EFFECTS OF TRAFFIC NOISE: SOUTH-EAST FREEWAY, BRISBANE*

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ABSTRACT

A survey was conducted of 288 residents living within 100 m of the South-East Freeway, Brisbane, to determine the magnitude and distribution of the effects of the freeway traffic noise. Respondents were asked to self-report their annoyance and were questioned regarding other effects of noise such as shutting of windows and disturbance to sleep. The location of respondents reporting each effect is shown. The distribution of annoyance scores is discussed in terms of the freeway geometry, and an attempt is made to relate annoyance to distance from the freeway. The validity of the annoyance scale used was established by its correlation with the reporting of other effects of traffic noise.

INTRODUCTION

1. A survey was conducted of residents living adjacent to the South-East Freeway in Brisbane to ascertain if, and by how much, they were affected by noise from vehicular traffic using the freeway. This paper describes the magnitude and spatial distribution of noise annoyance and other noise-related effects reported by the residents living near the freeway. Information on the incidence of noise annoyance around the freeway can be used to identify where the traffic noise might be considered to be a problem. It is the starting point in the consideration of the warrant for (a policy decision, not a technical one), and the utility of, noise reduction techniques on the existing roadway, and any proposed roadways of similar design.

MEASURING THE EFFECTS OF ROAD TRAFFIC NOISE

2. Langdon (in Alexandre *et al.* 1975) has recently summarised the problems of measuring the effects of road traffic noise and concludes that, for the present, data collection methods must rely on social surveys, and are thus restricted to measuring attitudes and reported experience. In measuring the effects of transportation noise, surveys to date (e.g. Griffiths and Langdon 1968; Fog and Johsson 1968; Aubree 1973) have basically used some form of scale on which respondents indicated their annoyance, and a series of questions as to how noise interfered with aspects of everyday life. Similar techniques were adopted for the present study.

3. Theoretical models of human response to noise have been proposed (Borsky 1970; OECD 1971) and a modified model, incorporating the physical characteristics which affect the noise exposure of an individual, is shown in *Fig. 1*. The model is presented for clarity, and should not be regarded as comprehensive. For example, other behavioural effects, such as changes in concentration or task performance and physiological reactions, such as startle response, could be added. It could also be argued that some of the effects such as interference with television and conversation might be independent of the human variables.

4. The freeway social survey attempted to obtain data on all the factors shown in *Fig. 1*, but this paper examines only the results of the survey pertaining to the shaded part of the model; that is, reported annoyance, and other reported effects of noise.

SOUTH-EAST FREEWAY STUDY AREA

5. The South-East Freeway, surface roadways, and the study areas are shown in *Fig. 2*. The physical profile of the freeway and study area is given in Appendix A, but the most important features affecting traffic noise and noise annoyance are summarised here.

(a) As the freeway is only part of a staged construction plan, it presently operates below capacity outside of peak hours. This is likely to change as more facilities are added to the system.
(b) The percentage of heavy vehicles using the freeway (> 1500 kg) at the time of the study was less than 5 per cent of total vehicle volume. This also is likely to change as more facilities are added.
(c) Because of duplication of terminal freeway ramps, 37 per cent of the total length of freeway in the study area had houses fronting ramps rather than the main carriageway. Some ramps carried relatively low traffic volumes.
(d) The freeway traversed the study area on embankment or in cutting with few at-grade sections.
(e) The surface streets, Juliette and Cornwall, carried heavy traffic volumes to and from the freeway.

It is important to have an understanding of the geometry of the freeway and its relationship to the natural surface as well as traffic patterns in the study area before examining the results of the social survey.

6. A study of noise levels in the area near the freeway (Brown 1975) indicated that the changes in noise level introduced by the freeway were generally restricted to within 100 m of the outside traffic lanes. On this evidence it was planned to survey 100 per cent of the households within 100 m either side of the freeway, but excluding those households likely to be subject to more noise from other sources than from the freeway. 'Household' was defined as any living unit with a unique postal address.

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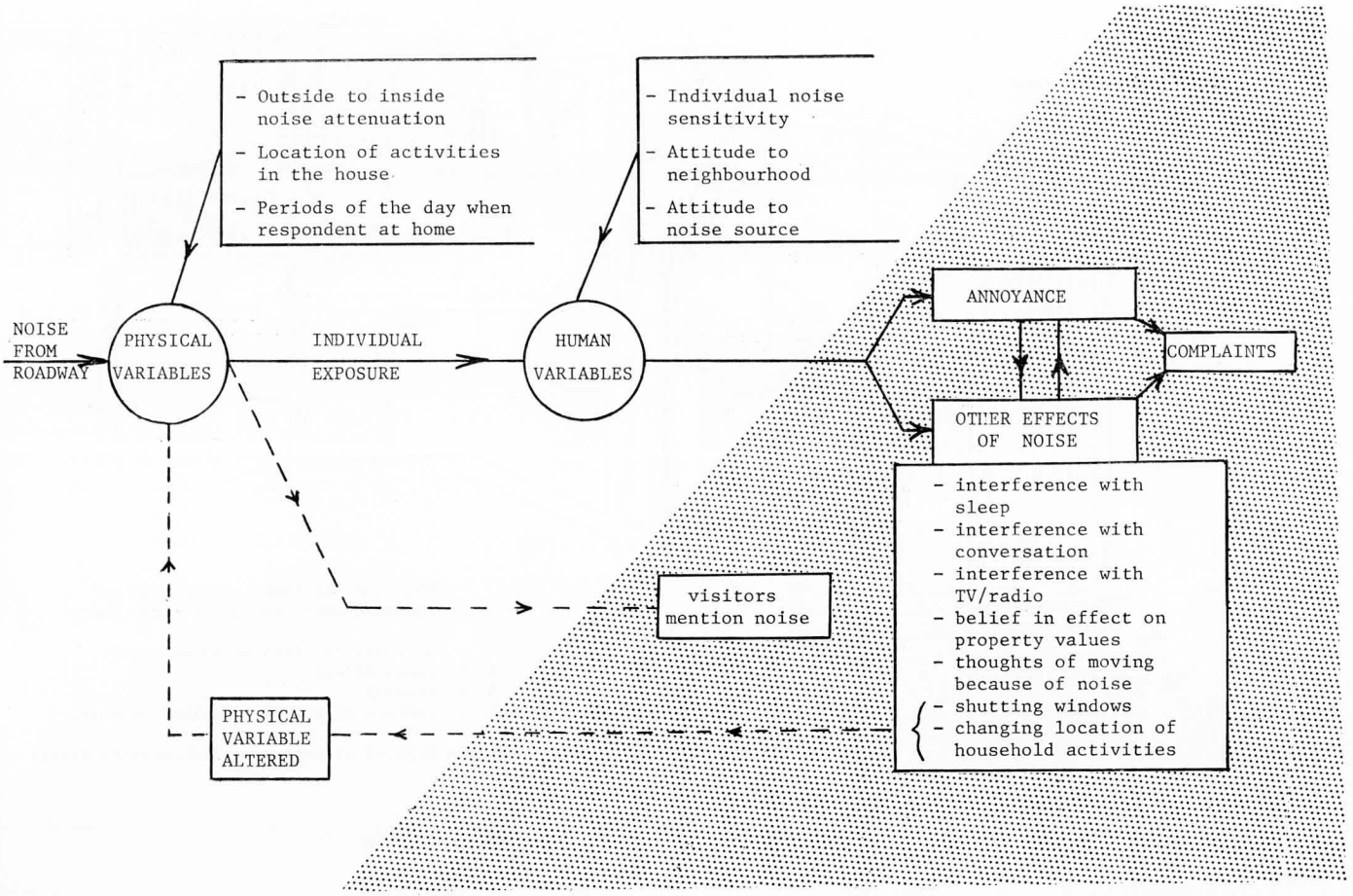

