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TRAFFIC ACCIDENT RESEARCH UNIT

DEPARTMENT OF MOTOR TRANSPORT N.S.W.

CRASHES AT RAILWAY LEVEL CROSSINGS

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B.Sc. (Tech.)

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The Traffic Accident Research Unit was established within the Department of Motor Transport, New South Wales, in May 1969 to provide a scientific approach to the traffic accident problem.

This paper is one of a number which report the results of research work undertaken by the Unit's team of medical, statistical, engineering and other scientists and is published for the information of all those interested in the prevention of traffic accidents and the amelioration of their effects.

D. R. Coleman

Commissioner.

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ABSTRACT

The 486 accidents reported by Police to have occurred at railway level crossings in New South Wales in the four years 1966 to 1969 were studied. Less than half were collisions between a motor vehicle and a rail vehicle. The remainder were mostly collisions between motor vehicles and fixed objects such as the crossing gates, fences, signposts and so on. The distribution of reported motor vehicle speeds in the latter group approximated the normal distribution. However the reported speeds of motor vehicles that collided with rail vehicles followed the negative exponential distribution. This implies that exposure time at the crossing has an influence on the incidence of accidents. Consequently there is a possibility that a legal requirement that a vehicle stop at a crossing it is otherwise free to cross may increase rather than decrease its risk of collision by prolonging the time it will spend in the conflict area. At some crossings sight distances, the approach speeds of trains and the performance limits of motor vehicles will so combine thatautomatic train-actuated warning devices will be the only reliable protection against collision.

Surveys of motor vehicle speeds at crossings having a variety of environmental conditions and methods for controlling road traffic showed that a crossing open to motor vehicles has little influence on the speed of them, and that the drivers traversed the crossings at speeds which were not significantly different from their speeds on adjacent road sections with similar geometry and other characteristics. The distribution of vehicle speeds traversing crossings approximated the normal distribution.

The spatial distribution of both groups of accidents (motor vehicle/rail vehicle collisions and motor vehicle/fixed object collisions) over the 2,790 level crossings in New South Wales followed a Poisson (random) distribution.

INTRODUCTION

The aim of this study is to appraise on the basis of research data, including the results of field studies, the validity of arguments and counter-arguments about two requirements of the New South Wales traffic law affecting the duties of motorists at level crossings.

In New South Wales, Regulation 69A under the Motor Traffic Act requires the person driving a motor vehicle of any type on a public street not to exceed 15 m.p.h. when the vehicle is approaching and within 100 yards of a railway level crossing without gates. The same Regulation also imposes in respect to such crossings requirements that in some circumstances drivers of motor vehicles not only stop within prescribed distances from the crossing but also refrain from proceeding until it is safe to do so. These circumstances are that if there is a "STOP" sign the requirements apply to vehicles of all types, whereas in the case of vehicles carrying explosive or inflammable loading they apply even if a "STOP" sign is *not* displayed.

Critics of the first of these provisions - the 15 m.p.h. speed limit for all vehicles approaching crossings without gates - advocate its repeal on the ground that it is completely out of keeping with conditions at many crossings, is rarely, if ever, complied with in practice and, in any event, is not provided for in the National Road Traffic Code - the model set of Regulations that has been endorsed by the Transport Ministers of all Australian States and the Commonwealth with the aim of achieving uniformity in the motor traffic laws in Australia. Supporters of the provision, on the other hand, urge its retention as a necessary countermeasure to level crossing accidents which, characteristically, have severe consequences.

The requirement that,irrespective of the circumstances, drivers of lorries like petrol tankers bring their vehicles to a halt at "open" crossings (as referred to above) seems to have been accepted for some years as self-evidently a desirable safety precaution. However, it has recently been called into question on the ground that a stop may actually aggravate the inherent danger at uncontrolled level crossings because the lorry, having halted, and often being heavily laden, will be incapable of moving across the railway lines as quickly as if it had not stopped. The period for which the lorry is exposed to the risk of collision because it is in the area of conflict (that is, the time it will take to cross the railway tracks) will then be longer and the danger thereby prolonged. Another aspect is the degree as distinct from the duration of danger. The environmental factors of main influence in this respect include, in particular, the distance at which an approaching train can be seen. These factors are commented on later.

Railway level crossing accidents involving collisions between motor vehicles and railway rolling stock* are usually traumatic events resulting in a highly emotional public reaction. However, as an accident type they are relatively insignificant in the overall traffic accident context; they account for less than one tenth of one percent of all reported accidents. The severity of these accidents, however, is approximately eight times the New South Wales average in terms of fatalities per accident and approximately one and a half times the average in terms of injured persons per accident. Although the severity of this type of accident is quite high, there are other classes of accidents with similar severity; for example, accidents where vehicles collide with fixed objects have a severity

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* In this study "rolling stock" means any type of vehicle constructed to travel on railway lines. It does not exclude locomotives which the term "rolling stock" sometimes includes.

approximately twice the average in terms of both fatalities and injuries per accident and, while collisions with fixed objects may not be quite as severe for each individual accident, the total numbers account for almost 20% of all persons killed and 15% of all persons injured in traffic accidents in New South Wales.

