The Capacity of Pedestrian Crossing Phases

Date: 18 August 2025
Project name: JCT Symposium 2025
Company: JCT Consultancy
Prepared by: Phil Shoobridge

The West Wing
1 Glass Wharf
Bristol, BS2 0EL
United Kingdom
T +44 (0)117 457 2500
www.jacobs.com

1. Problem Identified

1.1 Introduction

How many people can cross the road in a single cycle of a signal-controlled stand-alone crossing? Traffic signal schemes often have extensive modelling work undertaken to investigate how the junction, or network, will accommodate the predicted traffic arising as the result of the scheme. Some situations may involve large transport interchanges or venues with large concourses for pedestrian movements. Specific software such as LEGION and Viswalk exists for schemes of that type. However, a single crossing can affect the way in which people navigate a street and whilst surveys can be undertaken to identify the location to best capture crossing movements, the number of people able to cross each time the Invitation to Cross Period is displayed tends to remain unknown and unconsidered.

This paper aims to examine the advice available on crossing capacity, how accurate a first-principles calculation could be and whether there are wider applications.

1.2 Background

A scheme which involved the closure of a pedestrian underpass beneath an urban dual carriageway threw up a question regarding the number of people who used that facility at a specific time of day.

In addition to the underpass, an existing, at-grade, staggered Puffin crossing would be modified to become an in-line, single-movement Puffin and the only pedestrian crossing facility at that location. The underpass was being closed to provide space for a parallel at-grade cycle facility as its internal dimensions were unsuitable for cyclists.

Collected data confirmed that during an intense 15-minute period, 279 people travelled in one direction with a split between the underpass and at-grade signal-controlled alternative of 86% to 14%. By contrast, 61 people with a 61% to 39 % split between underpass and Puffin moved in the opposite direction.

As previously noted, this at-grade crossing would be converted from a staggered facility to a straight across layout which would remove groups of users having to wait on the centre island. Nearby building lines constrained widening, so simply increasing the distance between the stud markings was not an option. The question arose: would the modified crossing safely cope with the loss of the underpass?

2. Available Advice

2.1 Traffic Signs Manual Chapter 6: Traffic Control

Clause 15.7.5 states:

The width of a pedestrian crossing is determined by the pedestrian flow. An extra 0.5 metres (m) should be added to the minimum width of 2.4 m for each 125 pedestrians per hour above 600 averaged over the four peak hours, up to the statutory maximum width of 10 m.

The implied pedestrian capacity of a 2.4m wide crossing is therefore 600 people per hour. But, is that for one-way or two-way flow?

It could be inferred from this that a 'normal' crossing would be able to cope with 150 people overall in a 15-minute period. Would the modified crossing, albeit wider, be able to cope with 279 people moving in a single direction over that same period?

2.2 Transport for London (TfL) Modelling Auditing Process

J.306 Pedestrian Modelling requires pedestrian flows to be entered in a manner consistent with the traffic flow time reference defined in J.202 e.g. per minute, per hour or per time segment used in any associated traffic analysis.

This was clearly for data consistency only, rather than offering advice on capacity.

2.3 TfL Pedestrian Comfort Guidance

Steps 2.1 and 2.3 within that document are used to arrive at a Comfort factor based upon the number of people per hour per metre using a crossing and its width. The greater the width relative to the number of people naturally indicates a better comfort factor. Whilst this process has thresholds indicating the ratios at which pedestrian comfort decreases, it requires a survey of the number of users rather than indicating what is possible at a crossing.

2.4 Summary of Advice

With available documents giving advice more focussed on the hourly capacity rather than what could be achieved within each cycle, it was necessary to revert to first principles.

3. First Principles Calculation

The space available, the designed facility and a more detailed examination of the pedestrian demand profile needed to be investigated.

3.1 Peak Pedestrian Demand

A detailed survey of crossing users had been previously undertaken. The following table covers the busiest period identified.

Table 3.1 Pedestrian Demand - Afternoon peak busiest 15 minutes

Direction	Total	Using Underpass	Using At-grade Puffin
1 to 2	279 people (100%)	239 people (86%)	40 People (14%)
2 to 1	61 people (100%)	37 people (61%)	24 people (39%)

3.2 Proposed Design

Crossing Distance kerb-to-kerb: 16.7m

Speed of road: 40 mph, though physical features meant Speed Discrimination Equipment could only be applied to one approach and was not required for the other.

