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Analysis of pedestrians at intersections

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Abstract:

The problem area discussed in the paper is related to the level of service provided to pedestrians at signalised intersections with pedestrian signals. The paper is based on field surveys conducted in 1996 in NSW and NT at seven signalised intersections. The getting it right theme of this conference is explored here in the context of pedestrian flow management. The objective is to investigate whether pedestrian movement has been dealt with adequate level of technical professionalism.

Pedestrian behaviour and related historical aspects are documented in the paper. The incentive for adoption of more effective management of the pedestrian phases is the presence of soft violations where certain pedestrians try to outguess the length of the remaining flashing red period. It is seen that signal violators reduce the average delay below the design amount but this is associated with safety implications

Field survey findings here show that an ambiguity in design guidelines has lead to a generally poor level of service in terms of average delays experienced by pedestrians at intersections with pedestrian signals.

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Introduction

It is important to realise that a large proportion of pedestrians are at another time drivers and passengers of the vehicular traffic flow. In major demand centres it is likely that pedestrian numbers are in the same order of magnitude as the terminating traffic in that locality. However, in traffic planning work, the efficiency of the motor traffic flow is regarded paramount at the expense of the pedestrian flows generated from such traffic. Optimality of this policy is not properly investigated.

The field survey conducted during the research project reported here has shown that the amount of signal violations at certain signalised pedestrian crossings is up to 51% At those signal crossings, about half the pedestrian flow has opted to not wait for the green signal. These violators reduce the observed delay but this method is unacceptable for transport planners due to obvious safety considerations. In keeping with the theme of this forum the question is asked whether we got it right in our pedestrian signal design. Why is this violation rate so high?

This paper looks at the possibility of improving the signal timing arrangements with the view of reducing the delays experienced by pedestrians at signalised crossings. These crossings are generally found in urban areas and the analysis shows that pedestrians are often the user group that face the largest delay at such intersections.

The objective here is to investigate how pedestrian signal operations can be improved an better serve the pedestrians. The delay from being held by the signal and pedestrian impatience are the main cause of signal violations. It is interesting to question whether pedestrians are showing some degree of contempt to these devices, lack of confidence on the signal operation, or lack of understanding of messages. Analysis here shows that signals are working at less than optimum from the pedestrian point of view

The method proposed in this paper is intended to achieve the above objective of reduced pedestrian delay without any additional delay passed on to motorised traffic. What is attempted is a rethinking of the signal timing arrangements such that pedestrians can be processed more effectively during the signal time allocations made for them.

Pedestrian signals

There are number of different types of pedestrian signals. Pretimed signals, Pedestrian actuated signals, pelican crossings and signalised crossings with pedestrian refuges are some of the common applications in Australia. Also there are number of different arrangements related to the signal phase sequencing such as (a) early release or late release in relation to turning traffic; (b) concurrent phases where pedestrian walk signal is active while a conflicting vehicular traffic is also permitted; (c) exclusive phase; and (d) scramble phase arrangements where simultaneous pedestrian flows in number of directions are allowed

The meaning of pedestrian signal phases are defined in Australian Standards AS1742.10 (1990) Clause E2.3. These signals use a combination of flashes, colours and illustrations to command pedestrians. Pedestrian signals as a norm are based on a two lamp configuration whereas motor traffic signals have three lamps. The lack of a third lamp for a third message is circumvented by using a flashing lamp for one message.

1. The green signal displaying an icon of a walking pedestrian tells pedestrians that they may commence crossing the carriageway. The minimum duration specified for this signal is six seconds. This signal is displayed by the bottom lamp of the two lamps, and that lamp is used only for this signal. This convention is important for colour blind pedestrians. At some signals where moderate to high pedestrian volumes are observed this signal may be supplemented by an audible rapid beep and/or tactile pulse for peoples with various forms of disabilities.

2. The flashing red icon of a standing person has similarities to the amber signal for vehicular traffic, and signifies that a conflicting traffic movement may commence soon. This signal attempts to transmit two important messages. Firstly, if you are on the carriageway, continue to complete the crossing. Secondly, do not to leave the kerb or the refuge if you are already on one. These two messages attempted to be conveyed by this signal has major implications on our analysis presented later.