Fig. 1 — A conceptual model of the relationship between road traffic noise exposure and its effects, including the physical and human variables which intervene in the relationship. The present paper examines only the shaded area of the model

Fig. 2 — The South-East Freeway, Brisbane, showing the study areas A, B, and C

7. On these criteria, 357 households were included in the study area. Houses fronting Cornwall Street and Juliette Street were not excluded, because even though these streets were locally the dominant source of noise, a large proportion of traffic on them was directly generated by the freeway. The study area is conveniently divided into three sub-areas, A, B and C, and where necessary in the text these will be subscripted with e and w indicating the eastern and western sides of the freeway.

SOCIAL SURVEY

CONDUCT OF THE SURVEY

8. The household interviews were completed in August-September 1974. The freeway had been in operation for 18 months prior to the survey, though the opening of an additional ramp at the city terminus of the freeway increased traffic volumes in July 1974. Of 357 interviews attempted, 288* were satisfactorily completed. At least three calls-back, and up to five at some households, were made in attempts to complete missing interviews. Interviews not completed were due to:

no one contactable at home	15	(4.2 per cent)
could not speak English	9	(2.5 per cent)
refused to be interviewed	46	(12.8 per cent)

Excluding those non-contactable, the refusal rate of 16 per cent was slightly higher than expected considering the care taken to circularise respondents beforehand, notifying them of the proposed survey. The sex of the respondent at each household had been randomly determined before the survey, with an equal number of each sex specified. Respondents were to be over secondary school age (17 years). The interviewer was requested to make at least

*Replies of 'don't know' to some of the questions, and occasional missing data has led to minor discrepancies in total sample size shown in some of the figures and tables.