In order to obtain an understanding of some of the influencing factors associated with these accidents a detailed study was undertaken of the 486 traffic accidents which occurred at railway level crossings in New South Wales during the four year period 1966 to 1969. Only 218 of the 486 accidents were road vehicle/rail vehicle collisions, the remaining 268 being either single-vehicle accidents where the motor vehicle collided with railway crossing gates, fences, signs and so on, or collisions between motor vehicles.

At the end of 1969 there was a total of 2790 level crossings on public roads in New South Wales. 45 of these were protected by half-boom gates in conjunction with Type "F" flashing light signs as described in Australian Standard No. CE.1-1960 (the SAA Road Signs Code). These signs consist of a white reflectorized diagonal cross bearing the words "Railway Crossing" in black letters and surmounting in the following order (1) a white sign showing in black numerals and letters the number of railway tracks to be crossed; (2) twin flashing red lights horizontally disposed 2ft. 6 in. apart; and (3) a square sign having a black background and bearing the words "Stop on red signal" in reflectorized white letters. Another 59 of the crossings were protected by Type "F" flashing light signs only, 132 had attended gates (full or part time), 12 had gates controlled from signal boxes and 100 had SAA Code Type "D" signs. These consist of a white reflectorized diagonal cross bearing the words "Railway Crossing" in black letters (as for Type "F") surmounting the standard regulatory "Stop" sign - an octagon with both the background (red) and the word "Stop" (white) reflectorized. Of the 2,434 other crossings, approximately 490 were on fenced lines with unattended gates, 300 on fenced lines with no gates (cattle grids only) and the remainder open, unattended crossings on unfenced lines. There were also approximately 3,500 private level crossings on New South Wales Government Railway lines and approximately 200 level crossings on private railway lines.

RESULTS

As well as a detailed analysis of level crossing accidents which occurred during the four year study period, an examination was made of the trends over the past fifteen years in the number of level crossing accidents and the numbers of persons killed and injured in these accidents. As a comparison a similar examination was made of the trend of the totals for all accidents in New South Wales in the same years. These data are shown in Table 1.

It is interesting to note that while the total number of accidents and the number of persons killed and injured for New South Wales has increased almost linearly over this fifteen year period to approximately double the 1955 figures, the number of accidents and the number of persons killed and injured at railway level crossings has remained virtually constant. Linear regression line equations of the data are shown in Table 2. The slopes of the linear regression lines for the level crossing data, when tested, statistically, did not differ significantly from zero ($P<0.05$).

It may be argued that the considerable amount of crossing protection implemented over this period has been instrumental in holding these accidents constant in the face of a continuing upward trend in other accidents. However, it might be more realistic to attribute this result more to the randomness and low probability of occurrence of this type of accident coupled with the fact that the total number of crossings has remained virtually unaltered over this period of time. The hypothesis that the number of persons killed and injured is an almost linear function of the number of level crossings is supported by this constancy and by the similarity of rates for level crossings in the other Australian States in terms of accidents, killed and injured per crossing (see Table 3). Further support is given by the fatality rate per crossing in the U.S.A. This has an average of 0.0064 deaths per crossing per year over the past 10 years, and the number of fatalities at level crossings has remained relatively constant over the same period.

Moreover, the number of accidents involving rolling stock recorded for unprotected crossings did not differ significantly from that expected (the expected number being derived from the proportion of unprotected crossings in the total number). This indicates that the accident rate per crossing for unprotected crossings is not significantly different from that for protected crossings.

The 268 crashes which occurred at or on the approaches to level crossings but did not involve rail vehicles were divided into three groups of about equal size. These groups were collisions between motor vehicles ("rear-end" impacts, for example) single vehicle crashes where the vehicle collided with the crossing gates, and single vehicle collisions with fixed objects other than the crossing gates such as fences and signposts. While these accidents were not as severe in terms of fatalities per accident, they approached the severity of rolling stock accidents in terms of injuries per accident.

The spatial distribution of level crossing accidents followed the Poisson distribution. Those accidents involving rolling stock were distributed over the 2790 level crossings in New South Wales as a Poisson process with parameter r_1, equal to the overall rolling stock accident rate per crossing (see Table 4). For accidents not involving rolling stock the spatial distribution was similar with the parameter for this distribution being r_2 (see Table 5).

A characteristic pattern of reported vehicle speeds was exhibited in accidents involving rolling stock. The distribution of these speeds follows very closely the negative exponential distribution (Figure 1), whereas the distribution of the reported speeds for those not involving rolling stock approximated the normal distribution except for those accidents resulting from the operation of boom gates and lights (Figure 2). The reported speeds for these latter accidents resulted in a higher than expected frequency of speeds below 15 m.p.h.

To determine the factors that influence vehicle speeds at level crossings, speed surveys were carried out at thirteen level crossings covering a range of environmental conditions and methods of protection. The results of these surveys are summarized in Tables 7 and 8. It was observed that the speeds of vehicles negotiating level crossings varied over a wide range, but the only influence that crossings seemed to exert on motor vehicle speeds was to produce lower speeds where the surface of the crossing was inferior to that of the roadway on the approach. Where the geometry and characteristics of the crossing were of at least equivalent quality to the adjacent road design, the speed distribution of vehicles negotiating the crossing did not differ significantly from that at the adjacent road sections. At each of the locations the speeds recorded approximated the normal distribution, as is characteristic of "free" vehicle speeds on the road.

