TRANSPORT AND ROAD RESEARCH LABORATORY
Department of Transport

RESEARCH REPORT 55

SAFETY ASPECTS OF THE SINCLAIR C5 ELECTRICALLY ASSISTED PEDAL TRICYCLE

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1985

ISSN 0266-5247

CONTENTS

ABSTRACT

The Sinclair C5 has been designed to meet the new regulations which eased the legal operating requirements for electrically assisted pedal bicycles and tricycles. The present report discusses an assessment of the likely accident rate for the C5 on public roads and attempts to relate this to the rate for pedal cycles. It is not yet possible to reliably assess the rate from actual accidents and so factors contributing to the most important accident situations are studied. Conspicuity during daylight seems to be comparable to that of pedal cycles when there is a clear view of the C5, but problems arise from its low height. Braking is good once the brakes are bedded-in. Stability and handling appear to be adequate and the consequences of rolling it over are probably less serious than from falling off a pedal cycle. Operating considerations and the protection offered by the C5 are both briefly discussed. It is concluded that the accident rate of C5s might be similar to that for pedal cycles, although accident and injury circumstances may be very different.

1 INTRODUCTION

The marketing of the Sinclair C5 electric power assisted tricycle last winter was greeted with interest because it was a novel concept that might appeal to various sectors of the general public. An idea of the configuration and scale of the C5 is given in Plates 1 and 2. Inevitably doubts were raised about its safety and it was arranged that this should be assessed at TRRL. This report presents the outcome of this work.

With a conventional road vehicle it is usual to estimate its safety directly by collecting information about the numbers and types of accidents involving the vehicles and relating these numbers to estimates of the total distance travelled by all such vehicles in the same area and over the same period of time. The accident rate (the numbers of accidents involving the vehicles per unit distance travelled) can then be estimated and other similar statistics produced. It is not yet possible to do this for the C5 powered tricycle because only a few have been used on public roads and only a few accidents have been reported. This means that no quantitative assessment can be made. All that can be done is to measure the performance of the vehicle regarding various features which affect its safety. This is what has been attempted and conspicuity and braking aspects have been investigated. Comments are made on these results and on other features related to safety in the light of experience for the overall safety performance of the new vehicle.

All road vehicles must comply with the regulations appropriate to their classification. The Sinclair C5 electric tricycle is classed with electric power assisted bicycles and tricycles which are exempted from almost all operating regulations if they do not exceed certain design restrictions, (The Electrically Assisted Pedal Cycles Regulations 1983). Sinclair Vehicles Ltd contracted Lotus Cars Ltd to check that the C5 meets these restrictions and their unpublished report shows that it does so in every detail in which it could reasonably be expected to conform. This means that the C5 can be used by people aged 14 and over as if it were a pedal cycle and so there is no vehicle tax, no need for insurance, no driving test and no driving licence required before it can be used.

2 ACCIDENTS

2.1 PEDAL CYCLES

The classification of the C5 as being an electrically power assisted tricycle suggests that it is appropriate to consider whether its accident performance is likely to be better or worse than that of pedal cycles. The pedal cycle fatal user casualty rate is 6.3 per 10^8 km which is about 12 times that for drivers of cars, but is only a half of that for riders of motorcycles. This information, together with further details on accidents, casualties and the vehicles involved, comes from Road Accidents Great Britain 1983 (Dept of Transport 1983) which reviews the pedal cycle accident situation.

An important distinction must be made between single vehicle accidents involving cycles only and accidents involving other vehicles as well. There is an almost full reporting of fatal casualties to pedal cyclists and about 90 per cent of these occur in collision with other vehicles. However, for non-fatal casualties, the situation is quite different and many are single vehicle incidents. This is not apparent from the official statistics because many non-fatal injuries go unreported and very many of these are single vehicle incidents. In particular many children are injured by falling off their pedal cycles, without any other vehicles being involved and it is not easy to be certain how many of these occur on or off public roads.

Over 50 per cent of fatalities to pedal cyclists result from collisions with cars and 20 per cent with goods vehicles. These fatalities may be divided up another way. Unpublished reports by TRRL show that about 40 per cent of fatal collisions occur when the bicycle is struck from the rear and the cyclist is riding straight ahead. Another 10 per cent occur when the cyclist is attempting to turn right and he is struck from behind. A further 20 per cent occur when the pedal cyclist is emerging from a side turning or entrance. Less frequently various situations occur when the pedal cycle is struck by a vehicle approaching head-on. Reported non-fatal accidents have a rather different distribution of circumstances with rear impact into pedal cycles being a less frequent feature than for fatal accidents.

