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Screening the Road Network for Sites with Promise

Ezra Hauer, Jake Kononov, Bryan Allery, and Michael S. Griffith

Network screening is the first step in the site safety improvement process. The product of network screening is a list of sites that are ranked by priority for the conduct of detailed engineering studies. In turn, cost-effective projects are formulated from the studies. With the purpose of laying the foundation for improved network screening, the role of network screening is clarified, and how project cost and safety benefit can be anticipated at the time of screening is examined. The strengths and weaknesses of alternative assumptions on which the anticipation of safety benefit can be based are discussed. A way to guard against misallocation of resources due to the randomness of accident counts is suggested, and a method for finding peak sites within road sections is proposed.

Screening is the low-cost examination of all entities of a population. Thus, for example, administering a mammogram to all women over 50 is screening for breast cancer. The aim of screening is to select a relatively small subgroup from a large population, members of which are then subjected to a more detailed and costly examination. The rationale is that only the selected subgroup, not the entire population, merits detailed and costly attention. In this context, “entities” are road sections and intersections; these make up a road network—the “population.” Road network screening can be done at little cost because it relies on the computerized use of electronically stored accident, traffic data, and site data. The product of road network screening is a list of sites ranked in order of priority for the conduct of a more detailed and costly examination. This examination, often called a detailed engineering study (DES), is applied to the sites ranked near the top of the list. The purpose of the DES is to formulate cost-effective projects.

The sites on the ranked lists go by a multitude of names: HALs (high accident locations), PILs (priority investigation locations), SWIPs (sites with promise), and so forth. The reasons for designating a site as a HAL, PIL, or SWIP are diverse. Some rank sites by accident rate (accidents per vehicle-kilometers or per entering vehicles), some use accident frequency (accidents per km-year or accidents per year), some use a combination of the two, and some use the proportion of accident types considered susceptible to treatment. Another dimension of diversity in practice is that rank may be determined by the magnitude (of either rate or frequency) or, as is more common, by the amount by which the rate or frequency exceeds what is normal. In addition, there is diversity in the way accident severity affects ranking. In all this, concepts borrowed from statistical reliability and quality control are applied. For reviews, see Hauer (*1*) and Persaud (*2*).

The “sites” are either intersections or segments of roads. It is not clear what length of a road should be considered a site. The usual approach is to divide roads into segments of fixed length and to consider each such segment a site. In New York State, each segment is 0.3 mi long. In Ontario, 0.5-km segments are used. Thus, the definition of site is an added element of diversity.

Which of these diverse methods is best, and can it be further improved? These questions were addressed in a project that aimed to improve network screening in the Colorado Department of Transportation. The Colorado effort was a precursor to the current FHWA initiative to develop a comprehensive highway safety improvement model (CHSIM), now underway.

The aims of this paper are

1. To clarify the role of network screening in the site safety improvement process;
2. To suggest a way for judging the performance of alternative screening methods;
3. To air the implications of the “most-bang-for-the-buck” (MBB) principle on network screening;
4. To suggest how project cost and safety benefit can be anticipated at the time of screening;
5. To examine the strength and weaknesses of alternative assumptions on which the anticipation of safety benefit is based;
6. To suggest a way to guard against misallocation of resources due to the randomness of accident counts; and
7. To suggest what should constitute a “site” for the purpose of network screening.

NETWORK SCREENING AS PART OF A PROCESS TO IMPROVE SITE SAFETY

Consider the three-step process for site safety improvement shown in Figure 1. The role of Step 1 is to examine periodically the entire road network in order to generate a list of sites ranked in order of priority by which DESs should be conducted. The role of Step 2 is to generate “prospectively cost-effective” projects. Prospective cost-effectiveness is the estimate one can obtain at the end of the DES and consists of an estimate of project cost and of the prospect for accident frequency and severity savings. The role of Step 3 is self-evident. Interlaced among the three steps are three research programs, the first of which is discussed in the following text.

After sites are ranked by two alternative screening methods and DESs are completed at top-ranked sites, it is possible to say, provisionally, whether one screening method is better than another. To illustrate, consider the “bad” and the “good” ranked lists of sites in Table 1.

E. Hauer, 35 Merton Street, Apt. 1706, Toronto, Ontario M4S 3G4, Canada. J. Kononov and B. Allery, Colorado Department of Transportation, HQ Safety and Traffic Engineering, Safety Engineering and Analysis Group, 4201 E. Arkansas Avenue, Denver, CO 80222. M. S. Griffith, FHWA, Turner-Fairbank Highway Research Center, 6300 Georgetown Pike, McLean, VA 22101.

