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The Statistical Analysis of Highway Crashes in Taiwan

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Abstract

This research provides information about traffic safety in Taiwan and programs implemented to improve traffic safety. A reportable traffic crash data covering different classes of roads in different geographical areas in Taiwan under various weather, environmental, and roadway conditions were examined. The elements that were investigated in this study were fatalities and injuries, distribution of the main causes and contributing factors as well as the association between them. Further analysis involved modeling the effect of the contributing factors on injury rates. The previous analysis indicated that speeding, use of alcohol or drugs, and defective traffic control devices or safety devices produces more injury related crashes than normal. Poor sight distance and environmental conditions such as bad weather and poor light conditions were found associated with higher injury rates than normal as is night time and Saturdays. This research could provide insight into the areas where more emphasis is needed for effective safety programs. Basically, there are several different ways in which improvements in highway traffic safety can be approached and requires consideration of three elements—the driver, the vehicle, and the roadway. Policy level safety efforts address driver behavior issues such as speeding and alcohol/drug related crashes that cause more fatal and severe injuries. Such policy programs include programs such as vehicle-inspection programs, driver licensing, testing, and training programs, minimum drinking age, and penalties for drunk driving. Policy level programs are usually supported by legislation at governmental level. However, they should be based on well-founded research that such programs potentially improve safety. Traffic accidents are one of the critical reasons to cause deaths in Taiwan based upon the Interior Department

analyses. The major task in this research is to study crashes on our nation's highway system to improve safety. The occurrence of crashes and their interactions of factors as well as their magnitudes, i.e., the relative proportions of the various crash types, are analyzed in this study. Besides, the contributing factors as well as the injury rates are closely examined. By doing so, effective corrective measures to mitigate the different crash types can be assembled to improve highway safety.

Keywords: traffic safety, contributing factors, injury rates, corrective measures

1. Introduction

A number of issues need to be addressed regarding crashes on our nation's highway system to improve safety. They include but not limited to actions that lead to the occurrence of crashes and their interactions, as well as their magnitudes - the relative proportions of the various crash types. In addition, the contributing factors and the injury rates must be examined closely for significant differences. By doing so, effective corrective measures to mitigate the different crash types can be assembled to improve highway safety.

2. Source and Analysis of Data

The data for this analysis were obtained from the Department of Transportation in Taiwan for the period January 2000 to December 2000 [Department of Transportation, 2000]. The data cover the different types of roads, geographical areas, weather and environmental conditions, and certain roadway conditions. Initial examinations of the crash data indicated that some of the variables were over classified and those were reclassified for the purpose of this analysis. The focus of the analysis was on contributing factors and effects of environmental and roadway elements. The variables that were studied include time of day, day of week, fatalities and injuries, weather, light conditions, pavement conditions, sight distance, type of crash, cause of crash, and road conditions.

3. Distribution of Injury-Related Crashes

The objectives of many safety programs are to reduce severity of crashes and its occurrence. Therefore descriptive statistics was used to summarize the reclassified data in terms of injuries (fatal and nonfatal) as presented in Table 1. The statistics software package by SAS Institute was used in the analysis of data presented in this paper [SAS, 1990]. Also shown in the table are the various subclasses or levels of each variable. These subclasses are used consistently through out the paper. In summary the descriptive statistics shows that speeding, use of alcohol or drugs, and defective traffic control and vehicular safety devices cause more injury related crashes compared to other causes. In addition, poor sight distance and poor weather (windy, foggy, and cloudy) were found to be associated with higher injury rates than normal conditions. Also, night time crashes were found to involve more injuries than those that occurred in daylight. The analysis also shows that vehicular-rail crashes have more injures involved than the other crash types. Finally, Saturdays had unusually higher injury rates.

