THE ACCIDENT RISK MEASURING MODEL FOR URBAN ARTERIALS

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ABSTRACT

In Taiwan, the fatal accident rate was 146 per million populations in 2008, roughly 1.8 times the Organization for Economic Co-operation and Development average rate. Many studies have focused on traffic safety and attempted to identify methods for preventing traffic accidents. However, the analytical models used most frequently, including Statement Statistic, Regression Analysis, Factor Analysis (FA), Cluster Analysis (CA), and Data Mining, assess the correlations or relationships between one dependent variable and independent variables. Those methods cannot indentify overall causal relationships and cannot combine different accident indexes to define accident risk. This study uses Structural Equation Modeling (SEM) to construct a theoretical framework for traffic accident risk analysis for urban arterials. Different accident indexes, such as accident number, fatality rate, injury rate, and casualty rate, are combined to construct an accident risk evaluation model, to explore factor significance, and to identify relationships between factors. These factors include driver characteristics, vehicle characteristics and road characteristics. This study segmented urban arterials according their geometry, and determined accident risk for each section. Analytical results show that accident risk on urban arterials can be calculated by combining accident number, injury rate, and casualty rate. Driver characteristics and road geometry, particularly the road division pattern affect accident risk significantly; however, vehicle characteristics did not, indicating that one can focus on driver behavior and road design when attempting to decrease road accident risk.

Key words: traffic accident risk; Structural Equation Models (SEM); urban arterial

INTRODUCTION

Casualties and property loss caused by traffic accidents are considerable. Statistics for 2006 from the Department of Health, Executive Yuan, show that accidents were the fifth leading cause of death in Taiwan. The number of deaths in 2006 due to traffic accidents was 8,011, of which 4,637 (58%) were caused by motor vehicle accidents. The social costs of traffic accidents are significant. Therefore, many studies have discussed issues associated with accidents. Although the purpose is to prevent accidents, previous research mostly used narrative statistics, factor analysis (FA), discriminate analysis, or a regression model in analyzing accident characteristics and identifying road sections prone to accidents, or constructed an accident prediction model. However, these methods only indentify accidents on different road sections or drivers with different attributes and their relevance; they cannot clearly define the causal relationships between factors. Some recent studies have utilized data mining to identify key accident-related factors. Nevertheless, data mining can only identify specific accident risks (e.g., accident rate, number of deaths, and accident injuries). That is, data mining cannot identify correlations among accident risk factors—causes, drivers, vehicles, and roads—or cause-and-effect relationships This study focused on urban arterials, applied Structural Equation Modeling (SEM), and integrated accident rate, accident fatality, and accident injury rate to identify key factors associated with accident risk. Drivers, vehicles, roads, and cause-and-effect relationships associated with accident risk are discussed. Key accident risks factors were identified, and an assessment and prediction model was constructed.

This study, by constructing an accident risk framework, discusses three transportation elements—drivers, vehicles, and roads—and their correlations with road accident risk. By defining the key factors, this study discusses the component elements of each characteristic and their influence on accident risk.