STEPS	*PRODUCTS*
1. Network screening for SWiPs	*Ranked list of sites*
⇨ 2. Conduct of detailed engineering studies	*Cost-effective projects*
(⇨ Research: Provisional evaluation of screening methods)	*Safety improvements*
⇨ 3. Project selection and implementation	
(⇨ Research: Evaluation of project effects)	
(⇨ Research: Evaluation of screening & DES methods)	

FIGURE 1 Three steps of a process for the safety improvement of sites and related research.

Suppose that Screening Method A produced a list of sites ranked by priority for the conduct of DESs, and that DESs were completed at the 10 sites ranked highest. With the DES results in hand, the numbers in the right column of the "bad list" can be entered. In the bad list there is no clear correspondence between the rank in screening and prospective cost-effectiveness. This means that a DES was done at some inferior sites (e.g., Sites 4, 8, and 9) and costly engineering effort was misdirected. In addition, some promising sites did not get a DES, and thereby the opportunity to improve safety more cost-effectively was missed. Consider now the "good list" produced by Screening Method B. After the DESs were conducted at these sites, the numbers in the prospective effect/unit cost column ("Prospective Accident Savings/Project $") were entered. Now the rank by screening and the rank by cost-effectiveness show a close correspondence. This indicates that Screening Method B well anticipated the results of the DESs and directed attention to deserving sites. This is why it is a good list.

It is now clear that the larger the correlation between the rank based on screening and the rank based on prospective cost-effectiveness as established by a DES, the better the screening method. It is also clear that one can evaluate provisionally which of two screening methods performs better only after DESs were conducted on their top-ranked sites. Why evaluation is provisional is explained in the section on anticipation of project cost and safety benefit in network screening. As shown in Table 1, the determination of which methods for network screening work well is a research task. Only after such evaluative research is completed in a few jurisdictions will professionals know, provisionally, which of several screening methods is to be preferred.

The nature of the challenge is now clear. To produce a good ranked list of sites for the conduct of DESs one has to well anticipate what the prospective cost-effectiveness at sites might be, while basing the anticipation only on information that is available *before* the conduct of a DES.

THE MBB PRINCIPLE AND ITS IMPLICATIONS

The guiding principle, unstated until now, was that money should go to where it achieves the greatest safety effect. This is the "most-bang-for-the-buck" (MBB) principle. The MBB principle has controversial implications. And yet, to balk at implications of the MBB principle means that it is justified to save one accident when, for the same money, more than one could be saved. Such justifications are not easy to find. Therefore, in this paper, the guidance of the MBB principle is heeded.

One implication of the MBB principle is that network screening will tend to direct attention to sites at which the accident reduction potential is the largest. For the accident reduction potential to be large, accident frequency (accidents per km-year or accidents per year) has to be large. Thus, the MBB principle tends to send money to large accident frequency sites.

Some screening methods make use of the accident rate (accidents per vehicle-km and accidents per entering vehicles). A site can have a high accident rate if it has few accidents but also little traffic. The quest for a large accident reduction potential implies that a DES should not be done at such sites. It follows that accident frequency, not rate, is the natural metric for screening. This is another consequence of the MBB principle.

A third consequence of the MBB principle is that the search for sites at which the accident reduction potential is large may favor the heavily traveled urban and suburban sites, not the less used rural sites. This tendency could be mitigated by the fact that projects in urban and suburban areas are more expensive.

Another major implication of the MBB principle is that the metric for ranking at the time of network screening is the anticipated cost-effectiveness. How can one anticipate project cost and safety benefit by computerized methods and using only routinely available electronic databases at a time before specific projects have been defined?