Table 1 Injury Rates by Contributing Factors and Crash Types

Main Cause	Injuries per Crash	Standard Deviation	Number of Cases
Speeding	1.47	0.98	4202
Failed to yield	1.30	0.61	7701
Disregard of traffic control or regulation	1.31	0.65	14367
Inattentive	1.30	0.63	7793
Alcohol and drugs	1.43	0.82	4078
Follow too closely	1.34	0.72	3570
Out of control vehicle	1.32	0.80	267
Improper maneuver	1.27	0.66	6795
No violation	1.20	0.48	321
Defective traffic control or safety device	1.40	1.33	346
Driver or passenger moving violations	1.35	0.53	305

Table 1 Injury Rates by Contributing Factors and Crash Types (Continued)

	Injuries per Crash	Standard Deviation	Number of Cases
Weather			
Rainy	1.32	0.73	6533
Cloudy/Foggy/Smoggy/Windy	1.38	0.80	6100
Sunny	1.32	0.66	37112
Light Conditions			
Daylight	1.29	0.67	28152
Dawn/Dusk	1.33	0.72	2826
Night with light	1.37	0.69	16274
Night without light	1.45	1.02	2479
Sight Distance			
Poor	1.43	1.04	3285
Adequate	1.32	0.68	46460
Crash Type			
Vehicle-Pedestrian	1.31	0.55	4298
Vehicle-Vehicle	1.33	0.69	40691
Vehicle-Roadway object	1.30	0.95	4719
Vehicle-Rail	1.46	1.50	37
Road Defect			
Uneven/Bumpy	1.40	0.83	50
Protrusion	1.36	1.15	296
Pothole	1.32	0.64	267
No Defect	1.33	0.78	49132
Road Obstacles			
Yes	1.33	1.05	1901
None	1.33	0.69	47844
Pavement Surface Condition			
Snowy	0.86	0.59	37
Slippery	1.38	0.71	24
Muddy	1.29	0.54	100
Wet	1.33	0.73	7797
Dry	1.33	0.70	41787
Pavement Type			
Asphalt	1.10	1.44	49
Concrete	1.31	0.62	26758
Macadam	1.36	0.79	22800
Other	1.12	0.35	119
None	1.20	0.45	19
Day of Week			
Sunday	1.30	0.66	7036
Monday	1.32	0.75	6987
Tuesday	1.29	0.63	7067

Wednesday	1.30	0.62	7194
Thursday	1.32	0.67	7243
Friday	1.35	0.73	7537
Saturday	1.43	0.87	6681

Note: Overall mean injury rate = 1.33. Injuries include fatal and nonfatal. Shading denotes higher than normal injury rates.

Table 1 Injury Rates by Contributing Factors and Crash Types (Continued)

	Injuries per Crash	Standard Deviation	Number of Cases
Time of Day			
0	1.39	0.73	1422
100	1.44	0.84	1131
200	1.41	0.79	947
300	1.41	0.78	795
400	1.44	0.83	739
500	1.33	0.72	894
600	1.34	0.82	1157
700	1.30	0.83	2657
800	1.26	0.63	2909
900	1.25	0.63	2385
1000	1.27	0.60	2209
1100	1.27	0.61	2282
1200	1.31	0.63	2394
1300	1.31	0.65	2243
1400	1.31	0.71	2391
1500	1.32	0.68	2567
1600	1.32	0.77	2681
1700	1.32	0.67	3290
1800	1.31	0.62	2976
1900	1.37	0.85	2450
2000	1.37	0.71	2163
2100	1.38	0.70	2618
2200	1.39	0.68	2486
2300	1.38	0.73	1959

Note: Overall mean injury rate = 1.33. Injuries include fatal and nonfatal. Shading denotes higher than normal injury rates.

4. Distribution of Total Crashes

Figures 1 through 10 show the distribution of the crashes among the contributing factors and crash types are summarized below.