LITERATURE REVIEW

This study constructs a theoretical framework for accident risk by analyzing road accident research, methods used, and variables to identify accident risk factors. Chen (2004) applied data mining to identify factors affecting freeway traffic accidents. More buses often led to a. high accident rate. Liu (2005) applied regression analysis to examine factors affecting the accidents of senior drivers and freeway drivers. Both Ordered Logit and Ordered Probit were applied to discuss driver injury. Wu (2005) constructed an analytical model for motorcycle accident characteristics at intersections and on road sections using FA and the Poisson Regression Model. Lai (2005) constructed a regression prediction model for accident rate and accident casualties using Narrative Statistics, the Logit Regression Model, and the Probit Regression Model. A significant difference existed between urban arteries with/without of a physical division. The urban arterial with physical division had the lower accident rate than without. Lai (2006) utilized Narrative Statistics, and Logit Regression and Probit Regression models to create a regression prediction model for accident rate and accident fatality on bus lanes. A significant difference existed between accident rate and accident characteristics regarding different design type of bus lane. In Taipei City, roads which were divided into fast lanes and slow lanes and bus lane set on the outer fast lane is safest. Etienn (2006) employed Logit Regression Analysis to discuss causes that led to serious head injury in road accidents. Age, gender, and with/without protective gear were related to serious head injury. Ariana et al. (2006), who analyzed factors that affected suburban traffic accidents, found that age, vision, time, driving speed, and with/without protective gear were key factors. John et al. (2007) used a Mixed Logit Model to construct a prediction model for serious road accidents. Variables related to traffic flow, such as average daily traffic flow, percentage of heavy vehicles, and number of access roads, and variables related to road characteristics, such as curvature and road friction were significant variables impacting road accident risk. Using simple and bivariate analysis, Wong and Chung (2007) applied a rough set approach for accident chains to analyzing the impact of accident for different factors. They found that a single factor accident chain had poor quality and a multi-factor accident chain should be used when analyzing accidents. These studies suggested that factors affecting accident risk include drivers, vehicles, and roads and these factors may affect each other. Therefore, this study applies FA and SEM to analyze these three characteristics as well as the cause-and-effect relationships between these factors and accident risk indices.

RESEARCH SCOPE AND METHODOLOGY

This study focused on downtown arteries in Taipei City, an area bordered by Huanhe South Road in the west, Keelung Road in the east, Minzu East and West Roads in the north, and Roosevelt Road in the south. From 2004 to the present, many mass rapid transit (MRT) lines have been under construction in Taipei City. This construction has affected road planning and traffic. To avoid construction-related factors affecting research results, this study used accident data for 2003 in model construction. In respect of methodology, this study employed SEM with driver, vehicle and road as independent variables, and accident risk as the dependent variable. All data related to these road sections were compiled into four categories. In accident risk assessment, accident rate, fatality rate, injury rate, and death/injury rate were indices for assessment. Accident rate and casualty rate of each road section were expressed by number of accidents and number of casualties per million vehicle kilometers traveled (MVKT).

Accident rate = Number of incidents / (Number of vehicles * road length / 1,000,000) (1)
Fatality rate = Number of deaths / (Number of vehicles * road length / 1,000,000) (2)
Injury rate = Number of injuries / (Number of vehicles * road length / 1,000,000) (3)
Casualty rate = Number of casualties / (Number of vehicles * road length / 1,000,000) (4)

Number of vehicles refers to the number of vehicles all year, and was calculated as total number of vehicles travelling in both directions during morning peak hours multiplied by 5110. That is, we assume daily traffic flow was 14 times peak traffic flow (K=0.7). The total traffic flow was then calculated by the number of days covered by data (365 days), *i.e.*, 14*365=5110. The K value in this study is for data actually measured by screen line traffic count result for downtown Taipei by the Taipei City Government. The value for morning peak hours (2 hours) was divided by 2, and then divided by the value for all day (24 hours).

In addition to applying SEM, this study also utilized FA to elucidate the relationships between each variable. Additionally, SPSS and AMOS were applied for descriptive statistic and model construction, respectively. A description of SEM is provided as follows.

According to Chiu (2003), SEM is a statistical methodology used for discussing and analyzing sophisticated multivariate research data. Generally, SEM is under the category of advanced statistics, a multivariate statistics category. However, SEM integrates two statistical techniques—FA and path analysis (PA)—and is applied widely. Swiss statistician Jöreskog proposed the relevant concept of SEM in the 1970s. After LISREL, an analytical tool, was developed, discussions and technical development of SEM theory became common. Figure 1 shows a basic procedure for model construction by SEM. This method, SEM, is valued in many research fields. In particular, it has been adopted by the social and behavioral sciences. However, it has seldom been applied for accident analysis. For model construction of SEM, a number of software packages are readily available, such as LISREL (Jöreskog & Sörbom, 1989, 1996), EQS (Bentler, 1985 & 1995), AMOS (Arbuckle, 1997), MPLUS (Muthén & Muthén, 1998), CALIS (Hartmann, 1992), and RAMONA (Browne, Mels & Cowan, 1994). SEM was adopted by this study.