3. The steady red signal of the icon of a standing person informs the pedestrian to stay clear of the carriageway, and remain on the refuge or footpath. A conflicting vehicular movement has been permitted and carriageway is not safe for the pedestrians.

The above explanation assumed the availability of lamp faces with graphic icons. The signal lamp faces may use symbols, text or only colour depending on local preferences. An alternative to this arrangement may be the use of advanced warnings for on coming traffic ahead of a pedestrian crossing, particularly in rural applications. Sparks and Cynecki (1990) has described the investigation of the level of success of a push button activated flashers as advanced warning implemented in New Jersey, U.S.A. It should be noted that this alternative method is not the recommended practice and field trials so far have not shown much success in reducing the speed of on coming traffic. This project does not consider this alternative method and limits the analysis to the conventional two lamp pedestrian signals in conjunction with traffic signals for conflicting vehicular flows.

There are two main method available in allocation of signal timing for pedestrians. Pre-timed signals and pedestrian actuated signals form these two categories. Pre-timed signals allow a pre-determined amount of time for pedestrians during each signal cycle. The pedestrian actuated system caters for pedestrians on the need basis but requires additional hardware to facilitate pedestrian requests. The simplest of this form involve a push button that can be activated by a pedestrian on the kerb. Reading et al. (1995) reported developments in pedestrian detection technology and recent advances made in visual based automatic detection methods for pedestrian signals. The advantage of these methods, from traffic management point of view, is that automatic detection methods can be configured such that pedestrian demand level can also be determined and input to signal timing algorithms to achieve optimum green time allocations. The push button technology tells of the presence of a pedestrian but is incapable of determining the number of pedestrians waiting for the particular crossing.

Do all pedestrians understand pedestrian signals? It appears that there is a certain amount of misinterpretations that give rise to a wide range of differing responses at signalised pedestrian crossings. Lelani and Baranowski (1993) have documented problems associated with these misunderstandings and efforts by transport planners to overcome this problem through community educational campaigns. The essence of the educational package is in explaining what each signal means. Steady green icon means start crossing. Flashing red icon means do not start crossing but complete crossing if on the roadway. Steady red icon means pedestrians should not be on the roadway. Note that these messages are consistent with descriptions of the three phases mentioned above.

Field survey

Preliminary investigations related to this project work have relied on data from six signalised pedestrian signal locations in Sydney and one site in Darwin (Yau, 1996). This survey was conducted in mid 1996.

Signalised intersections with pedestrian signals were selected in the site selection process and screened according to two requirements. For the sites in Sydney it was decided to select sites that are in close proximity to regular traffic counting sites of the Roads and Traffic Authority. This is to eliminate the need for separate traffic counting surveys to be performed. The second requirement related to observer positioning. Only sites where the observer can be located unobtrusively to ensure no behavioural modifications of pedestrians to the presence of a formal observer were selected. Six sites in Sydney and one site in Darwin are selected for the survey. The survey conducted here is organised as a task that can be completed by a single person within a limited amount of time as the field work was performed by an engineering student of the University of New South Wales as part of his project work requirements (Yau, 1996)

Design aspects

Design method for pedestrian signal timing as described in Akcelik (1981) simply specifies a minimum displayed green time (G_m) by making an allowance for the kerb to kerb walking time (t_{kk}) for pedestrians. This can be expressed as:

$$G_m = 6 + t_{kk}$$

Akcelik (1981) recommends a minimum walking speed of 1.2 m/sec, closely in agreement with overseas practice, in computing the allowable walking time

Other researchers have pointed out specific deficiencies of the above formulation, particularly in relation to its inability consider the magnitude of flows of pedestrians. For example, Virkler (1982) has addressed this particular deficiency and proposed a modification that accounts for the safe walking of a group of pedestrians rather than a single 'average' pedestrian. In more recent work, the need to include level of service concept is discussed by Virkler (1996).

In earlier work, Lin (1977) and Cresswell et al. (1977) have also suggested green time optimisation strategies for various types of pedestrian crossings.

Survey of crossing times

Table 1 shows pedestrian signal timings obtained by a survey of the seven sites. Each site was investigated for at least 30 signal cycles in the determination of the average measurements.