3.3 Estimating Parameters for Crowd Space

An Internet search suggested 10 square feet (0.93m^2) is required per person to wait comfortably, but in a crowd this figure can be reduced as low as 4.5 square feet (0.42m^2) per person. Users typically gather together at Puffin crossings to wait for the Invitation to Cross period i.e. the green man signal for pedestrians, looking out for the green man display on the respective nearside pole. This waiting area would not typically be as densely populated as a busy tube train but nonetheless could comprise a similar density during the busiest periods. Our calculations, relying upon industry expertise and analysis, incorporate this information, anticipating a typical amount of space per pedestrian of somewhere between these two values. The methodology adopted for undertaking calculations is as follows.

Several surveys suggest that 6 square feet (0.557m^2) is typically required per pedestrian in a crowd. Rounded up this gives a dimension of 0.6m^2, giving a waiting person slightly more space. This distance also corresponds with the Transport for London Pedestrian Comfort Guidance document which in Step 1.4 states 0.6m as the typical pedestrian width (standard body ellipse) at standing locations. The square root of that value would give 0.77m i.e. the theoretical side of the square a person would occupy/ use.

Applying that to the site in question: the pedestrian crossing design had 7 red tactile paving slabs, with each measuring 0.4m x 0.4m wide. This equates to a crossing width of 2.8m. Dividing that width by 0.77 it gives the number of people accommodated across the crossing and waiting area width: 3.6 people. It could be assumed that the '0.6m' is the required space for a child, but for additional robustness in the calculations, it is preferred to round this down to 3 individuals allowing more space between waiting pedestrians.

In summary 3 people could comfortably wait abreast at the proposed crossing.

3.4 Estimating People Movements

The design for the single-movement Puffin crossing had a 9 second pedestrian 'Invitation to Cross' period . The typical walking speed of pedestrians using pedestrian crossings is 1.2 metres per second. The Department for Transport Traffic Signs Manual Chapter 6 – Traffic Control (2019) states the following in respect of typical walking speed:

Paragraph 11.7.1. *'A walking speed of 1.2 m/s is conventionally used to calculate timings for crossings. This results in timings that are suitable for the majority of crossings. The clearance period* *is key, as this is what allows people to clear the crossing if they step off the kerb as the green symbol goes out. If this is properly calculated, it will ensure there is sufficient crossing time.'*

3.5 The Front-Rank Advances

The distance the front row of 3 waiting pedestrians could be expected to travel during the pedestrian green would be 9 (seconds of green invitation to start crossing period) multiplied by 1.2 (average walking speed in metres per second) which equates to 10.8m. If that distance is then divided by 0.77 for the number of 'rows' of pedestrians that could enter the crossing under a green signal, this equals 13.94.

This figure can be rounded down to 13 rows. It should be noted that once the pedestrian green signal period ends, users are not supposed to step off the footway and begin to cross.

If the width of each waiting row of pedestrians (3) is multiplied by the number of 'rows' of pedestrians which could be expected to start to cross during the green man period (13) this equates to a maximum number able to safely cross during a single crossing green man period as 39 people from each side of the road. Therefore, this suggests a theoretical maximum number of 78 pedestrians crossing the carriageway with a maximum of 39 moving from each side. As this number of pedestrians would face significant head on conflict whilst using the crossing, it is proposed to halve this figure to ensure the calculations are robust and likely more realistic. Therefore, the maximum number of users who could safely cross from either side during any green man period is 39.

3.6 Would the Design Cope?

Applying that outcome to the original situation, the following table shows the busiest minutes for using the crossing, which were recorded during a typical week. During these few minutes of use on a Thursday there appeared to be around an 85% use of the crossing from Direction 1. This is reversed on weekday mornings, albeit the numbers of users were more spread out across this period reducing the peak impact.

Table 3.6: Peak Number of Recorded Users Crossing Per Minute by Direction

Busiest Time of Day	Day of Week	Crossing 2 to 1	Crossing 1 to 2	% Crossing 2 to 1	% Crossing 1 to 2	Total
15:55	Thursday	5	33	13%	87%	38
15:49	Thursday	7	29	19%	81%	36
15:53	Thursday	6	29	17%	83%	35
15:51	Thursday	2	31	6%	94%	33
15:59	Thursday	5	25	17%	83%	30
08:38	Thursday	18	4	82%	18%	22
16:01	Saturday	14	7	67%	33%	21

If it is assumed in line with the counts undertaken that typically during busy periods the same proportion of users crossed on the new crossing where the maximum capacity was 39 pedestrians, at 15:55. for example. 5 pedestrians could again cross from Direction 2 to Direction 1 and 34 pedestrians could cross in the other direction.