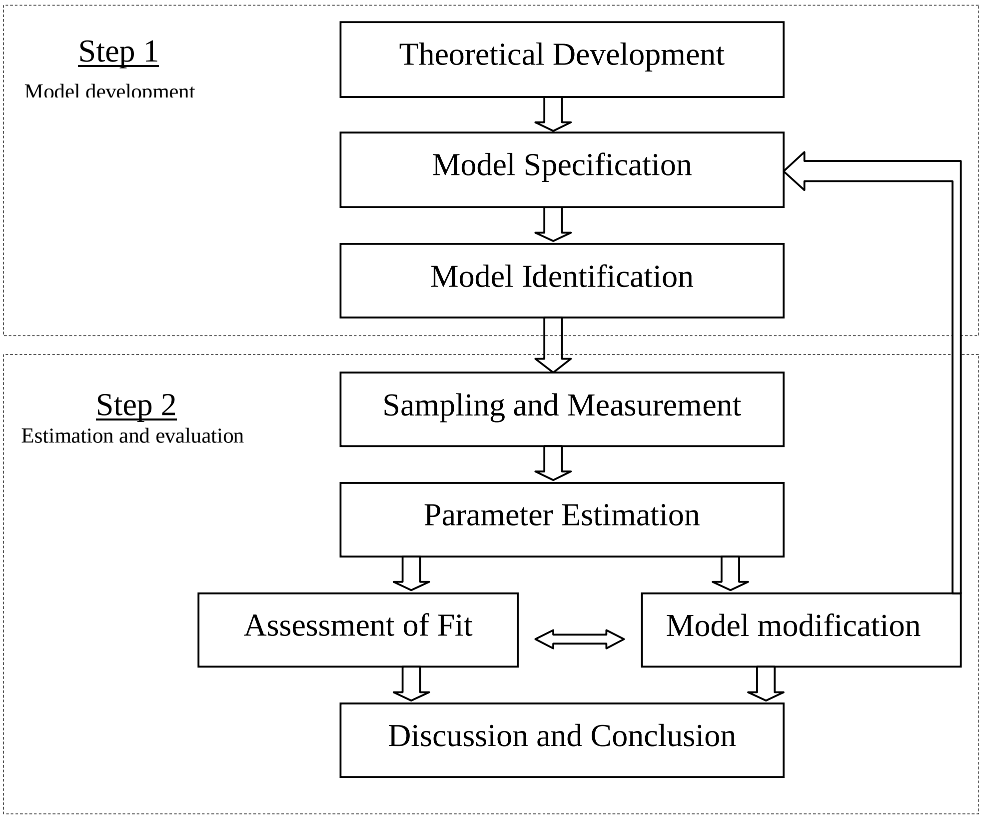

Figure1 The basic procedure of SEM (Chiu, 2003)

DATA CONTENT AND VARIABLES

Data Content

Road sections: This study covered 26 roads, and divided these roads into 249 sections according their geographic design elements, such as number of lanes, division type and the intersection with another arterial.

Accident data: Accident data were retrieved from the accident database of the Traffic Police Corps., Taipei City Police Department, including A1 (fatal included), A2 (injury included) and A3 (no fatal or injury included) accident data from January 1 to December 31, 2003. The database was designed to record each person involved in each accident as one record. So, if an accident involved two or more people, then the database calculated two or more records. By data batching, records for the same accidents were compiled. In total, 7148 accidents were analyzed.