TABLE 1 Example of a Bad and a Good Ranked List

Bad List		Good List	
Top sites based on Screening Method A	Prospective accident savings/Project $	Top sites based on Screening Method B	Prospective accident savings/Project $
1	0.5	1	3
2	0.7	2	1.5
3	1.3	3	1.2
4	0.1	4	0.9
5	0.9	5	0.7
6	1.2	6	0.6
7	0.7	7	0.6
8	0.3	8	0.6
9	0.3	9	0.5
10	0.8	10	0.4

ANTICIPATION OF PROJECT COST AND SAFETY BENEFIT IN NETWORK SCREENING

Consider first the task of anticipating project costs. At the time of screening little can be known about specific safety improvement projects; these are formulated later, during the DES. Even so, to assume that nothing can be said about future project costs is not right. Known at the time of screening are the road and intersection type (two-, four-, or multilane roads; in an urban, suburban, or rural setting; in flat, rolling, or mountainous terrain; three- or four-legged intersections; signalized or not; etc.). The length of the road section and the annual average daily traffic (AADT) are also known. It should therefore be possible to ascertain what were the average costs of safety-motivated projects for similar roads under similar circumstances and thus to anticipate the cost of future unspecified projects. Thus, the anticipated project cost is an average of a wide distribution.

Consider next the problem of anticipating the safety benefit at the time of screening, when site-specific problems have not been diagnosed and remedies not specified. Just as with project cost, the anticipation of safety benefit is bound to be of the nature of an average of a wide distribution. Two main alternative assumptions have been used for this purpose in the past:

1. Assumption *a*: The effect of remedial action is to reduce the expected accident frequency and severity of target accidents by some fixed proportion. Therefore,

$$\text{Anticipated safety benefit} = \text{expected accident frequency} \times \text{constant}_a$$

2. Assumption *b*: The effect of remedial action of some kind is to reduce the *excess* of the expected accident frequency and severity over what is normal or over what is safest at similar sites. Therefore,

$$\text{Anticipated safety benefit} = \text{expected excess accident frequency} \times \text{constant}_b$$

More will be said about the two constants in the following text.

Examining Assumption *a*

Assumption *a* is widely used; it is embedded in the concept of accident modification functions (AMFs, also called accident reduction factors) that play the role of constant$_a$. Virtually all that is known about the safety benefit of countermeasures, either through before–after studies or through multivariate statistical modeling, is eventually cast into the AMF vessel. The resulting AMFs are then used to estimate the safety benefit of countermeasures. Thus, for example, for a rural two-lane road, the widening of 3-m lanes to 3.3 m is thought to reduce expected target accidents to 0.81 of their original frequency (*3*, p. 30). To illustrate, if 10 target accidents were expected before lane widening, 8.1 should be expected after widening, a reduction of 10 × 0.19.

Assumption *a* is also in accord with the fundamental concepts of probability theory. In probability theory there is a "chance-setup" (*4*, p. 13) on which repeated "trials" are conducted, each trial having an "outcome" that occurs with a certain "probability." The expected number of outcomes of some kind is the product of the number of trials and the probability of that outcome. In the present context, a road or intersection is the chance-setup; the passage of a vehicle is trial; the outcome is either "accident" or "no-accident"; and the number of accidents is the product of the number of passages and the probability of an accident. A countermeasure is thought to alter the probability of the accident outcome to materialize. It follows that the effect of a countermeasure is to change the expected number of accidents in the same proportion as the probability of an accident during a passage has been changed. This is the essence of Assumption *a*.

Accident modification functions (and thereby Assumption *a*) are a central construct in the interactive highway safety design model (IHSDM). Therefore, if the site safety improvement model (CHSIM) now in development, is to work in tandem with IHSDM, Assumption *a* must be a strong contender.

To illustrate how Assumption *a* plays out in screening, let 10 accidents per year be expected at Site X, and 5 at Site Y. Consider the application of the same unspecified countermeasure to both sites. The anticipated safety benefit at Site X is 10 × (constant$_a$) whereas at Site Y it is 5 × (constant$_a$). Inasmuch as the countermeasure is not specified at the time of screening, and if Sites X and Y are of the same kind, there is no reason to think that constant$_a$ differs between the two sites. Therefore, under Assumption *a*, the anticipated safety benefit at Site X is necessarily twice that at Site Y, irrespective of the countermeasure. If the expected cost of a generic project is the same at both sites, Site X will have priority for the conduct of a DES over Site Y because its anticipated cost-effectiveness is twice as large. Sites with more expected accidents will tend to get a DES before sites with few expected accidents do.

The authors assumed that Sites X and Y are of the same kind (e.g., both are two-lane rural roads). In this circumstance one may use the argument of "Consider the application of the same unspecified countermeasure to both sites" which makes the magnitude of constant$_a$ irrelevant. However, were X and Y not of the same kind, one would have to have separate estimates of constant$_a$ for sites of type X and of type Y.