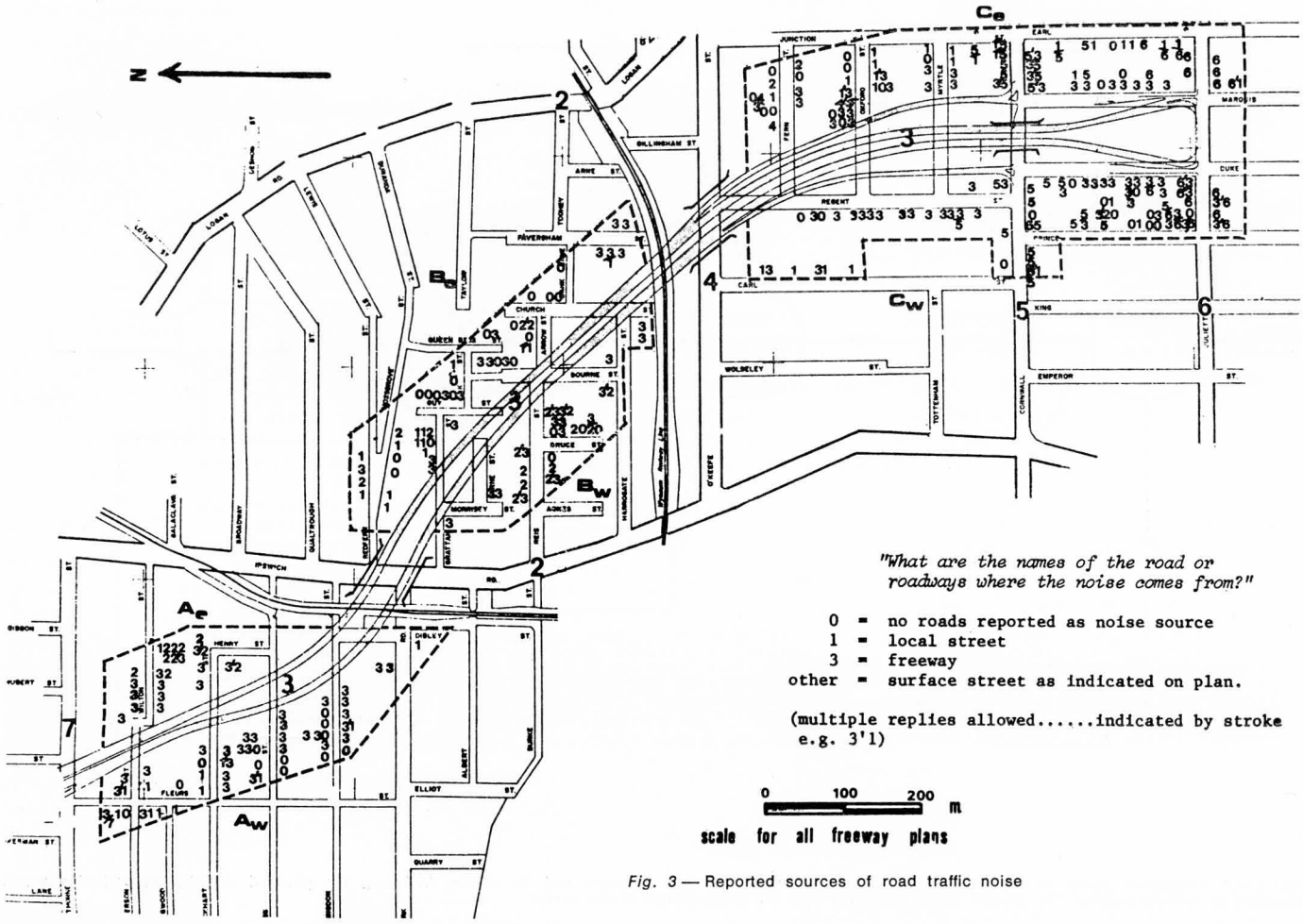

Fig. 3 — Reported sources of road traffic noise

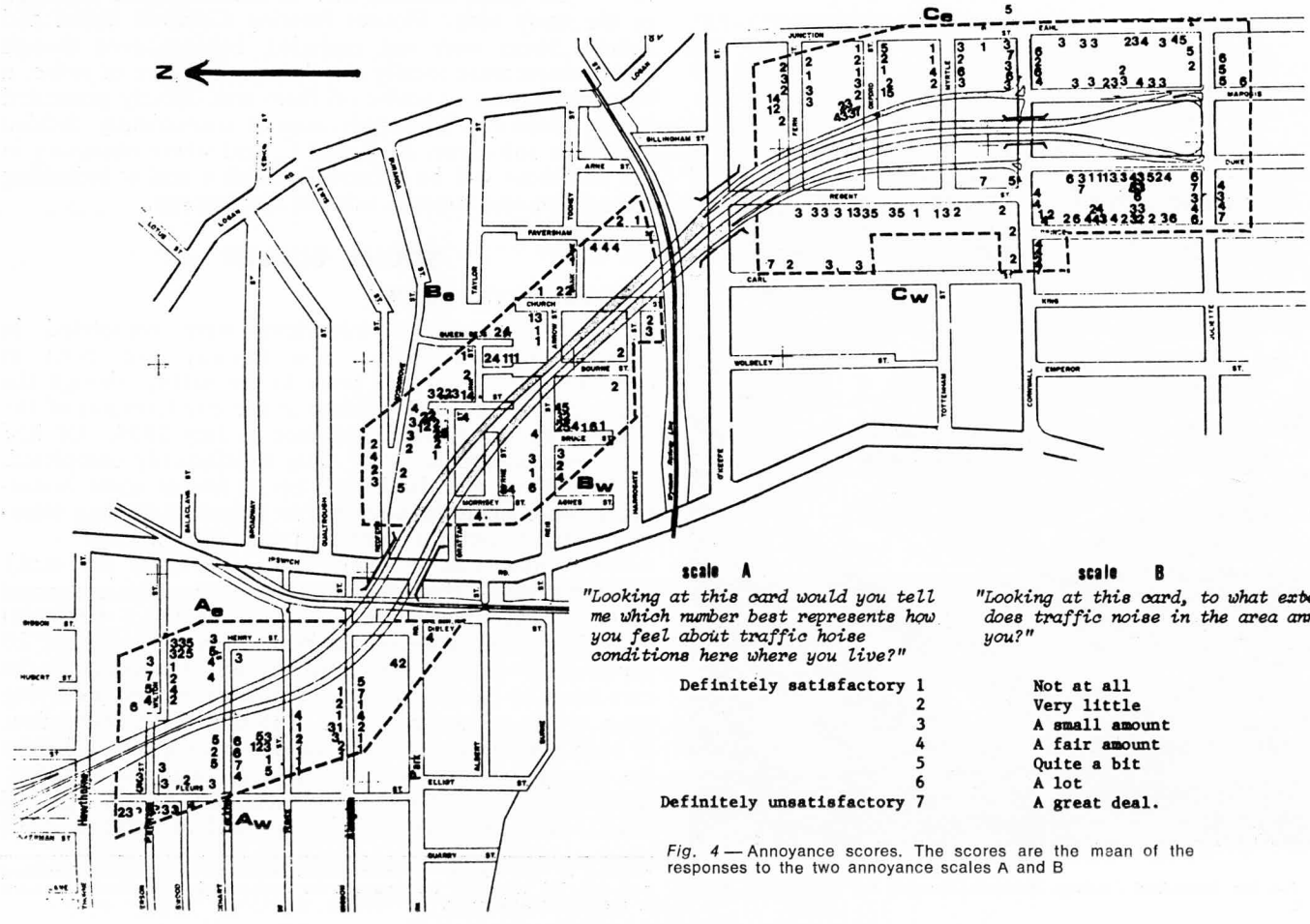

Fig. 4 — Annoyance scores. The scores are the mean of the responses to the two annoyance scales A and B

TABLE I

Question	Proportion Endorsing Item
Do you ever notice road traffic noise around here?	0.82
Do you ever complain to yourself about noise here?	0.14
Do you ever complain to a member of your household about noise here?	0.24
Do you ever complain to a friend or neighbour?	0.24
Have you ever made an official complaint?	0.04
Have you ever made more than one official complaint?	0.01

three calls-back to obtain the person of the required sex. If there was no possibility of obtaining the specified person (e.g. only one person in the house), or after three calls-back, the interview was to be completed with any adult who was available. Using this procedure, 55 per cent of successful interviews were with female respondents, and 45 per cent with male respondents. (From the 1971 Census, proportions for adult Brisbane population were 52 per cent female, 48 per cent male.)

THE QUESTIONNAIRE

9. The questionnaire was adapted from one developed by the Building Research Establishment for its second survey on road traffic noise (W. E. Scholes, pers. com.), though several significant changes were made. The content of the questionnaire will be discussed elsewhere and only the questions on annoyance and other effects of noise are discussed below.

ANNOYANCE SCALES

10. Three different measures of annoyance were used in the present study. Two measures were simple rating scales, and the third measure made use of six questions adapted from Bottom and Croome (1969). These six questions, which are shown in *Table I,* reflected varying degrees of noise annoyance and it was hoped to form them into a Guttman scale (Guttman 1944) in order to obtain a numerical index of annoyance. Although a scalogram analysis of responses to these six items produced an acceptably high reproducibility coefficient (0.969) it was found that the proportions of respondents endorsing the items were not adequately distributed over the acceptable range of 0.2 to 0.8. Using items outside this range causes the reproducibility coefficient to be artificially inflated (Green 1954) and reduces confidence in the validity of the scale. Because of the small number of items in the scale and because half of them were outside the acceptable range, it was decided not to use this third measure of annoyance.

