IRTENZ

Technology 2000

PETER WARING/JOHN LONG

ACCIDENT RISK ANALYSIS

SUMMARY

Major road crashes involving multiple deaths or injuries can have political and legislative effects much greater than similar numbers of deaths or injuries spread out over numerous vehicle crashes. Such events occur so seldom that standard statistical analyses of crashes will be unable to demonstrate to road safety authorities and transport ministers the level of risk that they face in administering transport safety systems. This paper demonstrates a method of assessing the likelihood of such events over a given period of time.

INTRODUCTION

Although a major vehicle crash, for example of a bus with a truck, may make only a minor contribution to the overall road toll, the political and legislative effect on New Zealand road transport and on the Land Transport Safety Authority (LTSA), may be vastly more significant than the scale of the death and injury toll might indicate. In recent years multiple death crashes between buses and trucks have occurred in Australia and Canada, and such events may happen in any country at any time. A crash involving a school bus and a logging truck would be particularly emotive, as the Canadian experience shows, and it is prudent for the LTSA to determine the risk of such an event occurring in the short term. If likely, then preventative measures may be strengthened.

Unfortunately, the usual approach to determining the risk of road crashes, based on large numbers of crashes and standard statistical methods, is inappropriate to discover if what can happen is a one in five-year crash, a one in ten-year crash or a one in a hundred-year crash. There are, however, means by which the possibility of such a crash within a particular timeframe can be assessed. If the risk derived by such methods is small there is still the possibility of such an event happening in the short term, but a high risk requires urgent attention. In New Zealand in the last 5 years four school buses have been narrowly missed by crashing logging trucks, so the risk is far from academic. One method of assessing the risk is the application of Monte Carlo analysis.

Monte Carlo Analysis

This type of analysis is not new, and, as might be expected, it takes its name from a close association with gambling, particularly the use of a roulette wheel to generate random numbers. A French mathematician first used the method in 1768. However, the need for the generation of large volumes of random numbers limited its use until computers became available.

It first gained public prominence during the development of the first atomic bomb, when it became vital to know if a stray neutron from a random disintegration of an uranium 235 atom, or from a cosmic ray, could prematurely initiate the chain reaction. A premature chain reaction would blow the components of the bomb apart before sufficient criticality had been obtained to allow a multi-kiloton release of energy.

Obviously, it was not possible to detonate enough bombs to discover what the risk of a failure was. Other methods had to be used. Monte Carlo analysis enabled the risk of a premature and half-hearted explosion to be assessed.

The method ascribed the chances of a stray neutron occurring to depend on the generation of a random number which represented the time at which it appeared. Other random numbers represented the chance of the stray neutron initiating a self-supporting chain reaction. Since the specific time was associated with the approach of the bomb components to criticality, the size and speed of the subsequent energy release could be determined. If this process is run over and over again for many, many stray neutron appearances, the risk of an undersized explosion can be determined to an acceptable degree of probability. Fortunately, the first digital computers had been developed in time to assist with the process, otherwise the labour of computation would have been prohibitive. Nonetheless, atomic bombs have sometimes produced more of a pop than a bang.

Today, there are multitudes of software packages available which apply Monte Carlo analysis to a vast range of problems in chemistry, physics and engineering. It is used to solve problems in air traffic control and electron transfer. Its use in traffic engineering, however, appears to be limited, and, where road vehicles and safety are concerned, it appears to be limited to investigating potential collisions between automatically guided vehicles on intelligent roads.

Method Development

Crashes between school buses and trucks could be said to be more or less as random as the appearance of a stray neutron. They may not be, but they occur so seldom that there is insufficient information for any more elaborate assumption. Bus timetables and routes, however, are as determinate as the assembly of critical masses. In New Zealand, school buses and trucks operate on the same roads at the same times of day, although some types of transport operations in some areas voluntarily keep their trucks off the road during the times of operation of school buses.

