IMPROVED ESTIMATES OF THE SAFETY EFFECTS OF ACCIDENT REMEDIAL SCHEMES

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Introduction. A structured programme of action for the remedial treatment of road accident blackspots basically involves a four-phase process: identification, investigation, implementation and evaluation[1-4].

The identification phase involves the initial identification of high-risk sites based on the accident count and/or rate during an identification period, usually three years in duration.

The investigation phase involves a detailed site investigation to select from among the identified sites those where there are sufficient common causal factors in the accident pattern (such as inadequate visibility or skid-resistance) to indicate that effective treatment is possible. Proposals for appropriate remedial measures can then be developed.

The implementation phase involves ranking sites according to the likely cost-effectiveness of treatment: sites where treatment is likely to be most cost-effective are then selected for inclusion in a phased plan for implementation. The assessment of cost-effectiveness requires a knowledge of the expected accident reduction associated with the proposed remedial measures together with the scheme implementation costs.

Finally, in the evaluation phase, the effectiveness of the remedial treatment should be monitored in order to assess the extent to which targets are being met and to allow the quantified effects of various forms of treatment to be fed back into future studies.

The initial identification of high-risk sites on the basis of observed frequencies potentially introduces errors into subsequent phases of the process due to the phenomenon known as the regression-to-mean (RTM) effect. This effect arises because the initial selection of sites based on the accident frequencies will bias the selection towards sites which, due to random fluctuation, have suffered an abnormally high accident frequency during the identification period. In a subsequent time period, random fluctuations mean that the accident frequency at these sites will on average decline, even without the implementation of remedial measures.

The occurrence of the RTM effect has been demonstrated in various studies of accident frequencies in two consecutive time periods at *untreated* sites[5-7]: where sites are selected on the basis of a high accident frequency in the first time period, a decline in the average accident frequency can be observed at the selected sites in the second time period, with an increase at sites not selected. Thus evaluation based on a simple before-and-after study of accidents at treated sites will tend to overestimate treatment effectiveness, the observed accident reduction including both the reduction attributable to treatment and the reduction due to the RTM effect. A comparison of a number of evaluation studies has indeed demonstrated that, in studies where RTM effects are controlled for, a smaller accident reduction is attributed to blackspot treatment[8]. If the results of studies where RTM effects are not fully controlled for are fed back into the assessment of the cost-effectiveness of subsequent schemes, errors will be introduced at the implementation phase: not only will the cost-effectiveness of treatment be overestimated, but, if the size of the RTM effect varies between sites, the rank order may also be in error.

The RTM effect has been quantified at *untreated* sites, but the magnitude of the effect may not be the same at treated and untreated sites. It has, for example, been argued that, since the investigation phase of the blackspot treatment programme aims to identify sites with a *real* accident problem (with common causal factors and not just one arising as a result of random fluctuation) the RTM effect would be expected to be less at a site selected for treatment than at a site not selected, but with a smaller accident count[9].

It is also possible that the magnitude of the RTM effect may vary with accident type since, for some types of treatment, the identification phase may be based on the frequency of accidents of a particular type, not just accident totals: a minimum number of wet-road accidents in the case of surface treatment or a minimum number of night accidents in the case of streetlighting provision or improvement. Indeed, the requirement for cost-effective treatment programmes may bias site selection towards sites with larger numbers of more expensive accidents: killed and serious injury (KSI) accidents rather than slight accidents. Where sites are selected for treatment on the basis of exceptionally large

Table I. Distribution of accident types at the treated sites during the before, lag and intermediate periods

	Before	Intermediate	After
Number of sites	906	906	906
Total number of accidents	7464	2783	3365
Accidents by severity			
— Number of KSI accidents	1761	612	660
— Number of slight accidents	5703	2171	2705
— % KSI	24 %	22%	20%
Accidents by road surface			
— Number of wet-road accidents	3406	1181	1334
— Number of dry-road accidents	4058	1602	2031
— % wet-road	46%	42%	40%
Accidents by lighting conditions*			
— Number of night-time accidents	1961	648	854
— Number of daytime accidents	4706	1740	2094
— % night-time	29%	27%	29%

*For one county data split by lighting condition were not available and thus the data by lighting condition are for only 777 sites, not 906 numbers of accidents of a particular type, a correspondingly large decrease due the the RTM effect might be expected for the target accident type. A before-and-after study of accidents at treated sites may then give a distorted picture of the effects of treatment, overestimating the reduction in some accident types while correctly estimating or underestimating the reduction in others.

