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THE EFFECT OF VEHICLE LIGHTING ON PEDESTRIAN MOVEMENT IN WELL-LIGHTED STREETS

by

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ABSTRACT

An experiment has been carried out to find how the type of lighting shown by an approaching vehicle affects the behaviour of pedestrians crossing well-lighted roads (away from crossings) at night.

Results were obtained by the analysis of cine film taken from a car using either sidelights or dipped headlights travelling as near as possible to 32 km/h (20 mile/h) in two-way streets in Central London.

The vehicle lighting had no significant effect on how far ahead of the car or how quickly pedestrians crossed the road, or on the proportion (about 80%) of those stepping into the road who actually crossed in front of the car. With both types of lighting about 90% of pedestrians in the road were first seen on the film as dark objects against a light background (i.e. in silhouette).

The gap accepted by 50% of pedestrians in the road and rejected by 50% (i.e. the threshold gap) was found to be 26 m (84 ft). This agreed with threshold gap/vehicle speed relationships obtained under experimental conditions on the Laboratory track.

The relative positions of oncoming vehicles and pedestrians in the road were recorded, and it was found that 30% of all pedestrians observed on the road were first seen near to the path of travel of an oncoming vehicle.

1. INTRODUCTION

Many studies have been made of the use of dipped headlights in lighted streets. The effects of vehicle lighting on pedestrian movement have so far only been studied under experimentally controlled conditions(1).

In order to study the effect of vehicle lighting on pedestrian movement in busy, well-lighted streets a test car was driven around a number of streets in Central London at steady speed, using either sidelights or dipped British type headlights. The behaviour of pedestrians was recorded on cine film taken from the driver's seat and the film later analysed to see if differences existed between the observed behaviour under the two lighting conditions of the test car.

It has been shown that the use of dipped British type headlights by an approaching vehicle makes it more difficult for a driver to see pedestrians standing close to its path of travel[(2)]; (this is not true for the European type beam, dim-dip beam etc). The films were also analysed to see how frequently this circumstance occurred.

2. METHOD OF STUDY

All the results given in this report were obtained by the analysis of cine film. No results were obtained by observations made whilst actually travelling in these streets. The car was equipped with a cine camera in the position normally occupied by a drivers head (the car being left hand drive). It was driven on two different evenings after night had fallen around busy streets in Central London keeping as near as possible to 32 km/h (20 miles/h), a variation of ± 10 per cent being considered acceptable. Where prevailing traffic conditions prevented this, either filming was stopped or a record was made that during that part of the run in question the car was not travelling at 32 km/h (20 mile/h) ± 10 per cent. Any pedestrians noted in the road at this point during the analysis of the film were excluded. Filming was carried out in two-way streets only.

On the first evening the car used sidelights from about 8.00 p.m. – 10.00 p.m. then changed to dipped headlights from 10.00 p.m. until midnight. On the second evening the order was reversed, dipped headlights being used first, then sidelights.

A good level of illumination was present on all roads where filming took place (see plates 1 and 2). On one of the streets this was due mainly to the presence of illuminated signs and shop-fronts as opposed to street lights (see plate 1).

The films were later analysed in the following manner:

Each time a pedestrian was seen on the road the following information was obtained:

(i) Whether they crossed from left to right or vice-versa and whether they interrupted their journey in the centre of the road.

(ii) What type of background they were first seen against, namely cars, buildings, road surface or illuminated shop fronts.

(iii) When first seen whether they were in silhouette or not.

(iv) Whether they were wearing light or dark clothing.

(v) Whether or not they crossed the path of the observation car.

<u>Note.</u> Pedestrians seen in the road who had a further vehicle travelling in the same direction as the observation car, positioned between the observation car and themselves, were

not included in the study.

(vi) The presence of opposing vehicles when pedestrians were first seen in the road and when they crossed the path of the observation car.

(vii) The time taken by each pedestrian to cross the road. This was later related to how far away from the car they were when they crossed.

(viii) How far away the pedestrians were from the car.

(a) When first seen,

(b) When crossing its path – defined as appearing level with the mid point of the car bonnet.

This was done by measuring the image height of each pedestrian on the screen when first seen in the road and when crossing the path of the car. Thus knowing the focal lengths of the camera and projector lenses, the distance from screen to projector and assuming the average height of each pedestrian was 170 cms (67") (obtained by taking a weighted mean of the average heights of male and female English adults), the approximate distances from the pedestrians (in the above two positions) to the observation car could be calculated.

