Accident Analysis and Prevention 127 (2019) 172–176

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Safety, security, and serviceability in road engineering

Michael S. Pritchard

Western Michigan University, Kalamazoo, MI, 49008, United States

ARTICLE INFO

Keywords:
Design
Expertise
Road engineering
Pedestrians
Safety
Security
Serviceability

ABSTRACT

Road engineers have special responsibilities to design and maintain roads that are safe, secure, and serviceable. This paper explores some of the challenges such responsibilities pose, especially from the vantage point of non-engineers whose lives are deeply affected by the work of road engineers. It also supports the thesis that road engineers need to be prepared to consult and work with professionals in other fields than engineering in order to fulfill their responsibilities well.

1. Design challenges

Engineers are intimately involved in the design, construction, and maintenance of our public roads in a multitude of ways. These roads serve us in cities, small municipalities, and less densely populated countrysides. Freeways and toll roads provide us with faster, more efficient ways of travelling both through and often around these areas. Minimally, roads must be serviceable for their users—such as those going to work, to school, to the hospital, visiting friends, shopping, seeking entertainment, vacationing, or transporting goods in large vehicles. These roads also need to be designed to accommodate the needs and concerns of pedestrians who walk alongside them and need to find safe passage across them. So, the possible uses of roads vary widely, as do their surrounding social, commercial and environmental conditions. Engineers attending to these matters are expected to engage their expertise responsibly in making engineering decisions. In addition, they are expected to call on the expertise and experience of non-engineers when this is needed to more fully understand and take into account factors relevant to making good engineering decisions.

In this paper I will focus on several aspects of road engineering, each of which introduces complicating matters for engineers whose special expertise is in the area of road design, maintenance, and adaptation to the need for changes. My thoughts are those of someone whose educational background is in philosophy, not engineering. So, I offer the perspective of a recipient of the work of engineers, not a provider of such work. I begin with some reflections on the passage of time and its significance for the work of road engineers.

2. Road engineering and the passage of time

A complicating matter for road engineers is the fact that, with the passage of time, needs and conditions related to already constructed and functioning roads can change dramatically. Anticipation of future changes when planning roads can help, but many needed changes cannot be taken fully into account until much later. There can be unexpected changes in road usage, perhaps resulting from new housing developments, or the addition of commercial uses of surrounding land (e.g., restaurants and shopping malls). Freeways and other more or less unobstructed roads may be built to provide faster routes for getting through or around a city that an old highway still goes through, stoplight by stoplight. The old highway might now serve as a “business route” for the major thoroughfare. Roads are not designed to last forever. But they can last a very long time, and this is something that road engineers must try to take into account as they consider how the road might best serve current needs and interests in the area and what its role is likely to be in the future as needs and interests change.

In light of this, how are the ethical responsibilities of road engineers to be identified and understood? For some general answers to this question, we can turn first to relevant codes of ethics for professional engineers. For road engineers, ASCE’s code for civil engineers is perhaps as appropriate as any. Although that code, like most other engineering society codes of ethics, says that the paramount duty of engineers is to protect the health, safety, and welfare of the public, it does not (and should not) say that this is the sole duty of engineers. However, in light of the long history of engineers engaged in projects involving issues of safety (including road construction and maintenance), the explicit mention of duties to the public is, surprisingly, a relatively recent addition to engineering codes of ethics. Prior to the early 1970’s such

E-mail address: Michael.pritchard@wmich.edu.

https://doi.org/10.1016/j.aap.2019.02.026
Received 14 January 2019; Received in revised form 18 February 2019; Accepted 24 February 2019
Available online 17 March 2019
0001-4575/

codes focused primarily on the duties of engineers to their employers and clients. These duties include exercising engineering competence and good judgment in one's work in general; refraining from falsifying or deliberately distorting data in one's work, in preparing reports, and in making public statements; respecting confidential matters in relation to one's work; trying to avoid or minimize involvement in conflicts of interest; and so on. Perhaps it was assumed that concern for public safety was a given. However, public concern about a number of accidents involving engineers in prominent ways (e.g., in the automotive and airline industries), as well as growing public concern about various forms of environmental degradation traceable to industrial processes raised the question of whether such concerns were being adequately addressed in engineering codes of ethics.