It was apparent from the results of these surveys that the speed limit of 15 m.p.h. currently imposed by Motor Traffic Regulation 69A on motor vehicles that are approaching and within 100 yards of a level crossing without gates has a negligible effect on the speed of those vehicles. For example, the crossing with the lowest recorded mean speed of 16 m.p.h. was protected by half-boom gates, flashing lights and bells, and because of this protection the speed limit was the road speed limit of 35 m.p.h. The level crossing with the highest mean speed recorded was an open crossing without protection, and was therefore subject to a speed limit of 15 m.p.h. However, the mean speed recorded was more than three times this legal limit, and the speed distribution did not differ from the adjacent road section where the speed limit was 60 m.p.h. The 85th percentile speed of 59 m.p.h. at the crossing was consistent with the road speed limit.

DISCUSSION

Accidents at level crossings are comparatively rare events in the total accident scene and, for individual crossings, are usually very rare indeed. It is well-nigh impossible therefore to assess objectively *as accident countermeasures* the various types of traffic engineering treatment applied to crossings (except, of course, total elimination of conflict by building a bridge or tunnel - something that guarantees a 100% "cure").

Similarly, it is unreliable to compare, *by measuring accident experience*, the relative risk levels within any group of crossings. In practice therefore, priorities for improvements in the form of signs, lights, gates (and, perhaps, even grade separation) must have been determined on other criteria including, no doubt, response to the intense local public reaction that often follows a level crossing accident notwithstanding its rarity and, hence, *relative* unimportance in the total local accident situation.

Endeavouring to achieve a reduction in this type of accident by imposing regulations on the speed of motor vehicles negotiating level crossings would seem fruitless when it is considered that the effectiveness of regulations depends to a great extent upon their acceptance by the motoring public, and, in turn, upon the level of enforcement.

It is obvious from the speed surveys conducted that drivers simply do not obey the present speed limit of 15 m.p.h. on open level crossings. However, the attitude of drivers in travelling at these speeds is not unreasonable when the level crossing is considered in the context of the general road environment. For, although the severity of accidents at level crossings is higher than the average, the actual *risk* of involvement in such accidents is extremely low.

Normally the motor vehicle driver accepts as a part of the driving task a certain level of risk, and, in general, his behaviour is such that this risk is maintained at a relatively constant and acceptable level. The approach speeds recorded at level crossings are consistent with what he correctly perceives as a low level of risk of collision.

This attitude to risk, displayed by most drivers, is a major reason why they generally obey reasonable restrictions imposed on them in the interests of reducing or minimizing the risk of accident or injury. However, when restrictions are imposed which from the motorists' viewpoint are illogical, unnecessary or unreasonable, their observance is notoriously poor, as is the case for the 15 m.p.h. speed limit under discussion.

This concerted judgment of drivers has been one factor in the fairly extensive use of speed zoning whereby, for example, the general built-up-area speed limit of 35 m.p.h. has been increased in sections of streets where road design, traffic conditions and roadside development and activity justify such changes. In contrast, however, the corresponding judgment drivers display in concert in relation to the level crossing limit has not been permitted so far to exercise a corresponding moderating influence.

On the other hand, however, where hazardous road conditions exist which are not obvious from the driver's viewpoint, it has been the practice in highway and traffic engineering to endeavour to remove the hazard by road reconstruction and improvement. Frequently, when this is not economically feasible, it is the practice to provide the road user with adequate signposting or signal systems to identify the unseen or less obvious hazard and provide warning of its presence. The respect for and observance of these devices is generally quite high, and as a result they are usually effective as accident countermeasures.

Extending this reasoning to railway level crossings, a number of unsatisfactory and anomalous situations manifest themselves as a result of the regulations. For example, there are many uncontrolled open level crossings where the 15 m.p.h. limit exists, particularly on rural highways, where conditions are such that it would be possible for motor vehicles to negotiate these crossings with an acceptable level of safety at speeds in the region of 60 m.p.h. Similarly, there are many other level crossings where although such vehicle speeds may not be compatible with adequate safety, intermediate speeds somewhat in excess of the current 15 m.p.h. speed limit would be appropriate. On this basis, therefore, a blanket restriction for all crossings is neither appropriate nor acceptable when due consideration is given to the extreme variation in conditions which exist at level crossings.

Pursuing this line of reasoning, the most practical approach would appear to exist in the provision of appropriate advice of the maximum safe speed for negotiating each uncontrolled crossing by the use of "advisory" speed signs in conjunction with the standard signposting arrangement. The consistency and logic of such a policy should lead to better observance of the maximum safe speed for each crossing because it will be known to motorists that each such speed has been tailored to the particular conditions at the individual crossing - including, in particular, sight distances and train approach speeds - and is not a purely arbitrary blanket limit imposed without regard to local conditions.

There will, of course, be open crossings where by itself a reduction of speed, even to the point of stopping, will never suffice because of local features including, in particular, short sight distance. To avoid putting drivers in the position of playing a form of Russian roulette with trains at these sites, it will probably be necessary to accept that stricter controls like automatic train-actuated warnings or protective devices are the only solution that will afford real, rather than illusory, protection.