By calculating the distance away at which a pedestrian stepped into the road and whether or not he crossed in front of the car it was possible to determine the relationship between percentage of pedestrians crossing in front of the car and distance from the car. The distance at which 50 per cent of pedestrians would cross can then be calculated. This is called the threshold gap, determined in the experiment when the approaching car was travelling at 32 km/h (20 mile/h). The value obtained was compared with results of an earlier experiment[1] conducted under controlled conditions on the Laboratory track at Crowthorne when the approaching car was travelling at 48, 64, and 80 km/h (30, 40 and 50 mile/h respectively).

Filming took place during November, 1966 and February, 1967.

3. RESULTS

The discussion of the findings is for convenience divided into three sections.

(a) The effects of vehicle lighting on pedestrian movement across the road.

(b) Study of pedestrian background and visibility.

(c) The presence of opposing vehicles.

The results from each evening's filming with the car using the same type of lighting were compared statistically and showed that no significant differences had occurred between the two evenings. This suggests that the data used in this report are representative of a normal situation.

3.1 The effect of vehicle lighting on pedestrian movement across the road

3.1.1 The distances from an approaching car at which pedestrians stepped into the road and then crossed the road. The distance of each pedestrian in the road from the observation car was calculated by using the method described in Section 2. Results with the two lighting conditions were kept separate.

As stated earlier, when a vehicle was present between the observation car and a pedestrian on the road, and was moving in the same direction as the observation car, the pedestrian was not included in the study. In practice, due to the frequency with which vehicles were encountered moving in the same direction ahead, no pedestrians were recorded beyond 82 m (270 feet) from the observation car.

TABLE 1

Number of pedestrians stepping into the road at various distances from the car (using sidelights or dipped headlights)

Distance in metres (feet)		Number and percentage of pedestrians at indicated distance away when first stepping into road			
		Sidelights		Dipped Headlights	
0–9	(0–29.5)	0	(0%)	1	(1%)
9.1–18.1	(30–59.5)	4	(4%)	5	(5%)
18.3–27.3	(60–89.5)	10	(11%)	12	(13%)
27.4–36.4	(90–119.5)	14	(16%)	8	(9%)
36.6–45.6	(120–149.5)	11	(12%)	15	(17%)
45.7–54.7	(150–179.5)	20	(22%)	12	(13%)
54.9–63.9	(180–209.5)	12	(13%)	19	(21%)
64.0–73.0	(210–239.5)	7	(8%)	6	(7%)
73.1–82.1	(240–269.5)	13	(14%)	13	(14%)
TOTALS		91	(100%)	91	(100%)

The figures given in Table 1 indicate as expected that with both sidelights and dipped headlights the presence of a car affected the pedestrian decision to step off the pavement. Up to a distance of 18.3 m (60 ft), the number is less than a random (therefore approximately even) distribution and in the range 45.7 – 63.9 m (150–209.5 ft) greater than the random.

The distribution of numbers of people stepping into the road when the car was various distances away using either sidelights or dipped headlights were compared statistically and there was found to be no significant difference. Thus although the car had an effect on how far away people were when they stepped into the road, the lighting system used by the car did not affect their judgement.

TABLE 2

Number of pedestrians crossing the path of the car when it was various distances away

Distance in metres (feet)		Number and percentage of pedestrians at indicated distance away when crossing path of the car			
		Sidelights		Dipped Headlights	
0–9	(0–29.5)	0	(0%)	0	(0%)
9.1–18.1	(30–59.5)	7	(10%)	2	(3%)
18.3–27.3	(60–89.5)	19	(27%)	20	(27%)
27.4–36.4	(90–119.5)	14	(20%)	17	(23%)
36.6–45.6	(120–149.5)	10	(14%)	14	(19%)
45.7–54.7	(150–189.5)	7	(10%)	8	(11%)
54.9–63.9	(190–209.5)	11	(16%)	7	(10%)
64.0–73.0	(210–239.5)	0	(0%)	3	(4%)
73.1–82.1	(240–269.5)	2	(3%)	2	(3%)
TOTALS		70	(100%)	73	(100%)

Table 2 and Fig. 2 show the percentage of pedestrians who were counted from the film crossing the path of the car when it was various distances away, using either sidelights or dipped headlights. Again it can be seen, with the car using either sidelights or dipped headlights that few pedestrians were counted crossing the path of the car when it was up to 18.1 m (60 feet) away and few where it was over 64 m (210 feet) away. More were counted, than represented by an even distribution, crossing when it was between 18.3 m (60 ft) and 36.6 m (120 feet) away. In fact with both lighting conditions about 50% of all pedestrians counted, cross the path of the car when it was between these distances away.