Examining Assumption *b*

The central concept in Assumption *b* is the *excess* of the expected accident frequency and severity over what is normal at similar sites. This excess has been called "potential accident reduction" by McGuigan (*5*). The same approach is favored by Persaud who calls it the "potential for safety improvement" in his research on screening (*6, 7*). Assumption *b* is implicit in all the popular screening methods that use an "upper control limit" (which is a fixed number of standard deviations above what is normal for similar sites).

Assumption *b* is attractive and natural. Its attraction rests on the belief that if a site has more (or more severe) accidents than what is normal at similar sites, there must be some site-specific causes that explain the excess, and that if causes are identified, they could be remedied, and the excess reduced. It follows that only the excess is reducible.

Assumption *b* is not free of difficulties. One weak point stems from the notion that excess is defined with respect to the average at similar sites. It is in the nature of the average that at about half of the similar sites one expects fewer accidents than the average. Therefore, the notion that only the excess over the average can be reduced is flawed. If one can find causes that make a site to have an above average expected accident frequency, one should be able to also find causes that make a site to have below average accident frequency. Therefore it should be possible to improve sites to have below average accident frequencies. The concept of excess might be salvaged by redefining it to be against some attainable lower limit. Tarko et al. (*8*) define the lower limit as what is attainable by a change of factors that can be practically altered (e.g., traffic control or road geometry). They suggest that the lower limit be such that only a small fraction (say, 10%) of existing locations would be safer. This would reflect the belief that the safety of the safest 10% of existing locations could not be further improved by practical measures, a belief that is difficult to substantiate. An additional difficulty is that the understanding of how close one can get to the lower limit with what countermeasure effort is presently missing.

A related weakness of Assumption *b* resides in the notion of "similar sites." To illustrate the difficulty, assume that the average accident frequency of two-lane rural roads with 3-m lanes is larger than the average for such roads with 3.3-m lanes. Consider now Site X which has 3-m lanes and the same expected accident frequency as the average for other such roads with 3-m lanes. If roads with 3-m lanes are considered "similar," then Site X has no excess, no DES will be done at this site, and widening of its 3-m lanes will not be considered. In contrast, if roads with 3.3-m lanes are chosen as being "similar," there will be an excess, a DES might be done, and lane widening could be one of the countermeasures considered. Thus, by deciding what is similar, one also decides what is and what is not a countermeasure. Unlike the previous weakness which, in principle, could be alleviated (by using "lower limit" instead of "average"), this weakness is difficult to rectify. The problem is where to stop. It is insufficient to consider two-lane roads with 3.3-m lanes to be similar because then four-laning would not be considered. A four-lane undivided road can still be made safer by adding a median. Should one therefore consider four-lane divided highways "similar" to two-lane undivided roads? The regress is practically infinite. To resolve this problem it would be necessary to agree beforehand what is the set of all legitimate countermeasures. With such an agreement, "similar" would be sites where all the agreed-upon countermeasures were implemented. This is the position taken by Tarko et al. (*8*). The issue has been stated and examined by Persaud et al. (*7*).

To illustrate how Assumption *b* would play out in screening, consider again Sites X and Y at which 10 and 5 accidents are expected per year. If sites similar to Site X have, on the average, 9 accidents per year and sites similar to Site Y normally have 2 accidents per year, the anticipated safety benefit at Site X is $(10 - 9) \times (\text{constant}_b)$, whereas at Site Y it is $(5 - 2) \times (\text{constant}_b)$. Inasmuch as the countermeasure is not specified at the time of screening, and if Sites X and Y are of the same kind, there is no reason to think that constant_b differs between the two sites. If now the expected cost of an unspecified project is the same at both sites, Site Y will have priority for the conduct of a DES over Site X because its anticipated cost-effectiveness is three times larger. This is the reverse of the result obtained in the earlier corresponding illustration for Assumption *a*. It follows that the ranked lists produced under the two alternative assumptions will not be the same. Assumption *a* will tend to bring to the top sites at which the accident frequency is high, whereas Assumption *b* will rank highly sites at which the excess of an "average" is high. As noted earlier, if Sites X and Y are not of the same kind, one would have to have separate estimates of constant_b for sites of type X and of type Y.

