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Costing of Road Crashes by RUM Code and Speed Limit.

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Abstract

Economic analysis of treatments proposed to reduce the number and/or the severity of crashes occurring at "blackspots" require cost estimates of crashes by road user movement code. As these treatments are proposed in different speed environments, the cost estimates need to be for different speeds in the range from 50 to 110 km/h. Similarly, for major road projects, where road crash rates per vehicle kilometre and an average cost per crash are used to estimate total crash costs before and after project implementation, it is desirable that the cost per crash be available for generic road types at each speed in the range from 50 to 110 km/h. These average costs per crash should be derived from estimates of costs per person killed or injured plus the damage costs either per vehicle involved or per crash. This paper describes the method used to estimate per crash costs by road user movement code by speed limit and the per crash cost by generic road type by speed limit from costs per person injured and damage costs per crash.

General introduction to need

Estimates of road crash costs are used at three different levels

- At a macro level for estimating the total costs of all crashes over a large area (for a State or the whole of Australia)
- At a road project level where there is a predicted change in the total number of crashes with no change in the proportions of the type of crash
- For 'black spot' evaluations where there is an expectation that the proportions of each type of crash based on the road user movement (RUM) codes will change with a corresponding change in the severity of crashes.

This paper describes a method of estimating the average cost of a crash by RUM code by speed limit from independently estimated values of person injury costs and the property damage and clean up costs of crashes that are prepared for major road project evaluations.

Data for model calibration

The data available consisted of 6 years of road crash data from Western Australia for the years 1995 to 2000. When a crash occurs, it must be reported to the police if

- A person is injured
- The total property damage in the crash exceeds $1000

Approximately 23% of the reported crashes resulted in casualties and 77% were property damage only. The data was mixed urban and non-urban including some urban freeways and covered legal speed limits of 60, 70, 80, 90, 100 and 110 km/h. The speed limit was recorded on about 90% of the records. In some cases the value recorded was less than any legal speed limit indicating that in some cases either the estimated speed of travel or the estimated speed at impact had been recorded. This means that some of the recorded speeds at the higher values within the legal speed limit range are probably also less than they should be. With no way of identifying these cases, the recorded speed was accepted at face value. Records with speeds missing or less than the lowest legal speed limit were ignored.

Description of the model

In addition to varying with the type of crash and the speed of travel, the likelihood of a person being killed or injured in a crash depends on the total number of persons involved in the crash. This varies with the number of vehicles involved which varies across the RUM codes, hence the decision to estimate outcomes in terms of persons per vehicle involved. For each RUM code, it was assumed that the number of vehicles involved is independent of the speed limit.

The method consists of three models to predict the crash outcomes as follows

a. the probability of a person being killed per vehicle involved in a crash
b. the probability of a person being admitted to hospital per vehicle involved in a crash
c. the probability of a person requiring medical treatment per vehicle involved in a crash.

Each of the three models has the same form of

$$O = A_{RUM} * (Sp / 60)^{B}$$

where
O = outcome in number of persons killed / injured per vehicle involved
Sp = speed limit
B = Calibration constant (one per model)
A = Calibration constant specific to RUM code and model

A fourth model of the same form was also estimated to calculate the probability of the crash being a casualty crash. In this case the probability has to be checked to see that it does not exceed 1.0 and if necessary is reset to 1.0. The estimation of the probability of a crash being a casualty crash allows the use of two damage only values per crash, one for casualty crashes where the damage is usually more severe, and one for the property damage only crashes. It also allows for the calculation of the total crash cost for all reported crashes for each RUM code to be expressed as the cost per reported casualty crash for use in those states where property damage only crashes are not reported.