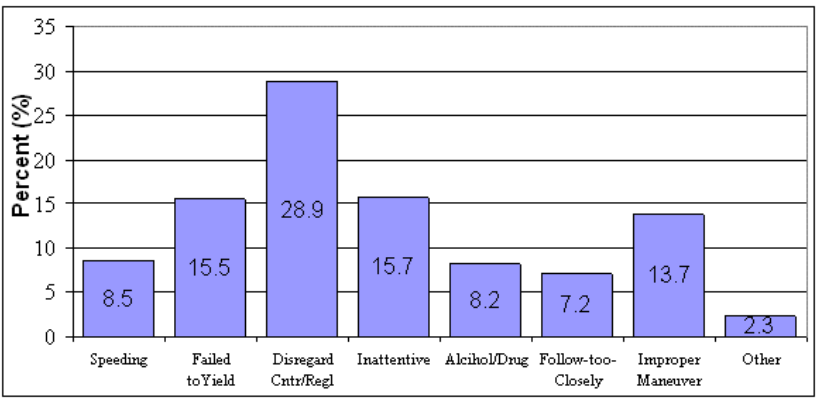

Figure 1 Cause of Crashes

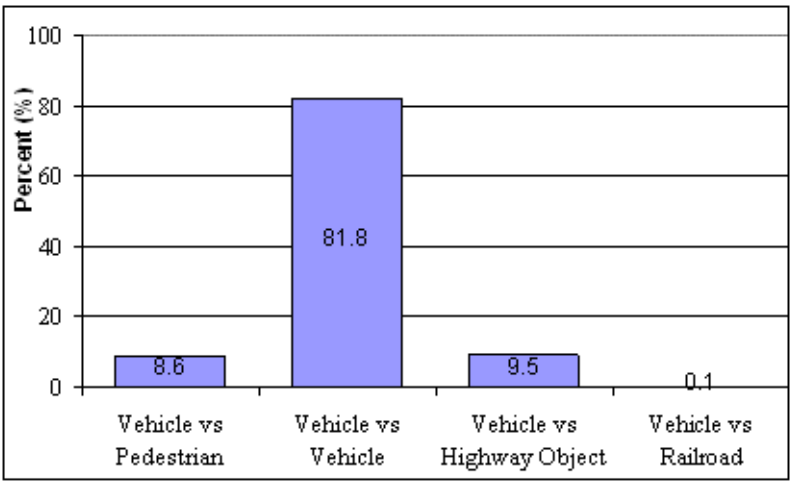

Figure 2 Crash Types

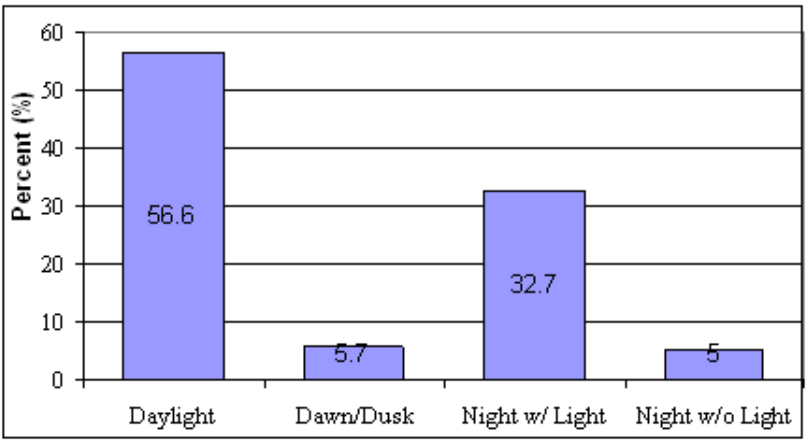

Figure 3 Light Conditions

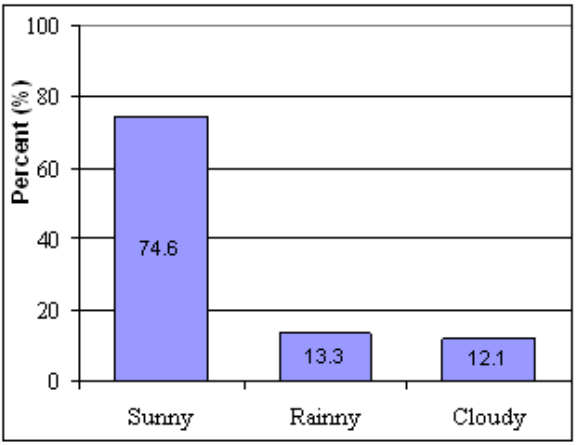

Figure 4 Weather Conditions

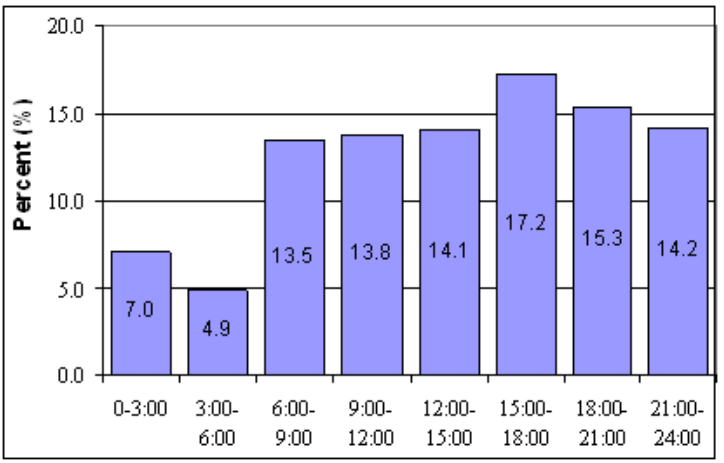

Figure 5 Time of Day

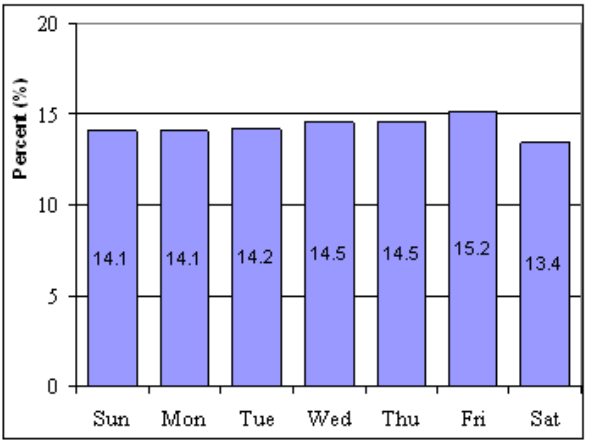

Figure 6 Day of Week

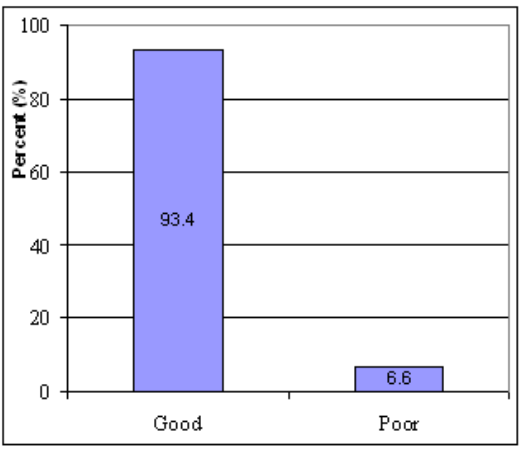

Figure 7 Sight Distance

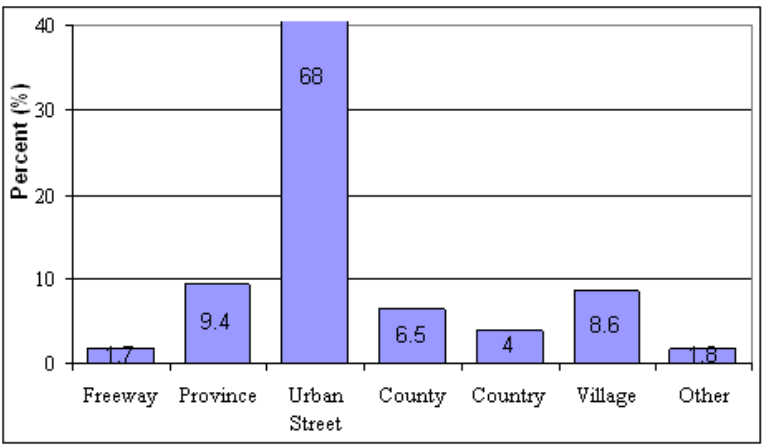

Figure 8 Road Classifications

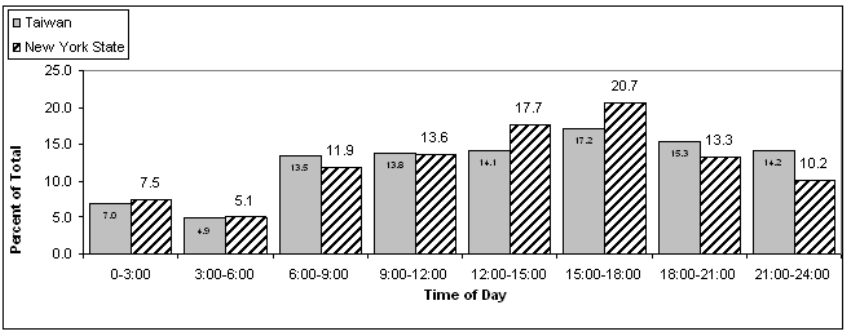

Figure 9 Crash Occurrences by Time of Day

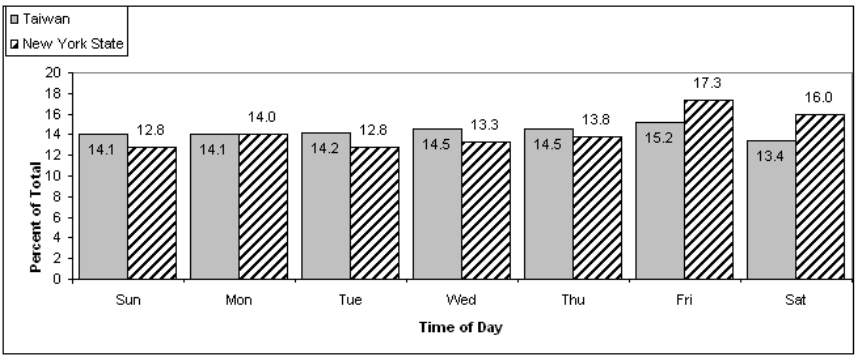

Figure 10 Crash Occurrences by Day of Week

A. Cause and Type of Crash

A breakdown of the crashes shows that over 28% of the crashes were caused by drivers' disregard of traffic control devices or traffic regulations. Failure to yield right-of-way and inattentiveness each accounted for nearly 16% of the crashes. Improper maneuver represented nearly 14% of the

crashes while driving under the influence of alcohol/drugs and speeding each attributed to 8% of the crashes.

On the different types of crashes, our analysis found that vehicle-vehicle crashes were the predominant crash type; they were attributed to 81% of the crashes. Vehicle-pedestrian crashes and vehicle-highway object crashes accounted for 8.6% and 9.5% of the crashes, respectively. Approximately 6.5% of the crashes involving fatalities while 93.5% involve injuries or property damage only. Close examination of Figure 3 shows that of the nonfatal crashes only 4.5% were without injury.

B. Roadway Geometrics

Poor and substandard designs cause highway crashes. Such substandard designs lead to inconsistent transitions to and from horizontal curves, poor sight distances, poor pavement conditions, and unnecessary highway obstacles. The analysis showed that poor sight distance was the cause of nearly 7% of the total crashes; highway obstacles, 4%. Inadequate signs to warn, guide, or direct motorist and malfunction traffic control devices were each attributed to less than 1% of the crashes.