On a Saturday morning, if following the recorded two-thirds and one third directional movements, then 26 pedestrians could cross from Direction 2 to Direction 1 and 13 pedestrians could cross in the other direction during a single green man period.

3.7 Initial Outcome

Somewhat conveniently, it would appear that the crossing could accommodate the number of people wanting to cross during the very intense peak. The adoption of the less optimistic dimensions and assumption that no-one starts a crossing manoeuvre during the all-red clearance period increased the confidence in the final outcome.

3.8 Estimating an Hourly Capacity

With the capacity per cycle identified, it is possible to use that to arrive at a capacity per hour.

Converting that into a maximum number of people per hour requires an examination of the number of cycles of the facility that can take place. As some of the time periods are variable, it means the maximum and minimum duration of cycle times must be established. Table 18-2 from Chapter 6 lays out the 7 Periods that make up the cycle time of a nearside crossing.

3.9 Maximum cycle time

- Period 1 - Vehicle maximum green of 30 seconds
- Period 2 - Mandatory leaving amber of 3 seconds
- Period 3 - All-red period of 5 seconds if the Speed Discrimination Equipment loops insert an inter-green extension
- Period 4 - Invitation to Cross period of 9 seconds, which should be a reasonable duration for a user travelling at 1.2 m/s to establish themselves on the crossing
- Period 5 - Minimum All-red clearance of 7 seconds due to the inter-green of a parallel cycle phase
- Period 6 - All-red clearance with a Pedestrian Comfort Factor of 3 for Consecutive Mode of 12 seconds
- Period 7 - Mandatory starting amber of 2 seconds
- Total cycle time = 68 seconds

The number of people moved in an hour of maximum cycles

- Total number of cycles of the crossing in a 1-hour period (3,600 seconds divided by 68) = 52.94 cycles
- People per hour would be the number previously estimated multiplied by the number of cycles (39 x 52.94) = 2,065 people per hour
- Halving that to guard against over-optimism = 1,032 people per hour

- Assuming the previous split of 2/3rd to 1/3rd gives 688 people in one direction and 344 people in the other.

3.10 Minimum cycle time

- Period 1 - Vehicle minimum green of 7 seconds and no green extensions – obviously unlikely
- Period 2 - Mandatory leaving amber of 3 seconds
- Period 3 - All-red period of 3 seconds - the typical minimum of 2 seconds plus 1 second for the higher speed environment
- Period 4 - Invitation to Cross period of 9 seconds as before
- Period 5 - Minimum All-red clearance of 7 seconds due to the inter-green of a parallel cycle phase
- Period 6 – zero, i.e. no on-crossing extensions – again, obviously unlikely
- Period 7 - Mandatory starting amber of 2 seconds
- Total cycle time 31 seconds

The number of people moved in an hour of minimum cycles

- Total number of cycles of the crossing in a 1-hour period (3,600 seconds divided by 31) = 116.13 cycles
- People per hour would be the number previously estimated multiplied by the number of cycles (39 x 116.13) = 4,529 people per hour
- Halving that to guard against over-optimism = 2,265 people per hour
- Assuming the previous split of 2/3rd to 1/3rd gives 1,510 people in one direction and 755 people in the other.

3.11 Comparison of Maximum Against Minimum

Table 3.11: People moved per hour of Maximum and Minimum Cycle Time by the Designed Crossing

People Moved	1 Hour of Maximum Cycle Time	1 Hour of Minimum Cycle Time
Total	1,032	2,265
2/3rd split	688	1,510
1/3rd split	344	755

The Minimum Cycle Time results in more people crossing as the Invitation to Cross Period appears more often. However, it is only a theoretical maximum as the conditions for that to occur are extremely unlikely.

Averaging the two would not provide a realistic answer, so adopting a figure towards the lower end of the range would be the more realistic value.