11. Of the other two annoyance scales (see *Table II*), the first (Scale A) was a numerical rating scale with only the end categories verbally labelled: 'Looking at this card would you tell me which number best represents how you feel about traffic noise conditions where you live?' This measure had been used extensively in other noise surveys (e.g. Griffiths and Langdon 1968). The second (Scale B) was a semantically labelled rating scale: 'Looking at this card, to what extent does traffic noise in the area annoy you?' — which has been found useful in other social surveys conducted by the Psychology Department, University of Queensland. It should be noted that no psychometric investigation of the interval properties of this latter scale has been carried out, although the ordering of the categories has been validated. It was believed that verbal labelling of all categories of response, as in Scale B, could help in anchoring the meaning of the categories for the subjects. It should also be noted that while the responses to scale B explicitly specified amount of annoyance, those for Scale A related to how satisfactory the noise conditions were considered to be, and did not explicitly specify annoyance.

12. Respondents were more inclined to give higher ratings on Scale A than on Scale B and this may reflect the fact that noise levels could be considered unsatisfactory without being accompanied by high levels of annoyance. Careful inspection of *Table II* shows that the modal response category for Scale B is mostly one category below the modal category for Scale A. In spite of this general trend there is a tendency for high scores on Scale A to be scattered evenly over the range for Scale B. In short, there is a rough correspondence between the two scales with the most serious mismatches at the upper extreme of Scale A.

13. Since both of these rating scales are index measures rather than representational measures (Dawes 1972), the ultimate choice of a scale must be based on how well these indices relate to external variables such as behavioural indices of noise disturbance. At this stage the safest course seems to be to use both measures to arrive at an average annoyance score. This last index may prove more reliable than either one of the others taken on its own. It is realised that by averaging these scales, interval assumptions regarding their metric are being made. In this instance, it is considered an acceptable compromise

TABLE II

CROSS-TABULATION OF RESPONSES ON THE TWO ANNOYANCE SCALES

Scale A 'Looking at this card, would you tell me which number best represents how you feel about traffic noise conditions where you live?

Scale B 'Looking at this card, to what extent does traffic noise in the area annoy you?'

N = 288		Scale B							
Scale A		Not at all	Very little	A small amount	A fair amount	Quite a bit	A lot	A great deal	
Definitely satisfactory	1	47	12	3	0	0	0	0	62
	2	19	25	4	0	0	0	0	48
	3	8	35	13	2	1	0	1	60
	4	5	15	19	7	3	0	0	49
	5	2	3	10	12	3	2	1	33
	6	0	4	2	2	5	2	0	15
Definitely unsatisfactory	7	0	3	0	4	3	5	6	21
		81	97	51	27	15	9	8	288

because the scales are regarded as index measures and the ultimate validity of even the derived average score will depend on its relationship with external indices of noise disturbance (see para. 47). Throughout this paper, the term 'annoyance score' will apply to the average of responses on Scale A and Scale B, rounded upwards. The 1 to 7 score indicates degrees of increasing annoyance.

14. In using such self-report measures of annoyance it is important to take note of the criticisms of Arnold (1974). As she points out, the term 'annoyance' can cover a multitude of different experiences and this variable may therefore be difficult to measure reliably by a single rating scale.

'TANGIBLE' EFFECTS OF FREEWAY NOISE

15. As well as reporting their annoyance with the freeway noise, respondents were questioned about the way noise intruded into their everyday life (e.g. interference with sleeping, reading, etc. — factors which have elsewhere been termed the behavioural effects of road traffic noise (OECD 1971)). Other questions gauged respondents' opinions on the relative noisiness of their area, whether visitors mentioned traffic noise etc. It is believed that respondents were reporting on tangible experience* to this type of questioning, and perhaps more confidence can be placed in the accuracy of their replies than in their self-reporting of their attitude, that is, annoyance. Nevertheless, there are difficulties in constructing a meaningful scale of the effects of road traffic noise using these tangible indicators. The relative importance of each indicator cannot be gauged, and even within say, the effect on sleep, traffic noise may produce a wide range of magnitudes of the behavioural disturbance. However, though a meaningful scale cannot be constructed, it is useful to examine not only the spatial distribution of these effects around the freeway, but also the correlation between these tangible effects and respondents' self-assessed annoyance. If the correlation is high, then confidence that the tangible effects of traffic noise have been reported accurately can encourage confidence that reported noise annoyance constitutes a meaningful quantity. Further, the effects can help to 'calibrate' the annoyance scale by providing some insight into the significance of a particular annoyance score.

16. The survey asked the following questions on tangible effects.

(a) Effects on behaviour

How often do you have to shut your windows because of traffic noise?
How often does the noise still disturb you while windows are shut?
How often does the traffic noise disturb your sleep?
How often do you have trouble hearing the radio or television because of traffic noise?
How often does the traffic noise interfere with conversation inside the house?

(b) Other effects of traffic noise

Have you ever thought or done anything about moving away on account of traffic noise?
Do the people who come to visit you mention the traffic noise?
Do you ever complain to a member of your family about the traffic noise here?

(c) Other relevant opinions

On the whole, would you say this is a quiet or noisy area relative to other areas?
Do you think the freeway has improved or detracted from the value of this property?

Answers to questions on behaviour comprised a four-point scale: never, sometimes, a lot, or, nearly all the time.

SURVEY RESULTS

17. In the presentation of the survey results, outlines of the houses have not been shown on the freeway drawings, and annoyance scores and other effects have been deliberately not located accurately in order to maintain the confidentiality of respondents' replies. While this procedure adequately represents the distribution of annoyance around the freeway, some information has necessarily been lost, such as accurate distances of respondents' houses from the freeway and the shielding effects houses have on one another. In particular, in multiple household buildings close to the freeway, some residents were fully exposed to the traffic noise while others were very well protected. In all figures responses from multiple household buildings have been shown as clusters of scores, and representation of the above shielding effect has not been possible. For example, the cluster of scores at the freeway end of one of the culs-de-sac in area C_e (see *Fig. 4*) represents replies from six respondents in the same building.

18. To ensure that self-reports of traffic noise annoyance were, in fact, reports of freeway noise annoyance, respondents were asked to indicate the names of the roadways from which they heard noise. Multiple answers were allowed. Their answers are shown in *Fig. 3*. A 'local street' is defined as the street, not being one of the major roadways, on to which the respondent's house fronted. An '0' indicates that the respondent never heard road traffic noise (ascertained from an earlier question). *Fig. 3* confirms, rather clearly, that the chosen study area was wide enough. In very few locations along the boundaries of the study area (100 metres from the freeway) was the freeway cited as a roadway from which noise could be heard, and in nearly all of these the freeway was mentioned in combination with another roadway. On the eastern boundary of study area A, Ipswich Road was cited as the main source. Less clearly on the western boundary, the local street was the major source of noise, with also a high frequency of no-naming of roadways. Most parts of study area B were effectively shielded by the freeway cutting, and particularly in B_e there was again a high frequency of no-naming of roadways. In B_w the noise from Ipswich Road was dominant along the 100-metre boundary. In study area C the freeway was rarely named as a source along either of the 100-metre boundaries, but particular note should be taken of the consistent reporting of not only the freeway, but also Cornwall and Juliette Streets (labelled 5 and 6) at the freeway terminus.