From crash data accumulated by the Land Transport Safety Authority (LTSA), it is well established that trucks crash, regrettably quite often, on the roads where there may be school buses at the same time. Given enough time and truck crashes, it is probably inevitable, unless preventative measures are introduced, that a truck and a school bus will be in collision with major loss of life. If this event is unlikely in the next 50 years, however, then it is not a major cause for immediate concern, even though the risk is always present. At least four recent (within the last six years) near misses have occurred, in one of which a log from a crashing logging truck hit a school bus, so that an actual crash with a bus within a timeframe of a few years appears to be quite possible.

Mathematical Model

Monte Carlo analysis, applied to a relevant mathematical model, can enable the probability of such a crash occurring in the short term to be determined. To take a simple model, assume that a single school bus operates over a 20 kilometer round trip, morning and afternoon. The bus operates at a constant speed of 20 km/h without stops. The morning trip is from 8.00 am until 9.00 am, and the afternoon trip from 3.30 pm until 4.30 pm.

Assume trucks operate over the same route, but from 6.30 am until 10.00 pm, and that a truck can crash at any time during the day, and at any place along the school bus route. It is quite simple to programme a computer to choose two random numbers, one representing the time of day, and the other the place on the route where the crash occurred. The numbers can be chosen to represent a particular second during the day, and a particular metre location along the road. Another assumption is that the bus is involved in the crash if within 50 metres of where it occurred when it occurred (this distance was chosen from observation of the road length affected by typical truck crashes).

The model was run on a computer until a crash occurred between a truck and the bus, and the number of truck crashes that occurred before the bus was involved recorded. After running approximately one million simulated truck crashes, resulting in hits on 600 buses, the average number of truck crashes that occurred before the bus was involved was found to be approximately 1,600. It is obviously necessary to run the model for enough truck and bus crashes to establish statistically valid probabilities for the times and places where the crashes occurred.

One bus crash for every 1600 truck crashes appears to be quite a comforting number. In any given region of New Zealand that a school bus may be operating on a 20 km route, the number of truck crashes was not thought likely (at the time of starting to prepare this paper) to be more than one or two per year. No-one is going to be overly concerned if a crash is unlikely within a period of 500 or more years. Even if all the bus routes and truck crashes in New Zealand are considered, the risk does not appear unduly large from this model. However, we have been disconcerted to find that on one 12 km stretch of road, used daily by three school buses, around 22 logging truck crashes have occurred in an 8 year period, and most of these crashes do not appear on the LTSA crash database.

Furthermore, analysis of the results is not so comforting. If the results are grouped according to how many truck crashes occurred before a bus crash, for example in groups of 500 from 0-500 to 3500-4000 say (Fig 1, series 1), and in groups of 100 to 400-500 (Fig 2 Series 1), it can be seen that the distribution of crashes is not a Gaussian distribution about the mean, but is highly skewed. There is a probability of 26% that a bus will be involved in the first 500 truck crashes, and a probability of 46% for involvement in the first 1000 truck crashes. There is even a 10 % probability of a bus being involved in the first 200 truck crashes. (The distribution is actually binomial, with a probability p of 1/1600. For an infinite number of truck crashes, instead of approximately 1 million, the probability of a bus crash in 500 truck crashes is 0.27, and in 200 truck crashes is 0.12).

During the middle months of 1997 (and for occasional periods since then), logging trucks alone were crashing on New Zealand roads at a rate of 150 per year, so that prudence suggested widening the scope of the model, particularly in terms of the types of crash most likely to occur, and then seeing if similar high levels of risk still existed. To do this, a more complex model was required. As the complexity increases it becomes more difficult to find a solution mathematically rather than by Monte Carlo analysis.

On a real school bus route, there will be corners. From the LTSA's heavy vehicle crash database, it was already known that a preponderance of truck crashes occur on corners. The logging truck crashes referred to above all took place on corners. A truck crashing on a right-hand corner is likely to go off the road, whereas on a left-hand bend the crashing vehicle is likely to go straight into other traffic. Only crashes on left-hand corners were considered likely to involve the bus.

For the purpose of the more complex model, it was assumed that 60% of truck crashes in the model occurred on corners, and that 50% of those crashes were on right-hand bends. Ten bends were also assumed to be evenly spaced along the bus route.