The basic problem is, of course, that it is not usually possible to observe directly the accidents which would have occurred after treatment had the treatment not been implemented: accident data are obtained for two periods only, typically during the three years before and after treatment. It is possible to control for the RTM effect indirectly by using a control group of untreated blackspots or by using statistical models[2,10], but such indirect methods will potentially be subject to errors arising from the assumptions underlying them. These difficulties mean that the typical accident reductions achieved by various remedial treatments are not well understood.

The objectives of the research described here were thus to use a more direct approach to establish the magnitude of the RTM effect at treated sites, and hence the true treatment effects of various remedial measures on both total and target accidents. The approach used is based on the fact that, in practice, there will tend to be a lag between the identification and implementation phases of a blackspot programme — the period of time required for the investigation phase. It is thus possible to obtain data for three time periods rather the usual two: for the *identification period* during which a site meets the selection criterion for inclusion in the accident remedial programme; for the time between identification and implementation of remedial treatment (the *lag period*); and for the period *after* treatment. Any change in accidents between the *identification* and *lag* periods can be assumed to be due to RTM effects; the change between the *lag* and *after* periods is the *true* treatment effect.

The potential practical problem with the use of lag period data is that from a statistical point of view the lags need to be as long as possible, whereas from a road safety point of view they should be as short a possible. In an actual blackspot treatment programme the use of lag period data for studies of treatment effectiveness may well not be considered appropriate: it could be considered vital to implement treatment as rapidly as possible to avoid further loss of life and the duration of the lag period may then not be adequate for use in evaluation. In this study, however, which was based on historical rather than current data, it was possible to select sites where, for a variety of reasons, there had been an identifiable lag between identification and treatment.

The research described in this paper forms part of an EPRSC-funded project to obtain improved estimates of the effects of accident remedial schemes on both total accidents and accidents disaggregated by severity, road surface and lighting conditions. In addition to the results presented here, an empirical Bayes technique has also been developed and validated by comparison with the lag period data. Details of the predictive accident models required for the empirical Bayes technique have been published[11,12] and further reports are in preparation.

Table II. Summary of treatment types and categories

Treatment category (No. of sites)	Treatment types included (No. of sites)
All surface treatments (338)	Anti-skid surfacing (180), including: calcined-bauxite (30); unspecified high-PSV aggregates (28); brand-named anti-skid surfacings (49); and unspecified anti-skid surfacings (73) Retexturing (60) Unspecified surface treatment (98)
Mini-roundabout provision (32)	Conversion of major-minor priority junction to mini-roundabout (32)
Other junction improvements (294)	Delineation and signing (59) Channelisation (33) Traffic signal provision (24) Traffic signal modification (24) Red-light camera (29) Unspecified junction modifications (125)
Link realignment (47)	Horizontal and vertical realignment (47)
Other link improvements (106)	Delineation and signing (64) Safety barriers (8) Unspecified link improvements (34)
Streetlighting schemes (18)	Provision of streetlighting (18)
Traffic management schemes (200)	Traffic calming, including horizontal and vertical shifts and unspecified traffic calming measures (63) Pedestrian crossing provision/improvement (53) Warning signs (69) School signs (6) Change of speed limit (9)

The data

Data were obtained for some 1 500 *high-risk* sites (i.e. those which had been selected for inclusion in the accident remedial programmes of 10 local authorities in the U.K.). The required data for each site included:

(*i*) the type and date of treatment; and

(*ii*) the observed accident frequencies in the treated section (classified by severity, road surface condition and lighting condition) during each of the three time periods: the identification period; the lag period; and the period after treatment.