2.2 C5 ACCIDENTS COMPARED WITH ACCIDENTS TO PEDAL CYCLES

The accident situation for pedal cycles is taken as a basis for considering what the situation might be for the C5 electric tricycle if it were to be used in large numbers. The following paragraphs discuss some of the likely differences.

Bicycles are not very stable and riders fall off them frequently, but fortunately only rarely with fatal consequences. It may be expected that the C5 will perform much better in this respect, not only because the vehicle should be relatively stable but also because the resulting injuries should be much less severe. Of three early accidents to the C5, two were cases of tipping over on to its side. In one this was caused by the C5 being driven off a pavement over a kerb. In the other the C5 was steered too violently and rolled on to its side. In the first of these cases there was a suspected upper arm fracture but this was not confirmed.

The C5 by its design is essentially a one speed machine when under power and this speed (20 km/h) is slightly above what appears to be the average speed at which pedal cycles are ridden. The difference seems unlikely to influence the accident pattern greatly. The previous Section 2.1 shows that impact from the rear is the major concern for fatal accidents to pedal cycles and so this possibility is considered in this paper for the C5.

Poor braking of pedal cycles, which sometimes results from poor maintenance, is another problem which contributes to accidents on hills and in traffic. A later section of this paper discusses the situation for the C5.

In comparison with pedal cycles, most public concern for the C5 has been expressed about its conspicuity and this is particularly because of its low height and the low height of its rider. A preliminary test programme on this aspect is reported. The third accident which has come to official notice was possibly of this type. It seems that a pedal cyclist did not see a C5 because of the presence of a car and so he rode into the side of the C5. The pedal cycle was badly damaged in the impact.

3 CONSPICUITY

3.1 CONSPICUITY OF C5 FOR THE DRIVER OF LARGE COMMERCIAL VEHICLES

Drivers of HGVs are not well positioned to see pedestrians or small less conspicuous vehicles close to their vehicles. Checks have been carried out by placing the C5 in 18 positions around three large vehicles (Figure 1). Ten qualified HGV drivers sat in the driving seats of a Leyland Roadtrain and in a Ford Transcontinental and 5 qualified PSV drivers sat in the driving seat of a Bristol VR bus. These drivers were asked to carry out their normal pre 'moving off' procedure and to note whether they could see the C5 or its rider. A tabulation of their findings is given in Table 1. Two versions of the C5 were chosen for comparison with a pedal cycle. These were A—a standard C5, B—a standard C5 with a small 'Dayglo' pennant reaching 1,400 mm above ground and flying from a flexible mast attached to the front offside and, C—a shopper bicycle. (The pennant is a TRRL addition and is quite different from the High Vis Mast which is a standard Sinclair accessory designed for night-time conspicuity.)

The results in Table 1 show that the standard C5 cannot be seen just ahead of the cabs of the HGVs, although the pennant can just be seen. There is also a blind spot just to the nearside of the cab. The C5 cannot be seen just to the rear of the platform semi-trailer by most people. The bicycle could be seen just ahead of the cab because of the height of the head

