COMMENTARY

Unsuitability of the Epidemiological Approach to Bicycle Transportation Injuries and Traffic Engineering Problems

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Abstract
Bicyclists and transportation professionals would do better to decline advice drawn from characteristically epidemiological studies. The faults of epidemiology are both accidental (unpreparedness for the task) and essential (unsuitability of the methods). Characteristically epidemiological methods are known to be error-prone, and when applied to bicycle transportation suffer from diversion bias, inappropriately broad-brush categorisations, a focus on undifferentiated risk rather than on danger, a bias towards unsafe behaviour, and an overly narrow perspective. To the extent that there is a role for characteristically epidemiological methods, it should be the same as anywhere else: as a preliminary or adjunct to the scientific method, for which there is no substitute.

As part of their overall project,[1-4] the BICE (Bicyclists' Injuries and the Cycling Environment) group make an ambitious claim: that individual cyclists, cycling instructors, and transportation professionals ought to pay attention to epidemiological studies of bicycling-related safety and infrastructure, and adjust their individual riding habits, instruction, and construction accordingly. I contend to the contrary that none of these should so act on the basis of any characteristically epidemiological studies, no matter how well done by epidemiological standards. This for a variety of reasons, encompassing both the theory of the discipline and practice of the profession.

1. Epidemiological standards
The visitor to epidemiology cannot but be struck by the gap between its theory and its practice, so different from the standards of the experimental sciences. Though no less detrimental, sometimes this gap bears on more or less subtle matters.[5] But at least as far as bicycling is concerned, in correlational studies of all sorts, often it bears on even the most basic. For example, a recent and elaborate statistical reanalysis is constructed around the false claim that increasing the sample size increases the risk of Type I errors. [6, 7] For example, statistical significance is fundamentally different from health significance. Yet the authors of a recent study on cycle tracks insist on conflating them. [8-11] Even a study whose ostensible goal is to distinguish between the two quickly confuses them.[6, 7] For example, every epidemiologist knows that cases and references should be either matched on or correctly adjusted for all factors that are not consequences of the treatment but that are associated with it, and that are associated
with the outcome of interest conditional on the treatment. Whether through using improvised, never-tested, implausible proxies for danger to cyclists, such as damage to the bicycle[12, 13] or danger to motorists;[11] not addressing intoxication or other direct safety habits of the bicyclist;[12, 13, 14, 15] neglecting condition (as opposed to type) of the road surface,[2, 4, 11, 12, 13, 14, 15, 16] or in situ differential geographic orientation of infrastructure types with respect to sun glare,[2, 4] or frequencies of cross-streets,[11] or amount of cross traffic,[2, 4, 11] or volume of turning traffic,[2, 4, 11, 16] or presence of metered parking or alcohol-serving establishments,[2, 4, 11] or the geometries and conditions that produce controlled versus uncontrolled falls— not speed itself, but in synergy with direct, sliding or grabbing contact, posture, friction at and geometry of the surface, high side or low side, attachment to or separation from the bicycle, etc. (all injury studies)— or any of numerous other examples, no such study of bicycling safety has ever come close to that standard. It is Utopian to believe that through some epidemiologically accessible generic proxies, whose ability to account for the underlying factors could never be validated, one ever could.

To briefly illustrate, consider first the simplest fall of all, a topple to the side at zero forward velocity. Riders on road bicycles— who nowadays almost all wear helmets, and before were early adopters— experience such falls when, particularly upon using a new pedal system, they fail to unclip at a stop. Sometimes the outcome is an upper limb fracture, and damage to the relatively fragile bicycle. But for a rider on a city bike, such as from bicycle-sharing schemes— who typically does not wear a helmet— such a fall is typically no fall at all, because with the open frame, open pedals, and quasi-standing posture, the rider simply steps to the side. Next consider the same pair, only in low-side falls after slipouts on a high-speed curve. Road riders, attached to their diamond-framed bicycles in a compact posture, have since the early days experienced these minimal vertical drop falls without head impact, although perhaps with a trip to both hospital and shop, for at least road rash of rider and mount. But the rider on the city bike, with its open frame and pedals and high, protruding handlebars, easily comes off the bicycle foot-first in a quasi-standing posture, with arms already outstretched, resulting in an uncontrollable fall with severe head impact and limb injuries likely. Meanwhile the heavily overbuilt city bike, with its protected mechanisms and without the weight of the rider, may suffer little or no real damage.

Now consider a series of these events, analysed via a classic, highly praised epidemiological design:[12, 13] it would show helmets as providing 100% protection against head and brain injuries— even though not one helmeted rider actually hit their head or helmet.