Model calibration

The method of calibration was to assume a value for the power of the speed variable and then to calculate the constant for each RUM code to make the estimated outcomes for that RUM code across all speeds equal to the observed outcome. The model was calibrated by minimising the objective function

$$Obj\ function = \sum_{Sp=1}^{N} \sum_{RUM=1}^{N} (Obs - Est)^{2} / Obs$$

using a trial and error process. The observed value was used on the bottom line to maintain a constant divisor from one trial to the next. Also if the estimated value was used, it creates a bias in favour of estimates being high rather than low. The first calibration run used each RUM code individually to create a matrix of factors of RUM code by model. With 85 used RUM codes and 6 speed limits, and just over 1000 fatal crashes, there were a proportion of cells with no entries, particularly for the most severe injury categories. To overcome this, after the first calibration run, the matrix of factors by RUM code and model was examined in conjunction with the total number of crashes for each RUM code to see which RUM codes could be grouped in order to raise the number of entries in each cell and to reduce the likelihood of cells being empty. Where the crash type was similar, and the total number of crashes for the RUM code was less than about 4000, the codes were grouped if the factors for the number of persons admitted to hospital and the number of persons requiring medical attention were similar for both RUM codes. In this examination, the factors for the number of persons killed was not used, as this model was the one that suffered most from lack of entries. This reduced the number of RUM codes from 85 to 36 groups. The model was then re calibrated using the 36 groups. This still leaves a number of cells with zero persons killed.

Data for proof of calibration

Three pairs of files were extracted from the database to be used to check the accuracy of the model. The first pair of each set contained the number of crashes for each RUM code at each speed to be used to estimate the crash costs according to the chosen disaggregation. The second file of each pair contained the recorded outcome in terms of persons injured plus the number of crashes to be costed as the observed cost. The three pairs of files disaggregated data by

a. posted speed limit
b. region
c. State highway number

Model verification

To prove the model accuracy, the prices quoted in Thorensen, et al (2001) were used. These prices are

Per person

Fatal	$1 202 000
Serious Injury	$304 000
Minor Injury	$12 700

And per crash

Property Damage	$6 300

These prices were applied to the actual outcome to give the observed cost and to the model predicted outcome to give the predicted cost. The results of the comparisons of predicted outcome cost versus observed outcome cost are plotted in **Figures 1, 2** and **3.** The average observed cost per crash by region is plotted in **Figure 4.** The costs by RUM code by speed limit will be published in Thorensen et al (2003) both for all reported crashes and per reported casualty crash.