Although current engineering codes typically give priority to the duty to protect public health, safety, and welfare, they provide only a general framework for understanding engineering responsibilities rather than addressing more specific areas, such as road engineering. Nevertheless, it is clear that road design, construction, maintenance, and alteration all raise concerns about safety to drivers, passengers, pedestrians, and others nearby. Given this, the expectation that road engineers will attend to these concerns as a matter of responsibility should be evident. Specifically what meeting this expectation requires is another matter.

A central objective is to obtain reliable information about the frequency and severity of road accidents and their relation to the design, construction, and maintenance of roads in particular kinds of areas (e.g., light traffic, heavy traffic, flat areas, hills, mountains). A complicating factor is that transportation needs are not static. Populations, commercial enterprises, and road usage in particular areas change. Furthermore, new roads, road improvements, and other changes come at considerable cost. Road engineers are expected to, as best they can, anticipate the need for such changes, taking carefully into consideration the cost of making them. This requires more than guesswork. Making road related changes costs both time and money—usually in large amounts. Responsibly handled, this requires strong empirical evidence that the introduction of such changes will, in fact, serve the ends for which they are intended.

How should questions of safety be approached in road design? The U.S. Department of Transportation makes a basic distinction between *nominal* and *substantive* safety (Hauer, 2015). Whether a highway satisfies criteria of nominal safety is determined by specified standards of, say, lane width for certain kinds of roads. For example, 12 feet is the standard width for Interstate lanes. A design proposal for 12 foot lane widths satisfies the nominal standard, whereas a design proposal for an 11 foot width does not. However, nominal safety does not indicate actual or expected safety performance of a roadway. In contrast, substantive safety refers to actual safety performance on particular roadways, with the accident record being the crucial determinant. Understandably, the determination of the substantive performance of a roadway is critical in making good decisions in road design. However, there is another, more problematic, factor that is commonly recognized by road engineers. This is people *feeling safe*, their *sense of security*. Although one can feel safe and still be involved in an accident, one's sense of security as a driver or pedestrian is a matter of some importance, both in itself and insofar as it may affect substantive safety (actual accident rate).

How might road engineers best take into account considerations of security, or feeling safe, when designing roads? This requires knowledge of how perceptual and psychological factors come into play as drivers and pedestrians negotiate their way around the roads that road engineers design and help maintain. Of course, some of this knowledge comes from road engineers being drivers, passengers, and pedestrians themselves. But it cannot be assumed that their personal experience plus the engineering expertise that they have acquired through their formal engineering education or subsequent engineering experience is sufficient to yield sound judgment about how secure drivers, passengers, and pedestrians in general feel about the road configurations and conditions with they must deal.

So, road engineers recognize that, in such matters, they need to rely on assistance from those whose expertise lies in other areas than road engineering. For example, there are psychologists who study human perception (such as our responses to different distances, colors, shapes, and signs) under possibly stressful conditions, particularly when decisions must be made quickly and precisely, either alone or with others. Also, of course, evidence can be gathered from representative surveys and interviews of drivers, passengers, and pedestrians themselves. Such surveys and interviews might reveal interesting and important information that would not appear in reports on substantive safety alone. The latter reports would pertain only to actual accidents. But drivers, passengers, and pedestrians might well wish to report on what they take to have been near misses. They might also wish to report on their fears of being involved in accidents in certain kinds of circumstances on particular roads. This has to do with their sense of security on the roads, a matter of considerable importance regardless of any record of actual accidents.

