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Addressing the unjust treatment of pedestrians at signalised intersections

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Abstract

The reasons why pedestrians wait longer than other categories of road user at signalised intersections are investigated. On the basis of literature review, tests of relevant software, interviews with practitioners and reviews of international exemplars, practice is found to be centred on keeping the (vehicular) traffic moving, and practitioners hindered from altering their approach by a lack of relevant data and by design tools that reflect a historical emphasis on facilitating motorised traffic. The scope for change is explored through the presentation of an argument from first principles for greater equality. Given that forcing equal waiting times would probably cause unacceptable levels of disruption, alternatives are discussed that would deliver a fairer distribution within the constraint of maintaining flow on the network. The possibility of seeking equality of waiting times across an area such as a town is identified as a potentially promising way forward.

Keywords: walking; pedestrians; traffic signals; traffic; mobility; justice; equity

1. Introduction

Signalised intersections are commonplace around the world and, to the extent that they provide pedestrians[1] with some protection from vehicular traffic, they are used for crossing the road. In fact, they are so common and familiar that their characteristics are frequently ignored. Moreover, the fact that they embody some engrained unequal treatment of user categories – for example, pedestrians often have to press a button to request an opportunity to cross

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[1] Throughout this paper, we use the terms *pedestrian* and *walker* as shorthand for the range of people who use pedestrian facilities on the road network, including users of wheelchairs and mobility scooters, runners, skateboarders, roller-bladers etc.

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whereas drivers do not – is as easily overlooked. Given walking is the most environmentally sustainable mode of them all, there is good reason to scrutinise the treatment of walkers at signalised intersections: are the principles of "planning for people" being adhered to?

The area of transport/mobility justice (hereafter transport justice) has been burgeoning in recent years (Grant and Bowen, 2021) and, alongside the growing literature, there is a cadre of transport researchers who characterise their interests in terms of justice, fairness and/or equity. Perhaps because this is still a relatively young sub-discipline, much effort goes into attempting to define fundamental concepts and principles. Where empirical work is being done on the distribution of "goods" as they relate to transport, the overwhelming majority of activity lies in "macro-level accessibility" (Jones and Lucas, 2012): who can gain access to which opportunities at what cost. (The other principal area of activity centres on the societal distribution of negative externalities such as road violence, pollution and noise.) There is therefore considerable scope for inquiries into the distribution of transport goods beneath this macro level.

Hence the focus of this paper. We recognised signalised intersections as an interesting manifestation of the perennial competition in transport for scarce resources, in this case access to contested space in order to continue on one's journey. The work was originally motivated by the authors' subjective observation that pedestrians typically receive a relatively poor level of service when negotiating signalised intersections, in terms of time spent waiting to cross, the typical number of crossing stages required, and the degree of diversion from their desire line. All of these seemed less favourable for pedestrians than for vehicles negotiating the same intersections. If this perception is well founded (and we provide evidence to support it below), this presents an immediate case to answer from the perspective of transport justice: why should pedestrians wait longer and have to go further out of their way than other categories of road user? And what more equitable arrangements are feasible? We have mentioned above the perspective of environmental sustainability, which points to perhaps going further than simply seeking equity amongst modes, instead giving lower-carbon options preferential treatment. It must also be said that there are strong arguments for examining this issue from the perspectives of public health and of safety – longer waits are associated with a greater propensity to cross on red (Schmöcker et al., 2008).

As we approached the task, we imagined that it would be a straightforward matter of examining the parameters used in the design and operation of traffic signals and adjusting them to make them more favourable for walkers. But our inquiry quickly revealed that the situation is more complex than that: in addition to the technical aspects, it involves the conjunction of skills, practice, attitude and policy.

2. Method

Literature review: using Scopus, Web of Science and Google Scholar, we conducted a wide-ranging search for relevant literature concerning the design and operation of traffic signals and the politics underlying this practice. In addition, we looked for sources on comparing user experience on the road network. We also sought information about relevant work done to address issues of justice in the context of traffic management.