Some discrepancy exists between the average observed crossing time and the computed crossing time obtained from the road width divided by walking speed as suggested in Akcelik (1981). Based on that method, for n three metre wide lanes, Akcelik (1981) allows 2.5n seconds as the average walking time. A linear regression analysis of the last two columns in Table 1 indicates that the average observed walking time in seconds is given by:

$$t'_{kk} = 2.1\, n + 1.5$$

During the field work it has been noted that observed walking behaviour deviates from the theoretical basis in another way. On occasions, pedestrians fail to walk perpendicular to the carriageway. In particular, at the site in front of the University of New South Wales it was observed that many students opted to walk in a diagonal manner because of the position of the University entrance relative to the bus stop at the other side of the highway. Notwithstanding the above discrepancies it is acknowledged that the kerb to kerb walking time allowed according Akcelik (1991) is adequate. This amount is on the conservative side which is important from the point of view of the pedestrian safety.

Pedestrian delay

Assuming random arrival of pedestrians at the site, the average delay (d) for pedestrians is obtained by:

$$d = r^2 / 2\, c$$

where r is the effective red time for pedestrians and c is the cycle time of the signal. Akcelik (1981) rightly mentions that the effective red time, r, includes the flashing red signal time. This is necessary because during the flashing red time, the message to the pedestrian is 'do not begin crossing', and whoever arrives at that time is expected to

Table 1. Pedestrian Signal Timings at Seven sites

Location	Signal	Green Time (seconds)	Flashing Red (seconds)	Displayed green (seconds)	Number of Lanes	Observed Average Crossing time (seconds)
Smith/ Knuckey, Darwin	Pretimed concurrent	7	21	28	6	11
Anzac Pde/ Maroubra Rd Maroubra	Pedestrian actuated, refuge early release	6	16	22	6	15
Anzac Pde at UNSW gate, Kensington	Pedestrian actuated, refuge exclusive	6	18	24	4	15
Castlereagh/ Market, Sydney Town Hall	Pedestrian actuated scramble	8	18	26	4	14
Bronte Rd/ Grosvenor/ Oxford, Bondi Jn	Pedestrian actuated scramble	8	16	24	3	8
Alison Rd/ Belmore Rd/ Cook Rd, Randwick	Pedestrian actuated, early release	8	12	20	4	10
George St/ Rawson Pl Haymarket	Pedestrian actuated concurrent	8	20	27	7	15

wait till the next pedestrians green signal See Figure 1 for a graphic explanation of various signal phases. The horizontal scale of this diagram is selected as time, often measured in seconds for the purpose of signal timing work

There is a certain degree of confusion in this simple step of delay computation because of the mis-usage of red time instead of effective red time in calculations. In vehicular signal design work the amber phase is only a small proportion of the signal cycle whereas in pedestrian signals the equivalent flashing red is a comparable proportion to green phase. Thus inclusion or not inclusion of the flashing red makes a considerable difference to the pedestrian delay computation. It is important to note however, that Akcelik (1981) has repeatedly stated the correct method and included the flashing red in the effective red time Virkler (1996) has also agreed with this particular aspect

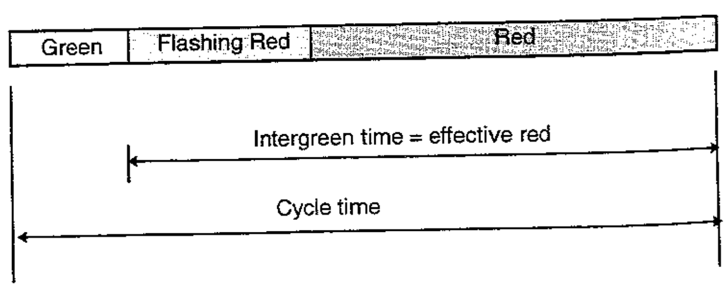

Figure 1 Pedestrian signal phase terminology

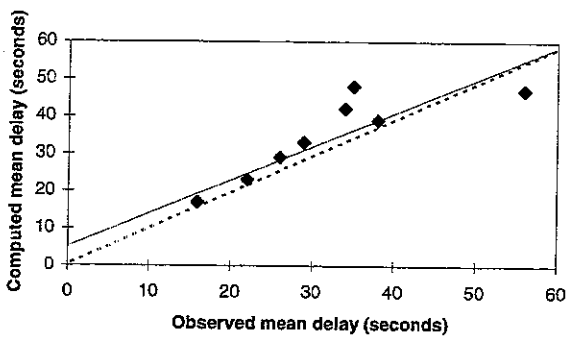

Figure 2 Comparison of Observed and Computed Pedestrian Delays

Comparison of average delays computed according to the above methods and what is observed at above sites, and shown in Figure 2, are in some agreement. In general though, data points are above the dotted line shown in the figure indicating that observed mean delay is somewhat lower than the computed value because some pedestrians opt to ignore pedestrian signals to avoid excessive delays at these locations. Virkler (1996) has presented a model where the fraction of pedestrians who do not obey the signal are specifically ignored from the delay computation.