Distributions for both lighting conditions were compared statistically and there was found to be no significant difference between the two sets of figures. To test whether differences over shorter lengths, for example the first 18 metres shown in table 2 were significant, many more observations would be needed. But at least we can say that vehicle lighting appears to have no effect on how far people were on average from the car when they crossed its path. This was also found to be the case when an experiment was carried out under controlled conditions on the Laboratory Track[1] with good street lighting. In an earlier study[3] observations were made with the car travelling at about 20 mile/h, but unlike the present study, results were still included when the car was travelling more slowly due to prevailing traffic conditions. It was found then that almost 60% of all pedestrians who crossed the path of the car did so when the car was between 9.1–27.4 m (30 and 90 feet) away. Thus maintaining the car at a steady 20 mile/h (± 10%) has had the effect of making more pedestrians cross the path of the car a greater distance away. (A comparison with the results of a track experiment[1] where cars were driven at greater speeds is discussed later.)

When the car was driven on sidelights 77% of the people counted who stepped off the pavement carried on across the road, crossing in front of the car. With dipped headlights the equivalent value is 80%. There was no statistically significant difference between these values, thus vehicle lighting had no effect on the proportion of people deterred from crossing in front of the car after stepping off the pavement.

3.1.2 A study of the threshold gap.

Each time a pedestrian stepped into the road his distance from the approaching car was calculated and it was recorded whether or not he crossed in front of the car, i.e. whether he accepted or rejected the gap. Thus the percentages of pedestrians accepting various distances were obtained. Cases where pedestrian judgement may have been influenced by vehicles approaching in the other direction have been excluded. Since there was found to be no difference in the distributions of numbers of pedestrians crossing in front of the car at various distances away when using sidelights or dipped headlights both sets of results have been combined to increase the precision of the data in finding the threshold gap. Figure 3 shows the percentage acceptance plotted against distance from the car. This sigmoid curve illustrates the transition in pedestrian judgements from those gaps which in every case were not accepted (0 per cent acceptance) to those gaps which were accepted in every case (100 per cent acceptance): The curve shows that this transition is a gradual process. The pedestrian-car distances on the rising part of the curve are those where there was uncertainty and were sometime accepted and sometime rejected, the probability of acceptance increasing with increasing gap size.

To obtain the threshold gap (defined as the gap which 50% accepted) accurately the method of probit transformation(4) was used, giving a gap of 25.6 m (84 feet).

In the experiment under controlled conditions carried out on the Laboratory track,(1) the threshold gap was calculated when an oncoming car seen in good street lighting approached subjects at each of the following speeds 48.3, 64.4 and 80.4 km/h (30 40 and 50 mile/h respectively).. Again in this track experiment there was found to be no difference in threshold gap whether the car used sidelights or dipped headlights.

The threshold gap values were plotted against the three values of approach speed used in the track experiment and the one value of speed i.e. 32.2 km/h (20 mile/h) (± 10%) used in the experiment (see Fig. 4). All four points were found to lie on a common straight line indicating good agreement between the two experiments.

3.2 A study of pedestrian background and visibility

TABLE 3

Type of background against which pedestrian was initially seen

	Background				Total
	Parked cars	Illuminated shops	Road surface	Wall or building	
Number	49	69	21	43	182
Percentage	27%	38%	11%	24%	100%

It can be seen from Table 3 on analysing the films that 38% of all pedestrians in the road would have been first seen against an illuminated background. These pedestrians were probably the easiest for the oncoming driver to detect whilst the 24% seen against a dark non-illuminated background were probably less easy to detect. Those seen against a dark background however were not necessarily observed (off the film) on being lighter than this background. The pedestrian/background relationship is discussed below.