Summary Comments

It is presently unknown whether Assumption *a*, Assumption *b*, a hybrid of the two, or something entirely different would better anticipate the safety benefit. Therefore, no matter how persuasive a discussion of the strengths and weaknesses of alternative assumptions might be, it would be premature to favor one or the other. Both should be tried and evaluated. A provisional method of evaluating which screening method performs better has been suggested earlier. It is now possible to explain why such an evaluation can be only provisional. Recall that in Figure 1 one had to fill in estimates of prospective cost-effectiveness obtained during a DES. To do so the analyst has to use AMFs and apply them to expected accidents. This is tantamount to endorsing Assumption *a*. (There are, at present, no estimates of AMFs that pertain to excess accidents. Therefore, there is no way to estimate prospective cost-effectiveness when based on a reduction in excess accidents.) As a result, the rank in screening based on Assumption *a* is likely to correlate better with the prospective cost-effectiveness (that is based on the same assumption) than with the rank in screening that is based on Assumption *b*.

Assumptions *a* and *b* for the anticipation of project costs and safety benefits are relatively simple-minded. They make no use of the rich, coded, and easily available information about accident circumstances. If such information was used to identify possible factors of accident causation, it would be possible to anticipate promising remedial measures. By recognizing unusually large proportions of injury accidents, single-vehicle accidents, accidents in darkness, wet weather accidents, and so forth, it would be possible to improve estimates of anticipated project costs and safety benefits. Along similar lines, Persaud et al. (*7*) contemplated the possibility of screening the network for target accidents that may be subject to specific countermeasures. The art of using all coded accident information for screening is now underdeveloped. Methods that use this information with effect may perform better than those based on either Assumption *a* or *b*.

GUARDING AGAINST RANDOMNESS

When Assumption *a* is used to anticipate safety benefits, an estimate of the expected accident frequency for each site is needed. This will be called "estimate_a." When Assumption *b* is used to anticipate safety benefits, an estimate of the excess accident frequency is needed for each site. This will be "estimate_b." Estimates are always surrounded by uncertainty. The danger is that a site may appear to have a large accident frequency or large excess frequency, and therefore rank high in priority for the conduct of a DES, merely because of a random fluctuation in accident counts. To guard against misdirecting engineering effort toward such undeserving sites, the precision with which frequency or excess is estimated ought to be taken into account. To illustrate the issue consider Sites Y and Z in Table 2.

This example has been constructed so that at both sites the excess of accidents is 3 per km-year. The values after the ± sign are one standard error. At Site Y the excess of $5 - 2 = 3$ accidents per km-year has a standard error of $\sqrt{(2.2^2 + 0.5^2)} = 2.3$. Thus the excess is $3 / 2.3 = 1.3$ standard errors from zero. At Site Z the excess of $1 - 0.4 = 0.6$ accidents per year for a 0.2-km-long segment has a standard error of $\sqrt{(1^2 + 0.1^2)} = 1.0$. This is only $0.6 / 1 = 0.6$ standard errors from zero. The excess of 3 at Site Y is more likely to be genuine than the same excess at Site Z. Therefore, Site Y should be ranked higher than Z.

TABLE 2 Illustration for Sites Y and Z

Road section	Y	Z
Length [km]	1	0.2
Expected at this site [accidents/year]	5±2.2	1±1
Expected at similar sites [accidents/year]	2±0.5	0.4±0.1

To guard against the misdirection of costly effort to undeserving sites one can insist on a standard of statistical precision that must be met for a site to be eligible for inclusion in the ranked list. To specify the required statistical precision, use of "limiting coefficients of variation" is suggested. The coefficient of variation of an estimate (*CV*) is the ratio: (standard error of estimate) / (expected estimate). The same concept is used in reliability-based engineering design (*9*, p. 133). Let CV_a be the limiting coefficient of variation when ranking is based on Assumption *a* and CV_b the corresponding value when ranking is by Assumption *b*. Only sites for which (standard error of estimate_a) / (estimate_a) $< CV_a$ and sites for which (standard error of estimate_b) / (estimate_b) $< CV_b$ will be placed on the lists. Values of CV_a and CV_b are to be chosen by the analyst. The following can serve as guidance. The estimated value is usually within $100 \times 2 \times CV$% of the true value and almost always within $100 \times 3 \times CV$%. Thus, if a limiting *CV* of 0.033 is chosen, the estimated value is usually within 7% and almost always within 10% of the target.

WHAT IS A SITE?