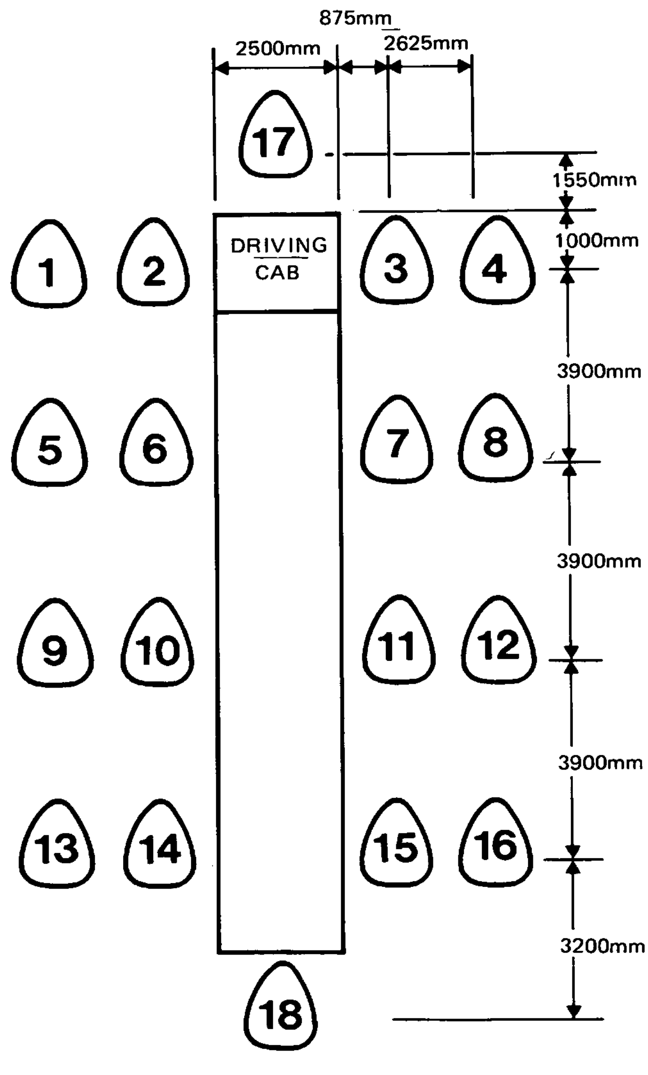

Fig. 1 Test positions for checks on conspicuity of C5 close to commercial vehicles

TABLE 1

Numbers of subjects not seeing a C5 placed in 18 positions around three large vehicles

C5 and bicycle configurations—A standard C5
B C5 with pennant
C Cycle (shopper)
Positions are shown in Figure 1

Large Vehicle	Roadtrain			Transcontinental			VR Bus		
Test Configuration	A	B	C	A	B	C	A	B	C
Position									
1	9	10	0	9	10	2	0	0	0
2	10	9	10	10	10	10	0	0	0
3	1	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	10	10	10	0	0	0	5	5	5
6	0	0	0	1	0	0	0	0	0
7	0	0	1	0	0	0	0	0	0
8	1	3	1	1	1	0	5	5	5
9	6	5	7	7	7	4	2	3	3
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	2	1	2
13	2	1	2	4	2	7	1	1	1
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	10	0	0	10	0	1	0	0	0
18	6	7	0	10	10	10	0	0	0
Total observations	180	180	180	180	180	180	90	90	90

of the rider. It could not be seen just to the nearside of the cab and behind the semi-trailer of the Ford Transcontinental. There were no important blind spots immediately around the bus for any of the three machines tested.

From a safety point of view there are obvious problems for HGV drivers seeing the C5 when starting to move forward, when turning to the left and when reversing. The pennant might be of some help for the C5 in the forward start situation provided that it is sufficiently large.

3.2 CONSPICUITY OF THE C5 WHEN IT IS APPROACHING THE SUBJECT IN DAYLIGHT

From TRRL work, about 20 per cent of fatal accidents to pedal cyclists could involve the conspicuity of pedal cyclists from the front. Tests have been carried out on the conspicuity of the C5 with its rider approaching a subject seated in a test car who is coping with a task equivalent to driving his car. He (or she) reads a series of digits from a display directly ahead of him and eventually detects the presence of something approaching, which is visible only in his peripheral vision. The set-up is described by Watts (1984a) who gives the mean detection distances for pedal cycles quoted in Table 2. Results for the C5 are also given but the number of subjects was only 26 with three trials for each configuration in these more recent trials. It is to be noted that the C5 approached the subject against a background of dark woodland setting but with a stationary white car directly behind the C5 as seen by the subject as it approached. The car was positioned there to simulate, in some small degree, the visual confusion which is at the root of the conspicuity problem. The detection distance is the distance at which some approaching object is first noted but the object is not distinguished for what it is. Figure 2 shows the wide scatter between subjects that can also be deduced from the large Standard Deviations in Table 2. At a first consideration of these results there seems to be little advantage in having conspicuity aids, but a closer inspection does show that the numbers of subjects not noticing the C5 until