For some of the sites the data records were incomplete and some of the sites were not treated during the study period. Of the 1 035 treated sites for which complete data records were available, 906 sites had lag periods of six months or more, 681 had lag periods of one year or more and 210 sites had lag periods of two years or more. The analysis was based on the 906 sites with lag periods of six months or more. The average duration of the lag period was 18 months. The duration of the identification period was three years for all but one of the local authorities (for which it was five years), giving an average identification period of 3.22 years. The 'after' periods were up to three years after treatment, with an average value of 2.55 years. Nearly 14 000 accidents occurred at the selected sites over the three time periods. Table I summarises the distribution of the accidents by time period and accident type.

The nature of the treatments included in the sample are summarised in Table II. The treatments were grouped into seven categories as indicated in Table II, based on the similarity in the nature of the treatment and the similarity of the effects of treatment. Thus, for example, there was no significant difference in the effects of the various types of surface treatment and these were thus grouped together in a single category. The conversion of priority junctions to mini-roundabouts was, on the other hand, significantly more effective in reducing accidents than any other junction improvements and thus mini-roundabouts were treated as a separate category. Streetlighting schemes were treated as a separate category because their effects on night-time and daytime accidents were considered to be of particular interest, but the sample size was too small to give conclusive results.

Analysis

The magnitude of the accident reduction due to treatment and of the RTM effect was estimated for each treatment category, both in terms of total accidents and in terms of accidents disaggregated by severity, road surface and lighting conditions. It was decided that the most useful way of expressing treatment effectiveness was as a percentage reduction in the 'identification period' accidents. This measure was used because the main purpose of the estimates is to assess the likely cost-effectiveness of remedial treatment. At the implementation phase of a blackspot treatment programme the only information normally available about accident frequencies would be the observed accidents during the identification period, and thus estimates of the percentage reduction in these would seem appropriate.

In estimating treatment effectiveness and the RTM effect it was assumed that at a site:

x_B = the total accidents observed during an identification period of t_B years;

x_L = the total accidents observed during a lag period of t_L years; and

x_A = the total accidents observed during an after period of t_A years.

The true reduction in accidents, θ, attributable to a particular treatment category is then given by

$$\theta = \left(\frac{\sum x_L / \sum t_L - \sum x_A / \sum t_A}{\sum x_B / \sum t_B} \right) \quad \ldots\ldots (1)$$

and the percentage reduction is 100θ, where the summations are over all sites receiving a type of treatment within the specified treatment category. Similarly, the change in accidents due the RTM effect, R, is given by:

$$R = \left(\frac{\sum x_B / \sum t_B - \sum x_L / \sum t_L}{\sum x_B / \sum t_B} \right)$$

$$\text{or } R = 1 - \frac{\sum x_L / \sum t_L}{\sum x_B / \sum t_B} \quad \ldots\ldots (2)$$

and the percentage reduction is $100R$. The biased estimate of the treatment effect, B, is:

$$B = \left(\frac{\sum x_B / \sum t_B - \sum x_A / \sum t_A}{\sum x_B / \sum t_B} \right)$$

$$\text{or } B = 1 - \frac{\sum x_A / \sum t_A}{\sum x_B / \sum t_B} \quad \ldots\ldots (3)$$

the percentage reduction is $100B$ and it can be seen that:

$$\theta = B - R \quad \ldots\ldots (4)$$

In order to obtain confidence intervals it is also necessary to estimate variances. The distributions of R and B are skewed and estimates of the variances can best be obtained using a log transformation. $Ln\ R$ and $ln\ B$ are approximately normally distributed with variances estimated by:

$$Var(lnR) = \frac{1}{\sum x_L} + \frac{1}{\sum x_B} \quad \ldots\ldots (5)$$

$$\text{and} \quad Var(lnB) = \frac{1}{\sum x_A} + \frac{1}{\sum x_B} \quad \ldots\ldots (6)$$

Table III. Estimates of reductions due to treatment and regression-to-mean effects