Examination of signal-design software: we first conducted an initial survey of tools used in the design and operation of traffic signals. We then chose three to study in more detail – Junctions (produced by TRL), VISSIM (PTV) and LinSig (JCT Consultancy) – and afterwards obtained a licence for VISSIM on the basis that it appeared the most sophisticated of the three. Drawing on junction design information provided to us by Transport for London, we used this application to model a range of junctions in order to test its range and performance in the context of our inquiry.

Analysis of timings at sample junctions: we were provided by Transport for London with details of signal timings for a random selection of signalised intersections in central London and analysed these in order to understand the real relative wait times of different categories of road user. We did this by first calculating the total red time experienced in each cycle by each stream (of either vehicles or pedestrians). Using this and the cycle time (separating AM and PM peaks where these differ), we calculated expected waiting time based on a random arrival. Finally, we calculated the median value of the set of expected waiting times for vehicular streams. We then did the same for pedestrian streams.

Exploratory interviews and gathering of international best practice: we conducted interviews with representatives of two major UK-based consultancies which position themselves in the fields of transport, engineering and placemaking and which do a considerable amount of signals engineering as part of broader transport and publicrealm projects. We also interviewed a signals engineer at Transport for London (which manages all traffic signals in the city). The purpose of these interviews was to understand practitioners' attitudes to the treatment of pedestrians at signalised intersections as well as their understanding of the state of the art in terms of both practice and the technical and analytical tools available.

To balance a UK focus in our data collection, we also approached relevant experts in the cities of Paris, Berlin and Vienna, all of them recognised in differing ways for an "enlightened" approach to catering for pedestrians, in order to understand whether and how these cities approach the issue of justice at signalised intersections.

As we developed the proposals that appear towards the end of this paper, we tested them both with certain of our practitioner interviewees and with a European Commission official specialising in ethics.

3. Current practice

Our first observation is that pedestrians do tend to wait longer at signalised interchanges for a green signal than drivers and other categories of road users. For example, Carsten et al (1998) claim that in the UK aggregate delay for pedestrians at signal-controlled crossings is typically ten times that for vehicles, and that this difference increases when an urban traffic control system is being used. But this is elderly evidence and it is unclear whether it pertains only to intersections so it is useful to refer to our analysis of current timings data for a sample of junctions in London.

We analysed three junctions, all of them in central London. The median expected waiting times for vehicles and pedestrians are presented in Table 1.

Table 1. Median expected waiting times (vehicles and pedestrians) at three central London intersections

Intersection	Vehicles, AM peak (PM peak), seconds	Pedestrians, AM peak (PM peak), seconds
Elizabeth Street - Buckingham Palace Road - Elizabeth Bridge	10 (12.1)	24.0 (24.8)
Thurloe Street - Old Brompton Road - Onslow Square	26.3	29.5
Fulham Road - Harwood Road	19.7 (13.6)	33.1 (23.6)

We acknowledge that this hardly constitutes irrefutable proof of an imbalance – three intersections is too small a sample and the difference at the Thurloe Street junction is admittedly small; in addition, we have chosen the median value across streams because of a lack of data on flows, so the actual mean waiting time experienced by users of these intersections may differ from these reference numbers. But these junctions are all in central London, where pedestrian densities are high and where a combination of policies has been introduced to discourage motorised traffic. And London saw a general improvement in pedestrian facilities in the early part of this century including "longer green-man phases" (Ryan, 2008). Despite this, we see pedestrians waiting a significantly longer time than vehicle users in two of the three examples. And we feel confident in claiming that a sample that represented the range of London's geography would show this contrast more starkly because it would include locations with much lower densities of pedestrian movement. These findings therefore contribute to the case for our inquiry.

Why, though, is it the case that pedestrians wait longer? The answer is partly historical: despite their origins in road safety, traffic signals soon became instruments for managing vehicular demand (Norton, 2008). As the volume of motorised traffic grew in wealthier countries during the twentieth century, the need to accommodate it successfully became the primary concern of highway engineers. The increasing amount of traffic made environments more hostile for walking which contributed to a decline in travel by that mode (Parry, 2018), thereby reinforcing the perception that motorised traffic was the top priority. As signals systems became more sophisticated, the concept of optimisation emerged, and individual junctions or groups of junctions were designed with the aim of either maximising capacity (for vehicles) or minimising delay (for vehicles) (Gallivan and Heydecker, 1988). In addition to the unequal wait times described above, this trend is reflected in more visible ways, the most striking of which is the absence of crossing facilities at many intersections, whilst we mentioned earlier the widespread requirement for pedestrians to request permission to cross. Elsewhere, staggered crossings are seen, where pedestrians must cross the carriageway in two stages which are offset laterally from each other. This inconvenience is the price for maximising the capacity of a junction for vehicles (Philpotts, 2015).