Violations

Yau (1996) has monitored the violation rates at the seven signalised crossings studied to investigate factors contributing to such violations. It is seen that the tendency of pedestrians to make the crossing in violation of the pedestrian signal decreases with the increase in vehicular traffic flow on the carriageway and also with the average crossing time experienced by pedestrians. For example, according to a regression analysis the peak amount of violations is about 45% at zero flow of traffic and drops by about 5% for each 10000 AADT on the conflicting vehicular traffic stream. A tendency to have increased violation rates with the increase in the flashing red time is also observed, but the evidence is inconclusive about this last point.

Observations of pedestrian behaviour show there are possibly two types of pedestrian signal violation actions. In general, the violator disobeys the message conveyed by the signal. However, some pedestrians, referred to as soft violators here, disobey the signal but manage to cross the road in a safe manner because there are no conflicting vehicular movements allowed on the carriageway. There is an opportunity for soft violations when there is a relatively long flashing red time. Figure 3 attempts to describe different types of violation actions

Figure 3 adopts distance on the vertical scale and consider the height of the diagram as the kerb to kerb length. A is a signal complying pedestrian shown by the sloping

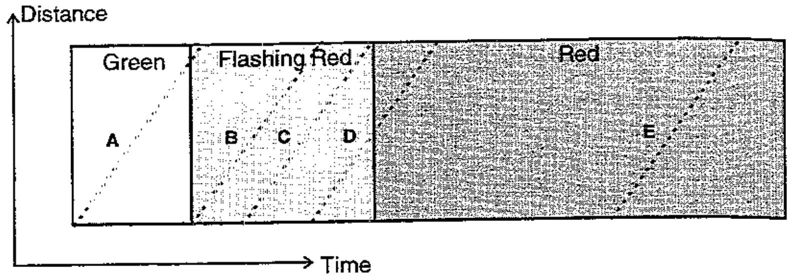

Figure 6. Violation categories

trajectory line. A leaves the kerb at the beginning of the green and reaches the other side during the safe period. B is also a signal complying pedestrian but begins the crossing at the end of green. B is also able to reach the other side of the roadway during the safe period

Anyone attempting to begin the crossing between B and C trajectories are in violation of the message conveyed by the flashing red which prohibits commencement of a crossing. However, some of these pedestrians are able to complete the crossing before a conflicting vehicular movement is allowed. For the lack of a better term, pedestrians between trajectories of B and C are referred to as soft violators.

E is a serious violator stepping on the carriageway when vehicular movements are allowed. This action may possibly be performed safely during times of low vehicular flows but is fraught with extreme danger.

D is also a serious violator although the crossing commences during the flashing red. This person perhaps misjudged the length of flashing red. Motorists are likely to be most annoyed by these violators as they occupy the carriageway and prevent vehicular movements to begin and test the alertness of drivers.

Signal retiming opportunities

Consider the first site mentioned in table 1. Presently, the average pedestrian green time is 7 seconds followed by 21 seconds of flashing red The average crossing time is 11 seconds, and therefore for about the last 10 seconds, of the flashing red period the pedestrian crossing is not in use if all pedestrians obey signals. It is possible to alleviate this situation by reducing the flashing red by 10 seconds and using that amount to increase the pedestrian green phase. This leads to a green phase of 17 seconds followed by flashing red of 11 seconds still resulting in the same total (28 seconds in this example) computed from the conventional design method as explained before But the advantage of the proposed method is that the effective red is reduced by 10 seconds and this reduces the average waiting time for pedestrians.