Traffic Flow

Traffic flow data at each intersection in this study were from a 2003 traffic flow survey at intersections (Traffic Engineering Office, Taipei City Government). Traffic flow for a road section was calculated as the traffic flow at intersections during peak morning hours. When a road section had no traffic flow data, the traffic flow value for a neighboring section on the same artery was used.

Model Framework and Variables

To construct an accident risk assessment model, this study analyzed relevant research for Taiwan and abroad. Factors affecting accidents were compiled (Figure 2). This study gathered and compiled data against each line in Figure 2 from research at home and abroad. Only when a relationship exists in research results was it included in the theoretical framework (Table 1), and the variables and measurement methods considered by this research are listed in Table 2.

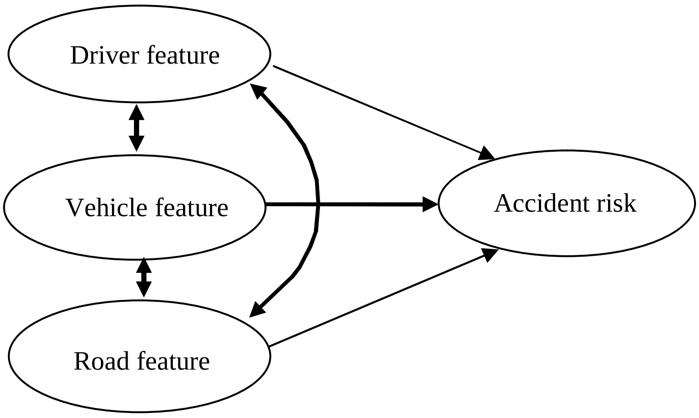

Figure 2 The framework of accident risk assessment model

Table 1 Factors affecting road accident considered by literatures

Type	Factor	Literature
Driver feature	Sex	Delen et. al. (2005), Huang (2005), Huang (2006), Wong and Chung (2007), Ariana et. al. (2006), Etienne et. al. (2006)
	Age	Su (2002), Delen et. al. (2005), Huang (2005), Wang (2005), Chen (2006), Huang (2006), Etienne et. al. (2006), Wong and Chung (2008)
	License	Huang (2005), Wang (2005), Wu (2005), Chen (2006), Huang (2006)
	Drink	Su (2002), Tsai (2003), Huang (2006)
Vehicle feature	Traffic volume	Su (2002), Huang (2005), Wang (2005), Huang (2006), Etienne et. al. (2006), Milton et. al. (2007),
	Vehicle type	Su (2002), Tsai (2003), Delen et. al. (2005), Huang (2005), Wang (2005), Chen (2006), Etienne et. al. (2006), Huang (2006),
Road feature	Geometric design	Su (2002), Wu (2005), Wang (2005), , Milton et. al. (2007)
	Street light	Tsai (2003), Huang (2005), Wu (2005)
	Traffic island	Su (2002), Wang (2005), Huang (2006), Wong and Chung (2007), Wong and Chung (2008)
	Edge line	Huang (2005), Huang (2006)
	Interchange	Huang (2005), Milton et. al. (2007)
	Bus exclusive lane	Lai (2005)
	Roadside parking	Su (2002), Huang (2005), Huang (2006)
	Date attribute	Tsai (2003), Wu (2005), Wang (2005), Ariana et. al. (2006)
	Weather	Tsai (2003), Huang (2005), Wu (2005)
	Light	Tsai (2003), Huang (2005), Wu (2005), Huang (2006), Wong and Chung (2007),
	Location	Tsai (2003), Huang (2005), Wu (2005), Huang (2006), Wong

and Chung (2007), Wong and Chung (2008)