Again for this model, using random number generation, it can be left to the computer to decide if the crash occurs on a bend or on a straight length of road, on a left-hand or right-hand bend, and at which bend along the route the truck crash occurs. However, this second hypothetical model demonstrates some worrying features, despite the addition of an extra degree of realism making some difference to the level of risk. Although, at first sight, risk appears to have been reduced by increasing realism in the model.

For example, the average number of truck crashes before a bus was involved increased to around 2,100. However, with the crash data again grouped and plotted on the same basis as for the simple model (Fig 1, Series 2 and Fig 2, Series 2), the distribution was again highly skewed. The probability of a truck crash involving a bus in the first 500 crashes is 21%, and in the first 1,000 crashes 37%. In the first 200 crashes, the probability of a crash involving a bus, at just under 10%, has hardly changed.

Final Model

The final model investigated was the real-life situation on the 12 km stretch of road on which logging trucks have been crashing at a steady (and ongoing, two have crashed recently) rate. Fig 3 is a map of the area, showing where the log truck crashes have taken place. It can be seen that all of the recorded crashes have occurred on corners. On this stretch of road three school buses operate, and the cooperation of the schoolchildren was sought to determine the time of day at which the buses are at various points along the road. It was assumed that the trucks operate between 6.00 am and 8.00 pm, and that they can only hit a bus when the truck crashes on a left-hand bend, and also that the bus must be within 10 seconds of the corner and approaching the truck. The results are shown in Figs 4 and 5.

If the average number of truck crashes before a bus is involved obtained from the model is considered, the results, again, are comforting. One bus is hit for every 5,000 truck crashes, and, with approximately 20 crashes in 8 years, on average a school bus will be hit every 2,000 years. Our vehicle compliance officers and the Police Commercial Vehicle Investigation Units (CVIU) can apparently afford to turn their attention elsewhere.

However, the model again shows a highly skewed pattern. Thirteen bus crashes can be expected out of 600 total bus crashes for the first 100 truck crashes out of the total of approximately 3 million truck crashes run in the model. At the present rate of truck crashes on the stretch of road this implies a probability of just over 2% of a bus being hit by a truck in the next 40 years. Not a particularly high risk, but the parents of the children travelling on the school buses on this road, knowing how often they see a logging truck crash, are worried about the safety of their children, and are not particularly comforted by statistics and mathematical models. The LTSA and the Police CVIU have recently been paying extra attention to logging trucks using the road.

Fortunately, the rate of truck crashes per km on this road is not (according to LTSA statistics) mirrored on other highways used by both trucks and school buses. Even so, with rates of truck rollovers averaging 120 a year, and with many of these crashes occurring on roads where school, service or tourist buses operate, the risk of a major fatality crash in the near future is not negligible. Additional Monte Carlo analysis, applied to the data available from bus timetables, could be used to quantify the risk.