(i) All treatment types

Accident type	'True' estimate of reduction due to treatment			'Biased' estimate of reduction due to treatment			Estimated reduction due to RTM		
	Lower 95% limit*	Best estimate	Upper 95% limit*	Lower 95% limit*	Best estimate	Upper 95% limit*	Lower 95% limit*	Best estimate	Upper 95% limit*
Total accidents	20%	**23%**	25%	40%	**43%**	45%	15%	**20%**	25%
KSI accidents	20%	**28%**	35%	50%	**53%**	55%	20%	**25%**	30%
Slight accidents	20%	**22%**	25%	35%	**40%**	45%	15%	**18%**	20%
Wet-road accidents	20%	**25%**	30%	45%	**51%**	55%	20%	**25%**	30%
Dry-road accidents	15%	**22%**	25%	35%	**37%**	40%	10%	**15%**	20%
Night accidents	10%	**18%**	25%	40%	**43%**	50%	20%	**25%**	30%
Daytime accidents	20%	**26%**	30%	40%	**42%**	45%	10%	**16%**	20%

* In Tables III(i) to III(viii), rounded to nearest 5 per cent

(ii) All surface treatments

Accident type	'True' estimate of reduction due to treatment			'Biased' estimate of reduction due to treatment			Estimated reduction due to RTM		
	Lower 95% limit*	Best estimate	Upper 95% limit*	Lower 95% limit*	Best estimate	Upper 95% limit*	Lower 95% limit*	Best estimate	Upper 95% limit*
Total accidents	15%	**23%**	30%	40%	**46%**	50%	15%	**23%**	30%
KSI accidents	5%	**19%**	30%	50%	**57%**	65%	25%	**39%**	50%
Slight accidents	15%	**24%**	30%	35%	**43%**	50%	10%	**18%**	25%
Wet-road accidents	20%	**27%**	35%	65%	**67%**	70%	35%	**40%**	45%
Dry-road accidents	5%	**17%**	30%	0%	**12%**	20%	-20%**	**-5%**	10%
Night accidents	-5%	**11%**	25%	40%	**49%**	60%	20%	**38%**	50%
Daytime accidents	15%	**27%**	40%	35%	**44%**	50%	5%	**17%**	30%

** In Tables III(ii) to III(viii), a negative sign indicates an increase in accidents rather than a reduction

(iii) Mini-roundabouts

Accident type	'True' estimate of reduction due to treatment			'Biased' estimate of reduction due to treatment			Estimated reduction due to RTM		
	Lower 95% limit*	Best estimate	Upper 95% limit*	Lower 95% limit*	Best estimate	Upper 95% limit*	Lower 95% limit*	Best estimate	Upper 95% limit*
Total accidents	45%	**65%**	85%	60%	**68%**	75%	-20%	**3%**	25%
KSI accidents	25%	**59%**	90%	70%	**88%**	95%	-15%	**30%**	55%
Slight accidents	40%	**68%**	95%	45%	**61%**	70%	-40%	**-7%**	20%
Wet-road accidents	40%	**86%**	100%	35%	**59%**	75%	-85%	**-27%**	15%
Dry-road accidents	35%	**57%**	80%	60%	**72%**	80%	-10%	**16%**	35%
Night accidents	10%	**52%**	100%	20%	**54%**	75%	-60%	**2%**	40%
Daytime accidents	45%	**69%**	95%	60%	**72%**	80%	-25%	**4%**	25%

(iv) Other junction improvements

Accident type	'True' estimate of reduction due to treatment			'Biased' estimate of reduction due to treatment			Estimated reduction due to RTM		
	Lower 95% limit*	Best estimate	Upper 95% limit*	Lower 95% limit*	Best estimate	Upper 95% limit*	Lower 95% limit*	Best estimate	Upper 95% limit*
Total accidents	20%	**27%**	35%	35%	**42%**	45%	5%	**14%**	20%
KSI accidents	10%	**22%**	35%	30%	**40%**	50%	0%	**18%**	30%
Slight accidents	20%	**29%**	35%	35%	**42%**	45%	5%	**14%**	20%
Wet-road accidents	15%	**24%**	35%	30%	**38%**	45%	0%	**13%**	25%
Dry-road accidents	20%	**29%**	40%	40%	**44%**	50%	5%	**15%**	25%
Night accidents	10%	**23%**	35%	25%	**37%**	45%	0%	**13%**	25%
Daytime accidents	20%	**29%**	35%	40%	**44%**	50%	5%	**15%**	20%