In most databases, a road section is a stretch between two important intersections along which it is assumed that the AADT and some road features are approximately constant. In what follows, a road segment will denote a part of a road section. At present, what segment length is used for network screening differs from one jurisdiction to another. The purpose of this section is to shed light on the question of what should be defined as "site" in network screening; it could be the entire road section, it could be a segment of specified length, or it could be a segment of variable length. The merits and weaknesses of these options are examined in the following text.

Imagine that for a road section one could plot the detailed profile of the expected accident frequency at all points and that one also knows what is the expected accident frequency for similar roads, as shown in Figure 2.

If accident reduction is thought to be proportional to accident frequency (Assumption *a*), one would like to focus attention on the peaks of the solid curve. If accident reduction is thought to be proportional to the excess between the frequency on this road and what is normal [i.e., the difference between the solid curve and the dotted line (Assumption *b*)], one would still focus on the peaks of the solid curve. This is why in the other figures, the dotted line will be omitted.

Option 1: Site = Road Section

Consider the entire road section as one site for the purposes of screening. If so, the details of the curved profile are replaced by the average over the entire road section. Such averaging has two disadvantages. First, one loses the ability to identify peaks. Second, since averages for short sections are more variable than averages for long sections, short road sections will tend to have many false-positive peaks.

Option 2: Site = Segments of Fixed Length

Here each road section is divided into nonoverlapping segments of fixed length (say, 0.5 km as in Ontario). Now the averaging is over each segment as in Figure 3.

Segments will not coincide with the location of a peak or plateau, except by coincidence. The consequence is a general lowering of peaks. The subdivision of a road section into segments of constant length reduces the principal deficiency of Option 1. However, this is attained at the cost of reducing the precision by which the true average is being estimated. These insights indicate that the most attractive option would be to fit segment lengths to peaks while making them sufficiently long to maintain the limiting precision of the estimated average.

Option 3: Site = Peak of Variable Length

The intent here is to identify the peak that is just long enough to meet the required statistical precision. The road section is divided into 0.1 km (or 0.1 mi) basic subsections as shown in Figure 4. A window of size W is made up of W consecutive basic subsections. Initially, the left edge of the window is placed at the left boundary of the road section and the average within the window is computed. The window is then moved one basic subsection to the right and the average is computed again. This is done until the right edge of the window reaches the right boundary of the road section. The process is repeated for windows of all feasible sizes.

The largest of the averages so computed is the largest peak for a window of size W. Segment AA′ in Figure 4 is the highest peak when W = 3. Segment BB′ is the second highest peak when W = 3. Segment CC′ is the highest peak when W = 7. Of two segments of size W that overlap, only that with the higher estimated average is retained for

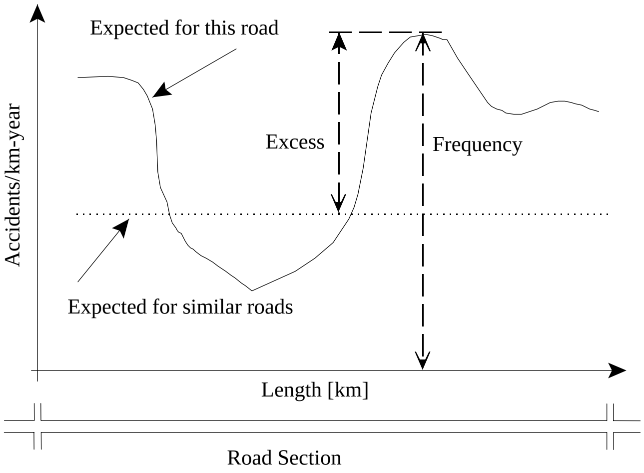

FIGURE 2 Safety profile.

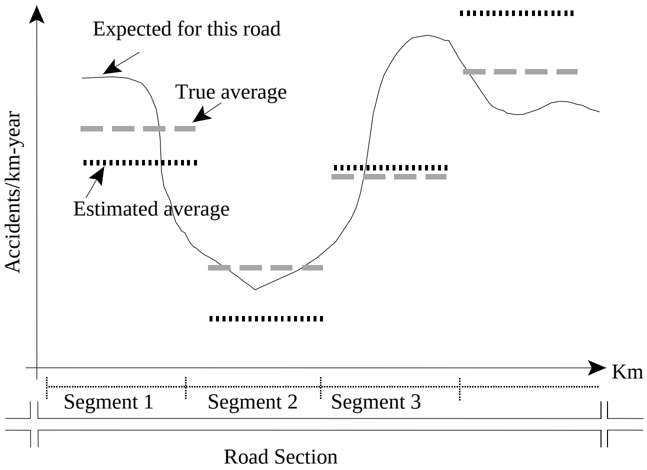

FIGURE 3 Safety profile and segment averages.