TABLE 4

Pedestrians in relation to the luminance of the background

	Vehicle lighting		Total
	Sidelights	Dipped Headlights	
Silhouette (Pedestrian darker than background)	84 (92%)	80 (88%)	164 (90%)
Reverse silhouette (Pedestrian lighter than background)	7 (8%)	11 (12%)	18 (10%)
Total	91 (100%)	91 (100%)	182 (100%)

Each time a pedestrian stepped into the road it was noted off the film whether he appeared darker than the background (silhouette) or lighter than the background (reverse silhouette). There was no statistically significant difference between the number seen in silhouette or reverse silhouette when the test car used sidelights or dipped headlights. In both cases the number seen in silhouette was about 90% of the total.

There were eighteen cases where pedestrians wearing light clothing appeared lighter than their background (see Table 4). This was not always the case however since there were nine pedestrians observed wearing light clothing, who were first seen in silhouette, i.e. against an illuminated shopfront they appeared darker than this background.

3.3 The presence of opposing vehicles

It has been suggested that pedestrians and other road users could more readily distinguish moving vehicles if drivers were required always to show dipped lights when on the move during the hours of darkness. However, dipped headlights may be unnecessarily glaring in good street lighting and thus lose part of their effectiveness. A controlled experiment carried out on the Laboratory's track showed that the use of conventional British type dipped headlights by an approaching vehicle makes it more difficult for a driver to see pedestrians standing close to its path of travel(2). However it is important to note that this deterioration in visibility does not occur with the more sharply cut-off European E type beam or the dimmed dip beam(5).

In Britain, drivers in the past have been advised by the Highway Code only to use sidelights where the street lighting is good. (see plates 1 and 2). In some places efforts have been made to encourage the use of dipped headlights, and these are practically all of British type, in all lighted streets on the ground that, despite disadvantages in particular conditions this is, on balance the safer practice.

In this study the presence or absence of opposing vehicles was recorded off the film each time a pedestrian stepped into the road or was first seen on the film to be waiting in the centre of the road. Thus the number of times that a pedestrian crossed the road near to a possible source of glare was obtained.

TABLE 5

Presence of opposing vehicles when pedestrians were at various places in the road

Position of pedestrian when first seen	Direction of pedestrian movement	Frequency of occurrence		Total
		No opposing vehicles present	Opposing vehicles present	
Pedestrian first seen in centre of road	left to right	0	0	12
	right to left	0	12	
Pedestrian first seen stepping into road (or waiting in kerb)	left to right	38	43	170
	right to left	52	37	

The experiment carried out on the Laboratory track showed that pedestrians are less easy to see when near the glare source of an approaching vehicle, i.e. those crossing the road from right to left or those waiting in the centre of the road when an opposing vehicle is present. Subjects in the experiment however were on average able to detect the pedestrian-like objects from as far away as 90 m (300 feet) irrespective of position on the road. This distance is greater than the greatest distances encountered in the real road conditions of this experiment. However, the track experiment showed that on average the distances away that subjects were able to detect the objects were increased by 40% when the opposing vehicle used sidelights or European E type dipped headlights.

As can be seen from Table 5, the conditions described above where pedestrians may be less easy to see occurred with 49 (12 seen in the centre of the road and 37 crossing from right to left when opposing vehicles were present) of the 182 pedestrians observed i.e. with 28%. (Practically all the opposing vehicles observed used sidelights and did not in fact affect the ability of the driver of the observation car to see any pedestrians.)

Of the remaining 72% of the cases where no opposing vehicles were present dipped headlights would have been an advantage since there would be no glare from approaching vehicles whilst pedestrians and other road users could more easily distinguish between moving and parked vehicles. If all vehicles used either the European E beam or dim-dipped systems(5) then this advantage would be retained without the disadvantage of excessive glare from oncoming vehicles.

4. CONCLUSIONS

1. The change with good street lighting from using sidelights to using dipped headlights on the approaching car had no detectable effect on:

(a) How far away on average pedestrians were when stepping into the road.

(b) How far away on average pedestrians were when crossing in front of the car (with both lighting conditions about 50 per cent of all pedestrians crossed the path of the car when it was between 18–36 m, (60–120 ft) away. This tends to confirm other work which shows that the type of vehicle lighting does not affect average risk taken if the street lighting is good).

(c) The percentage of pedestrians on the road who crossed in front of the car (about 80 per cent in both cases).

(d) How quickly pedestrians crossed the road.

It is however not possible to say whether different proportions of pedestrians who wished to cross were deterred by cars with sidelights or dipped headlights.