An emphasis on catering for vehicles may explain historical practice but policy has begun to shift, with an increasing emphasis on sustainable mobility (Banister, 2008) motivated in particular by the climate emergency. Now that there is concerted policy interest in promoting walking (motivated primarily by health and environmental concerns), how readily could practice change in response? The answer lies partly in having the right tools for the job, and our experimentation with VISSIM to simulate junctions provided valuable insights on this front. That VISSIM is sophisticated is not in doubt: it is highly flexible software and, in particular, its capacity to represent the movements of pedestrians is impressive. What we found, though, was that whilst we could model pedestrian paths through junctions in detail, there was no ready means of assessing a junction's comparative performance from the perspectives of pedestrians and other users. We discuss below the possibility of a deeper explanation for this. With respect to LinSig, whose creators describe it as "a computer software package for the assessment and design of traffic signal junctions" (JCT Consultancy Ltd, 2018, p. 1), the representation of pedestrians is simpler. It is therefore less of a surprise that it does not produce "side by side" outputs. For example, the standard information provided for a junction in LinSig includes "the total traffic delay on all Lanes associated with the Junction in PCUh" and "the delay per Pedestrian in secs/Ped" (JCT Consultancy Ltd, 2018, p. 58). These are visibly quite different quantities, the most significant difference being that an aggregate figure is shown for (vehicular) traffic whilst pedestrian delay is expressed per individual, a point to which we return in Section 4. The use of "traffic" to denote vehicular movement is also noteworthy. The limited capacity of LinSig to represent pedestrian movement in all its complexity was usefully demonstrated to us by consultants whom we interviewed, who turn to another software package (LEGION) when pedestrian numbers at a junction are large enough to require detailed study. Thus it seems that the standard software for junction design does not provide a convenient means for addressing the competing interests of pedestrians and other road users.

A connected issue is data: much larger volumes of data concerning the movement of vehicular traffic are typically collected than for pedestrian movement. This is beginning to change, particularly in light of the COVID-19 pandemic which has brought increased attention to active travel. But the imbalance remains and, for the majority of signalised intersections, no pedestrian data are available (Louch et al., 2020; Hubbard et al., 2008). As our discussion of principles will explore, it is not automatically the case that user volumes should dictate signal design and timings but they are a relevant consideration; the relative lack of pedestrian data is both a practical hindrance and further evidence of a historical bias in favour of motorised traffic.

We turn now from the tools to their users. Our findings could be pithily summarised as follows: signal engineering is perceived as the art of the possible (Coletta and Kitchin, 2017; Wagenknecht, 2020). There is a considerable amount of guidance regarding signal design and installation, some of it binding. For example, the UK's central government sets out principles to inform a decision to place signals at a junction, though it dictates that more specific rules should be set at a local level (Department for Transport, 2019). The concept of maximum green time appears in US documentation: "maximum green is used to limit the delay to any other movement at the intersection and to keep the cycle length to a maximum amount" (Koonce et al., 2008, p. 5_9). This is a rare reference in such documentation to the question of fair treatment, though it must be acknowledged that this text refers to competing streams of vehicular traffic. To the extent that pedestrian needs are considered from the perspective of timings, there is a presumption in the UK that the "intergreen" period (between the end of a crossing signal and green being shown to any conflicting traffic stream) should be sufficient to allow the relevant section of carriageway to be crossed at a nominal speed of either 1.0 or 1.2 m/s (Department for Transport, 2019). And there are certain restrictions concerning cycle length, since mean wait time is positively correlated with this quantity. For example, Transport for London advises that cycle length should only exceptionally be longer than 90 seconds (Transport for London - Surface Transport, 2012). Thus, these rules impose some constraints on signal operations, but they leave a considerable amount of latitude. The detailed design is left to the practitioner, responding to the characteristics of the specific site.