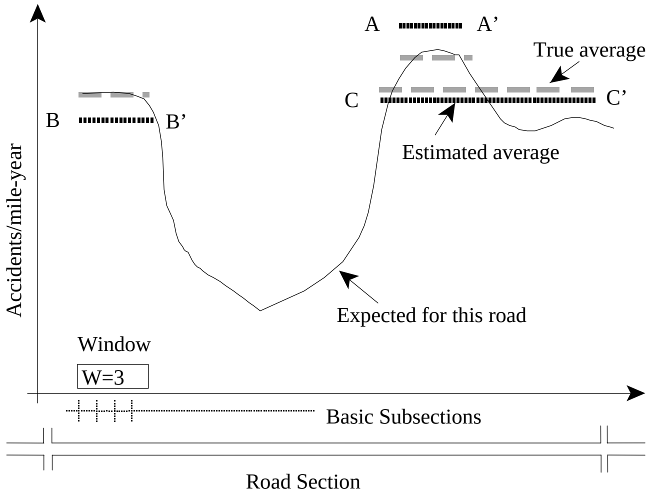

FIGURE 4 Safety profile and "window" averages.

further consideration. If on Segment AA′ the statistical precision criterion is met it, rather than Segment CC′, will be considered further. The reason is that the rank of AA′ is bound to be higher than the rank of CC′ and, if a DES is conducted, the vicinity of AA′ will be considered when a project is formulated. If the statistical precision criteria on AA′ are not met but they are met on CC′, only the latter will be retained for ranking. Of the three options considered, the last seems most promising. Its implementation requires a database in which accidents can be allocated to basic subsections of each road section.

SUMMARY AND DISCUSSION

There is renewed interest in site safety improvement and in better techniques of network screening. Network screening is the first step of the site safety improvement process. Its product is a list of sites ranked by priority to feed into the second step—the conduct of detailed engineering studies. The role of the second step, the DES, is to formulate cost-effective projects for implementation in the third step. It follows that a good screening method is that which ranks highly those sites at which the most cost-effective projects can later be formulated.

The challenge for network screening is to anticipate the relative cost-effectiveness of safety projects, to base the anticipation only on electronically stored data, and to do so before a detailed engineering study has been done and specific projects formulated. Anticipation of this kind is bound to be imperfect. The cost of future unspecified projects can be based on the average past experience when road type, length, AADT, surrounding area, and terrain are taken into account. The anticipation of future safety benefits of unspecified projects must be based on assumptions. One possibility is to assume that the safety benefit will be proportional to the expected accident frequency. Another possibility is to assume that the safety benefit will be a part of the excess over what is normal for similar sites. Both assumptions have strong and weak points. Still, they are only assumptions, presently without much empirical support. In addition, screening methods based on these assumptions use only a small part of the electronically stored information about accidents. It is therefore likely that screening methods based on more of the available information will perform better. The game is wide open and research to evaluate screening methods is urgently needed.

One approach to such an evaluation is to examine the correlation between the rank established by a screening method and the rank by cost-effectiveness as established during the DES. The screening method that shows the largest correlation performs best. The shortcoming of such a program of research is that at present, cost-effectiveness estimates rely on one of the aforementioned and unsubstantiated assumptions.

Having defined the purpose and product of network screening clearly, it is easier to picture properly what is the ill effect of the randomness inherent in accident counts. In screening one has to guard against the possibility that high priority will be given to a site because a random spike in accidents has occurred. To control the amount of misdirection of costly engineering effort, it is suggested to place on the list only sites at which the estimate of accident frequency or of accident excess has a coefficient of variation that is smaller than a certain limiting value.

At present there are various ways to define a "site" in network screening. After examining the merits of three options, the conclusion is that one should define "site" as the shortest segment of a road section at which the estimate of the expected accident frequency is largest while the coefficient of variation is smaller than the chosen limiting value.

In addition to the questions discussed here, there are several other basic issues in network screening that demand attention. Among those is the question of how should the severity of accidents influence the anticipation of safety benefit, how to estimate the expected accident frequency profile for a road section, and how to make use, for this purpose, of the entire accident history of a site rather than only the recent 2 to 3 years. These questions will be addressed in a separate paper.

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