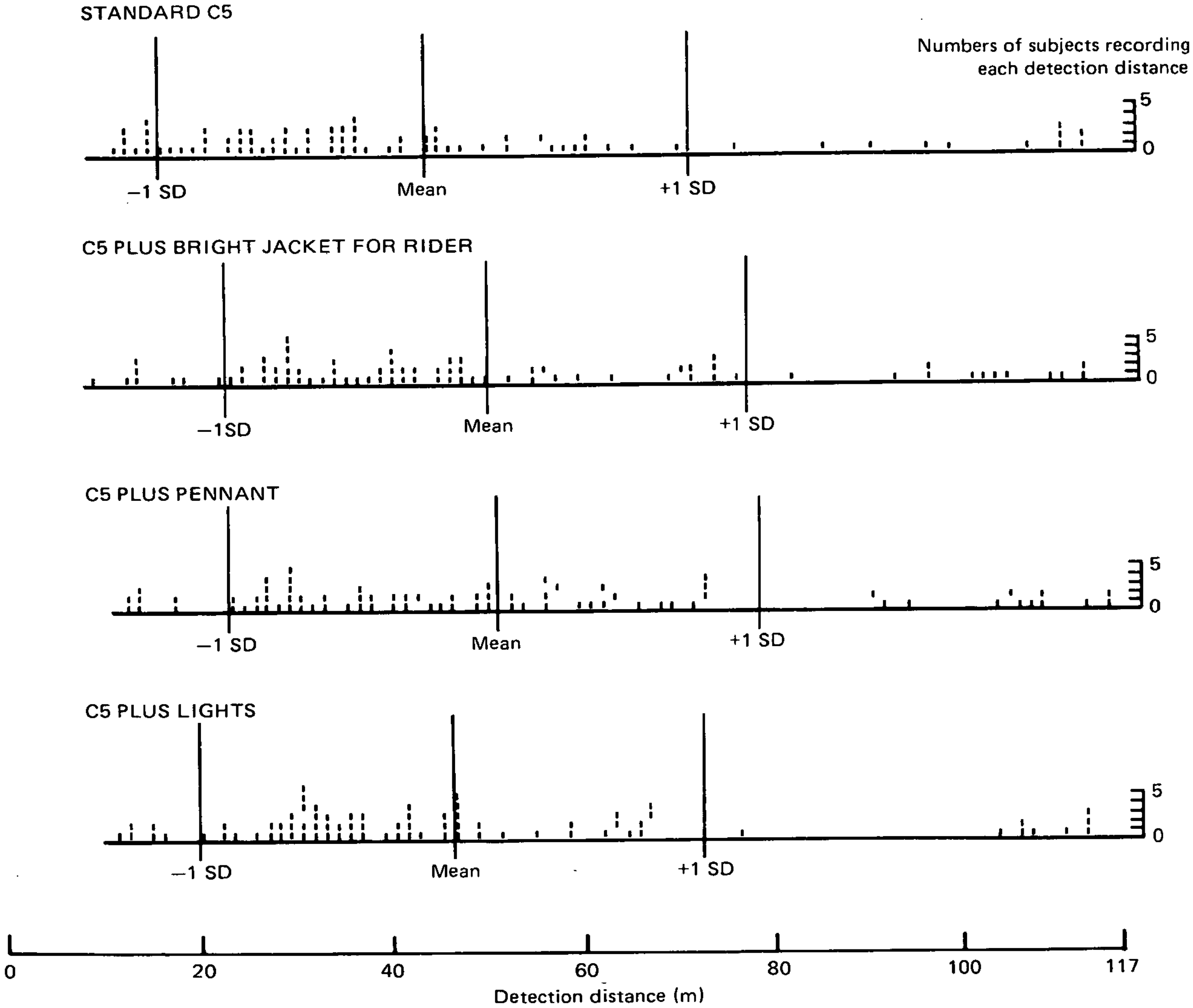

Fig. 2 Detection distances recorded by subjects in conspicuity trials of C5 — Frontal approach

TABLE 2

Conspicuity from the front

Options with Pedal Cycle	Mean detection distances (m)	Options with C5	Mean detection distances (m)(± SD)
Basic Rider with black jacket	49.6	Basic Rider with black jacket	44 (± 28)
Basic plus Sam Browne belt*	47.1	Basic plus jacket*	51 (± 28)
Basic plus hat*	53.9	Basic plus small pennant*	51 (± 28)
Basic plus waistcoat*	55.8	Basic plus front light on	46 (± 26)
Basic plus jacket*	63.2		

*fluorescent aids

it is less than about 20 m away are approximately halved with the yellow fluorescent jacket, the small orange fluorescent pennant and the front light on. This may be the justification for using such aids. Previous work (Watts 1984a) shows that large areas of bright contrasting colour are needed for marked improvements in conspicuity and so the modifications tried out may not be the best possible ones.