C. Environmental Factors

Because environmental factors are often times the cause of highway crashes, particular attention was focused on weather and lighting conditions. On weather, the analysis shows that 87% of the crashes were on sunny, cloudy and windy days without rains. Wetness affects driving conditions because of skidding, loss of pavement friction, and reduced visibility. Wet pavement has been a major safety concern that has been well studied and researched. Of all of the crashes analyzed, 84% occurred on dry pavement

and 16% on wet pavement. Lighting conditions affect visibility and has direct impact on crash occurrence. The analysis indicated that 57% of the crashes occurred in daylight, 33% at night with no light around and 10% at night with light around or at dawn or dusk.

D. Time of Day and Day of Week

The analysis indicated that crashes occurrence was evenly divided across the days of the week, with each day accounting for about 14% of the total crashes. While there are a lot of work related trips during the weekdays, the weekend trips have recreational and leisure as well as work-related trips.

The time of day showed some significant differences as depicted in Figure 9, for example the lowest crash occurrences were between midnight and 6:00 AM. The highest crash occurrences were between 3:00 and 6:00 PM. These patterns might be partly explained by the low traffic volumes during the early morning hours and the high traffic volumes during the afternoon rush hours.

Comparing crash statistics across countries is difficult because of differences in culture, lifestyle, economic conditions, and weather conditions. However, such comparisons provide insights about enhancing safety based on some of the differences mentioned above. With this in mind, we limited our comparisons only to time of day and day of week. Figures 10 and 11 show such comparison between Taiwan and New York State in the USA [Schlotzhauer and Littell, 1987]. The trends in both countries are similar and the minor differences may be partly due to the above mentioned differences.

5. Association of Contributing Factor and Main Cause

The primary interest here is association or independence between the contributing factors. To statistically examine the association or independence between the contributing factors, cell group frequency must be compared to the expected frequencies [McShane and Roess, 1990]. The Chi-Square test of independence was used to compare the frequencies of the observed crashes and the expected number of crashes for each cell group, i.e., the cross-classified cell group data in contingent table are too big to present in this limited page paper. We could only release some important information based on these data. The results of the tests summarized in Table 2 are described below.

Table 2 Association of Main Cause of Crash with Weather and Highway Conditions

Contributing Factors	Statistic	Degrees of Freedom	Value	Probability
Main Cause vs. Crash Type	Chi-Square	30	12057.5	0.001
Main Cause vs. Light Conditions	Chi-Square	30	3427.7	0.001
Main Cause vs. Sight Distance	Chi-Square	10	605.2	0.001
Main Cause vs. Fatality	Chi-Square	50	1762.7	0.001
Main Cause vs. Weather	Chi-Square	20	264.4	0.001
Main Cause vs. Pavement Surface Condition	Chi-Square	40	3427.7	0.001
Main Cause vs. Roadway Obstacles	Chi-Square	10	264.4	0.001
Main Cause vs. Roadway Defects	Chi-Square	30	3427.7	0.001

A. Main Cause versus Crashes Type

The Chi-Square test showed that there was a strong association between cause and type of the crash with a p-value of 0.001. This test also confirms that certain causes have significantly higher crash types than others. For

example: (1) Speeding, alcohol/drugs, and out-of-control related crashes have higher fractions of vehicle-highway crash types; (2) Failure-to-yield, follow-too-closely, and improper maneuver related crashes have higher fractions of vehicle-vehicle crash types; (3) Inattentiveness related crashes have higher fractions of vehicle-pedestrian and vehicle-highway object crash types; and (4) Disregard of traffic control or traffic regulations related crashes have higher fractions of vehicle-pedestrian crash types.