Table 2 Variables considered in this research

Type	Code	Factor	Measures
Accident risk	d1	Accident rate	no./million vehicle-km
	d2	Fatality rate	person/million vehicle-km
	d3	Injury rate	person/million vehicle-km
	d4	Death and injury rate	person/million vehicle-km
driver feature	a1	Sex	Percentage of male
	a2	Age	Percentage of 20-40 years old
	a3	License	Percentage of without license
	a4	License type	Percentage of occupation license
	a5	Drink	Percentage of drunk
Vehicle feature	b1	Traffic volume	Percentage of bus and truck
	b2	Traffic volume	Percentage of motorcycle
	b3	Vehicle type	Percentage of motorcycle
	b4	Vehicle type	Percentage of passenger car
	b5	Vehicle type	Percentage of commercial car
Road feature	c1	Road width	Millimeter
	c2	No. of lane	Lanes (bidirectional sum total)
	c3	Side walk	With:1; Without:0
	c4	Street light	With:1; Without:0
	c5	Traffic island	With:1; Without:0
	c6	Division type	Central separation island (With:1; Without:0)
	c7	Division type	Speed separation island (With:1; Without:0)
	c8	Division type	Central and speed separation island (With:1; Without:0)
	c9	Edge line	With:1; Without:0
	c10	Interchange	With:1; Without:0
	c11	Viaduct	With:1; Without:0
	c12	Bus exclusive lane	With:1; Without:0
	c13	Roadside parking	With:1; Without:0
	c14	Date attribute	Percentage of ordinary day
	c15	Weather	Percentage of rainy day
	c16	Light	Percentage of night
	c17	Location	Percentage of intersection

CONSTRUCTION OF THE MODEL FOR ACCIDENT RISK ASSESSMENT

Factor Analysis

To determine whether observation variables in each dimension are appropriate before model construction, each variable was subjected to FA. After the main components were analyzed using the maximum variance method (MVM), the factor loading of the five observation variables in four dimensions—injury rate, percentage of drivers without a license, percentage of motorcycles, roads with/without a sidewalk, and roads with/without roadside parking—was < 0.5. Consequently, these five variables were not included in model construction. Table 3 lists the FA results for each dimension.

Table 3 Factor analysis result

Aspect	Total variance explained	Variable code	Factor loading	Component
Accident risk	96.616%	d1	0.965	Risk 1
		d3	0.992	Risk 1
		d4	0.992	Risk 1
User characteristic	65.338%	a1	0.721	User 1
		a2	-0.808	User 1
		a4	-0.728	User 2
		a5	0.785	User 2
Vehicle characteristic	82.518%	b1	0.977	Vehicle 1
		b2	-0.977	Vehicle 1
		b4	0.707	Vehicle 2
		b5	0.825	Vehicle 2
Road characteristic	71.305%	c1	0.797	Vehicle 2
		c2	-0.503	Vehicle 3
		c4	0.712	Vehicle 6
		c5	0.847	Vehicle 4
		c6	0.894	Vehicle 1
		c7	0.838	Vehicle 2
		c8	-0.826	Vehicle 1
		c9	0.711	Vehicle 4
		c10	0.676	Vehicle 3
		c11	0.818	Vehicle 3
		c12	-0.540	Vehicle 3
		c14	0.712	Vehicle 6
		c15	0.833	Vehicle 5
		c16	0.787	Vehicle 5

Model construction

As driver, vehicle, and road were the three dimensions of impact factors for road accident risk, and the correlations may exist between these three dimensions, so this study set up the model framework like Figure 3. This study employed AMOS for model assessment. Originally, the independent variables contented 39 items. However, via the model fit procedure, interactions between the three dimensions (driver, vehicle, and road) were insignificant; thus, these three interactions were eliminated and the model fit process was repeated. Because there were too many variables that caused the unidentifiable problem, this study modified the model framework (Figure 4).