Figure 1 Plot of Observed versus Predicted total Crash Costs by Speed Limit

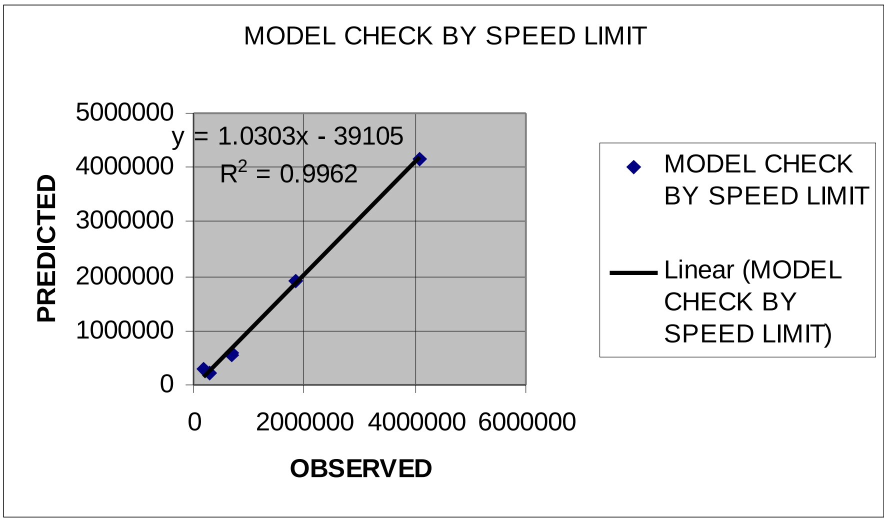


Figure 2 Plot of Observed versus Predicted total Crash Costs by MRWA Region

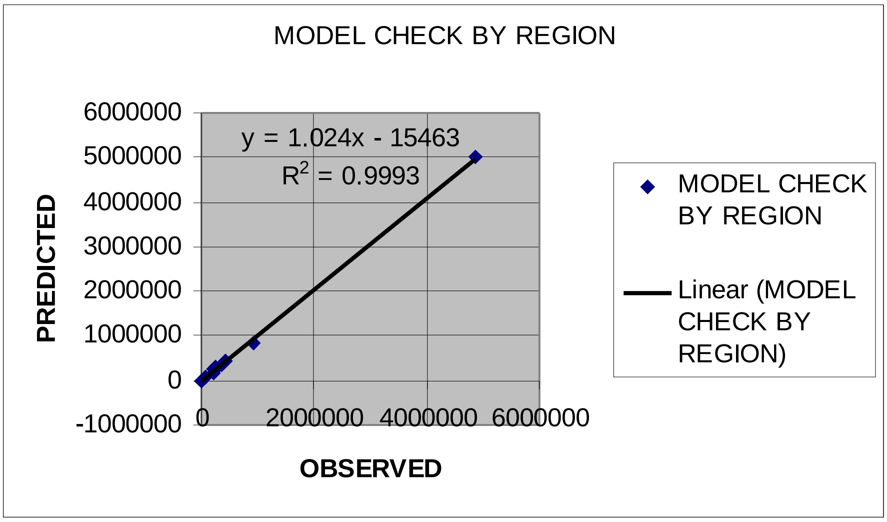


Figure 3 Plot of Observed versus Predicted total Crash Costs by Highway

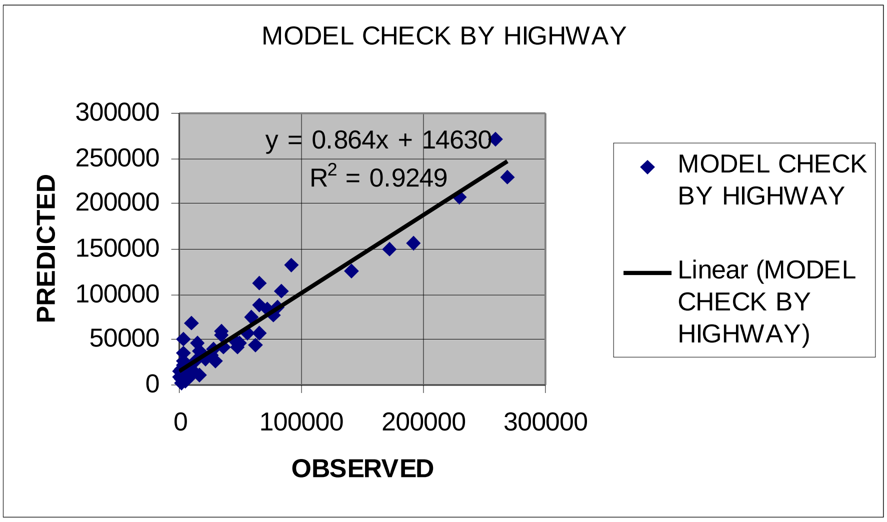
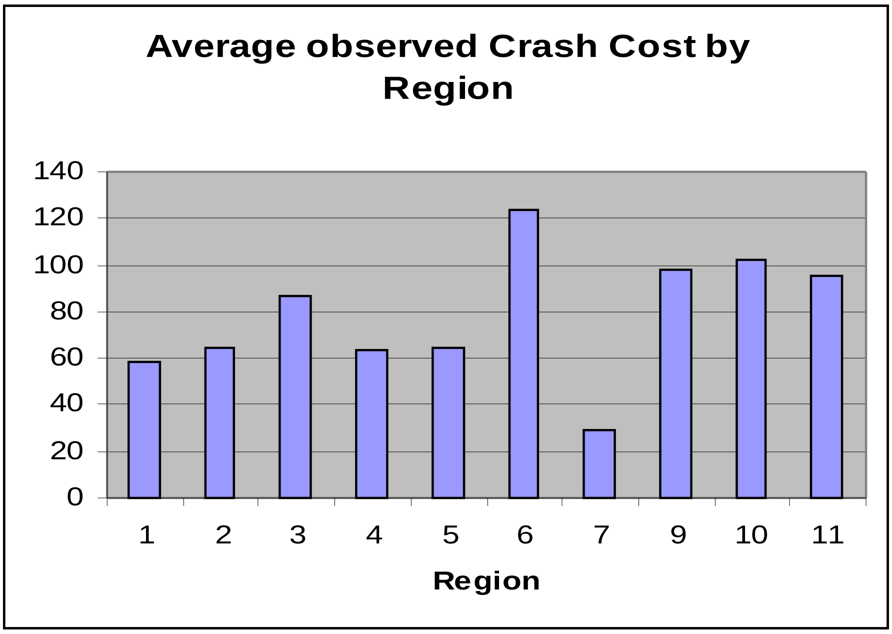