(v) Link realignment

Accident type	'True' estimate of reduction due to treatment			'Biased' estimate of reduction due to treatment			Estimated reduction due to RTM		
	Lower 95% limit*	Best est-imate	Upper 95% limit*	Lower 95% limit*	Best est-imate	Upper 95% limit*	Lower 95% limit*	Best est-imate	Upper 95% limit*
Total accidents	15%	**37%**	55%	50%	**63%**	70%	5%	**26%**	45%
KSI accidents	25%	**72%**	100%	40%	**66%**	80%	-70%	**-7%**	30%
Slight accidents	5%	**25%**	45%	50%	**62%**	75%	15%	**37%**	55%
Wet-road accidents	5%	**27%**	50%	50%	**68%**	80%	15%	**41%**	60%
Dry-road accidents	15%	**52%**	90%	30%	**55%**	70%	-40%	**3%**	35%
Night accidents	0%	**28%**	55%	50%	**70%**	80%	5%	**41%**	65%
Daytime accidents	15%	**42%**	70%	40%	**59%**	70%	-15%	**16%**	40%

(vi) Other link improvements

Accident type	'True' estimate of reduction due to treatment			'Biased' estimate of reduction due to treatment			Estimated reduction due to RTM		
	Lower 95% limit*	Best est-imate	Upper 95% limit*	Lower 95% limit*	Best est-imate	Upper 95% limit*	Lower 95% limit*	Best est-imate	Upper 95% limit*
Total accidents	0%	**10%**	20%	25%	**34%**	40%	15%	**24%**	35%
KSI accidents	15%	**32%**	50%	40%	**52%**	60%	0%	**20%**	35%
Slight accidents	-10%	**1%**	10%	20%	**27%**	35%	15%	**26%**	35%
Wet-road accidents	5%	**21%**	35%	25%	**36%**	45%	0%	**15%**	30%
Dry-road accidents	-10%	**2%**	15%	20%	**32%**	40%	20%	**31%**	40%
Night accidents	-20%	**-4%**	10%	25%	**36%**	45%	25%	**40%**	50%
Daytime accidents	5%	**17%**	30%	25%	**33%**	40%	5%	**16%**	25%

(vii) Street lighting schemes

Accident type	'True' estimate of reduction due to treatment			'Biased' estimate of reduction due to treatment			Estimated reduction due to RTM		
	Lower 95% limit*	Best est-imate	Upper 95% limit*	Lower 95% limit*	Best est-imate	Upper 95% limit*	Lower 95% limit*	Best est-imate	Upper 95% limit*
Total accidents	-25%	**5%**	35%	5%	**27%**	45%	-10%	**22%**	45%
KSI accidents	-30%	**17%**	65%	0%	**46%**	70%	-40%	**29%**	70%
Slight accidents	-35%	**0%**	35%	-10%	**20%**	40%	-20%	**19%**	40%
Wet-road accidents	-25%	**18%**	60%	-5%	**34%**	60%	-40%	**17%**	60%
Dry-road accidents	-40%	**-4%**	30%	-15%	**22%**	45%	-15%	**26%**	45%
Night accidents	-10%	**27%**	60%	30%	**56%**	70%	-15%	**29%**	70%
Daytime accidents	-70%	**-22%**	25%	-60%	**-9%**	25%	-40%	**13%**	25%

(viii) Traffic management schemes

Accident type	'True' estimate of reduction due to treatment			'Biased' estimate of reduction due to treatment			Estimated reduction due to RTM		
	Lower 95% limit*	Best est-imate	Upper 95% limit*	Lower 95% limit*	Best est-imate	Upper 95% limit*	Lower 95% limit*	Best est-imate	Upper 95% limit*
Total accidents	15%	**22%**	30%	35%	41%	45%	10%	**19%**	25%
KSI accidents	15%	**31%**	45%	45%	**55%**	65%	5%	**24%**	40%
Slight accidents	10%	**19%**	30%	30%	**37%**	45%	10%	**18%**	25%
Wet-road accidents	5%	**20%**	30%	35%	**43%**	50%	10%	**23%**	35%
Dry-road accidents	10%	**24%**	35%	35%	**40%**	45%	5%	**17%**	25%
Night accidents	10%	**27%**	40%	35%	**46%**	55%	5%	**20%**	35%
Daytime accidents	10%	**20%**	30%	35%	**39%**	45%	10%	**19%**	30%