B. Main Cause versus Severity of Crashes

The Chi-Square test showed that there was a strong association between cause and severity of crash with a p-value of 0.001. This test also confirms that certain causes have significantly higher severity than others. For example: (1) Inattentiveness, speeding, alcohol/drugs, and out-of-control related crashes have higher fractions of fatal crashes; and (2) Failure-to-yield, follow-too-closely, and improper maneuver related crashes have higher fractions of injury crashes.

C. Main Cause versus Light Conditions

The Chi-Square test showed that there was a strong association between the cause and lighting conditions with a p-value of 0.001. This test also confirms that certain causes have significantly higher crashes under certain lighting conditions as compared to others. For example: (1) Speeding, inattentiveness, and alcohol related crashes occur more than expected under night without lighting conditions; and (2) Failure-to-yield, follow-too-closely, and improper maneuver related crashes occur more than expected under sunlight conditions.

D. Main Cause versus Sight Distance

The Chi-Square test showed that there was a strong association between the cause and sight distance with a p-value of 0.001. This test also confirms that certain causes have significantly higher crashes under poor sight distance conditions as compared to others. For example: Speeding and inattentiveness related crashes occur more than expected in poor sight distance locations.

E. Main Cause versus Weather Conditions

The Chi-Square test showed that there was a strong association between the causes and weather conditions with a p-value of 0.001. This test also confirms that certain causes have significantly higher crashes under certain weather conditions as compared to others. For example: (1) Inattentiveness related crashes occur more than expected under rainy conditions; (2) Alcohol/drug related crashes occur more than expected under rainy conditions and cloudy conditions; and (3) Failure-to-yield and follow-too-closely related crashes occur more than expected under sunny conditions.

6. Analysis of Variance

The parametric method was used to examine the data in terms of injuries for significant differences with $\alpha = 0.05$ in injuries among the various groupings. The nonparametric Wilcoxon rank-summed test was used to test for significant difference in the mean of two groups. Both methods show significant differences in injury rates among the various groupings of the contributing factors. The results of the analysis of variance (ANOVA) for

the parametric method using the general linear model (GLM) procedure of the SAS statistical package are shown below [SAS, 1990].

The analysis of variance presented in Table 3 show that many of the contributing factors significantly affect injury rates. The variables "road defect" and "pavement type" were not significant. Since the F-value was significant at $\alpha = 0.05$, multiple comparison of means was carried out using Tukey method to identify which groupings of the factors are significantly different from the others [Montgomery, 1991]. The multiple comparisons indicated that each significant variable have one or more groupings that have significantly higher injury rates than the rest of the groupings.

Table 3 Tests for Significant Differences among the Groupings of the Contributing Factors

Contributing Factors (Source)	Degrees of Freedom	Type I SS	F Value	Probability
Main Cause	10	181.40	36.90	0.0001
Light Conditions	3	90.45	46.01	0.0001
Sight Distance	1	24.51	49.89	0.0001
Crash Type	3	47.77	32.40	0.0001
Weather	2	24.82	16.84	0.0001
Pavement Type	4	2.21	0.55	0.3431
Roadway Obstacles	1	2.28	4.63	0.0314
Roadway Defect	3	0.55	0.37	0.7725
Pavement Surface Condition	4	27.09	13.78	0.0001
Time of Day	23	32.41	2.87	0.0001
Day of Week	6	72.81	24.69	0.0001
Main Cause	10	154.83	31.50	0.0001
Light Conditions	3	12.10	6.17	0.0001
Sight Distance	1	25.40	51.85	0.0001
Crash Type	3	61.04	41.66	0.0001
Weather	2	17.24	11.73	0.0001
Pavement Type	4	2.14	1.09	0.3599
Roadway Obstacles	1	2.43	4.94	0.0262
Roadway Defect	3	0.63	0.43	0.7343
Pavement Surface Condition	4	28.60	14.53	0.0001
Time of Day	23	27.84	2.46	0.0001
Day of Week	6	72.80	24.69	0.0001

7. Approaches to Highway Safety

There are several different ways in which improvements in highway safety can be approached and requires consideration of the three elements - the driver, the vehicle, and the roadway.