Figure 4 Average Observed Crash Cost by Region



Cost of a crash by Generic Road Type by Speed Limit

All crashes occurring at an intersection were recorded against the road highest in the road classification system. For roads of equal classification, they were recorded against the road with the lowest road number. Crashes occurring between intersections were all located at the mid point and not at their actual location. The only way of separating urban crashes from rural crashes was by the Region or Local Government area in which it was recorded. Also there was no indication of whether the road was divided or undivided on the crash record. The only way that generic road types could be separated was by using the road number and the area. The gazetted Metropolitan Planning Region was taken to be urban and the rest of the state was used as Rural. This is not a clean break between developed and undeveloped as there are some rural type roads on the fringes of the Metropolitan Region and some of the rural regions contain major regional centres. One of the urban freeways was grade separated for the first half of its length and with intersections at grade on the second half. The grade-separated portion was extracted as urban freeway with the remainder being other urban road. In this way three generic road classes were extracted.

a. urban freeway
b. urban other roads
c. rural roads

For each category, a file was prepared giving the proportions of each type of crash at each speed limit. Using the calculated cost of a crash by RUM code for each speed, the average cost of a crash at each speed was calculated for use in project level analyses.

Effect of not pricing property damage only crashes

To test the effect of not having access to the numbers of property damage only crashes, for each RUM code, the total cost of all crashes including PDO's expressed as a cost per reported casualty crash was compared to the cost of a casualty crash. Selected ratios are reported in Table 1 for 60 km/h and 100 km/h.

Table 1. Effect of non casualty crash costs on the average cost of a casualty crash

	60 km/h	100 km/h
Pedestrian crash	1.01	1.00
Right angle crash	1.18	1.04
Head on crash	1.09	1.01
Rear end crash	2.15	1.40
Sideswipe	2.16	1.37
Overtaking head-on	1.05	1.00
Run off the road	1.14	1.04
All crashes	1.41	1.14

The effect of speed on the average cost of a crash is shown in Table 2 where the average cost at selected speeds is shown as the ratio of the average cost per crash at 60 km/h.

Table 2. Effect of Speed Limit on Average Cost per Crash

Speed	Ratio of average cost per crash
60 km/h	1.0
80 km/h	1.4
110 km/h	4.4

Conclusion

A model has been developed for estimating road crash costs by RUM code by speed limit. It has been shown that the relatively large difference in the average cost of a crash in urban and rural areas is explained by the different speed environment. A procedure is now in place to calculate new costs each time the unit costs of persons killed or injured are updated. In addition the procedure also updates the crash costs by generic road type by speed limit for use in project evaluation