And the (unwritten) golden rule which signals engineers must obey is to keep the traffic moving, with gridlock representing the most obvious sign that they have failed in their mission. Given that signals are typically installed at junctions that are busy (in terms of vehicular traffic), capacity will be at a premium and that which is allocated to pedestrians will not be available to vehicles. Moreover, because junctions are rarely isolated but instead both are affected by and affect neighbouring junctions in the network, engineers see themselves as having limited room for manoeuvre. Signal adjustments are therefore generally a matter of iteration (Wagenknecht, 2020), with the engineer testing marginal changes in search of improvements. Despite the well-developed concept of *optimum*, engineers do not rely on the algorithms of design software to find this, instead preferring to simulate a variety of options on the way to a viable arrangement. Thus, when we raised the notion of *justice* with the practitioners we interviewed, though it certainly resonated with them, their responses reflected both the history of signals as being "about motorised transport" and a sense that there was no room for principles in the highly contingent business of keeping the traffic moving. If a large number of pedestrians were crossing on red, for example, this was seen as a *safety* problem rather than evidence that pedestrians were being forced to wait unacceptably. Engineers might respond by increasing green time, but their goal in doing this would be for the number crossing on red to fall within an acceptable limit, rather than to address an unfair distribution of resources.

Turning now to the underlying concepts, the lack of a ready means of comparing user experience at signals "like for like" may not be the fault of the developers (as we hinted earlier in this section). Even a concept as simple as waiting reveals nuances if we ask whether a person is comfortable standing, whether it is raining, etc. This prompted us to examine work on levels of service (LOS) which has been carried out over many decades in an attempt to capture robustly the relative quality of user experience of the road network. The system developed by Fruin (1971) for pedestrian movement has proved enduring, whilst various efforts have been made to establish meaningful interpretations of LOS for other means of transport. Our interest lies in the relatively young field of *multi-modal* LOS measures, as initiated by the Florida Department of Transportation (State of Florida Department of Transportation, 2020). The intention behind such measures is to allow level of service in a given location to be graded across four modes (auto, transit, bicycle and walking). In principle, if users of a given mode were consistently experiencing a level of service C compared with another mode's A, this might be grounds for taking remedial action.

Before proceeding, we must first acknowledge that multi-modal LOS measures have a much broader scope than our inquiry, as they address the user's experience in all aspects of a journey. In fact, this breadth helps to explain the highly convoluted formulations that tend to have been developed in the various iterations of multi-modal LOS (Asadi-Shekari et al., 2013; Dowling et al., 2008). But they are relevant to our work in that, if they perform satisfactorily, we would presumably be able to adopt those elements that relate to signalised intersections as the basis for first establishing the baseline then assessing whether a given change would constitute an improvement. But we find them wanting in two significant ways. First, the extent to which waiting times at crossings features in the pedestrian element of LOS measures varies considerably, with only a minority including it (Zuniga-Garcia et al., 2018). Second, and more significant, the application of grade is done on a per mode basis and reflects expert opinion and expectation where each mode is concerned. Thus a grade of A for the pedestrian experience is a function of what has been considered excellent service for pedestrians in the past; a grade A for auto is similarly rooted in the experience of drivers. And so multi-modal LOS measures do not perform the, for us, essential task of bridging across modes such that a grade of A is objectively equivalent for all four modes (Zuniga-Garcia et al., 2018). This is important because people may (and in all probability have) become habituated to what is typical; we strongly suspect that a grade of A equates to a better experience for drivers than it does for walkers.

Not that we should blame LOS measures for this. Their designers have contended with a challenging task and it is merely unfortunate from our perspective that they do not provide us with a ready solution. And the difficulties they have faced are also seen in the more narrowly defined context of signal design. Wagenknecht's (2020) study of local-authority signal engineers concluded that, rather than apply a principle that would deliver fair distribution of goods, they practised "justesse", a continual incremental process that at best delivers marginal improvements: "he shrugs off the contradictory character of what 'everyone' seems to want and dedicates himself to small changes, working from one contestable compromise to the next" (Wagenknecht, 2020, p. 701). A similar story is told by Coletta and Kitchin (2017) who encounter practitioners operating according to rules of thumb, such as that 120-second cycle times impose unacceptable waits on those in the non-dominant stream. Other analysts reach a distinct but compatible conclusion, that the distribution of capacity at a signalised intersection is a political decision (Carsten et al., 1998; Schmöcker et al., 2008). But Schmöcker et al also cite surveys of the UK's transportation community that found reaching a consensus on what signal control objectives should be "is difficult" (Schmöcker et al., 2008, p. 456).