In some particular situation there may be special difficulties in seeing the C5 and these mostly arise because of its low height in relation to cars and other traffic. During testing in a car park a near miss occurred with a low hedge obscuring the C5 until it emerged at the combined entrance and exit, just as two cars were leaving. A rider astride a bicycle could be seen in similar circumstances.

3.3 CONSPICUITY OF THE C5 WHEN IT IS BEING APPROACHED FROM THE REAR IN DAYLIGHT

In total about 50 per cent of fatal accidents to pedal cyclists involve conspicuity from the rear and two-thirds of these occur during daylight, mostly with cars but some with goods vehicles being the striking vehicle. Tests have been carried out by simulating this situation by mocking up the rear appearance of the C5 on its front. It can then approach the subject in the test car in the same way as in the previous tests with the only important difference from a true rear approach being that the face of the rider rather than the back of his head is facing the subject. The results are given in Table 3 and Figure 3 which may be compared with Table 2 and Figure 2 which give the frontal approach results. The configurations tested included the standard basic one with the dark grey boot cover of the early C5s. The rider wore a black jacket. The second configuration was similar except that a rear 'number plate' with a bright fluorescent marking -C5- made up using LISA sheet was attached. The third configuration was similar to the first except that the 'rear' was painted with a standard chevron marking. The results apparently show that the standard (normal) rear detection distance (mean 52 m from Figure 2) is better than from the front (mean 44 m from Figure 3), but this may be because of a learning curve effect; the rear configuration was tested after the front ones on the same days by the same subjects. Apart from this there is little indication in Table 3 of much improvement from the use of the two aids tested. This is so whether the mean distance is taken into consideration or the numbers of subjects with detection distances of less than 20 m are counted. Larger and brighter conspicuity aids would seem to

TABLE 3

Conspicuity from the rear

Options with C5	Mean detection distances (m)(± SD)
Basic rider with black jacket	52 (± 28)
Basic plus -C5- plate	53 (± 28)
Basic but chevron markings	54 (± 28)