Bibliography

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Appendix

Table A.1 Description of RUM codes

RUM Code	Description
	PEDESTRIAN on foot, in toy/pram
00	PEDESTRIAN: OTHER
01	PEDESTRIAN: NEAR SIDE
02	PEDESTRIAN: EMERGING FROM NEAR SIDE
03	PEDESTRIAN: FAR SIDE
04	PEDESTRIAN: PLAY/WORK/STAND ON CARRIAGEWAY
05	PEDESTRIAN: WALKING WITH TRAFFIC
06	PEDESTRIAN: WALKING AGAINST TRAFFIC
07	PEDESTRIAN: IN DRIVEWAY
08	PEDESTRIAN: ON FOOTWAY
09	PEDESTRIAN: STRUCK BOARDING/ALIGHTING
	INTERSECTION – Vehicles from adjacent approaches
10	INTX (ADJ.APP): OTHER
11	INTX (ADJ.APP): THROUGH-THROUGH
12	INTX (ADJ.APP): RIGHT-THROUGH
13	INTX (ADJ.APP): LEFT-THROUGH
14	INTX (ADJ.APP): THROUGH-RIGHT
15	INTX (ADJ.APP): RIGHT-RIGHT
16	INTX (ADJ.APP): LEFT-RIGHT
17	INTX (ADJ.APP): THROUGH-LEFT
18	INTX (ADJ.APP): RIGHT-LEFT
19	INTX (ADJ.APP): LEFT-LEFT
	VEHICLES from OPPOSING Directions
20	OPPOSITE DIRECTION: OTHER
21	OPPOSITE DIRECTION: HEAD ON
22	OPPOSITE DIRECTION: THROUGH-RIGHT
23	OPPOSITE DIRECTION: RIGHT-LEFT
24	OPPOSITE DIRECTION: RIGHT-RIGHT
25	OPPOSITE DIRECTION: THROUGH-LEFT
26	OPPOSITE DIRECTION: LEFT-LEFT
27	OPPOSITE DIRECTION: U-TURN
	VEHICLES from ONE DIRECTION
30	SAME DIRECTION: OTHER
31	SAME DIRECTION: SAME LANE, REAR END
32	SAME DIRECTION: SAME LANE, LEFT REAR
33	SAME DIRECTION: SAME LANE, RIGHT REAR
34	SAME DIRECTION: SAME LANE, U-TURN
35	SAME DIRECTION: PARALLEL LANES, SIDESWIPE
36	SAME DIRECTION: CHANGE LANES-RIGHT
37	SAME DIRECTION: CHANGE LANES-LEFT
38	SAME DIRECTION: PARALLEL LANES-TURN RIGHT SIDESWIPE
39	SAME DIRECTION: PARALLEL LANES-TURN LEFT SIDESWIPE
	MANOEUVRING
40	MANOEUVRING: OTHER
42	MANOEUVRING: LEAVING PARKING
43	MANOEUVRING: PARKING
44	MANOEUVRING: PARKING VEHICLE ONLY
45	MANOEUVRING: REVERSING IN TRAFFIC
46	MANOEUVRING: REVERSE INTO FIXED OBJECT
47	MANOEUVRING: LEAVING DRIVEWAY
48	MANOEUVRING: LOADING BAY
49	MANOEUVRING: FROM FOOTWAY