3.12 Applying the calculation to a 'typical' crossing

Defining a 'typical' crossing could be considered difficult, but for the purposes of a calculation the assumptions are as follows:

Crossing type: Puffin

Speed of road: 30 mph road with an 85th percentile speed that does not require additional inter-green and a kerb-to-kerb width of 7.3m gives an assumed maximum crossing cycle duration:

- Period 1 - Vehicle maximum green of 30 seconds
- Period 2 - Mandatory leaving amber of 3 seconds
- Period 3 - All-red period of 2 seconds
- Period 4 - Invitation to Cross period of 5 seconds, which should be a reasonable duration for a user travelling at 1.2 m/s to establish themselves on the crossing
- Period 5 - Minimum All-red clearance of 3 seconds
- Period 6 - All-red clearance with a Pedestrian Comfort Factor of 3 for Consecutive Mode of 7 seconds
- Period 7 - Mandatory starting amber of 2 seconds
- Total cycle time 52 seconds

Number of Puffin cycles in an hour 3,600 ÷ 52 = 69.23

Using that number of cycles in the calculations above gives a minimum number of people hour of 727 in total, or 485 in one direction and 242 in the other.

The minimum duration cycle time would be 22 seconds, which gives 163.64 cycles per hour and a total of 1,718 people per hour, or 1,145 in one direction and 573 in the other. The following table compares the results.

Table 3.12: People moved per hour of Maximum and Minimum Cycle Time by a 'Typical' Designed Crossing

People Moved	1 Hour of Maximum Cycle Time	1 Hour of Minimum Cycle Time
Total	727	1,718
2/3rd split	485	1,145
1/3rd split	242	573

3.13 Comparison against the advice in Chapter 6

Taking the 600 pedestrians per hour suggested in Clause 15.7.5 as the maximum applicable for a 2.4m wide crossing and dividing by 69.23 (the number of cycles per hour) suggests that 8.6667 pedestrians can cross per cycle. In the earlier examples, that value would have been rounded down, but the 600 people per hour is a guide figure, rather than a calculated maximum.

The additional 125 pedestrians per hour that require widening the crossing by 0.5m would add 1.8 pedestrians per cycle.

The lower figure previously calculated was 727 which is very close to the 725 that Clause 15.7.5 of Chapter 6 stated would benefit from the additional 0.5m of width at a 2.4m wide crossing. The crossing examples have very similar widths i.e. 2.8m for the modified crossing and 2.9m for the theoretical widened 'normal', which suggests the calculation has arrived at a reasonable value. However, what appeared to give the proposed crossing its capacity was the duration of the Period 4 "Invitation to Cross" Period. The Period 4 value for the 'typical' crossing was 4 seconds less. A higher actual capacity for the proposed crossing could potentially be inferred from that, as more pedestrians would be able to legitimately start to cross with the longer Period 4.

3.14 Initial Conclusion

The similar hourly pedestrian capacity value for the 2.8m and 2.9m wide crossings was not apparent at the start of the examination, particularly as the guidance figure could be for two-way flows. Instead, the focus was on whether the intense period of demand could be accommodated. With the analysis performed, confidence in the very conservative figures adopted for the real-world situation appears to be well-founded.

4. Discussion and Conclusion

4.1 Limitations/ weaknesses in the calculation

4.1.1 Assumption of regimented pedestrian queuing.

People are more likely to wait in a more organic shape akin to a cloud or perhaps the bell of a trumpet.

4.1.2 Unofficial Use of Clearance Periods

No account is taken of those who might start to cross during all-red clearance Periods 5 and 6. This is due to the initial desire to be as pessimistic as possible with the calculation to withstand any scrutiny that might be applied.

4.1.3 Constraints from Competing Movements

Many crossings will also have a steady stream of people walking on the footways parallel to the road. They could interrupt the flow of pedestrians onto the crossing. The site in the original example did not have this as most of the attractors were away from the road.

4.1.4 Straight-Across Single-Movement Only

Only a straight-across layout was analysed. The calculations could be used to determine the size of an island if a staggered arrangement or triangle island based upon the number of people who might arrive each cycle. Perhaps it could be used to demonstrate a further safety issue if the anticipated number of people exceeded the available space and justify a straight-across layout.