In estimating the variance of θ there are potential problems with using a log transformation due to the possibility of negative numbers, and in any case the differences in the numerator mean that truncation at zero may not be such a problem. Using a *small perturbation* analysis, it was shown that good estimates of the variance could be obtained using an expression of the form:

$$\mathrm{Var}(\theta) = \left[\frac{\sigma_1^2}{\mu_1^2} + \frac{\sigma_2^2}{\mu_2^2}\right]\left[\frac{\mu_1^2}{\mu_2^2}\right] \qquad \ldots\ldots(7)$$

where $\mu_1 = \frac{\sum x_L}{\sum t_L} - \frac{\sum x_A}{\sum t_A}$

$$\mu_2 = \frac{\sum x_B}{\sum t_B}$$

$$\sigma_1^2 = \frac{\sum x_L}{\sum t_L^2} + \frac{\sum x_A}{\sum t_A^2}$$

$$\sigma_2^2 = \frac{\sum x_B}{\sum t_B^2}$$

Estimates were obtained for the effects of treatment on accident totals and disaggregated accidents, for each of the seven separate treatment categories and for all categories taken together. The estimates and their 95 per cent confidence intervals are given in Table III.

Regression-to-mean effect

It is clear from Table III that the RTM effect introduces substantial errors into the biased estimates of treatment effectiveness. Table III(i) indicates that, on average (over all treatment types and treatment categories), about half of the observed reduction in accidents (40 to 45 per cent) is attributable to remedial treatment (20 to 25 per cent) and half due to the RTM effect (15 to 25 per cent). The magnitude of the RTM effect varies with accident type, with the effect tending to be larger (in the range 20 to 30 per cent) for KSI, wet-road and night accidents and smaller for slight (15 to 20 per cent), dry-road and daytime accidents (10 to 20 per cent). (It should perhaps be recalled here that these RTM effects are based on data for identification periods of at least three years.)

There is some variation in the magnitude of the RTM effect with the treatment category, although in most cases the differences are not statistically significant. The variations tend to reflect the different selection criteria for different treatment types. Most notable is the case of surface treatment (Table IIII(ii)), where it is usual to select sites on the basis of an abnormally high number of wet-road accidents. For the surface-treated sites included in this study, 62 per cent of accidents in the 'before' period occurred on wet roads as compared with 46 per cent for all treated sites. The size of the RTM effect for wet-road accidents at surface-treated sites was thus not unexpectedly significantly larger than average (35 to 45 per cent as compared with 20 to 30 per cent over all sites) and was in fact larger than the reduction in wet-road accidents attributable to the effects of surface treatment (a reduction of 20 to 35 per cent). In contrast, for dry-road accidents at surface-treated sites there was no significant RTM effect.

The result is that the *biased* estimate grossly overestimates the effects of surface treatment on wet-roads accidents (by a factor of 2.5) while the biased estimate of the reduction in dry-road accidents was not significantly different from the true value. Link realignment schemes (Table III(v)) also exhibit a particularly large RTM effect for wet-road accidents with no significant effect for dry-road accidents: for these schemes the biased estimate again overestimates the effect on wet-road accidents by a factor of 2.5 while the estimated reduction in dry-road accidents is not significantly in error. The impression given by the biased estimates is that link realignment is marginally more effective in reducing wet-road than dry-road accidents: the true estimates indicate that in fact the reduction in dry-road accidents is greater by a factor of 2.

It might have been expected that the RTM effect for night accidents at sites subject to streetlighting schemes (Table III(vii)) would also have been greater than the average. In fact this was not the case, but, as there were only 18 such schemes included in the sample, this result requires confirmation.

It is notable that sites where junction improvement schemes were implemented (Tables III(iii) and (iv)) tended to exhibit smaller RTM effects than other sites and there is little variation in the magnitude of the effect with accident type. The errors in the biased estimates are consequently smaller at these sites.