Engineering studies of road safety are also problematic, but have already been subjected to important internal criticism.[17] The epidemiology of bicycling is in a trial and error stage, learning by making mistakes, not all of them understandable.[7, 8, 9, 18, 19] Epidemiological exploration exacts a statistical price: for example, Harris et al.[4] considered approximately 100 comparison infrastructure variables in the development of their models. Five of them found statistically significant ought to be so by chance alone. Considered individually, 14 were so found, while in multivariate combination, 11 were. Thus apart from any other problems, each resulting piece of advice they offer comes close to heads valid, tails not. At the other extreme, Lusk et al.’s[11] advice comes by way of adjusting their input data by an inscrutable subjective parameter, and using as criterion for not adjusting their results a single untested ad hoc parameter[9]— without sensitivity analysis of any assumption. This is not advice for cyclists to stake their lives on; nor by which we can allow anyone else to wager them for us.
Still, the study of bicycling by epidemiologists goes back only about three decades, almost all of it fixated on crash helmets, effectively none of it concerned with crash prevention, and never mind injuries other than to the head. Three decades from now, will the field have metamorphosed? If so, only after a realisation that the discipline of epidemiology as applied to bicycle transportation also suffers from limitations more fundamental than accidental.

2. Diversion bias

It is a known defect of epidemiology that it cannot distinguish between that which is prevented and that which is postponed[20]— or, as with the variant of the case-crossover method introduced by the BICE group, whose analysis is spatial rather than temporal,[5] diverted. This defect is maximal with the BICE case-crossover method, because it examines associations over minimal intervals[20], and maximally pertinent in transportation systems, because they are that, systems.

For example: because cycle tracks are fundamentally hazardous at junctions,[21, 22] in Vancouver they have been implemented with turn prohibitions.[22] But turning traffic that cannot turn there must turn elsewhere, and often have to do so multiple extra times while covering multiple extra blocks.[23] Thus measures to mitigate the hazards of cycle tracks multiply hazards elsewhere.[23] Similarly, diversion from cycle track streets to side streets with parking has been found in Copenhagen, but only the increased injuries on the cycle track due to vehicles turning to the side streets were studied, not the effect on side street safety.[24]

Diversion bias is not unique to the BICE variant of the case-crossover method, but afflicts any non-systemic analysis of transportation systems, whose problems flow, or back up and spill over, from one location to another, from one category of users to another, or from one severity of injuries to another. Transportation epidemiology is typically non-systemic, because it divides transportation systems between cases and controls, and is selective, excluding for example fatalities, the large majority of bicycling injuries, moped riders, pedestrians and property damage.[2, 4, 11] Finding controls outside the system risks irrelevance; while before-after studies are not characteristically epidemiological, but standard fare in science and engineering, where control can be achieved with or without a control group.

3. Transportation epidemiology is inappropriately broad-brush

Engineers design the features of road infrastructure on a scale of inches, knowing the substantial effects such variations may trigger (consider just curb heights). There is no way for epidemiology to cope with this level of subtlety: epidemiologists have to work with coarse categories, for the sake of statistical power. This is how it comes to pass that all the marked routes, lanes and tracks shown in the following citations are, by epidemiology's "evidence-based" proposals,[2, 4, 25, 26] recommended facilities.[27-31]

4. Epidemiologists study undifferentiated net outcomes, while cyclists and engineers instead need to know about the underlying hazards

By way of examples:

(1) Among the advantages of traffic circles are that they necessarily limit traffic speeds and reduce the number of basic conflict points[32], while only contingently impeding
flow. While traffic circles of some types are difficult for cyclists, contrary to the original neighbourhood-level study,[33] Harris et al. found a seemingly alarming surplus of injuries at Vancouver's simple residential traffic circles.[4] At least some of this surplus should be due to randomisation failure of control site selection: Vancouver's circles are associated to short non-intersection segments, while nearby reference intersections are associated to long segments,[33] creating a selection bias.[5] Diversion bias may also be a factor, as local maps show that nearby traffic diverters and similar may direct traffic to the circles.[33]

Yet the surplus was predominantly from rider-only accidents, "resulting from interactions with the infrastructure (e.g., hitting the curb, sliding on the sharp turn)". [4] A problem is that there is nothing sharp about the turn: the authors' illustration (their figure 4b, solid lines) depicts the diameter of the circle to be larger than the road width, when in reality the corresponding dimensions are stated as 6-8 m and 9-11 m respectively.[4] Photographs demonstrate a geometry less challenging than those of facilities claimed to have less than 1/20th the risk (compare the traffic circle photographs on pages 36 and 22 with those of favoured infrastructures on pages 22 and 24[34]). Correspondingly, assuming no extraneous factors (such as poor maintenance), there is no good reason for any rider to hit the curb. By process of elimination, the fault must therefore lie with the rider, such as through intoxication, use of a phone, or other distraction or lack of control. Since such rider-based causes are prominent in cyclist fatalities,[35] these injury events may have done their victims a favour. Meanwhile, should cyclists who do not ride intoxicated or otherwise uncontrolled base their route choices on the problems faced by those who do, or should traffic engineers change intersections to allow drink-riders or the like to navigate more easily through them?

This problem generalises to the entire study design, and to any study of only injured cyclists. Outcomes of safer riders are automatically under-represented in the data, while outcomes of the most reckless or otherwise unsafe are the most over-represented. The evidence base of the authors' recommendations for safe cycling routes, and of epidemiological recommendations more generally, is consequently biased to unsafe behaviour.