We suggest that these conclusions and practices are related: because deciding what the signal control objectives should be is difficult, practitioners fall back on a claim that this is not their job and instead concentrate on what they consider is their job: to keep the traffic moving. But, whether true or not, the claim that this is the territory of politicians ignores the important distinction between determining fundamental values (perhaps indeed a politician's job) and applying them (the practitioner's job). Nor do practitioners typically acknowledge that what they do (in keeping the traffic moving) has moral content and cannot be described as neutral.

We argue that, if for instance we agreed that no one should as a rule wait longer than anyone else, it would not be difficult to translate this principle into an operating strategy for traffic signals. And the fact that this has not happened is partly a result of the issues discussed in this section but also reflects a tacit recognition on the part of practitioners that the application of principles of justice to the operation of traffic signals could be highly disruptive. More specifically, it would probably conflict with the golden rule of keeping the traffic moving.

4. Towards a more just arrangement

We have set out above various ways in which the pedestrian's experience at signalised intersections may fall short of norms of justice; we have also offered some explanations as to why this may be the case. But none of the explanations so far encountered demonstrates that a more just arrangement is impossible. We therefore pursue in this section the definition of such an arrangement and consider its possible implications.

We start by offering the following argument:

4.1. Argument for just distribution of capacity at signalised intersections

Factual Claim 1: Very few people like waiting (to pass through an intersection).

Factual Claim 2: The longer people have to wait, the more irritating/uncomfortable it becomes, and the greater the probability of risky behaviour becomes.

Normative Claim: Therefore, no road user deserves to wait longer than any other road user.

Conclusion 1: Therefore, signals at intersections should be designed so that the mean waiting time per user in passing through the junction is equal across users.

Conclusion 2: In the event that it is not possible to apply Conclusion 1 to the full, signals at intersections should be designed to distribute waiting time per user as equally as possible across categories of road user, subject to relevant constraints.

4.1.1. Explanations and clarifications

We submit that our two factual claims would be accepted without hesitation by the vast majority of people. And, absent a compelling argument for treating some road users differently than others, we suggest that our normative claim follows axiomatically from the two factual claims.

With respect to the normative claim, an important distinction needs to be drawn here between waiting at the individual level and waiting at the group level. For example, how should we compare 11 people waiting one second each with one person waiting ten seconds? Signals at intersections have conventionally been designed on the basis of managing aggregate delay, thereby implicitly favouring larger groups of road users. Under this regime, the quantity of interest is (implicitly) total person-time spent waiting, with less attention paid to the distribution of that waiting time across users. Thus, 11 people waiting one second each would normally be considered more of a concern than one person waiting ten seconds. An important consequence of this approach, understandable though it may be, is that the largest traffic streams receive the most favourable treatment, thereby creating an incentive for travellers to continue the associated behaviour. Equally, the smallest streams (including pedestrians in the majority of cases) receive the least favourable treatment, which creates a deterrent. In contrast, implicit in the normative claim as we have cast it is that the time *an individual* spends waiting is the quantity of interest. Under this approach, the person waiting ten seconds would be more of a concern than 11 waiting one second.

We believe that Conclusion 1 follows axiomatically from our normative claim.

This claim could be debated from at least two (opposed) standpoints: first, those who are economically more productive might be argued to deserve a more rapid passage for the good of society at large; second, policy increasingly discourages the use of harmful forms of transport (in terms of safety, climate change or air pollution, say), and delay could here be used strategically as a deterrent – this connects back to our earlier point about possibly privileging sustainable modes. For now, we opt for the simplest formulation to test the strength of our argument; if it proves workable, subsequent modifications could favour given groups or modes as considered expedient.

We include Conclusion 2 in the expectation that Conclusion 1 may prove unworkable in some way.