Nevertheless, even solid empirical evidence about how different road configurations affect the sense of security of drivers, passengers, and pedestrians does not settle the question of what should be done. Ignoring such information is not acceptable, as the feeling of security matters greatly to drivers, passengers, and pedestrians. Still, not everyone is the same. Some are greater risk-takers than others. For some, it takes very little to be unnerved. Others may require much more to become unsettled, and still others may even welcome some degree of risk-related fear. In any case, taking all of this into account in designing roadways requires attending to the cost of making improvements that can be expected to keep perceptions of risk for most at an acceptable level. This is as much a normative as a quantitative matter of assessment. So, in the end, responsible design is not totally amenable to empirical, quantitative determination. This does not imply that engineering judgments on such matters are merely subjective; but it does imply that they are not merely quantitative either.

3. A case in point: roundabouts

The emergence of roundabouts as an alternative to traditional intersections with traffic lights nicely illustrates the importance of road engineers working with those who are not engineers. Designed to provide a safer and more efficient way of guiding traffic through intersecting routes of travel, the early designs of many roundabouts failed adequately to take into account the added risks faced by blind and low vision pedestrians.

Intersections with traffic lights are designed to accommodate pedestrians by providing them with crosswalks and, especially in areas where the pedestrian traffic is heavy, lights that are timed to indicate when cars are to stop and pedestrians are informed that they are permitted to cross within a restricted timeframe. Sometimes there is an accompanying recorded voice that specifies the same for pedestrians. In this way, even those who are blind or have low vision are provided with assistance in crossing safely; and they are aided further by the sounds of cars braking and coming to a stop. Ensuring that there are reliable ways of both enabling and protecting all pedestrians clearly falls within the province of road engineering responsibility. Although full appreciation of the special needs of blind and low vision pedestrians has been aided by experts in the blind and low vision fields and by blind and low vision pedestrians themselves, recognition of the basic responsibility of road engineers to attend to the needs of pedestrians is not new. The introduction of stop signs, yield signs, and permission to turn right on a red light after stopping have all required the careful attention of road engineers.

However, roundabouts present a special challenges for blind and low vision pedestrians in that they are designed not to require cars to come to a stop; and typically there are no traffic lights equipped with

auditory signals indicating that crossing the road is or is not permitted at given times.

In the United States a great deal of federally funded research has been devoted to trying to come up with affordable solutions to this problem. Such solutions need to preserve a roundabout's ability to reduce accidents, improve the flow of traffic, while at the same time enabling blind and low vision pedestrians to cross the entering and exit roads safely. It is important to notice that many of the authors of the growing literature on this topic are researchers who specialize in blindness and low vision studies, not engineering as such. For example, the authors of "Modern Roundabouts: Access by Pedestrians Who Are Blind," none of whom are engineers, observe that those who teach and do research in blindness and low vision, as well as blind and low vision pedestrians themselves, "will play an important role in educating engineers about access to roundabouts (Long et al., 2005)." They should, the authors conclude, "accompany engineers to roundabouts and assist them in experimenting with the task of making judgments about the status of vehicles on the basis of auditory cues." Finally, the authors say, "Researchers, traffic engineers, individuals who are blind, and O&M instructors must continue to work together … to gain a fuller understanding of the issues that roundabouts can create and the strategies that can help to resolve them."

Consulting with blind and low vision individuals is particularly important, as pedestrian security can be expected to be a crucial factor to consider. Safe passage may, indeed, be possible for those who feel secure enough with the cues available to them to attempt to cross in the designated areas. But what about those who lack such confidence and are reluctant to try? In his famous essay, "The Will to Believe," William James points out that in some circumstances believing that one can do something actually supports one's ability to succeed, whereas doubting that one may contribute to failure (James, 1896).