(2) Knowledgeable cyclists have known from the beginning that streetcar and train tracks are dangerous. Cycling instruction has always emphasised ways of mitigating their hazards, as in the following citation.[36] Unfortunately many cyclists are not knowledgeable and few take instruction, so unsurprisingly surplus injuries were found to accumulate near them.[4]

But suppose to the contrary that instruction were typical, and through hypervigilance, injuries near them were avoided. Then epidemiology and its "evidence-based" reasoning would tell cyclists to favour routes with streetcar and train tracks, and advise cities to install them.

Does this objection seem far-fetched? It shouldn't, because the equivalent has already happened, over and over again. For example, bicycle lanes have through systematic review received epidemiological approval.[25] In cities around the world these lanes, whether curbside of parked cars (therefore being cycle tracks) or roadside (ordinary bicycle lanes), typically run in the door zones.[37] They are thus an obvious hazard. What is the common remedy offered, by epidemiologists[38] and governments? Hypervigilance and luck, to be provoked by reducing turnover or putting the conflict on the passenger and curb side,[37, 38] large fines, stickers reminding drivers to watch out,
advice to open the door with the opposite hand or for riders to look through vehicle windows for occupants' heads, or even for occupants to open vehicle doors inch by inch. [37, 39] For example, bicycle paths, also given epidemiological approval, [25] often have sections deemed so dangerous by their designers that they come complete with signs or obstacles obliging cyclists to dismount and walk. [28, 31, 40] As cyclists have observed, on roadways one never sees signs obliging motorists to get out and push. [28, 31] The cycle tracks represented favourably by the BICE group are replete with engineering hazards, to the extent that the same photograph is used by the authors to depict both a recommended and a not-recommended facility. [41] The de Maisonneuve cycle track specifically studied and endorsed by Lusk et al. [11] is peppered with signage demanding hypervigilance at junctions. The Christophe Colomb segment also specifically studied and endorsed by Lusk et al. [11] had an underlying hazard that would never be accepted in any facility for vehicles other than bicycles: simultaneous green signal phases for conflicting traffic streams. Both hypervigilance and luck ran out in the summer of 2012, when a cyclist was killed by a truck in circumstances exactly as warned about on page 34 of the AASHTO manual. [8] Epidemiologists are still discrediting these guidelines, as ill-informed and sexist. [38]

5. Epidemiology is error-prone, and has institutionalised an unrealistic philosophy

Epidemiology's distinctive philosophical contribution is "evidence-based medicine", a version of empiricism. As briefly illustrated earlier, the problem is that empirical associations, obtained without observing their genesis or otherwise tracking the mechanism of their association, do not constitute evidence for anything. But EBM dismisses "mechanism-based reasoning" as simply a form of evidence, and the most inferior form at that. [42] In so doing, epidemiology verges on the anti-scientific, because the power of science is its special synthesis of reason and experience, key to which is mechanistic reasoning. This helps explain why epidemiology so often gets it wrong. [43-45]

EBM promotes systematic review as the best science, and rejects idiosyncratic review. Systematic reviews make no sense in fields dominated by systematic error—like bicycling safety—because they promise what nobody can deliver, the combination of breadth and depth. Naturally it is depth that is the worst casualty. Consider a recent, seemingly in-depth systematic review of the cycle-track literature. [26] It failed to find a single one of the errors found instead by decidedly non-systematic review. [46] All of these errors, some subtle and some obvious, were found by the community of cycling peers, not the community of epidemiological peers.

Is there a better way to investigate bicycling safety? How about the scientific method: careful observation of the genesis of accidents as they happen or are avoided, naturally and experimentally, preferably with the aid of instrumentation, guided by and guiding mechanistic theories. The rationale for doing epidemiology instead is either that the events are too rare or that ethical considerations make experimentation or close observation impossible. But the year is 2014, and technology has made the former contention obsolete, with automated cameras recording accidents and vehicular assaults around the world (many of the results available for viewing online), while ways can always be found to do the latter. [47-50] Once subjected to scientific investigation, confidently expressed epidemiological conclusions have not fared well. [51-54]

Is there then any role for characteristically epidemiological methods? If so, the same as
anywhere else: as a preliminary or adjunct to the scientific method, for which there is no substitute.

6. **Epidemiologists consider risks to be intrinsic properties of infrastructure types, rather than as joined to behaviours, influenced by social and psychological processes wherein they themselves are actors**

There is no space here to go into why safe cycling is no longer generally understood behaviour, or how the dystopian vision of the future lampooned by cyclists in the 1930s[55] became an ideal for the cycle track advocates of today, or the roles of the traffic engineering and epidemiological professions in these processes— these ideas are explored elsewhere.[55-57] Suffice it to say that epidemiologists have never studied safe cycling methods.

This may be because they do not know them. For example: in the presentation of their results for Velo-city 2012,[34] the BICE group have a photograph meant to depict the vehicular alternative to their proposals, as first articulated by John Forester:[58, 59] safe cycling on the roadway by according with elementary traffic operation, with special consideration for the facts that bicycles are narrow, balanced vehicles that are sometimes slow moving, and other times fast. Unfortunately, the photograph instead depicts multiple instances of fundamental violations of those practices. Is there an epidemiologist favouring segregated cycling who can identify them?

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**References**


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