4.2 Applications

4.2.1 Planning roadworks

If the number of users is known, or at least any intense peaks in demand can be identified, it provides an opportunity to avoid safety issues during the works. That could also forestall any negative publicity during construction. Physical works could be phased to make sure a suitable crossing, even if only a temporary layout, could be provided whilst the permanent scheme was under construction. Works could also be scheduled to avoid peak periods of demand.

4.2.2 Event management

Some locations may tend to have low demand for crossing a road, but occasional events can result in sudden, intense spikes in demand.

4.3 Refined crossing Design

The crossing characteristics that had the greatest impact on the capacity within a cycle appeared to be the width between the pedestrian studs and the duration of the Invitation to Cross period. The latter could be used to increase the pedestrian green during the busiest times either via a timetabled event in the signal controller's Master Time Clock, or preferably via kerbside detection so unexpected peaks in demand can be accommodated.

However, pedestrian green is rarely extended due to remaining pedestrian demand at signal-controlled facilities in the United Kingdom. Where peaks in demand are anticipated, the simplest solution would be to provide a wider crossing, e.g. an extra 0.5m per 125 people per hour as recommended in Chapter 6. However, some peaks may be well in excess of that and physical widening may be constrained by other factors.

At the MOVA Users Group Meeting in 2022 Sam Oldbury and Chris Kennett each showed examples of stand-alone crossings at which they had implemented increased pedestrian green based upon higher occupancy identified by kerbside detection. The former using fixed duration extensions and the latter with green extensions when occupancy remained at the medium or high level. These measures removed the need to widen crossings beyond the 4.0m width that might be considered 'normal'. Wider crossings are permitted up to 10m before special authorisation needs to be sought, but this can bring different sets of challenges for positioning demand buttons and traffic to pedestrian clearance times. Understanding an occasional need for increased crossing green could minimise the potential for local 'bad news' narratives.

Local authorities sometimes find it difficult to justify the expense of kerbside detection, particularly when it comes to refurbishment. Such units represent a lot of money perched 3.5m in the air, when all they might do is slightly reduce inconvenience to road traffic in a way that is difficult to quantify. However, the work referenced above has shown that the occupancy function available in some kerbside detection can be used to either call additional Invitation to Cross Period 4 durations, or to extend them up to a maximum to address peaks in crossing demand. If a crossing site has a significant 'attractor' such as a school, transport hub, or venue and the data on usage numbers is available, examination in the manner described above could be a way to target resources to improve safety and performance. If combined with MOVA 8 and its Special Conditioning Function, the service to all users could be improved, whilst minimising the site's physical footprint.

4.4 Conclusion

When calculating the capacity of a signal-controlled junction, there is a limit to how much the width of a lane increases capacity. Beyond a certain value, there is no benefit. The number of lanes and the green time available within a cycle have a greater impact on capacity. However, there is plenty of available advice and software to assist in improving the capacity and thus the junction's performance.

For pedestrian crossings, it initially appears that there is little available advice relating to their capacity. This could be due to the rarity of it being critical to a particular location. The analysis performed above demonstrates that the few short lines in Clause 15.7.5 Of Chapter 6 in the Traffic Signs Manual provide very useful information, though it took some effort to confirm.

In common with traffic lane capacity there are two similar values that determine the theoretical capacity of a pedestrian crossing:

- The width between the pedestrian stud markings; and
- The duration of the Invitation to Cross Period.

Each of these can maximise the benefit of the other and technology can be employed to maximise their benefit to users.

5. References

Traffic Signs Manual Chapter 6: Traffic Control Department for Transport ISBN 978 0 11 553744 8

Transport for London Model Auditing Process (MAP) Version 4.0 MQA-0685 edited by Lucy Beeston and Robert Blewitt

Transport for London Pedestrian Comfort Guidance 2010

6. Acknowledgements

My colleagues:

- Matthew Langdon of Jacobs who assisted me with checking the original concept, calculations and drafted a report that influenced this paper.
- Stephen Alexander for invaluable last minute proof-reading services and formatting assistance.

Sam Oldfield, then of WSP, but now with Yunex, for his excellent presentation at the 2022 MOVA Users Group Meeting on the work carried out using MOVA special conditioning for various interventions in Leeds.

Chris Kennett of Chris Kennett Consulting Limited for his similarly excellent presentation at the 2022 MOVA Users Group Meeting covering his use of kerbside detection and MOVA special conditioning to avoid having to widen a Toucan crossing outside a new school from 4 to 10 metres.