Comparison of the distributions of reported speeds for accidents, involving both rolling stock and non-rolling stock (figures 1 and 2), and the distribution of crossing speeds observed at a variety of locations allows some interesting conclusions. The negative exponential distribution of recorded rolling stock accident speeds indicates that these speeds do not follow the general pattern of approach speeds, which follows an essentially normal distribution. The influence of exposure time on the crossing is demonstrated by this accident speed distribution. The disproportionate frequency of the very low speeds in these accidents supports the hypothesis that the act of stopping or negotiating crossings at very low speeds may magnify the hazard or introduce additional ones. On the other hand, the reported accident speed distribution for the non rolling stock accidents is best described as a mixture of an approximately normal distribution with a uniform distribution over the range 0 - 15 m.p.h. The normal component of the distribution is what might be expected from the actual speeds recorded for vehicles negotiating crossings. The uniform component is almost entirely composed of those accidents resulting directly from the operation of automatic boom gates and lights, where vehicles either collide with the gates or with the rear end of other vehicles which have stopped suddenly.

Analysis of the spatial distribution of both rolling-stock and non-rolling-stock accidents adds weight to the concept that level crossing accidents are essentially random events and their occurrence is governed mainly by chance. The distribution of both types of accidents follows reasonably well the Poisson (random) distribution with parameters for each type of accident equal to the mean number of accidents per crossing in the four year study period (see Tables 4 and 5). This method of analysis also served to indicate those locations where the observed frequency of occurrence was significantly higher than that expected from the Poisson distribution. For example, on the basis of a random distribution of accidents over the 2,790 level crossings in the State, the chances of any crossing having more than, say, three accidents in the four year period is almost zero. Therefore, any location with more than three accidents could be considered to be hazardous in some way and in need of improvement.

For accidents involving rolling stock, only two locations were revealed by this analysis to have an accident frequency which was greater to a statistically significant extent and,therefore, presumably related to some environmental deficiency. However, this has already been recognised and both locations are currently being substantially improved, one by the installation of half-boom gates, lights and bells and the other by Type"F"flashing lights.

Those locations with a higher than expected frequency of non-rolling stock accidents are more numerous. However, these particular locations are associated either with exceptionally high traffic volumes or with substandard design geometry of the adjacent road sections, and hence the implementation of level crossing protective devices is unlikely to effect any significant reduction in accident rate.

Protective devices such as half-boom gates and flashing lights, while they do not in themselves guarantee safety, do provide protection against collisions with rolling stock in all but the most unavoidable of accidents. On the other hand, the cost of elimination of a crossing by the provision of grade separation, either with an overpass or an underpass, is likely to be up to ten times greater than the protection device and therefore virtually impossible to justify on the basis of inherent hazard alone. On a cost-benefit basis, grade separation at level crossings can only be justified if the road and rail traffic is such as to cause disproportionate delay and inconvenience to the road user.

For the level crossings in N.S.W. alone, the approximate cost of providing grade separation at all locations would probably be in excess of three hundred million dollars, somewhat out of proportion with the expected savings in terms of persons killed and injured and in property damage. From examination of the bald statistics on accidents occurring in N.S.W. at bridges and similar structures shown in Table 6, and having in mind that there are currently some 8,000 odd bridges (including culverts longer than 20 feet), it is apparent that these structures with which we would replace level crossings are just as much a hazard in terms of accidents and injuries per location, and of the same order of magnitude in terms of fatalities per location. This comparison, whilst being somewhat crude in that it does not take account of proper statistical controls such as relative exposure, does serve to illustrate that although grade separation does remove the hazard of collision with rolling stock it can introduce other hazards of the same order of magnitude.

The foregoing should not be misconstrued to contend that the elimination of railway level crossings is not desirable, but merely that the priority of this road accident countermeasure should be viewed unemotionally and without forgetting other countermeasures competing for the meagre funds available. Undue attention to a few spectacular level crossing crashes, while it might provide a salve to the feelings of a concerned community, will have a negligible effect on the road traffic accident problem as a whole.

It is clear from this study that the promulgation of a law imposing a uniform "blanket" requirement that road vehicles slow down or stop at level crossings that do not have train-actuated protective devices like gates or warning lights is a futile approach to the problem of abating the risk of collision between road vehicles and rail vehicles at such crossings. More serious however is that the requirement to stop, being more stringent, gives a heightened sense of safety in every instance whereas, in fact, that belief is purely illusory where the local conditions are such that the risk of collision is not reduced at all or, as is obviously worse, increased.

It follows that a rational approach to treatment of level crossings as an accident countermeasure necessitates individual treatment of each. Established traffic engineering techniques are available for this purpose. Management decisions taking into account priorities for other work are the only other pre-requisite.

In the event of such programmes being embarked upon decisions would, presumably, be necessary as to what changes in the law were called for. For example, could a system of "absolute" speed limits fixed individually for individual crossings according to the local environment be applied under existing powers? Secondly would some modification of Regulation 69A (the present requirement in New South Wales) be needed to provide that such fixed limits would over-ride the general 15 m.p.h. restriction? Such a provision would appear necessary in the transition period when measures for crossings were being determined individually or in the event of it being decided that there might always be a small residue of crossings that could not receive individual treatment. These legal or administrative questions are perhaps outside the scope of this discussion but they would not appear to be difficult to solve.