The challenge of roundabouts for many blind or low vision pedestrians might well qualify as just the sort of circumstance James had in mind. He illustrated his point by talking about the challenge of keeping one's balance while walking along the edge of a dangerous cliff. Confidence (or the lack of it) can make all the difference to one's ability to succeed. In light of what might seem to them to be serious safety risks, what might encourage blind and low vision pedestrians to summon up the courage to proceed? Here experts in areas other than engineering can help provide answers that will help road engineers. So might those who are blind or who have low vision.

Of course, it is not just the needs of blind and low vision pedestrians that road engineers have a responsibility to take into account planning crosswalks and sidewalks that run parallel to roads. The needs of all pedestrians should be addressed in regard to fair and reasonable opportunities for safe and efficient travel near and across roadways. This includes taking into account the importance of supporting the sense of security valued by all pedestrians and drivers alike.

4. Counterfactuals

Focusing some attention on 'security' rather than just 'nominal' and 'substantive' safety can take us into another area of concern—this is the world of counterfactuals, a world of "what ifs". A driver's sense of security, we have seen, may have no strong correlation with an actual increase or decrease in accidents. However, there are moments of reflection in which a driver might observe: "If I hadn't applied my brakes, I would have been side-swiped by that speeding vehicle that just missed me. I was lucky," or "If I hadn't been paying attention, I would have run right off the road into that ditch. There was no guard rail." These are counterfactual statements about what *could* have happened, but did not. The antecedents of such if-then statements are themselves statements—but they are false. The driver did apply his or her brakes in the first instance. The driver was paying attention in the second. In the first example, the driver might correctly surmise that he or she was simply lucky, or fortunate, to notice the speeding car begin to change lanes without leaving enough space to squeeze in safely. In the second example, the driver might be given credit for having an attentive disposition, thus reducing the likelihood of wandering off the road into a ditch. A guard rail could have prevented a more serious accident—a "just in case" preventive measure that, fortunately, was not needed in the present case. In short, the story of a road's safety should include typical counterfactual statements, not just a record of actual accidents.

Consider this analogy. A pair of narrow boards is laid across a fast flowing river to enable hikers to get safely to the other side. Those with confidence and good balance can cross safely without any rope or rail to grab if they should lose their balance. A few totter, but they manage to keep their balance and safely make their way across. Others look at the crossing and decide it is not safe for them to try. So far, no one has actually fallen into the river. Does this mean that the boards provide safe crossing? Perhaps for those who use them—although so far they may have been a bit lucky (e.g., that a strong gust of wind did not make them lose their balance).

Someone then decides to put a rope guard alongside the boards so that those feeling less secure can grab it if they wish. Now those using the boards continue to cross the river without incident; but those who avoided the crossing when there was no supporting rope also use it. They feel more secure in doing so, and it seems that they are justified in feeling this way. They correctly perceive that it is a safer crossing—perhaps even for those who were bold (or foolish) enough earlier to cross without the rope being available. A counterfactual can be applied to the original crossing: If one stumbles when stepping forward, or if a strong gust of wind unexpectedly comes along, or…, one will teeter and likely fall into the river. The list of conditionals that warrant such a consequent is crucial in determining the safety of the bridge. Safety is enhanced by introducing the rope rail—even if there are no accidents before or after its addition. Something similar can be said about road safety.

5. An intersection: perspective of a driver

I am not a road engineer. My career background is that of a professor of philosophy, mostly at Western Michigan University (WMU). Like millions of others, I drive a car to work. For many years I have made extensive use of a particular road, Stadium Drive, when driving to WMU and returning home. This road continues as a highway outside the city limits of Kalamazoo, Michigan.

Over the course of the many years I have driven on Stadium Drive, many changes affecting its use have been introduced—most obviously, shopping malls, restaurants, other commercial establishments, housing developments along the way, and the establishment of a research park for Western Michigan University.