2. The gap that was accepted by 50% of pedestrians on the road and rejected by 50% (i.e. the threshold gap) was found to be 26 m, (84 ft) the observation car being driven at 32 km/h (20 mile/h). This was found to agree with the threshold gap/vehicle speed relationship obtained under experimentally controlled conditions.

3. When first observed in the road (on analysis of the films) 38% of all pedestrians were seen against an illuminated shop front, 27% against parked vehicles, 11% against the road surface and 24% against a wall or building.

4. With both lighting conditions about 90% of all pedestrians observed in the road were seen in silhouette.

5. In almost 30% of the cases where a pedestrian was observed in the road, he or she was first seen close to the path of travel of an oncoming vehicle.

5. ACKNOWLEDGEMENTS

The members of the research team who took part in the investigation were G. D. Jacobs, A. E. Daniels, D. G. Wilson, Mrs Clements and Mrs Jacobs.
This report was prepared in the Road Layout and Lighting Section of the Safety Division.

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5. JEHU, V. J. Vehicle Front Lights. Traffic Engineering and Control 1965 7(7)

Plate 1.
Old Compton Street showing pedestrians in silhouette and reverse silhouette

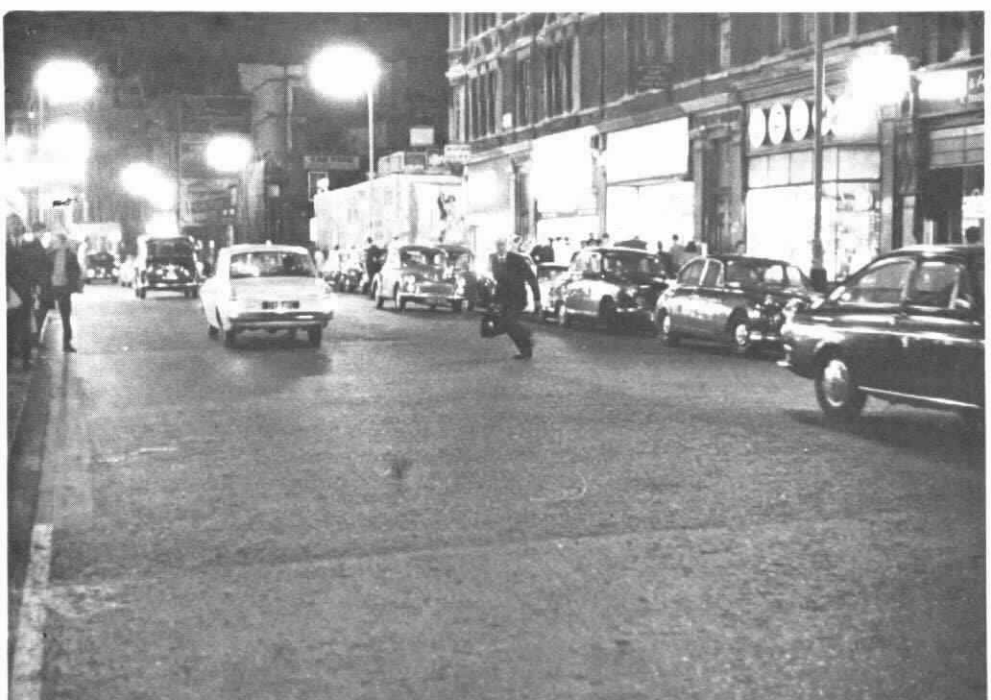

Plate 2.
Shaftesbury Avenue showing a pedestrian in silhouette.