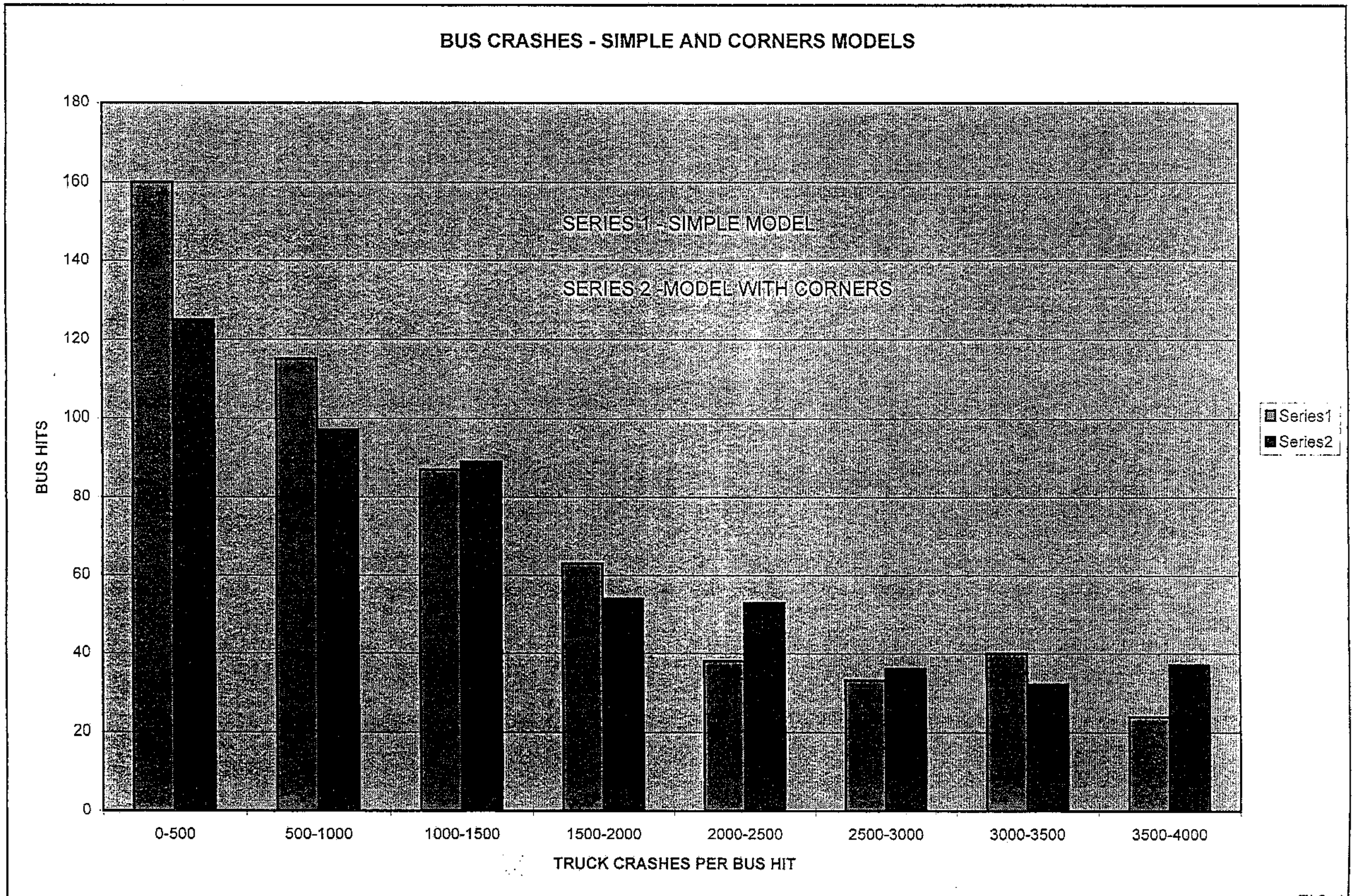
BUS CRASHES - SIMPLE AND CORNERS MODELS
SERIES 1 - SIMPLE MODEL
SERIES 2 -MODEL WITH CORNERS
BUS HITS
180
160
140
120
100
80
60
40
20
0
0-500
500-1000
1000-1500
1500-2000
2000-2500
2500-3000
3000-3500
3500-4000
TRUCK CRASHES PER BUS HIT
Series1
Series2