19. Respondents' self-assessed annoyance scores are shown in *Fig. 4*. As illustrated in *Fig. 1*, a respondent's annoyance is dependent not only on the noise level to which he is exposed, but also on intervening physical and human variables. It is postulated that the distribution of annoyance around the freeway reflects not only the traffic noise level pattern, but also the randomly distributed variables intervening in the external noise level/annoyance relationship. It is the random distribution of the intervening variables which presumably accounts for anomalous high annoyance scores amongst a group of low scores, and vice versa. But despite the anomalies, it is possible to visually average the scores over small areas and make observations about the relative magnitude of reported annoyance throughout the study area.

20. It is useful to combine *Fig. 3*, source roadways, with *Fig. 4*, annoyance scores, to examine the distribution of noise annoyance generated by the freeway alone.

*The term "tangible" is not completely appropriate, however, it will be used in this paper as the general term for the behavioural effects of noise, and all effects other than annoyance.

Respondents can be conveniently grouped into three categories:

(a) those identifying the freeway as the only source, or one of several sources;
(b) those not identifying any roadway as source; and
(c) those identifying a roadway as source, but not including the freeway.

In *Fig. 5,* respondents in category (c) have been shown shaded. In *Fig. 6,* respondents in both category (b) and category (c) have been shaded, leaving only those respondents who specifically mentioned the freeway as source. In *Figs 5* and *6,* noise from Cornwall Street and Juliette Street has been considered as noise from the freeway. Nearly all respondents in the first row of residences near the freeway indicated the freeway as a source of road traffic noise. *Figs 5* and *6* clearly show that, with increasing distance from the freeway, there is an increase in the reporting of no roadway as source, and an increase in the reporting of other roadways as source.

21. Area-average annoyance scores are shown in *Table III.* Not too much emphasis should be placed on these area-averages as they reflect the disposition of residences near and far from the freeway, and not only the annoyance generating capabilities of the freeway. The averages shown are based on *Fig. 5;* that is, averaging the scores only of respondents who identified the freeway as source, or who did not identify any roadway as source. It is quite clear that average annoyance scores were higher for households fronting Cornwall and Juliette Streets than for any of the study sub-areas, and also higher than the average annoyance scores of the first row of households fronting the freeway. Area A_e, where the freeway was at grade and where most households had line of sight to both carriageways, also gave a high average score. Area B_e was almost completely shielded with the freeway in cutting and subsequently had a low average annoyance score. The depth of the cutting was much less on the western side of the freeway (B_w) than the eastern side (B_e), with the result that annoyance scores there were generally higher.

22. Visually aggregating annoyance scores over small groups of houses aids interpretation of annoyance distributions within the sub-areas. Scores were relatively uniformly distributed throughout area A_e, with the highest scores reported from those households at the northern end which were level with the freeway. At the next street south, the freeway was on embankment, and households had line of sight to vehicles on the outbound carriageway only. Through area A_w, the situation was more complex. At the northern boundary the freeway was in cutting. It passed through an at-grade section at about the second street from the northern boundary, continued on a high embankment, then returned to the natural surface level before the southern boundary. High annoyance scores were reported by respondents near the at-grade sections (located at two streets, and beyond four streets, south from the northern boundary). Where the freeway was on embankment, reported annoyance was noticeably lower. The combination of noise screening by the shoulder of the embankment and restriction of line of sight from the houses to only the outside lane of one carriageway may explain this. The high annoyance in A_w was generally restricted to the first two or three houses adjacent to the freeway. Both distance and the shielding effect of other houses have generally resulted in low annoyance scores throughout the remainder of area A_w, even though traffic moving on the freeway was still visible from most residences. The frequency of reporting of high annoyance scores (5, 6 or 7) is higher throughout areas A_e and A_w than other parts of the study area, except for Juliette and Cornwall Streets and beside the on-ramps.

23. The freeway was in cutting throughout most of study area B, though the freeway emerged from cut at the northern and southern boundaries. Particularly at the southern end of area B the residences had line of sight to the freeway. The low annoyance scores throughout this area, particularly B_e, were attributed to the very effective shielding provided by the freeway cutting. At the southern end of the area, freeway noise had 'leaked' around the end of the cutting, for although the outbound freeway lanes were not at grade until after crossing the railway line, moderate but consistent annoyance was reported from this area. Although not generally obvious from the annoyance scores obtained, the first row of houses near the tops of the cutting were afforded little or no effective shielding by the cutting, with most of the houses having line of sight to both carriageways. There was a slightly higher reporting of moderate annoyance (mainly fours) in these first-row houses in area B, but there was a surprisingly high incidence of no annoyance (ones) reported in first-row houses in B_e. The self-reporting of low annoyance in several of these houses, despite high noise levels, was commented on by several of the interview staff. The authors can offer no explanation other than the aforementioned variability in respondents' exposure/annoyance relationship.

TABLE III

AREA-AVERAGE ANNOYANCE SCORES

Area	*Average Annoyance Score*	*Characteristics*[1]
A_e	4.0	Mostly at grade
A_w	2.9	Embankment/at grade
B_e	2.4	Cutting/at grade
B_w	3.3	Cutting/at grade
C_e[2]	3.0	Off-ramp
C_w[2]	3.3	On-ramp
First row households[2]	3.3	
Second row households[2, 3]	3.4	
Households fronting Cornwall St	5.0	Surface street
Households fronting Juliette St	4.9	Surface street

[1] see Appendix A for freeway longitudinal section
[2] excludes households fronting Cornwall and Juliette Streets
[3] excludes part of C_e and all C_w where surface streets are parallel to the freeway