Once a part of Highway U.S. 12, then the main road connecting Detroit and Chicago, Stadium Drive lost that function in the mid-1960's. This is when the construction of Interstate 94 made it possible for travellers to avoid going through Kalamazoo entirely. However, the above mentioned demographic and commercial changes actually increased the traffic flow along Stadium Drive. When I started using Stadium Drive as a means for travelling to and from work, it had already become a business route for Interstate 94, but it still served as a major artery for accessing central Kalamazoo, a city of 80,000 people, its businesses, and its university of more than 20,000 students.

For more than two decades I used Rambling Road as my specific point of entry and exit when travelling to and from work on Stadium Drive. Some years ago a traffic light was installed to help regulate the increasing flow of traffic through the intersection. However, the traffic light has no left or right turn signals for drivers from any direction. Stadium Drive has long had four lanes, two in each direction, and a 45mph speed limit at its point of contact with Rambling Road.

Rambling Road has two lanes and a speed limit of 25 mph. The intersection of Stadium and Rambling forms a T, as Rambling does not continue after it makes contact with Stadium. Drivers on Rambling may

turn left or right onto Stadium. Of course, those going left must wait for their light to turn green before turning. But those going right can proceed on a red light after coming to a complete stop and ascertaining that oncoming traffic from their left offers clear passage. My route to work involves making this right turn.

Initially, returning home and making a left turn off Stadium and onto Rambling posed no special problems. There is a short turn lane that enables drivers turning left to move out of the way of those continuing west on Stadium. Depending on the flow of oncoming traffic, often one could comfortably turn left with a green or yellow light.

But, given its changes in use, traffic patterns on Stadium Drive eventually underwent significant changes. Despite these changes, including increased traffic flow during rush hours, no turn signals were added at the Rambling Road intersection. However, I began to notice that many oncoming Stadium Drive cars were actually going through the intersection after their light had clearly turned red. In fact, one day I counted at least 6 cars passing through the red light—at 45 miles an hour. Apparently a short delay in when the green light for those entering Stadium Drive from Rambling Road had been introduced, and at least some Stadium drivers had noticed this. Unfortunately, it was now clear that I could no longer safely assume that oncoming cars would prepare to stop when presented with a yellow light. Even a red light would not allow me complete my turn. In addition to oncoming cars, I needed to worry about cars on Rambling Road beginning to turn left onto Stadium Drive, thus crossing my intended path. Like many older (and wiser?) drivers, I tend to err on the side of caution—especially when confronted with impatience by younger, more daring drivers. As a result, I now felt that going home by the route to which I had been long accustomed had become much more risky—unacceptably so during busy times. Of course, I am probably not the only one who felt this way. Many others making that left hand turn likely encountered the same problem and were similarly troubled.

But, one might ask, did this traffic light change result in more accidents at the Stadium/Rambling T? I have seen no data on this. That I, and perhaps many others, felt less safe at this intersection did not necessarily make it less safe from the standpoint of either “nominal safety” or “substantive safety”. But it did make it *seem* much less safe for drivers such as myself—even without any increase in accidents. Fortunately, I came up with a personal solution that did not require any improvement in the traffic light. I have less frustration and stress in travelling home from my place of work now; but this is only because I have changed my preferred route. I have found an alternative that is, although a bit longer, less harrowing and risky.

Others may not have such an easy alternative. Should they simply have to put up with this, or would it be preferable to invest in a set of lights at this intersection that includes turn signal? In addition to making accidents less likely, roads need to be designed to provide a reliable means for efficient and comfortable travel for all. This requires making suitable changes as conditions change through time; and it requires road engineers to pay careful attention to how making or not making such changes might affect the perspectives of drivers and pedestrians in those areas. This may require input from experts in other fields than road engineering, as well as directly from drivers and pedestrians themselves.

6. Concluding thoughts

Some years ago, ethicist William F. May astutely observed that highly professionalized, technologically driven societies like ours are marked by what he calls a “knowledge explosion” that comes with special expertise and an “ignorance explosion” that is shared by all of us who depend for our well-being on the responsible behavior of experts (May, 1988). But experts in one area may need to rely on experts on other areas in carrying out their responsibilities. We are all, to some extent, caught up in this “ignorance explosion.” As suggested above, road engineers, even in their own work as experts, depend on those who are not to help them do their work well.

