driver ($D1$); (4) the proportion of vehicles aged less than 5 years ($V1$); and (5) the capital of a bus company ($M2$).

Three more significant factors appeared in the major injury accident model than in the fatal accident model. That is, whether the bus company was running an intercity bus service ($E2$), the proportion of drivers working for the urban bus service ($E3$), and the average number of traffic convictions, excluding parking violations, per driver ($D1$), significantly affected the occurrence of major injury accidents, but they did not significantly affect the occurrence of fatal accidents. The companies running an intercity bus service experienced significantly more risk of being involved in major injury accidents than those not running an intercity bus service. In addition, the higher the proportion of drivers working for the urban bus service a bus company operated, the more major injury accidents the bus company would experience.

6.3. The minor injury accident model

The significant factors appearing in the minor injury accident model are the same as those in the major injury accident model (see Table 3). However, the values for the coefficients of these significant variables appear to have slight differences between these two injury models. These differences may imply some insights, and will be discussed in the following section.

Only two variables, including the proportion of new vehicles ($V1$) and the capital of a company ($M2$), appeared to have significant effects on the occurrence of fatal accidents. Because the number of fatal accidents experienced by an individual bus company in one year is quite small, the pure randomness may account for a major part of the observable variation of fatal accident counts (Fridstrøm et al., 1995). Thus, other potential factors seem unlikely to appear significant effects on the occurrence of fatal accidents as shown in the model. Consequently, the fatal accidents model appears to have fewer significant variables than the other models.

7. Interpretations and discussions

According to the estimated results of the three models in Table 3, we find that three explanatory variables are not significant in all three models, two explanatory variables are significant across all the three models, and the other three explanatory variables are only significant in the major and minor injury models. The coefficients of the first environmental variable that is used to distinguish whether the bus company was established after deregulation ($E1$), are not significantly different from zero for all three types of accident model. As discussed in the previous section, deregulation had changed the operation characteristics of bus companies, which in turn influenced the safety performance of these bus companies. Hence, the study results provide convincing evidence to confirm that new entrants would not experience a significantly higher risk of being involved in any kind of accident than the existing bus companies who joined the new intercity service, providing all the operation characteristics of bus companies after deregulation are reasonably captured in the other explanatory variables.

The bus companies running the intercity service ($E2$) experienced significantly higher risk of being involved in major injury and minor injury accidents than those without running the intercity service, but this effect did not significantly appear in the occurrence of fatal accidents. The new intercity bus companies are almost all novice operators in intercity bus operation and have indeed experienced a higher accident risk. Combining this study result with the findings of the first environmental variable, it might provide some evidence for answering the second research question in Section 3. That is, have the existing bus companies, on joining the new intercity service, experienced a higher risk of being involved in some types of accidents than those other existing bus companies that did not join the intercity service. This also seems to imply that the experience of existing bus companies in local bus operation is not necessarily beneficial to the intercity bus service operations.

In addition, all the intercity bus services make use of the freeways. The higher speeds of intercity buses are likely to result in injury accidents once the accident occurred. However, because pedestrians, bicyclists, and motorcyclists are not allowed on the freeways in Taiwan, it may be the case that the bus companies running intercity service have a higher risk of being involved in minor injury accidents than in major injury accidents.

The make-up of the traffic and the operation characteristics in the urban area are much more complicated than those on rural highways and freeways. Vehicles driving on the urban streets are expected to run a higher risk of becoming involved in traffic accidents, compared to those driving on freeways (Moses and Savage, 1992; Hamed et al., 1998). The study results reveal that the higher the proportion of service a bus company ($E3$) has to provide in the urban area, the more major injury and minor injury accidents it will be involved with. The lower driving speeds in urban areas may be part of the reason that fatal accidents will not significantly increase as the proportion of urban bus service increases. Furthermore, the higher the proportion of urban bus service the higher the risk of becoming involved with major

injury accidents rather than minor injury accidents according to the magnitudes of estimated coefficients between these two models. Similar results have also been found in relevant research (Moses and Savage, 1992; Zegeer et al., 1994; Hamed et al., 1998).

The average number of traffic convictions while driving buses, excluding parking violations, per driver significantly affected the occurrence of major injury and minor injury accidents, but it only marginally significantly affected the occurrence of fatal accidents. Apparently, the higher the illegal driver behavior of the drivers of a bus company, the more risk that company had of being involved in accidents. We also found that the illegal driver behavior of their drivers seemed to bring about more minor injury accidents to the bus companies as compared to serious injury accidents. Reducing the average number of traffic convictions per driver for a bus company has proven to effectively improve the safety performance of bus companies.

As to the two vehicle-specific factors in this study, it was found that the newer the fleet was the bus company operated, the lower their risk of becoming involved in all types of accidents. In addition, the effect of the new vehicle ratio on reducing the risk of involving fatal and major injury accidents is higher than on reducing the risk of being involved in minor injury accidents. Therefore, keeping a newer fleet will significantly reduce the risk of getting involved in serious injury accidents. Similar results have been found in relevant research (Zegeer et al., 1994; Hamed et al., 1998). For authorities, monitoring and controlling the fleet age of individual bus companies could be an effective approach toward improving the safety performance of bus companies.

The mechanical failure rate during operation did not significantly affect the occurrence of three types of accidents. The results of the models failed to provide evidence that mechanical failure rate during operation is a significant factor in causing bus-related accidents. Thus, the mechanical failure rate during operation may not be a good indicator to determine whether or not a bus company has higher accident risk.