FIG.1

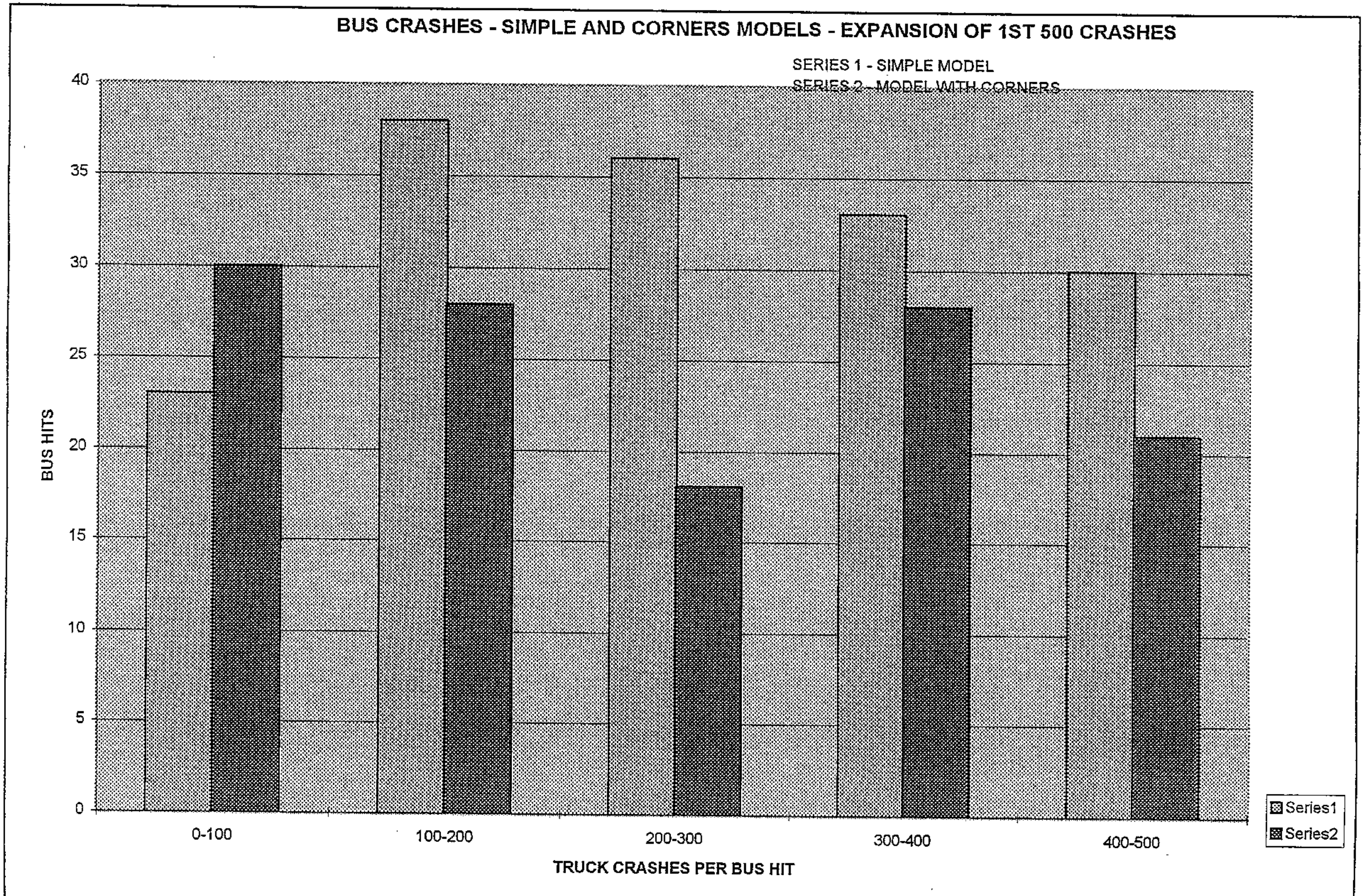

FIG.2

land transport safety authority

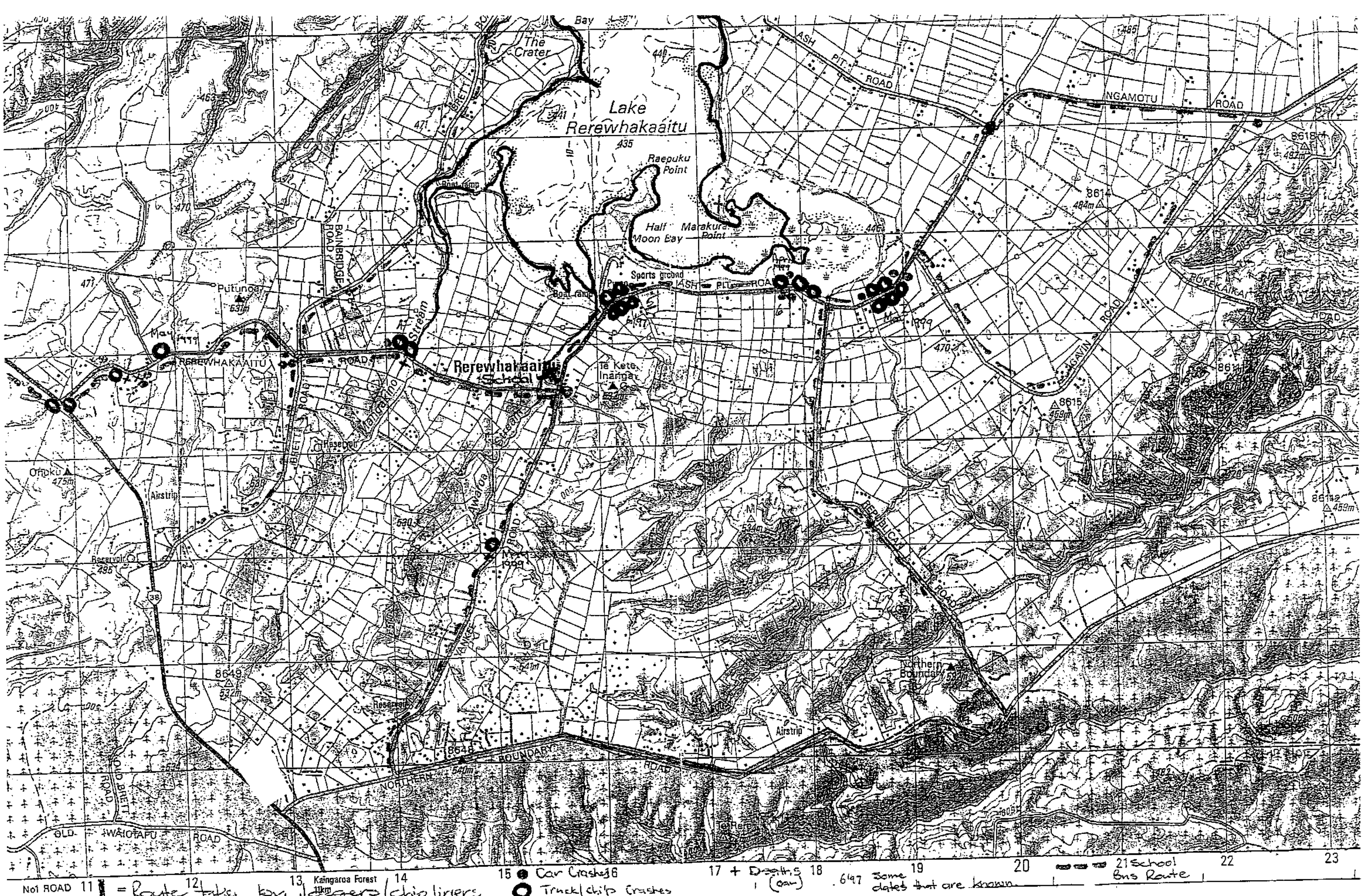

Fig. 3

transportsafe LAND TRANSPORT SAFETY AUTHORITY

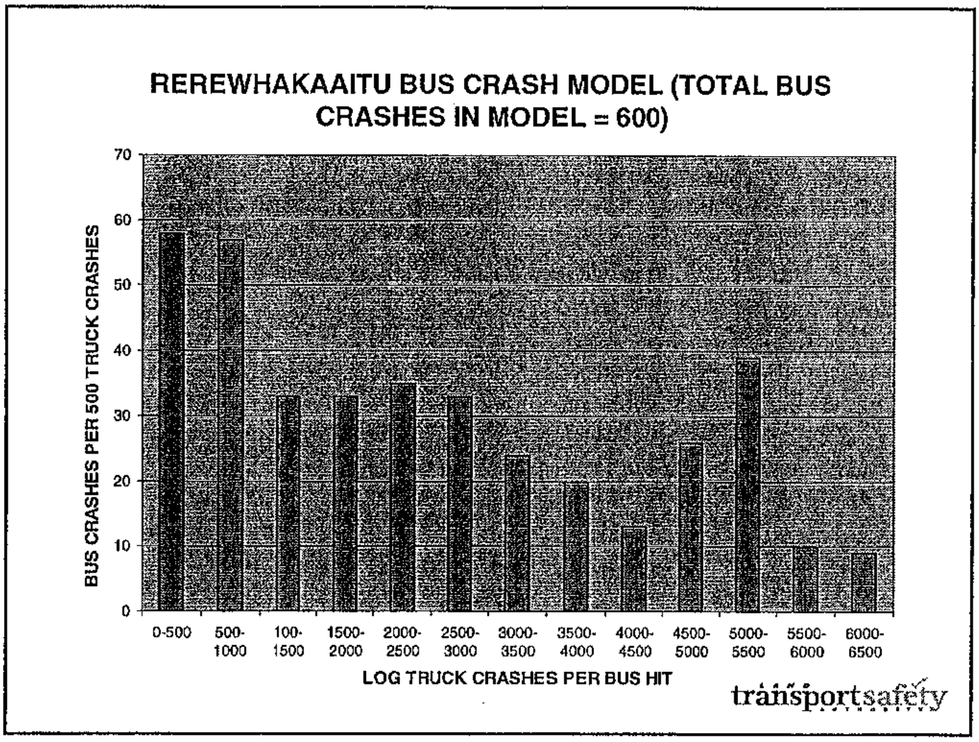
REREWHAKAAITU BUS CRASH MODEL (TOTAL BUS CRASHES IN MODEL = 600)
BUS CRASHES PER 500 TRUCK CRASHES
70
60
50
40
30
20
10
0
0-500
500-1000
100-1500
1500-2000
2000-2500
2500-3000
3000-3500
3500-4000
4000-4500
4500-5000
5000-5500
5500-6000
6000-6500
LOG TRUCK CRASHES PER BUS HIT
transportsafety