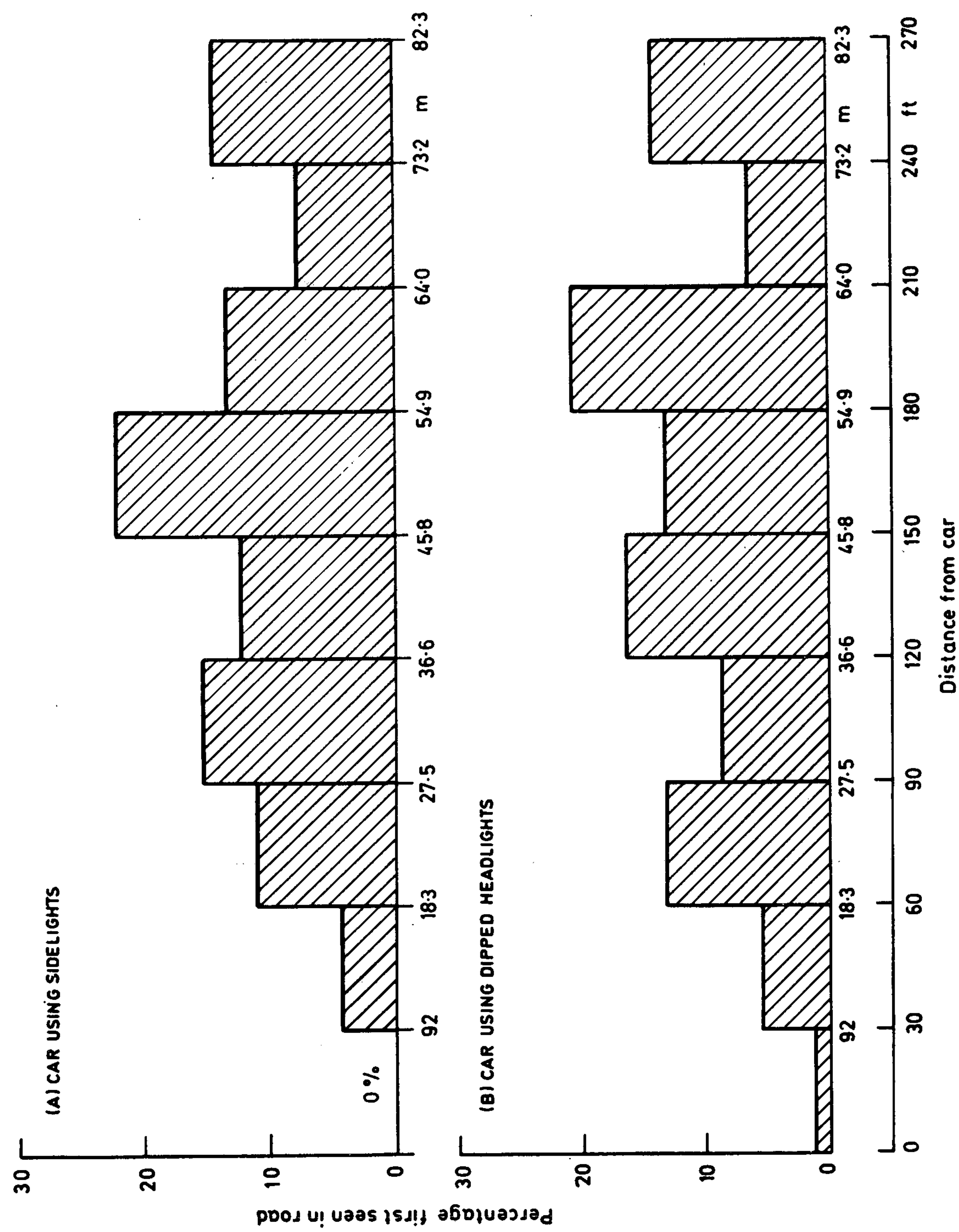

Fig. 1. THE PERCENTAGE OF PEDESTRIANS STEPPING INTO THE ROAD AT VARIOUS DISTANCES AWAY FROM AN ONCOMING CAR