Table A.1 (continued) RUM Codes used in Western Australia

RUM Code	Description
	OVERTAKING
50	OVERTAKING: OTHER
51	OVERTAKING: HEAD ON
52	OVERTAKING: OUT OF CONTROL
53	OVERTAKING: PULLING OUT
54	OVERTAKING: CUTTING IN
55	OVERTAKING: PULL OUT-REAR END
56	OVERTAKING INTO RIGHT TURN
	ON PATH
60	ON PATH: OTHER
61	ON PATH: PARKED
62	ON PATH: DOUBLE PARKED
63	ON PATH: ACCIDENT OR BREAKDOWN
64	ON PATH: OPEN CAR DOOR
65	ON PATH: PERMANENT OBSTRUCTION
66	ON PATH: TEMPORARY ROADWORKS
67	ON PATH: TEMPORARY OBJECT ON CARRIAGEWAY
69	ON PATH: HIT ANIMAL
	OFF PATH ON STRAIGHT
70	OFF PATH ON STRAIGHT: OTHER
71	OFF PATH ON STRAIGHT: OFF CARRIAGEWAY – LEFT
72	OFF PATH ON STRAIGHT: OFF CARRIAGEWAY – LEFT – OBJECT
73	OFF PATH ON STRAIGHT: OFF CARRIAGEWAY – RIGHT
74	OFF PATH ON STRAIGHT: OFF CARRIAGEWAY – RIGHT – OBJECT
75	OFF PATH ON STRAIGHT: LOST CONTROL ON CARRIAGEWAY
76	OFF PATH ON STRAIGHT: LEFT TURN-OUT OF CONTROL
77	OFF PATH ON STRAIGHT: RIGHT TURN-OUT OF CONTROL
	OFF PATH ON CURVE
	OFF PATH ON CURVE: OTHER
80	OFF PATH ON CURVE: OFF CARRIAGEWAY ON BEND RIGHT
81	OFF PATH ON CURVE: OFF CARRIAGEWAY ON BEND RIGHT-
82	OBJECT
83	OFF PATH ON CURVE: OFF CARRIAGEWAY ON BEND LEFT
84	OFF PATH ON CURVE: OFF CARRIAGEWAY ON BEND LEFT-OBJECT
85	OFF PATH ON CURVE: LOST CONTROL ON CARRIAGEWAY
	PASSENGERS AND MISCELLANEOUS
90	MISCELLANEOUS PASSENGERS: OTHER
91	MISCELLANEOUS: PASSENGER FELL IN/FROM VEHICLE
92	MISCELLANEOUS: LOAD STRUCK VEHICLE
93	MISCELLANEOUS: STRUCK TRAIN
94	MISCELLANEOUS: STRUCK RAIL CROSSING FURNITURE
95	MISCELLANEOUS: HIT ANIMAL ON/OFF CARRIAGEWAY
96	MISCELLANEOUS: PARKED CAR RAN AWAY
97	MISCELLANEOUS: VEHICLE MOVEMENT NOT KNOWN

Table A.2. Average observed crash Cost by Region

Region	Total Cost 000's	Average Cost 000's	Total No. of Crashes
Great Southern	269367.300	58.154	4632
South West	1004253.800	64.753	15509
Gascoyne	68511.500	86.833	789
Mid West	259620.300	63.508	4088
Goldfields	375407.800	64.815	5792
Kimberley	217603.900	123.991	1755
Metropolitan	5496580.000	29.334	187376
Wheatbelt South	223413.000	97.560	2290
Wheatbelt North	446582.000	102.545	4355
Pilbara	215957.300	95.177	2269
Total	8577322.200	37.479	228857

CV

The author has over 30 years experience in traffic forecasting and transport modelling covering such items as traffic forecasting models, road safety analysis, asset management and economic analysis of road projects. In addition to model calibration, traffic forecasting included development of an incremental assignment method that allowed for separate analysis of the effects of intersections on travel times and the variation in traffic flow throughout the day. Another project was summarising daily traffic volume data into actual travel speed ranges so that it could be integrated into a model for estimating vehicle emissions. Asset management encompassed pavement life and seal life prediction, estimating the change in road authority and road user costs if freight transferred from rail to road and development of a model to predict annual road maintenance costs. Road project analysis covered vehicle operating cost models and the development of a system for analysing road projects in an urban network that also included the effects of intersections and used the same assumptions about the spread of traffic throughout the day and the effect of intersections as used in forecasting the traffic. Road safety analysis covered such topics as developing road crash rates by road stereotype for rural roads and separate crash rates for intersections and for mid block by road type for urban network analysis. Recent work has looked at the safety of heavy vehicles relative to other traffic, the residual effect of speed camera enforcement, the likelihood of drivers being involved in crashes by age group and gender, data analysis and presentation of driver fatigue monitoring data and analysis and presentation of skid resistance data.