CONCLUSIONS

(1) The 15 m.p.h. speed limit on all vehicles approaching level crossings without gates and the requirement that lorries with dangerous loads like petrol and explosives stop at such crossings irrespective of local circumstances make, at best, a questionable contribution to reducing the risk of level crossing accidents.

(2) The special speed limit of 15 m.p.h. discussed in this paper is widely ignored by drivers. The likelihood is that those aware of it regard it as incompatible with reasonable driver behaviour. Whatever the explanation, the limit is of negligible benefit as an accident countermeasure in practice.

The prevailing speeds of road vehicles on the approaches to crossings are influenced mainly by the physical characteristics of the adjacent section of road. Any reduction in the prevailing speed necessary to reduce the risk of collision between road and rail vehicles is much more likely to be achieved by *combining* existing means for giving drivers adequate warning of the presence of the crossing and :-

(a) applying by signs (if necessary of a new type to be provided for by amendments to the law) a special speed limit assessed individually *for each particular crossing* by "speed zoning" techniques; or

(b) advising drivers of the maximum safe speed *for each particular crossing* by erecting advisory speed limit signs as is done for large numbers of curves on many sections of road in New South Wales.

Methodical surveys using established traffic engineering techniques could be made to apply these methods concurrently. Alternatively, one could be adopted to the exclusion of the other. This would not cut across existing works programmes for up-grading anti-collision protection at crossings by installing lights, gates and so on.

(3) From the viewpoint of *abating the risk of collision* (as distinct from consideration as to the consequences of collision if one does occur) there is no justification for singling out lorries carrying explosives, petrol and other prescribed dangerous materials as being subject to a requirement to stop at all crossings without gates irrespective of the circumstances.

The environmental factors that have a major influence on the risk of collision are the same in nature for all road vehicles irrespective of type. They include in particular the distance at which an approaching train can be seen by the driver of the road vehicle (or heard by him - but this is not a reliable parameter for reasons like ambient noise and wind speed and direction), the approach speed of the train, the time the road vehicle takes to cross the railway lines and get clear and (as an alternative to the last) the distance the road vehicle will take to stop before encroaching on the crossing if a train *is* approaching.

To disregard that these factors will interact in a different way from crossing to crossing - which is precisely what the present requirement to stop does - can increase rather than decrease the risk of collision. Forcing a vehicle to stop will usually result in it traversing the crossing more slowly with a consequent increase in exposure time. This increase will invariably be greater when, as is the case with heavy lorries - especially when laden, the rate of acceleration is low.

(4) To reduce the risk of collision (as opposed to merely creating the illusion of doing so) requires that the form of protection for each individual crossing be the subject of an individual rational decision made on the basis of available traffic engineering techniques. It should be practicable for such decisions to be made in the course of surveying crossings on a priority basis in order to establish for each crossing the highest safe approach speeds for vehicles generally.

(5) In cases where road-vehicle-to-train sight distances fall below a determinable minimum, automatic train-actuated warning or protective devices will be the only sure solution.

TABLE 1

Accident trends during the period 1955 to 1969

Year ending December	No. of accidents		No. killed		No. injured	
	At railway crossings	N.S.W. total	At railway crossings	N.S.W. total	At railway crossings	N.S.W. total
1955	138	32621	4	754	60	15437
1956	126	37379	20	820	70	17059
1957	161	41938	7	765	55	18131
1958	172	46639	9	824	126	19951
1959	165	50016	5	859	72	20910
1960	156	51316	18	978	45	22655
1961	141	48939	15	918	60	21839
1962	141	49725	5	876	58	21468
1963	161	55195	14	900	77	24652
1964	149	59233	12	1010	58	26631
1965	143	65348	18	1151	73	29157
1966	115	67094	15	1143	56	28981
1967	110	70641	9	1117	52	29501
1968	149	76288	22	1211	71	30919
1969	165	85188	11	1188	72	32752

Note: The recorded total for the four years 1966-1969 covered by this study was 539 (col.2). Close examination of the original data eliminated 53 of these which had been incorrectly categorised because of coding error or wrong information on the original reports. The study is thus based on the 486 remaining.

TABLE 2

Linear regression equations of data from Table 1

At railway level crossings

Number of accidents	:	$y = -0.77x + 152$	$(r = -0.19)$
Number killed	:	$y = 0.43x + 8.8$	$(r = 0.43)$
Number injured	:	$y = -0.57x + 72$	$(r = -0.14)$

New South Wales total

Number of accidents	:	$y = 3196x + 30270$	$(r = 0.97)$
Number killed	:	$y = 33.4x + 701$	$(r = 0.94)$
Number injured	:	$y = 1189x + 14493$	$(r = 0.98)$

Note: x is a code number for year
For example 1955 : x = 1 and so on.