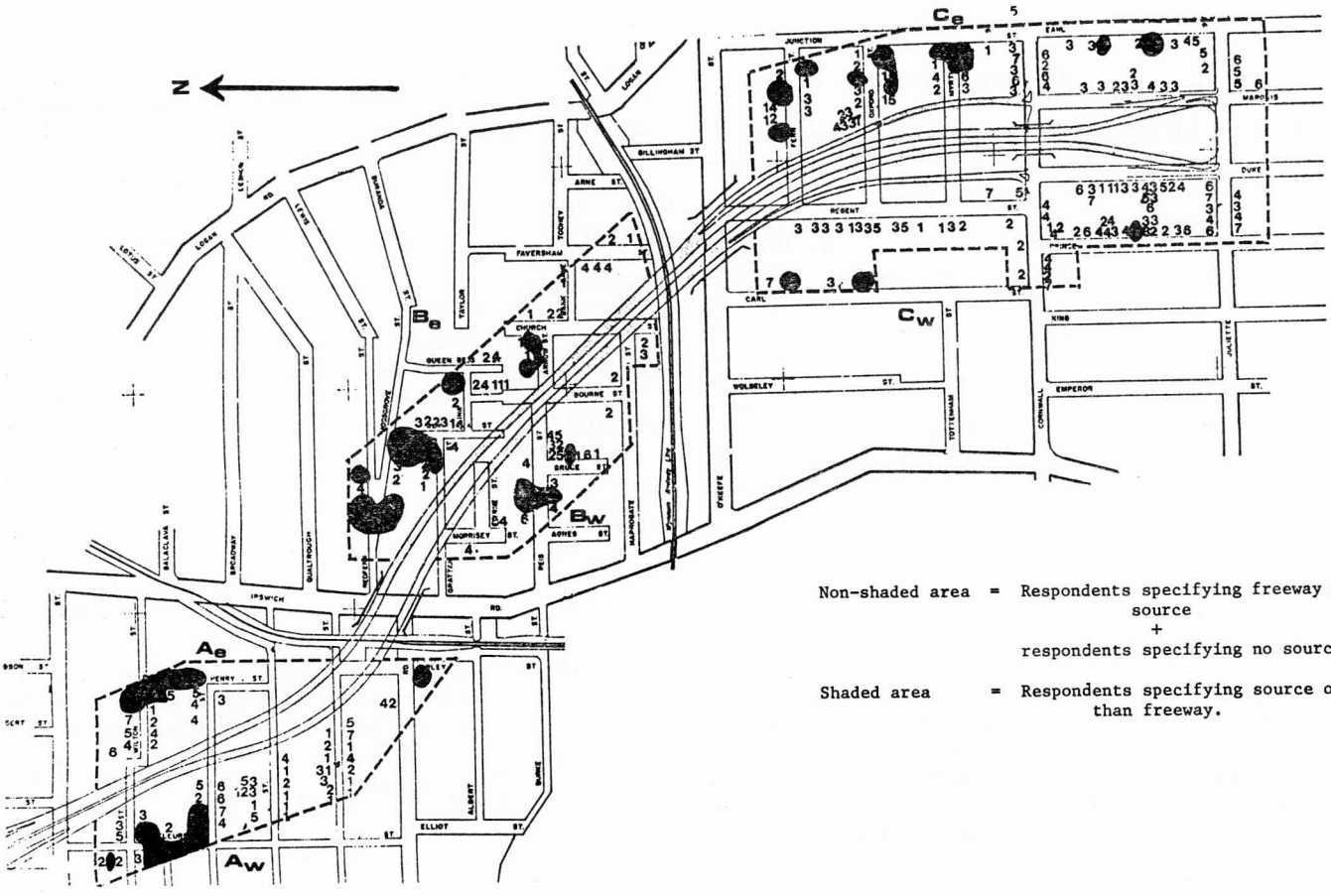

Fig. 5 — Annoyance scores — shading out respondents who specified roadways other than the freeway as source (combination of *Figs 3* and *4*)