The first general management variable, the ratio of driver to non-driver staff ($M1$), did not appeared to have significant effect for the models of fatal, major injury, and minor injury accidents. The study results indicated that a flat organizational structure would not increase the potential risk of being involved in fatal, major injury and minor injury accidents. This study failed to find a linkage between the occurrence of severe injury accidents and the management factor of the organizational structure.

The size of a bus company, which was represented by the capital of one company ($M2$), was shown to have significant effects on reducing all kinds of accidents. The results shown in Table 3 reveal that the larger bus companies experienced lower accident rates for all kinds of accidents. Moreover, according to the values of the estimated coefficients for corresponding models, the larger bus companies experienced more risk reduction in the involvement with severe injury accidents than in the involvement with slight injury accidents. Therefore, we can conclude that

larger-sized bus companies tend to be safer than small or medium-sized bus companies.

8. Concluding remarks

This study was undertaken to explore the factors affecting the safety performance of bus companies. A conceptual framework was developed based on the theory of organizational accidents, and environmental and organizational factors were assumed to determine the safety performance of bus companies. The deregulation of intercity passenger transportation in 1995 brought about the restructuring of the bus transportation industry in Taiwan, and provided an opportunity to gain an insight into the factors that influence the safety performance of bus companies.

A questionnaire was designed to collect the required data for this research. All the bus companies in Taiwan were asked to provide the relevant information for the year 2001 through their general managers or representatives. Forty-two bus companies, or about two thirds of the total bus companies in Taiwan, replied to the questionnaires. These bus companies that replied, except for the only intercity bus company established before deregulation, were then divided into three types of bus companies. They were, the new bus companies, the existing bus companies that joined the new intercity bus service, and the existing bus companies that did not join the intercity bus service.

Although the operational and organizational characteristics among these three types of bus companies are apparently different, nevertheless, the results of the ANOVA show that the exposure-based accident rates among the three types of bus companies are not significantly different. Based on this particular study result, we might make the conclusion that the deregulation of the intercity bus service would not deteriorate the safety performance of the bus transport industry as a whole, and that no actions were required to improve the safety performance. However, when we applied the causal factor analysis models to relate the safety performance of bus companies with their operation and organization characteristics, we found that the safety performance was in fact affected by the characteristics of bus companies. The effects of those influencing factors might be positive or negative. If the deregulation was implemented with some safety regulation policies, we might have the opportunity to pursue a better safety performance by the bus transport industry as a whole, rather than just prevent the deterioration of the existing safety performance.

The results of this study show that two environmental factors and three organizational factors of bus companies significantly affected their safety performance, and that different environmental and organizational factors impacted significantly on the occurrence of different accidents in terms of their injury severity. While the newcomers after deregulation did not experience a higher accident risk than the others, the operators of the intercity bus service appeared to have a higher accident risk than the others.

Only three organizational factors were found to have significant effects on the safety performance of bus companies. Especially, the proportion of vehicles aged less than 5 years, and the capital of the bus company were the significant factors to affect the occurrence of all kinds of accidents. While the average number of traffic convictions excluding parking violations was significant for the occurrence of major injury and minor injury accidents, they might result in more fatal accidents in the long run according to the theory of "the continuum of events" proposed by Hauer (1997). The other two organizational factors, the mechanical failure rate and the driver to non-driver staff ratio, were insignificant for the occurrence of fatal, major injury, and minor injury accidents.

This study provided the exploratory findings about the factors that affected the safety performance of bus companies. However, some limitations should be noted here before making conclusions and recommendations. First, the number of PDO accidents should be another important indicator for measuring the safety performance of bus companies, however, it was not included in this study for the reasons of data inconsistencies among bus companies due to different estimations of the lost cost of PDO accidents as well as the bus drivers' underreporting problems. It might influence our opportunity to find out some more significant factors affecting the safety performance of bus companies. Second, the number of accidents other than casualties was used as the indicator of safety performance of bus companies in this study. Casualties are more numerous than accidents, because some accidents involve multiple casualties, especially for buses. Some common casualties occurred during boarding and alighting from the vehicle as well as people falling within the vehicle or being hit by objects within the vehicle were not included in this study. Including casualty data might provide an insight to understand the safety performance of bus companies more comprehensively.

Based on the findings from this study, some safety improvement policies are suggested in conjunction with the implementation of economic deregulation. First, the more strict safety regulations concerning vehicles, such as setting the lower upper-limit of usage years for the vehicles, should be imposed to improve the safety performance of bus companies. Also, the minimum threshold of capital of companies that be allowed to enter the bus industry may need to be increased due to the higher risks of smaller size companies. In addition, authorities should improve the traffic environment of urban areas in order to reduce the occurrence of non-fatal bus-related crashes. Then, the bus companies that run intercity services may need the assistance of authorities due to lack of experience in intercity bus service operation. Furthermore, the limited resources available to monitor the safety performance of bus companies are suggested to focus on those companies that run intercity services, as well as those companies of small size, having older fleets, and a higher traffic conviction rate.

Finally, the findings are only derived from about two thirds of the total bus companies in Taiwan. In order to improve the understandings of safety performance of whole bus companies in Taiwan, government authorities should build a database contained the relevant data of all bus companies every year, analyze and estimate the similar accident risk models based on the framework developed in this study.

Therefore, the more evidence-based bus safety improvement policies could be derived from the results of such study easily.

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