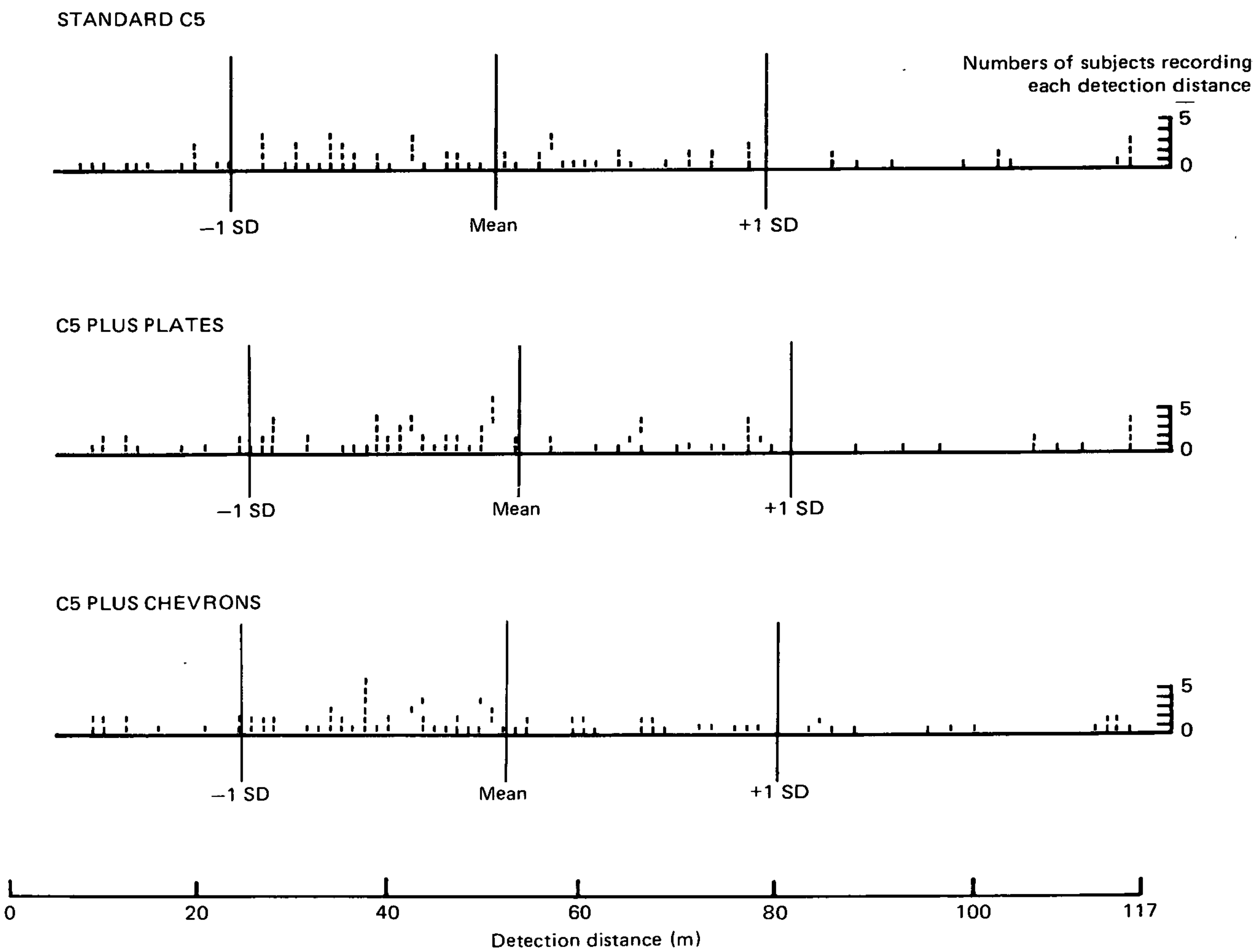

Fig. 3 Detection distances recorded by subjects in conspicuity trials trials of C5 — Simulated rearwards approach

be needed. It is known from the studies of the conspicuity of pedal cyclists that large areas of fluorescent materials are needed to make much difference in daylight. Clean white and yellow areas are also useful if sufficiently large. There is also the 'attention getting' factor of moving bright objects such as pennants. The movement of the conspicuity aid may explain the effectiveness of pedal reflectors which are small but are clearly visible in night-time conditions.

3.4 CONSPICUITY OF THE C5 DURING THE HOURS OF DARKNESS

Time has not permitted testing of this situation but the front light is of 5 watts with an adequate reflector and the High Vis Mast (a standard accessory) has a forwards facing reflector. The red rear light is of 5 watts with reflectors facing backwards. By pedal cycle standards this is a fully adequate provision (Watts 1984a). There may be a problem of recognition as distinct from detection which is discussed by Watts (1984b). Recognition is the realisation that the vehicle whose presence has been detected is in fact a C5. Recognition enables the oncoming driver to take appropriate action to miss the vehicle he has detected. Recognition distances are always much shorter than detection distances.

4 BRAKING AND STABILITY

The C5 is a tricycle with a brake on the single front wheel and a brake on the offside rear wheel which is operated separately as on a bicycle. The drive is on to the other rear wheel. The brakes are hand operated from the handlebars which are located under the rider's thighs. (See Plates 1 and 2). With this layout some reduction in maximum possible braking is accepted because not all wheels are braked. It is also possible that the C5 may yaw somewhat when either power or the rear brake is applied. With only one rear brake, the machine should always be stable when braked at the rear. Some complications may occur if either rear wheel is lifted from the ground in a violent manoeuvre.

The braking of the C5 has been checked under straight line conditions. The results of quick checks are given in Table 4. The brakes were applied as hard as reasonably possible. In all cases the rear wheel was locked. The results show that there was a marked improvement after the brakes were tested when new. They were subsequently tested at about 250 km of use. The 0.37 g locked wheel braking deceleration when new would be poor for a pedal cycle (Watts 1980). On the other hand few pedal cycles can reach the full C5 bedded-in braking of 0.70 g. (There is a great risk of being thrown over bicycle handlebars above about 0.56 g deceleration.) The spot check of the front wheel braking when the brake was thoroughly wetted but the road and tyre were dry showed that the front brake does seem to be affected but only by exceptionally large quantities of water (which would only be expected when crossing a deep puddle or ford). The braking was stable, presumably because only one of the rear wheels was braked and locked. This preliminary check on the brakes suggests that the system is satisfactory. The only problem was that on two occasions during testing, a brake cable lost its nipple.