A. Reducing Crashes Occurrence

Preventing crashes from occurring is the most effective means to improve highway safety but the most difficult to accomplish. The causes of traffic crashes are many and complex and on many occasions involve some form of driver error. Therefore, the most effective means to prevent crashes from occurring is the improvement of driver skills through training and testing programs and removal of drivers with bad crash and/or violation records from the highways.

Good highway and traffic designs and proper signing and marking reduce driver confusion and reduce the risk of driver error. Highway designs that avoid sudden changes in geometry provide good sight distance and smooth transitions between geometric elements can also reduce the chance of driver error. In addition, vital highway features such as horizontal and vertical alignment, roadside design, median barriers, and gore areas can improve highway safety. Driver training and removal of "bad" drivers from the highways are complex issues involving licensing and enforcement procedures.

B. Reducing the Severity of Crashes

A "forgiving highway" is one that is designed recognizing those locations at which crash are most likely to occur. These locations are

designed in such a way as to give drivers time and space to "recover" from errors and to minimize the severity of the crash when it occurs. Proper use of highway facilities such as guardrail, median barriers, impact attenuators, and breakaway signpost and light standards, and gore areas on freeway off-ramps kept free of objects, for example, can reduce the damage done when a vehicle leaves the travel lane or give indecisive drivers opportunity to recover from their error.

C. Improving Crashes Survivability

Crashes survivability primarily involves vehicle design, i.e., designs that absorb most of the impact of crashes without transferring it to the occupants. Such design features as energy-absorbing bumper systems, padded dashboards, seat belts, air bags, and similar measures are all attempts to improve crash survivability.

D. Policy Level Safety Efforts

Programs that attempt to address traffic safety on a policy level through legislation at governmental level attack various aspects of safety that have been identified through study and research. The listing below is a just a sampling of some of the more notable programs influencing traffic safety, such as National vehicle-inspection programs, National speed limit, National minimum drinking age, National driving while intoxicated programs, and National vehicle design standards.

As long as traffic crashes occur, all levels of government will attempt to deal with the problem programmatically. Such programs must be well founded in research and must attack aspects that potentially improve safety.

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台灣的公路車禍分析

摘要

本研究透過台灣交通事故資料，提供所需資訊，作為交通安全的改善依據，統計分析在各種氣候、環境與道路條件下，台灣不同區域各種等級道路的事故資料。量化性地了解不同道路所呈現傷亡率，並探討其形成的主、次因，以論述兩者關係及分配情形，進一步分析主要肇事因素與傷亡率的關聯與影響。先前的分析資料指出，超速、酒駕、設計不當的交通號誌、標誌，較易導致嚴重的傷害。視距或路狀不佳，如週末或夜間時段駕駛，因擁擠或亮度不足，其所造成的傷亡率亦較高。因而本研究可透過統計分析，了解所需強化的改善方式，以提供切合實際的交通安全規劃。並依交通三要素：人、車、路之變數，來擬定各種可行方案。在法令政策上努力宣導交通安全觀念；例如籲請駕駛人勿超速和酒駕，因其將導致嚴重的交通事故。在政策的配套上，應包括監理規劃、駕照考領及訓練、限定飲酒年齡及酒駕之處罰等相關法案；本研究可提供重要之理論基礎，供立法機關參酌，制定最佳的交通策略。內政部分析，目前台灣因交通事故而傷亡的情形相當嚴重。透過本研究可分析各種交通事故型態及相關比例情形，並調查各種肇事原因及傷亡比

例，進而針對不同的車禍種類，提出各項的矯正措施，以冀有效的提昇道路安全。

關鍵詞：交通安全、肇事因素、傷亡率、矯正策略