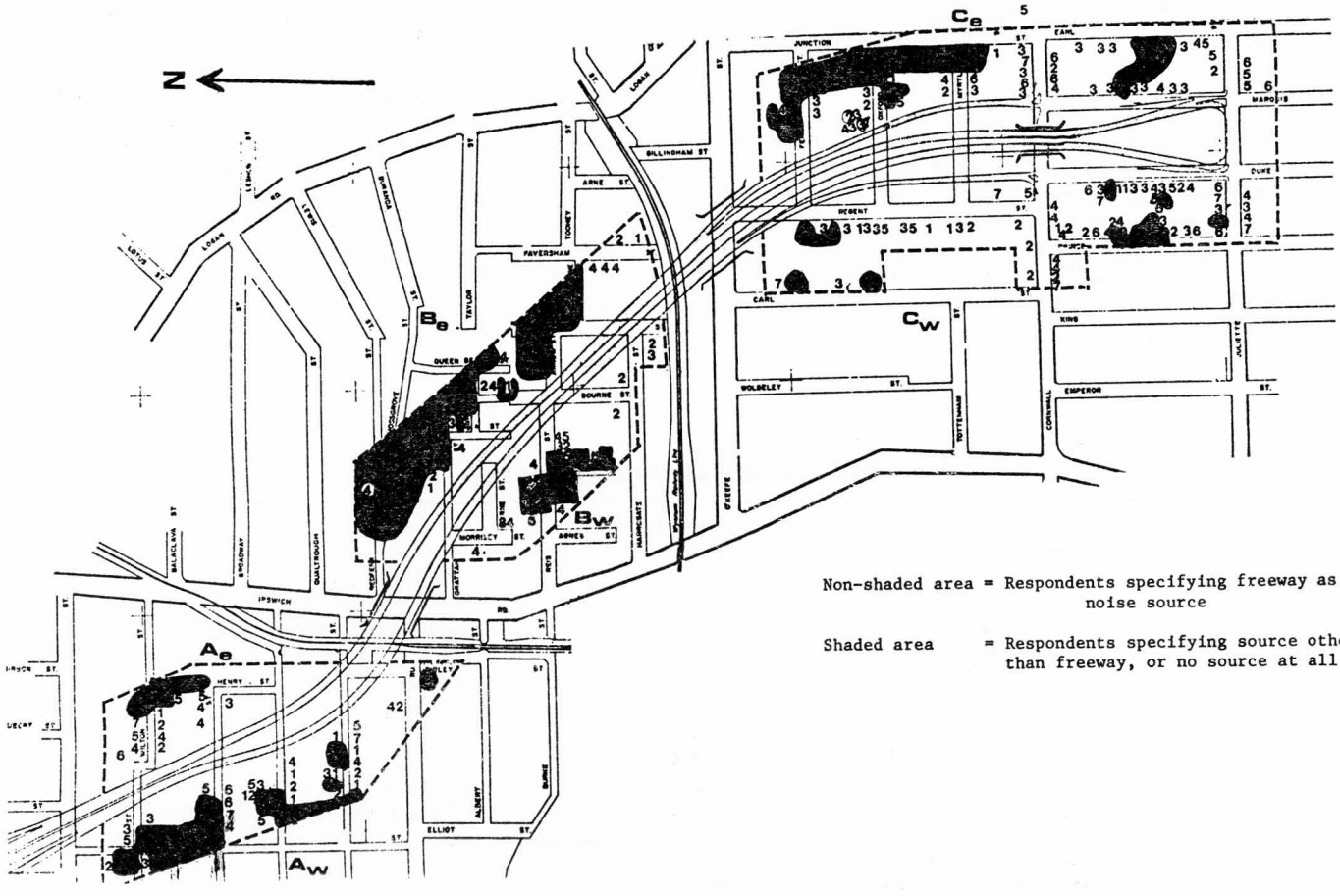

Fig. 6 — Annoyance scores — same as *Fig. 5*, but also shading out respondents who specified no roadway as source

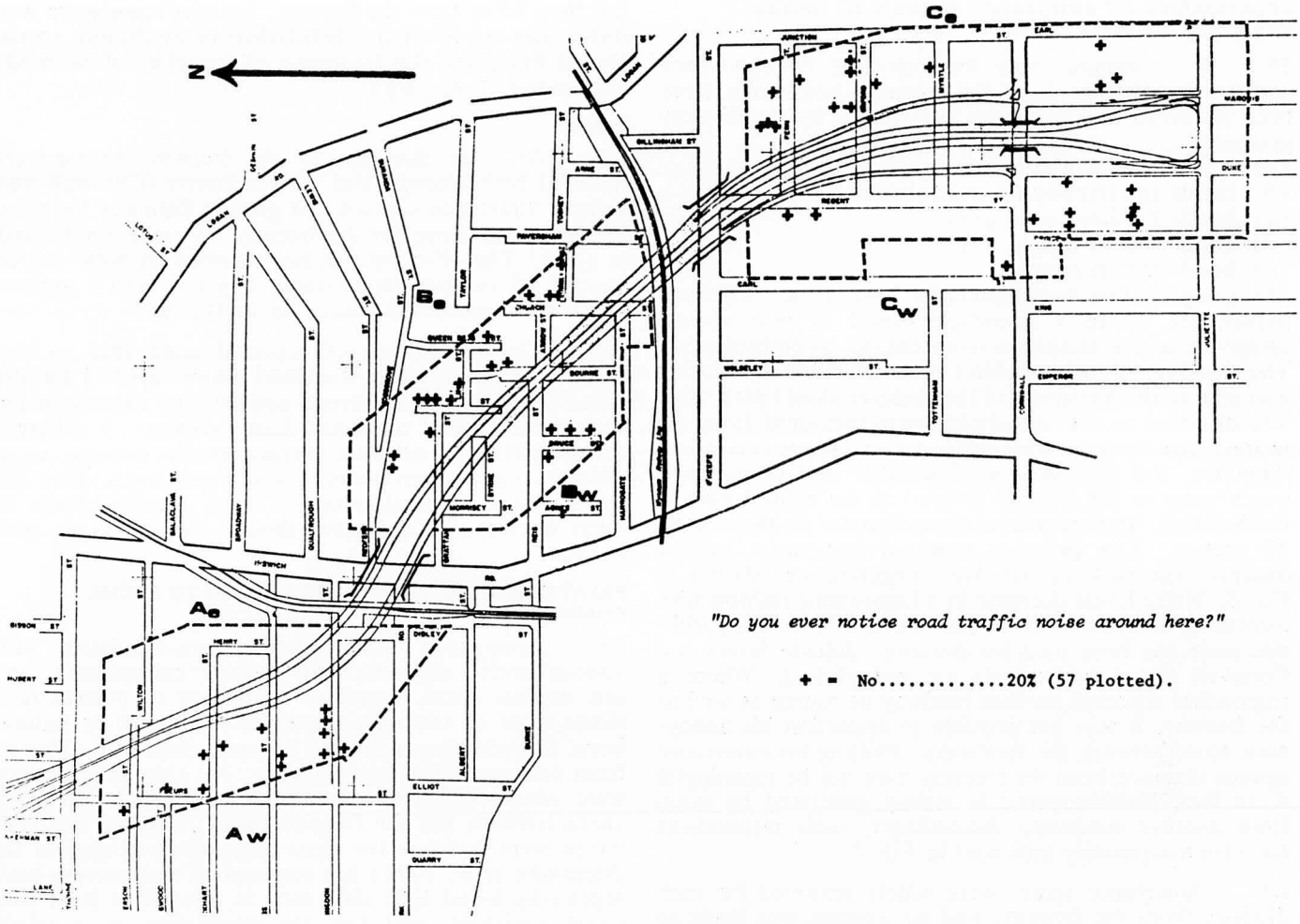

Fig. 7 — Respondents who never notice road traffic noise

24. Apart from the very high annoyance scores along Cornwall and Juliette Streets, the pattern of annoyance in area C was not particularly definitive. This was probably caused by the presence of the noise source roadways, Cornwall Street and Juliette Street, running perpendicular to the freeway (the effect is obvious in *Fig. 3*) and also by the streets forming the 100 metre boundary of area C_e. Minor through traffic on the latter generated some noise.

25. Most reporting of high annoyance would appear to have been restricted to respondents near the first half of the Juliette Street on-ramp where maximum vehicle acceleration occurred, and where the ramp was close to the houses. In houses near the top of the ramp, high scores were reported, but noise from Cornwall Street was mainly reported as dominant over that from the freeway ramp. Respondents in the houses between the Cornwall Street on-ramp and the surface street reported high annoyance, but those in the houses fronting the surface street generally reported only low annoyance. The distances between the latter houses and the on-ramp was large, and the on-ramp carried only low traffic volumes. The distances to the freeway proper were, of course, even larger.

26. Beside the off-ramps in area C_e, there were several reports of high annoyance, but in general, annoyance was consistently at a moderate level. Although confused by noise from Juliette and Cornwall Streets, the annoyance reported beside the Juliette Street on-ramp would appear to be somewhat greater than that reported beside the Juliette Street off-ramp. Certainly the range in annoyance scores reported was far greater beside the on-ramp. Except for residences adjacent to the Cornwall Street off-ramp, a significant fall-off in the levels of reported annoyance with increasing distance from the freeway did not occur in area C. Again, the influence of noise from the surface streets was considered responsible.