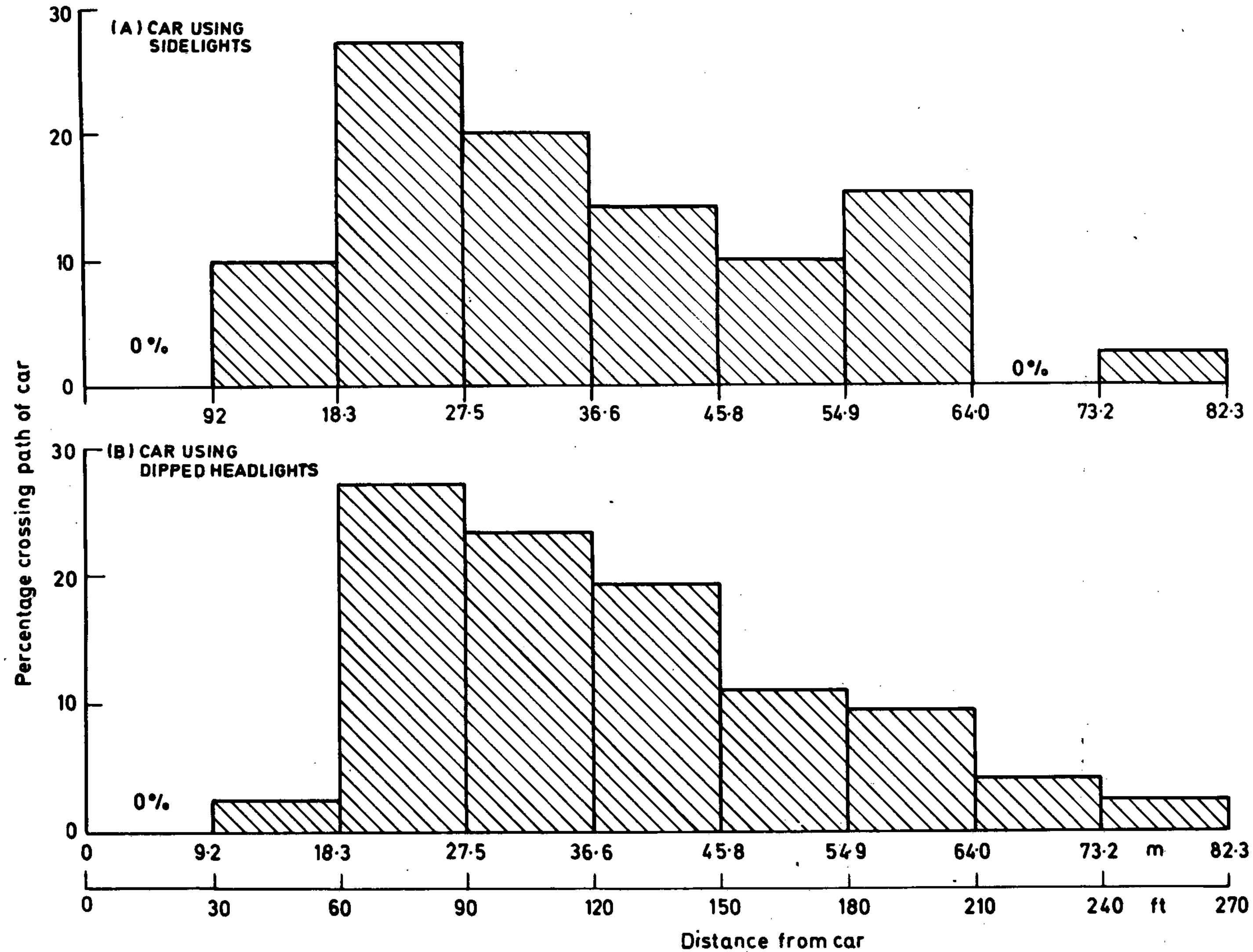

Fig. 2. THE PERCENTAGE OF PEDESTRIANS CROSSING THE ROAD AT VARIOUS DISTANCES AWAY FROM AN ONCOMING CAR.