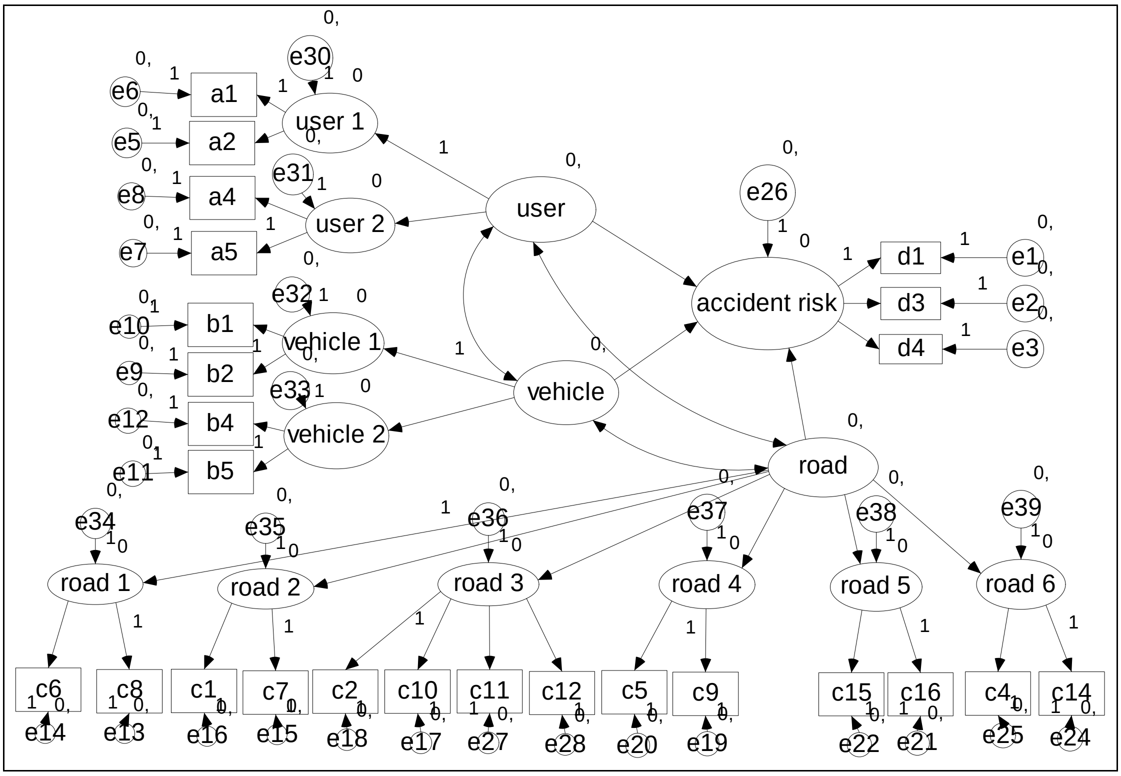

Figure 3 The original model framework

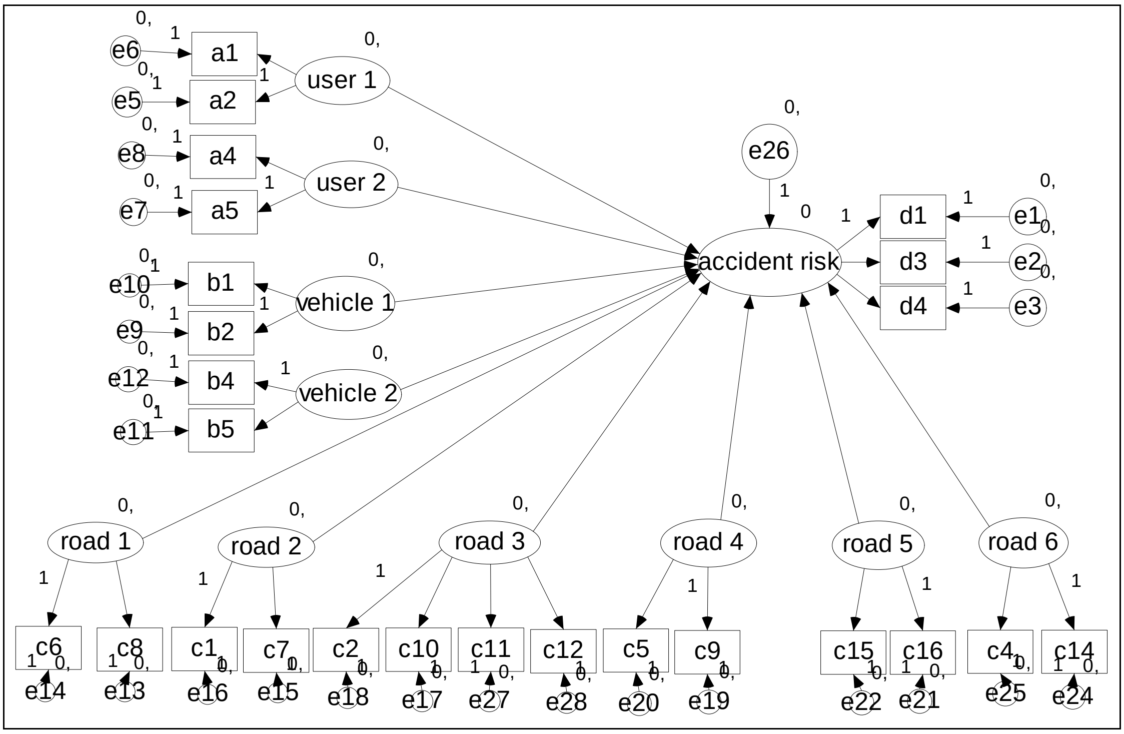

Figure 4 The modified model framework

Figure 5 and Tables 3 and 4 show model assessment results after the most insignificant items were excluded. The chi-square value of the modified model was 82.777, the p-value was 0.0, the normed fit index (NFI) was 0.971, and the comparative fit index (CFI) was 0.978, suggesting that the modified model has high reliability. Additionally, all of the four aspects (driver 1, driver 2, road 1, and road 2) included in the modified model were significant, and all items—a2 (percentage of drivers aged 20–40), a5 (percentage of drunk drivers), c1 (road width), c6 (with a central island) and c7 (with speed separation traffic islands)—were significant.

Assessment results of the modified model suggest that accident risk may be composed of accident rate, injury rate, and casualty rate. The driver and road dimensions had significant influence on accident risk. Road sections with high percentage of drivers aged 20–40 years or a wide road with speed separation traffic islands or with a central island had low accident risk; however, if a road section had a high percentage of drunk drivers, accident risk increased. Compared with the absolute value of standardized coefficients, the wide road with speed separation traffic islands decreased accident risk, the ratio of drunk drivers to increase the accident risk, and a high percentage drivers aged 20–40 years also decreased accident risk. Last, central islands decreased accident risk.