Treatment effects

On average remedial treatment reduces total accidents by 20 to 25 per cent. Two treatment categories seem to be notably more effective in reducing accidents: the conversion of priority to mini-roundabouts (Table III(iii)) which reduce accident totals by 45 to 85 per cent and are equally effective in reducing all accident types; and link realignment (Table III(v)) which reduces total accidents by 15 to 55 per cent and is particularly effective in reducing accident severity. Only one treatment category is notably less effective than the rest: other link improvements (Table III(vi)) reduce total accidents by only 0 to 20 per cent, although they are effective in terms of reduced accident severity.

The safety benefits of a range of remedial measures are summarised in a number of publications, although the data on which these summaries are based appear to come, at least in part, from studies in which RTM effects are not adequately controlled for [1-4].

Comparison of the reductions in Table II with these data confirm that, for most accident types and treatment categories, the *true* effectiveness of treatment is actually rather less than is normally assumed. The Institution of Highways and Transportation (IHT), for example, reports that anti-skid surfacing can give accident savings of 30 to 60 per cent, with an 80 per cent reduction in wet-road accidents[4]. This is not out of line with the *biased* estimates given in Table III(ii) (a 40 to 50 per cent reduction in total accidents with a 65 to 70 per cent reduction in wet-road accidents), but is significantly larger than the unbiased estimates (a 15 to 30 per cent reduction in total accidents with a 20 to 35 per cent reduction in wet-road accidents). Similarly, for junction improvements (excluding mini-roundabouts) the IHT reports expected reductions in total accidents typically in the range 20 to 60 per cent. This range can be compared with the biased estimates in Table III(iv) in the range 35 to 45 per cent and unbiased estimates of 20 to 35 per cent.

In some cases the RTM effect was not significant, so that the unbiased estimates obtained in this study were similar to (or even larger than) estimates obtained in other studies. The IHT, for example, reports that small and mini-roundabouts have the potential to reduce accident totals by 30 to 40 per cent and KSI accidents by 40 to 60 per cent: our unbiased estimates imply a reduction in accident totals of 45 to 85 per cent (best estimate 65 per cent) and in KSI accidents of 25 to 90 per cent (best estimate 60 per cent).

Conclusions

Using accident data for three time periods obtained at some 900 treated sites, the reductions in total and target accidents attributable to various types of remedial treatment have been estimated. Tables summarising the true potential safety benefits of remedial treatment (in terms of total accidents and accidents disaggregated by severity, road surface condition and lighting) are presented. The occurrence of the RTM effect at *treated* sites has been demonstrated and quantified. It has been shown that grossly exaggerated estimates of the safety benefits of remedial treatment will be obtained if RTM effects are not properly controlled for: averaged over all treatment types, about half of the observed reduction in total accidents is attributable to remedial treatment (20 to 25 per cent) and half due to the RTM effect (15 to 25 per cent). The magnitude of the RTM effect was found to vary somewhat with site type, with a tendency for lower values at treated junctions than at other site types. The magnitude of the RTM effect was also shown to vary with accident type: the effects tend to be larger for those groups of accidents targeted by treatment (KSI, wet-road and night accidents). For some treatment types (notably surface treatment and link realignment), comparisons of before-and-after data give a very distorted picture of the effects of treatment on different types of accidents.

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Kennedy & Donkin have been acquired by New York-based **Parsons Brinckerhoff.** Kennedy & Donkin of Godalming, U.K., have an annual turnover of £60M and current projects which include design of the automatic train control protection for the Kowloon-Canton Railway Corporation in Hong Kong. PB's current projects include Boston's Central Artery/Tunnel Project, the Cairo Metro and the Hong Kong Mass Transit Railway.

Mouchel Consulting have appointed **Keith** Jackson as a director to head the firm's Highways Consultancy Group, which incorporates Infrastructure, Network Management and Telematics. Malcolm Taylor, another newly-appointed director, returns from the Hong Kong office to manage the firm's Rail and International Consultancy Group.

Chris Connor is now divisional director in charge of Network Management within the Highways Consultancy Group.