The stability of the C5 is much better than is possible with a bicycle. It seems likely that if the bicycle had first been introduced in 1985, it would have been declared to be unsafe and unacceptable on account of the ease with which riders could fall off and hurt themselves! Although the C5 is reasonably stable, it is possible to tip it over sideways on a flat surface if the rider makes an excessive steering demand and then leans out of, rather than into, the resulting turn. The difference between a C5 and a bicycle is not in terms of the maximum lateral acceleration on a turn that can be achieved, but rather that either by mishandling a bicycle or when it is ridden in gusty conditions, it is possible to lose control and fall off. Serious injuries will probably not be frequent when a rider tips a C5 unless he is subsequently struck by another vehicle.

TABLE 4

Braking deceleration on a dry road surface

Brake condition	Brakes used	C5 use/condition	Speed	Deceleration
Brakes dry	Front only	as new	18.9 km/h	0.15 g
	Rear only	as new	18.6 km/h	0.26 g
	Both	as new	19.3 km/h	0.37 g
	Front only	after 250 km	20.6 km/h	0.32 g
	Rear only	after 250 km	19.5 km/h	0.48 g
	Both	after 250 km	19.2 km/h	0.70 g
Front brake wetted	Front only	After 250 km	19.0 km/h	0.19 g

5 PROTECTION

The pedal cycle offers little protection to its rider when an accident occurs whether the bicycle is struck by a vehicle or the rider loses control and falls off. The head of a cyclist is well above ground level and there is always the risk of an injurious head impact with the ground. The question for the Sinclair C5 is what is the level of protection for riders in the various likely accident situations and how does this compare with that for pedal cyclists.

5.1 SINGLE VEHICLE ACCIDENTS

Typical incidents might be:—

—loss of control so that the C5 overturns or leaves the road and then overturns

—the C5 strikes a roadside object

—the C5 loses forwards momentum on a hill, comes to a halt and rolls backwards.

An incident becomes an accident only if there is material damage and possibly injury to the rider or someone else. When control is lost with a C5 there will be some circumstances when it tips on to its side even if it does not roll over completely. It is likely that the C5 body will provide some protection from abrasion because the rider may well not be thrown out. The first recorded case of an injury did result from a C5 tipping over as it came off a kerb. The occupant suffered a suspected fracture of the arm and this might be typical of a low speed incident. It is thought that the rate of injury to occupants of C5s will be appreciably lower than for pedal cyclists involved in corresponding situations.

When the C5 strikes roadside objects there should be a reasonable level of protection in frontal impacts. It is understood that Sinclair have had impact tests carried out to verify this. With the level of braking available there should not be cases of excessive speeds building up downhill.

If the C5 comes to a halt on a hill and rolls backwards it may be expected to swing round and might then overturn with the consequences discussed above. There would not be much protection for the head if the C5 tilted backwards, but this should not happen.

5.2 IMPACTS INTO CARS

It is understood that Sinclair have had a series of simulated frontal crash tests carried out. These were exactly frontal and were carried out on a Hyge acceleration facility. They would simulate striking a flat rigid object and to some extent striking a car. It appears that the front of the C5 body restrained the dummy rider and it did not allow the dummy to come free from the machine. It is not clear whether injuries to the abdomen or thorax might be sustained in this process but the protection from the front structure might be less effective a restraint if the impact were not exactly head-on but somewhat angled. In any case it seems that there is much more protection than for a pedal cyclist involved in a similar incident.

The most frequent impact might be the front of a car striking the rear of a C5. The shape of the car front might be a critical factor for determining the consequences. A high front to a car could easily cause injuries to the C5 occupant. If the impact were angled or offset it seems possible that the car might roll the C5 over and then run it over, which could also easily result in fatal consequences. The third possibility is that the main impact might be taken by the rear seat structure and the occupant might then suffer spinal injuries. There seems to be little reason to think that overall injuries would be worse for a C5 occupant than for a pedal cyclist, although the mechanisms of injury would doubtless be different.

5.3 IMPACTS INTO HEAVY GOODS VEHICLES

Impacts into buses and coaches are likely to be similar to those into cars. However, impacts with HGVs may involve the C5 running under the HGV from the front, side, or rear. Impact into the rear of an HGV is likely to be uncommon, and some protection will be provided by rear under-run devices being fitted to new HGVs. Impact into the side of an HGV is not likely to be worse for the C5 than for a pedal cycle, provided regulation side guards are fitted. But impact into the front of an HGV may be more serious, because the normal bumper height may allow contact directly between the front of the vehicle and the C5 driver.