TABLE 3

Accidents, Killed and Injured

Average rates per crossing per year

State	Accidents	Casualty Accidents	Killed	Injured
New South Wales	0.053	-	0.0044	0.024
Victoria	-	0.021	0.0084	0.022
Queensland	0.074	0.027	0.0053	0.040
South Australia	0.078	0.019	0.0046	0.026
Western Australia	0.055	0.016	0.0049	0.021
Tasmania	-	0.014	0.0027	0.013
U.S.A.	-	-	0.0064	-

TABLE 4

Spatial distribution of level crossing accidents involving rolling stock (1966-1969)

Mean accident rate per crossing $r_1 = 0.064$

No. of accidents n	Observed frequency of crossings with n accidents f_o	Expected frequency of crossings with n accidents (from Poisson distribution) $f_e = \frac{r^x e^{-r}}{x!}$
0	2646	2618
1	121	167
2	20	6
3	1	0.1
4	1	0
5 - 9	0	0
10	1	0
>10	0	0

TABLE 5

Spatial distribution of level crossing accidents NOT involving rolling stock (1966-1969)

Mean accident rate per crossing $r_2 = 0.095$

No. of accidents n	Observed frequency of crossings with n accidents f_o	Expected frequency of crossings with n accidents (from Poisson distribution) $f_e = \frac{r^x e^{-r}}{x!}$
0	2645	2536
1	91	242
2	25	12
3	14	0.4
4	4	0
5	6	0
6	0	0
7	3	0
8	0	0
9	1	0
10 - 15	0	0
16	1	0
>16	0	0

TABLE 6

Accidents at bridges and similar structures

Year ending December	Total number of accidents	Persons Killed	Persons Injured
1955	470	11	194
1956	391	6	140
1957	622	23	250
1958	781	17	328
1959	654	23	242
1960	625	14	270
1961	612	40	290
1962	519	31	258
1963	617	24	282
1964	680	29	364
1965	671	27	355
1966	579	34	304
1967	447	33	201
1968	902	24	432
1969	962	17	462

TABLE 7

Environmental details of level crossings at which speed surveys were conducted

(For results of speed surveys see Table 8)

Location number	Location	Road width (feet)	Crossing surface condition	Horizontal alignment	Vertical alignment	Distance to nearest junction (feet)
1	Railway Road, Como	24	very poor	straight	downgrade with abrupt change	100
2	Old Bathurst Rd, Emu Plains	24	poor	straight	distinct crest	120
3	Koorawatha	21	good	curves	level	30
4	Werrington Rd, Werrington	24	good	curve	sth. side level, nth. side down-grade	200
5	Aston Street, Rosehill	24	very poor	straight	crest	25
6	Rockview	18	good	curves	level	30
7	Banksia St, Botany	42	good	straight	slight crest	100
8	Lake Albert Road, Wagga	54	good	straight	crest	138
9	Parramatta Rd, Granville	2x24 median	good	straight	level	400
10	Old Junee	18	good	nth. side straight, sth. side curve	level	50
11	Princes Highway, Loftus	2x24 median	good	open curve	level	1500
12	The Rock	15	good	open curve	slight rise	1000
13	Hume Highway, Berrima	21	good	straight	level	1500

TABLE 8

Details of speed surveys and accidents

Location number	Road speed limit m.p.h.	85%ile vehicle speed m.p.h.	Crossing protection	Vehicle speeds		Accidents involving rolling stock (1966-1969)		
				mean m.p.h.	S.D. m.p.h.	Acc.	No. killed	No. inj'd
1	35	20	½ boom gates, lights and bells	16	3.2	1	-	-
2	35	27	½ boom gates, lights and bells	23	4.4	-	-	-
3	35	27	warning signs	23	4.0	1	-	-
4	35	31	½ boom gates, lights and bells	25	5.9	-	-	-
5	35	31	½ boom gates, lights and bells	25	5.8	-	-	-
6	50 (prima facie)	33	warning signs	29	4.4	-	-	-
7	35	34	type 'F' lights and bells	29	5.6	2	-	-
8	35	36	warning signs	32	5.3	2	-	-
9	35	37	gates, lights and bells	33	3.5	-	-	-
10	50 (prima facie)	45	warning signs	40	6.2	1	-	-
11	45	45	type 'F' lights and bells	41	5.0	-	-	-
12	50 (prima facie)	49	warning signs	44	5.2	-	-	-
13	60	59	warning signs	48	6.8	2	-	1