4.2. Discussion

Whilst detailed examination is beyond the scope of this paper, we must briefly acknowledge the possibility of making more profound changes to the network instead of or in addition to retiming signals. For example, work has been done on the costs and benefits of removing signals or turning them off for parts of the day (Chandra, 2009); if removed, signals could be replaced by zebra crossings which serve pedestrians' interests better. In addition, the UK is rare in not permitting "give way on turning" and claims have been made for the benefits to pedestrians and others of changing this (Jones, 2017). And tentative findings from research into shared space suggest that changing the operating regime of a street environment may bring benefits to both pedestrians and drivers (Kaparias and Wang, 2020).

Returning to our main theme, it is easy to develop a scenario in which applying Conclusion 1 as we have interpreted it would lead to considerable disruption. Many junctions operate "at capacity", meaning that the junction can only just accommodate the approaching vehicle flows without causing queues of traffic that would disrupt neighbouring junctions. As we have seen, demand is accommodated at these junctions by allocating relatively more green time to the largest stream and, by implication, paring back the time allocated to other streams, notably pedestrians. One consequence is that the mean waiting time per user is reduced for the largest stream at the expense of other streams, typically including pedestrians. And, at such junctions, applying Conclusion 1 would mean that demand exceeded capacity on the dominant stream, leading to disruptive queueing.

On the assumption that applying Conclusion 1 to the letter would lead to unacceptable traffic disruption, this leads us to Conclusion 2. We can speculate as to what "relevant constraints" might be stipulated in this situation but it seems likely that the avoidance of serious traffic disruption would be one of them. Thus, at busy intersections, at best limited progress is going to be possible towards an equal distribution of waiting time at the individual level. But what can be done?

4.2.1. Maximum waiting time

One option is to define a maximum waiting time for pedestrians which must not be exceeded under any circumstances. In philosophical terms, this could be characterised as a sufficientarian response (Shields, 2016). The immediate challenge in such cases is arriving at a defensible value for the maximum, since there is no obvious "natural" level. This points to either using some form of deliberative process or deriving the value by technocratic means. If the latter, this would be likely to be a function of how junctions operate in the status quo and, more specifically, would probably reflect a desire to keep the traffic moving. That is, the maximum would be chosen such that the majority of junctions would comply without requiring retiming and only the most egregious pedestrian waits would be tackled. More important, whilst a maximum waiting time may improve the relative situation of pedestrians, it would not change the fact that pedestrians generally wait longer than users of vehicles. Nevertheless, the city of Vienna, widely lauded for its policies in favour of walking, has implemented such a policy (Urban Development Vienna, 2015), thereby demonstrating at least that it is a feasible intervention in a major city.

4.2.2. Distributed equality

Distributed equality is a different type of pragmatic response to the fact that applying Conclusion 1 is likely to be unworkable. If we picture a typical town, it is likely that some junctions will handle more vehicles than others and that signals at those junctions will accordingly be configured to give the greatest amount of green time to vehicular traffic. Under this arrangement, timings at other, less busy junctions would be deliberately designed to achieve a balance *at the town level* by giving a greater share of green time to non-vehicular traffic, i.e. pedestrians. Thus the spirit of Conclusion 1 would be achieved but at a higher spatial scale than the individual junction. We note that this approach would probably be likeliest to be feasible in locations where an effort has been made to concentrate vehicular traffic on a small number of "main" roads, restricting it on other roads to journeys for access only. A number of questions arise concerning the feasibility of this option but it merits further investigation.

5. Conclusion

Our exploration of the incidence and causes of unequal experiences of different categories of road users at signalised intersections led us to propose a possible way forward that would deliver a more just arrangement without creating unacceptable disruption. In doing so, we see the potential for additional fruitful research in an area which we call "meso-level" transport justice, following the standard definition of meso-accessibility (Jones and Lucas, 2012). We picture this work sitting between the macro-level work being done on the distribution of accessibility and micro-level investigations of whether people are able equitably to negotiate their immediate environments. Our perception is that, given how little attention is paid to the unequal treatment of road users at signalised intersections, many other areas would quickly reveal themselves as deserving investigation, such as the allocation of highway width and the incidence of severance. And, since so much of transport policy turns on competition for scarce resources, and our standard assessment tools do not serve us well in considering questions of justice, there may be much work to do.

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