It should be pointed out that nothing like this was emphasized in May’s article. May’s central concern was about what professionals do “when no one is watching.” This is, of course, an important question. Few of us have the time, interest, or opportunity to watch professionals do their specialized work for us; and even if we did, lacking their expertise, we probably would not understand what they were doing well enough to assess that work. Instead, we must simply trust them. May concludes that, given this sort of dependency, we need professionals to be trustworthy, that is to have virtues that ensure that they can be counted on to do their work responsibly and well. What I am adding here is that one of the virtues all professionals need is the disposition to seek out the assistance of others when this is vital for them to do their work well.

Road engineers have special expertise and experience that others do not. This carries with it broad responsibilities for which their special expertise alone is not always sufficient to satisfy them well. The roundabout example is a good illustration. But there are endless others that support the idea that road engineers often work best when they consult with others who do not share their expertise but who have invaluable contributions to make in helping road engineers do their work responsibly and well.

An anonymous reviewer of an earlier draft of this paper suggested that the particular examples I have focused on should be placed within a much larger, more general context. I have made a gesture in this direction in Section 2, above: **Road Engineering and the Passage of Time**. But much more could be said about the broader reach of the responsibilities of road engineers. The reviewer points out that road engineers need to address more than simply whatever specific problems they are assigned—such as how much load the concrete has to carry. “They ought to have a broad understanding of how a highway functions—as a conduit for traffic, as an incentive to build houses away from the city center since the highway allows for ‘easy’ entry back into the city, and so on.” That is, road engineering has important implications for much more than just the technical features of road construction and maintenance. How far these implications reach, and what how this should inform the overall responsibilities of road engineers warrants further attention. This essay is only a start.

The same reviewer suggests that the road of ethical exploration may be a bit bumpy. The reviewer mentions engineer Henry Petroski’s frustration with the U.S. Department of Transportation’s decision to go back to Highway Gothic as the font of choice for road signs. Petroski protests, “I for one find Clearview a huge improvement over Highway Gothic in terms of legibility, and I feel much safer driving in places where it’s on roadside signs (Petroski, 2016).” The reviewer comments: “No evidence was cited in the Department’s announcement—despite a great deal of evidence in support of Clearview making it far easier, especially for older drivers, to see road signs. So we have here what appears to be a case of engineers refusing to accept objective evidence that would encourage a ‘*sense of security*’.”

That a driver’s sense of security should be taken seriously by road engineers has been a central theme of this essay. That attempts to do so may be met with some resistance is disappointing, but this does not detract from the importance of continuing to make the effort.

Acknowledgements

I thank Ezra Hauer (Dept. Civil Engineering, University of Toronto) for suggesting that I undertake this project and for his invaluable comments and advice as I worked on various drafts. I also thank three anonymous reviewers for their insightful suggestions. Of course, this does not imply that they agree with what I say in this final version.

References

Hauer, Ezra, 2015. The Art of Regression Modeling in Road Safety. Springer. https://

safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/chapter1/1_nominal.
James, William, 1896. The will to believe. The New World, vol. 5. pp. 327–347.
Long, Richard G., Guth, David A., Ashmead, Daniel H., Emerson, Robert Wall, Ponchillia, Paul E., 2005. Modern roundabouts: access by pedestrians who are blind. JVIB (J. Visual Impairment Blindness) 99 (October) Number 10.
May, William F., 1988. Professional virtue and self-regulation. In: Callahan, Joan (Ed.), Ethical Issues in Professional Life. Oxford University Press, pp. 408–411.
Petroski, Henry, 2016. Easy-Reading Road Signs Head to the Offramp. New York Times February 25.