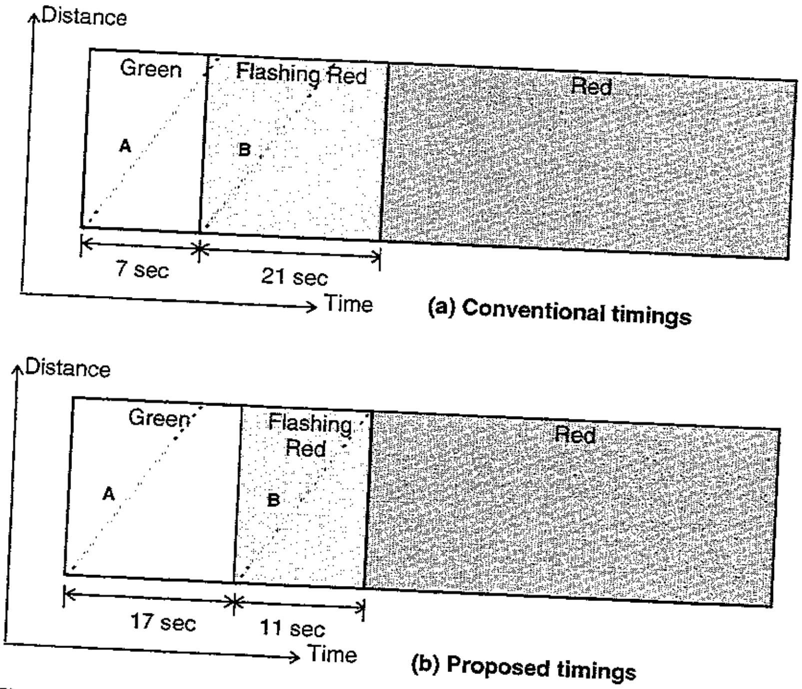

Figure 6. Pedestrian signal retiming example

Figure 6 shows the effect of the retiming proposal in a schematic manner. The total red time is not changed, in other words, green time provided to vehicular traffic is unchanged. The pedestrian green is extended and therefore the average waiting time of pedestrians is reduced.

The current average delay is computed at 32 second. This drops to 24 seconds with the proposed method Therefore, this rearrangement of timings would result in a 25% reduction in the pedestrian delay at this particular site.

Similar analysis have been performed for the other six sites as well. It is seen that for the sites investigated, the reduction in average pedestrian delay that can be achieved by this method without changing the green allocations for other road users is in the range of 3 to 30%.

Steps involved in the design procedure can be listed as follows For comparison purposes, relevant steps of the conventional method is presented first

Conventional method:

1. Obtain the displayed green time
2. Allow the minimum green.
3. Allocate the remainder as the flashing red

Proposed method:

1 Obtain the displayed green time.

2. Set the flashing red to the allowable walking time.

3 Allocate the remainder as the green time

It should be noted that the conventional steps as explained above is not obtained from the design guides but from analysis of what is implemented Design guides have not stated these steps explicitly. However, practitioners have interpreted the guidelines in the current manner

It is acknowledged that if the proposed process is adopted in conjunction with a red arrow for left turning vehicles, the increase in the pedestrian green is likely to affect the delay for left turning vehicles. The effect on left turners has been considered briefly in Yau (1996) and is beyond the scope of this paper. In general though, the work mentioned here is well applicable, without any further refinement, to sites with left turners selecting gaps of pedestrians in a concurrent signal arrangement where a leading turning movement is not provided Such locations generally have low levels of left turning movements.

It is also anticipated that, with the proposed design method, pedestrians will better appreciate the significance of the flashing red The current practice has led to pedestrians attempting to guess the remaining length of flashing red, and risk crossing the roadway in violation of the signal. A just sufficient flashing red is more in agreement with the expectation of the pedestrian and the message the flashing red wants to convey as specified in the Australian standards.

CONCLUSIONS

The proposed method is aimed at reducing the delay for pedestrians at signalised intersections without affecting other road users This method differs from the current practice in the way time is shared between green man and flashing red.

Note that the proposed method only differs in its allocation of the share of green time and flashing red time More green time is proposed, instead of the practice of providing a green duration closer to the minimum allowable as experienced in all seven randomly selected sites It is proposed that the flashing red time is kept closer to the allowable walking time from kerb to kerb.

Furthermore, the proposed method is anticipated to discourage pedestrian signal violations with the reduction of long delay experienced by pedestrians that often contribute to such violations and removing opportunities for soft violations during lengthy flashing red periods

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