6 OTHER FACTORS IN THE COMPARISON OF PEDAL CYCLE AND C5 ACCIDENTS

In addition to previous considerations, the following aspects of the accident problem should be considered. The factors for which the C5 may have additional risks to those for pedal cycles are listed first.

a) The C5 will probably be driven with its nearside rear wheel just clear of drain covers and other irregularities along the gutter. This is the typical position for a pedal cycle, but the difference is that the C5 then projects a further 350 mm or so into the traffic stream with a consequently greater risk of being struck.

b) The electric motor of the C5 has to be protected by various overload cut-out switches and there may be a problem if any of these trip during a manoeuvre in traffic. There is no three speed or gearbox and so the motor may trip on a hill at speeds below the

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Plate 1 Side view of the Sinclair C5

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Plate 2 Sinclair C5 alongside a Ford Transcontinental 16 tonnes GVW lorry

optimum speed for the motor. There is a comprehensive system of warnings of impending cut-out by means of flashing indicator lights and a buzzer, but the rider may not be able to avoid reaching the point of cut-out because it is not always possible to exert enough pedal effort just at the instant of cut-out to maintain a safe position. The pedal effort that can be applied may be restricted because there is no adjustment for riding position, equivalent to altering saddle height on a pedal cycle. The C5 may thus come to rest inadvertently in traffic or even roll back down a hill.

c) One advantage of a bicycle in an impending emergency is that it is easy for an agile cyclist to dismount and to get out of the way. The time it takes to get out of a C5 is longer than this: checks gave times of from two to three seconds when the rider had been previously warned to be ready to get out quickly. Times were much longer with the side panels in use.

d) It is suspected that drivers of C5s may be more reluctant to turn their heads to check for overtaking traffic than are riders of pedal cycles. This may be because they are seated in a conventional seat with a back and some side structure.

e) The poor conspicuity of pedal cyclists from the rear, the front and occasionally from the sides does appear to be a major safety problem. This is made more difficult by the fact that the ways of improving this feature by daylight and during the hours of darkness are very different from each other. Although the C5 has particular conspicuity problems which have been discussed, its design does incorporate some very good features. These are the provision of a good front light, a white body shell and a good rear light/reflector array. These should all improve conspicuity at night and the white body is particularly desirable by day. The conspicuity comparison and its effect on accidents cannot be assessed, but it is clear that the situation for the pedal cycle and cyclist is often poor.

7 CONCLUSIONS

This study suggests that the following factors influence the accident and injury rates for the C5 in comparison with those for pedal cycles:—

a) The C5 has a generally satisfactory braking system and its stability in normal use appears to be adequate, although when driven into a severe manoeuvre it can be turned on to its side. In both respects it is superior to a pedal cycle, not least because the injury outcome may be less severe.

b) There are some safety problems of the C5 which mainly stem from its non-adjustable pedalling layout. There may be difficulties when a rider fails to climb a slope and also when the motor cuts out when overloaded in traffic. The time to dismount is greater than from a pedal cycle.

c) The C5, when running normally, poses two problems. When ridden along the nearside of the road it takes up approximately 350 mm more of the road width than does a pedal cycle. The other factor is its conspicuity. It is invisible to an HGV driver when just in front of the HGV or just to the nearside of the cab. Its conspicuity from the front and rear by day is comparable with that of the pedal cycle and cyclist, which is poor unless the rider wears bright clothes. The low height of the C5 means that it cannot easily be seen in some traffic and road situations. However by night it would appear that the conspicuity of the C5 is relatively good.

d) The major injury problems are likely to result from impacts in the rear by cars and Heavy Goods Vehicles. Running the C5 head-on into roadside objects and vehicles may not be so serious because the C5 should restrain its occupant, according to impact tests carried out for Sinclair. Impacts into the side of the C5 may easily roll it on to its side, but the situation for the C5 driver is likely to be better than for the pedal cyclist.

From the results of the tests completed to date and from considerations about the accident rate of pedal cycles, it is concluded that the overall accident rate of the C5 might be similar to that for pedal cycles. The breakdown of the accident situations would be rather different with the C5, being better in some respects and poorer in others. Only if a large number of Sinclair C5s appear on the road will it be possible to collect sufficient accident evidence over a period of time to enable unequivocal statements to be made.

8 ACKNOWLEDGEMENT

The work described in this report was carried out in the Vehicle Safety Division of the Vehicle and Systems Assessment Department of the TRRL.

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Printed in the UK for HMSO
Dd822661 11/85 10170 (2304)