Fig. 4

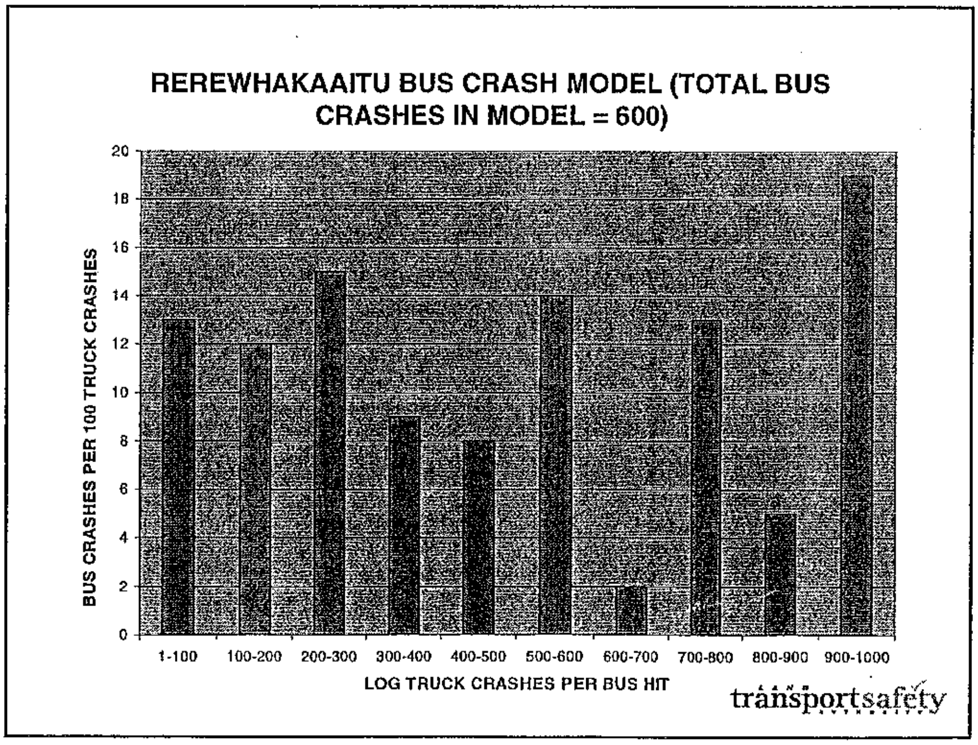
REREWHAKAAITU BUS CRASH MODEL (TOTAL BUS CRASHES IN MODEL = 600)
BUS CRASHES PER 100 TRUCK CRASHES
20
18
16
14
12
10
8
6
4
2
0
1-100
100-200
200-300
300-400
400-500
500-600
600-700
700-800
800-900
900-1000
LOG TRUCK CRASHES PER BUS HIT
transportsafety

Fig. 5