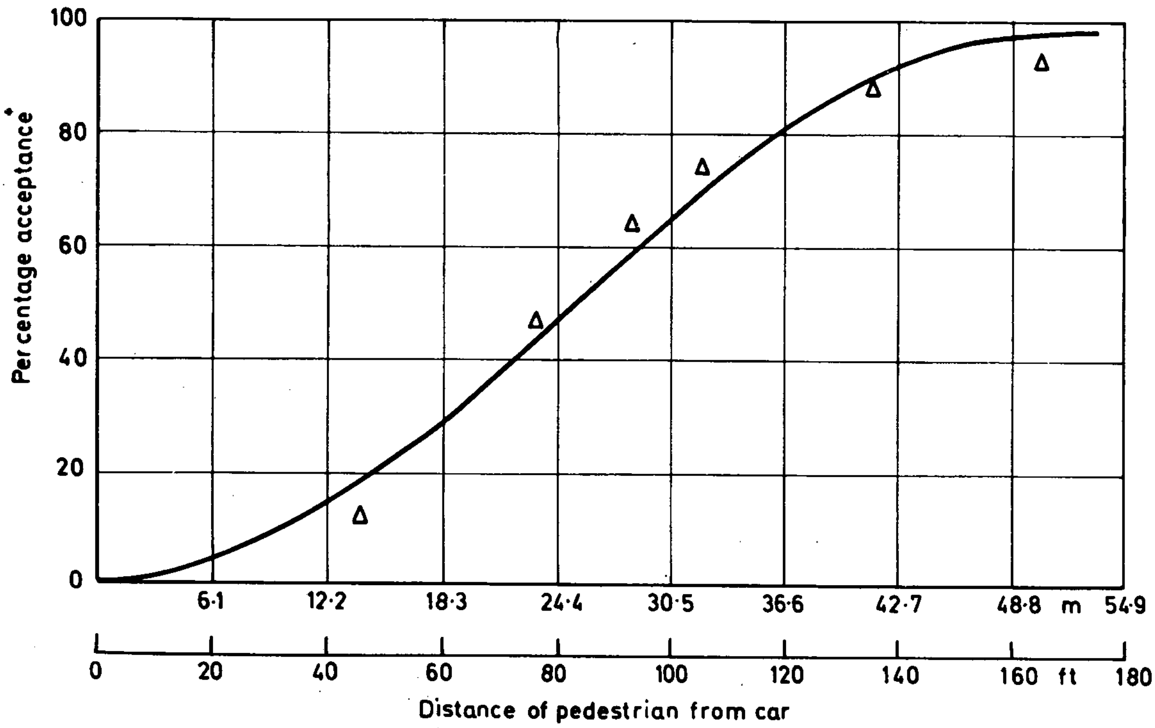

Fig. 3. THE PERCENTAGE OF PEDESTRIANS ACCEPTING GAPS OF GIVEN SIZE IN FRONT OF CAR

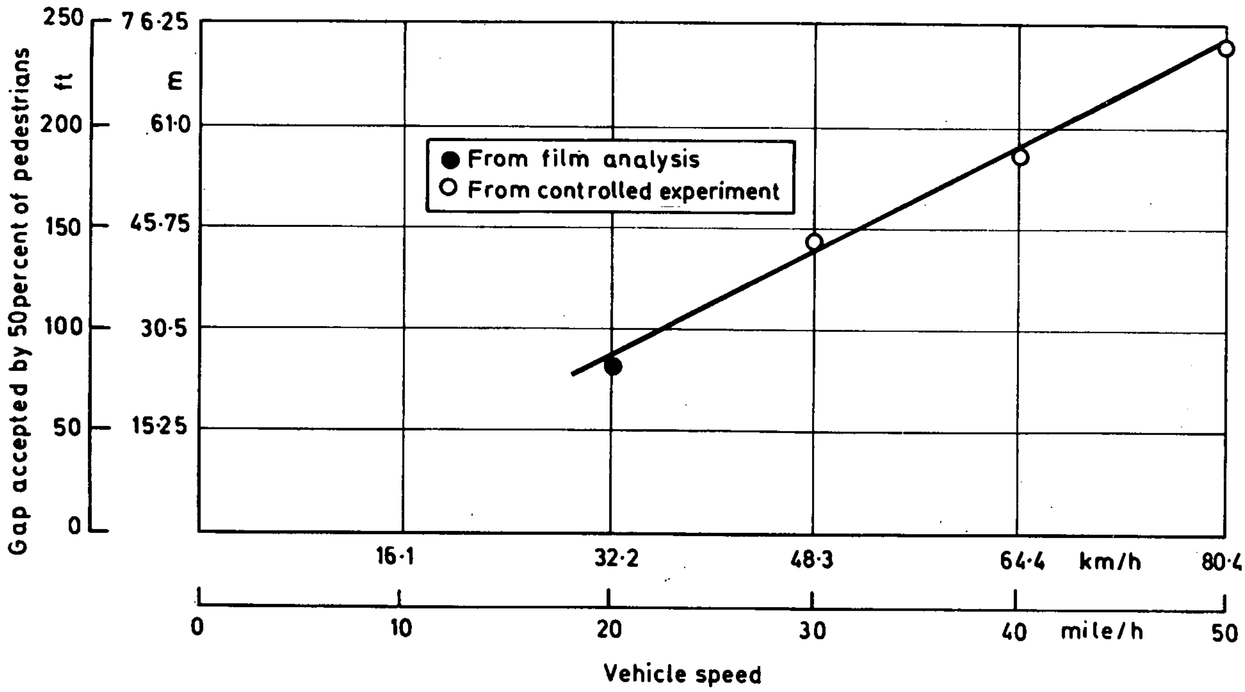

Fig. 4. GAP ACCEPTED BY 50 PERCENT OF PEDESTRIANS CROSSING THE ROAD IN THE PATH OF AN ONCOMING VEHICLE MOVING AT DIFFERENT SPEEDS

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ABSTRACT

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