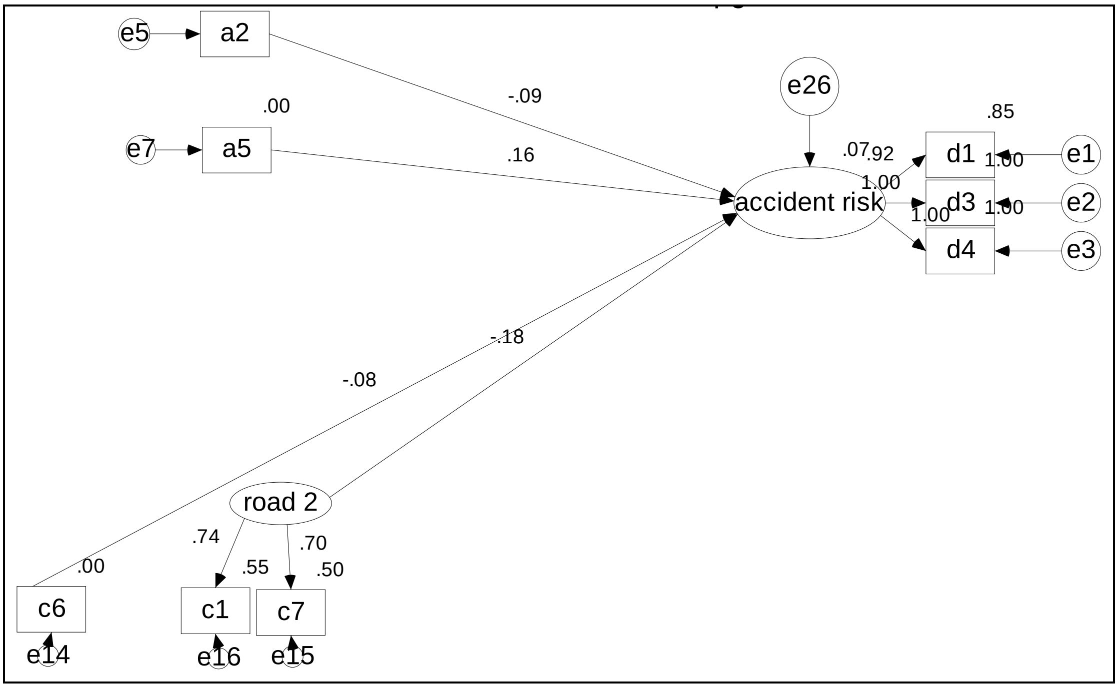

Figure 5 The result of the model assessment

Table 3 Final SEM analysis standardized coefficients list

Path			Estimate	P-value
accident risk	<---	road 2	-.183	.038
accident risk	<---	a2	-.090	.145
accident risk	<---	a5	.163	.008
accident risk	<---	c6	-.081	.187
d1	<---	accident risk	.924	N/A
d3	<---	accident risk	1.000	***
d4	<---	accident risk	1.000	***
c7	<---	road 2	.704	.031
c1	<---	road 2	.738	N/A

Note: “***” stands for a significant difference P≦0.001, “N/A” for not available.

Table 4 Results of test of goodness of fit

Test statistics		Ideal indicator value	Model test value
Absolute fit test	χ^2	The smaller the P-value, the better	82.777
	χ^2/df	< 5	4.357
	P-value	< 0.05	0.000
	RMSEA	< 0.08	0.116
Incremental fit test	NFI	Between 0 to 1, close to 1 is better	0.971
	CFI	Between 0 to 1, close to 1 is better	0.978
Parsimonious fit test	PNFI	> 0.5	0.659

CONCLUSIONS & SUGGESTIONS

This study applied SEM to construct an assessment model for road accident risk which is seldom been used by previous accident risk studies. Arteries in downtown Taipei City were incorporated into model construction. Analytical results show that applying SEM to accident risk assessment is feasible. Of the three main dimensions—driver, vehicle, and road—the driver and road dimensions had the greatest impact on road accident risk, while that of vehicle dimensions was insignificant. A high percentage of drivers aged 20–40 can reduce accident risk, while a high percentage of drunk drivers increased accident risk. The wider roads and roads with an island reduced accident risk. Study results show that user characteristics and road design are important factors to reducing accident risk. Traffic accidents are mostly caused by humans. However, to reduce accident risk, one should pay attention to road design. This study successfully constructed two accident risk assessment models. Whether the three dimensions—driver, vehicle, and road—are adequate for assessing accident risk may require further research. This study was restricted by its access to data. Although 39 variables were included, but due to data lack of some variables employed by some studies did not been incorporated into this study. We suggest that future research may collect such data and reconstruction the road accident risk model. This study was focus on urban arterials; we also suggest the methodology construction by this study may be applied to other type of road system, for example freeway, rural highway, etc.

Acknowledgment

The authors would like to thank the National Science Council of the Republic of China, Taiwan for financially supporting this research under Contract No. NSC 97-2221-E-147-004. Ted Knoy is appreciated for his editorial assistance.

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