FIGURE 1

Histogram of reported vehicle speeds for accidents involving rolling stock

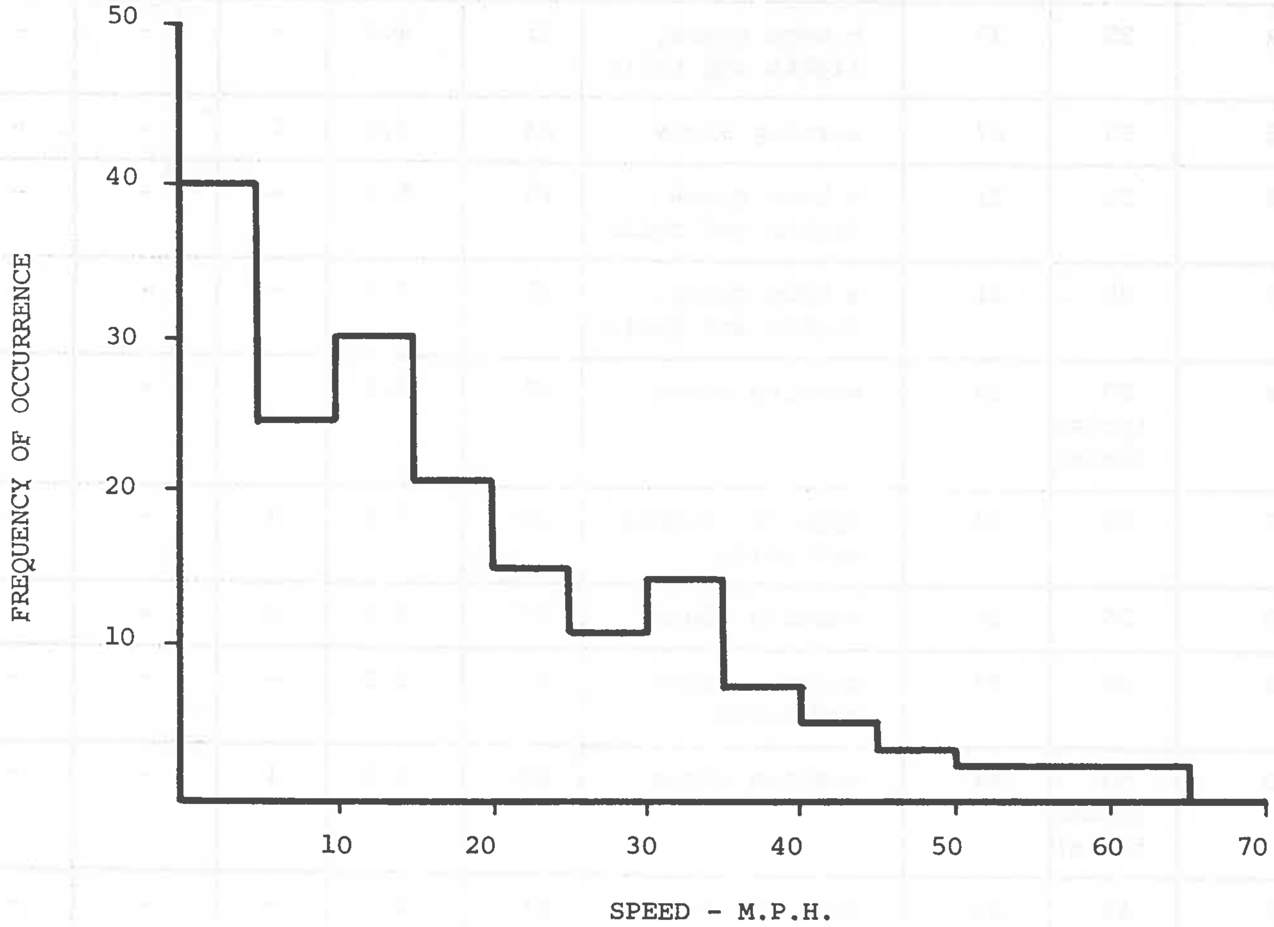
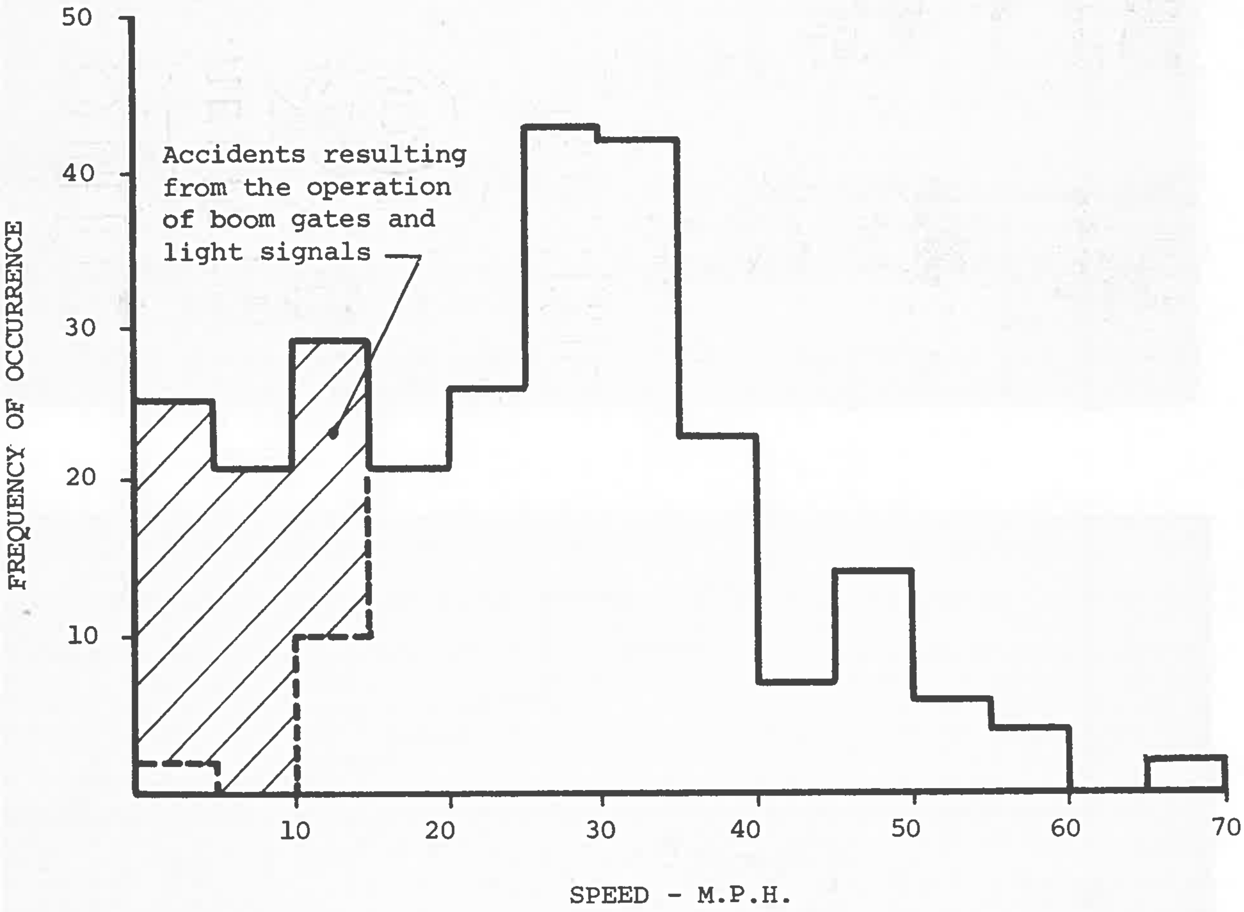
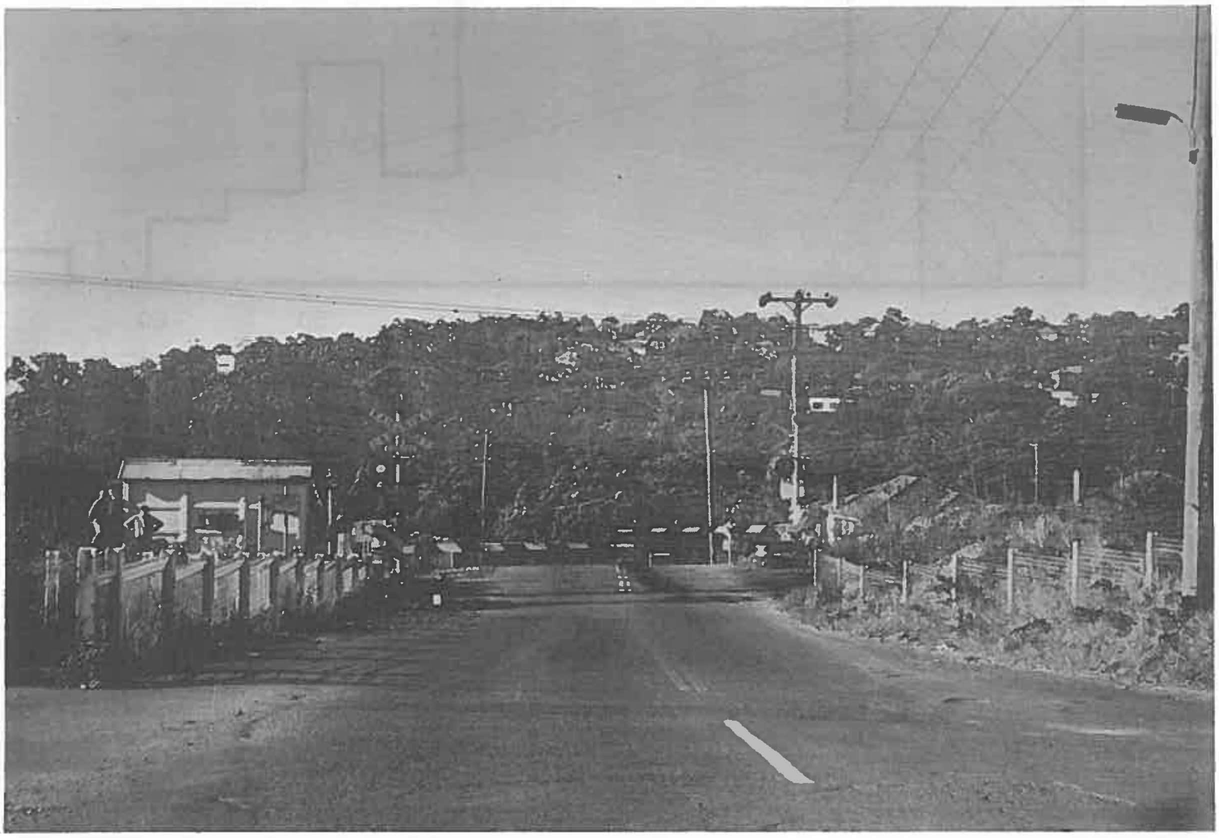


FIGURE 2

Histogram of reported vehicle speeds for accidents not involving rolling stock





Location No. 1
Railway Road, Como

Location No. 2
Old Bathurst Road, Emu Plains

Location No. 4
Werrington Road, Werrington

Location No. 5
Aston Street, Rosehill

Location No. 7
Banksia Street, Botany

Location No. 9
Parramatta Road, Granville

Location No. 11
Princes Highway, Loftus

Location No. 13
Hume Highway, Berrima