RESPONDENTS NEVER NOTICING ROAD TRAFFIC NOISE

27. When asked specifically whether they noticed road traffic noise where they lived, 20 per cent of the respondents in the study area indicated that they heard none. The distribution of these respondents is shown in *Fig. 7*. The distribution needs no explanation as it generally conforms to the previous discussion on the distribution of annoyance. The annoyance scores for those who answered that they did notice road traffic noise are tabulated in *Table IV*. The annoyance scores are reasonably consistent with the reporting of never noticing traffic noise.

TABLE IV

ANNOYANCE SCORES FOR RESPONDENTS WHO NEVER NOTICED ROAD TRAFFIC NOISE

'Do you ever notice road traffic noise around here?'

	Traffic Noise Annoyance Score						
	1	2	3	4	5	6	7
Number never noticing traffic noise (n = 58)	23	23	11	1	0	0	0

RELATIONSHIP OF ANNOYANCE SCORES TO DISTANCE FROM THE FREEWAY

28. In examining how the reporting of annoyance varied with distance from the freeway, households have been placed in five categories determined by the freeway geometry:
(a) beside the freeway in cutting;
(b) beside the freeway on embankment;
(c) beside the freeway at grade;
(d) beside the off-ramps; and
(e) beside the on-ramps.
The categorisation has necessarily been rather arbitrary, particularly where a household could fit into several categories at the transition from cutting to embankment. The 'leaking' of noise behind areas shielded by cutting also adds to the broadness of the categorisation (para. 23). The distances to the households were measured from the nearest edge of the nearest freeway carriageway (excluding shoulders, and independent of whether that carriageway was a ramp or the freeway proper) to the nearest part of the building. Distances have been rounded to the nearest 10 metres. The plots of reported annoyance against distance, for each of the five categories, are shown in *Fig. 8*. Noise levels decrease in a logarithmic fashion with increasing distance from a noise source, hence a logarithmic scale has been used for distance. Juliette Street and Cornwall Street respondents are not plotted. Where a respondent reported another roadway as source as well as the freeway, it was not possible to apportion his annoyance score between the roadways. Plotting his annoyance against distance from the freeway may not be meaningful if, in fact, his annoyance is mainly generated by noise from another roadway. Accordingly, such respondents have been separately indicated in *Fig. 8*.

29. Annoyance scores were widely scattered for each distance from the freeway, and no attempt was made to determine regression lines of annoyance on distance. Despite the scatter, the plots are not without value, and some observable trends are discussed below. It should be noted that, while the spread may be able to be reduced by incorporating data on the intervening physical and human variables of *Fig. 1,* the intervening variables will generally be outside the knowledge or control of a road designer, and any attempt to use an annoyance/distance relationship to determine the effects of noise on nearby residents will have to contend with the scatter as illustrated in *Fig. 8*.

Freeway on Embankment

30. Up to 35 m from the freeway, most respondents scored high on the annoyance scale (four or more). From 35 m to 65 m there was wide variation in annoyance scores, but with median score approximately three. Beyond 65 m respondents generally reported low annoyance (three or less) and most reported no roadway as source. Respondents with high annoyance scores at 70 m and 90 m both mentioned their local street as noise source as well as the freeway.

Freeway at Grade

31. The pattern is similar to the plot of freeway embankment, but the sample size on which to base generalisations is small. Beyond 55 m from the freeway no respondent scored higher than four on the annoyance scale, and the incidence of reporting of no source roadway was high. Respondents with annoyance scores at 70 m and 90 m included one of the major surface streets (Ipswich Road) as a source roadway.

Freeway in Cutting

32. Annoyance scores were noticeably lower where the freeway was in cutting. In particular, even at distances less than 25 m from the freeway, the maximum score was three. Beyond 35 m the distribution of annoyance scores altered little, and the frequency of reporting of no roadway as source was high.

Ramps

33. At close distances to the freeway, respondents reported both freeway and surface streets (Cornwall and Juliette Streets) as sources. At greater distances the plots are similar to those for the freeway on embankment and at grade. The off-ramp was not reported as noise source beyond 65 m, but the on-ramp together with a surface street, was reported as source up to 105 m.

34. The relationship of reported annoyance to distance from the freeway discussed above, applied for the urban fabric of surface streets and housing existing in the study area around the South-East Freeway. A different urban fabric, a different surface traffic pattern, or a different freeway geometry, could significantly alter the relationships. Generalisations of these specific results to other freeways or roadways should only be made with caution.

RELATIONSHIP OF ANNOYANCE SCORES TO SOCIAL CHARACTERISTICS

35. Annoyance scores were cross-tabulated with various social characteristics, namely respondent's age, sex, marital status, length of occupancy of present residence, type of tenure, occupation, immigrant or natural born, and educational level. The social data were obtained from answers to the questionnaire. No clear relationships were observed between reported annoyance and social characteristics, but the frequencies of many of the categories were too low for rigorous analysis. Langdon (in Alexandre *et al.* 1975) has commented that surveys have repeatedly found little difference in annoyance level with social variables, and that the population as a whole appears to be uniformly affected by noise.

DISTRIBUTION AND INTER-RELATIONSHIP OF TANGIBLE EFFECTS OF NOISE

Effects on Behaviour

36. *Figs 9* to *12* show the responses to the questions on the intrusion of noise into everyday life, as well as the spatial distribution of respondents indicating such intrusion. It should be noted that the figures show only those respondents who reported that the intrusion occurred 'a lot' or 'nearly all the time' (which, for convenience, will be termed severe). Respondents who reported that the intrusion occurred only 'sometimes' are not shown. Visual examination of the figures reveals similarity in the location of different disturbances; if not actually the same respondent, then the same general area. This is to be expected as the disturbances are inter-related. The figures are useful in highlighting those locations where traffic noise was reported as intruding into everyday life.

37. The reported frequency of behavioural effects induced by traffic noise is summarised in *Table V*. Except for conversation interference (where reporting of interference was lower), the frequency of reporting of shutting windows, sleep and television/radio interference was similar in the 'sometimes' and 'a lot' categories, but differed markedly in the 'nearly all the time' category.

38. Examination of the data indicates that few respondents reported a high frequency of all behavioural effects. Rather, those who were affected in some way reported ony one or two effects as severe. This is best seen in *Table VI*. From the table, only five respondents reported all four effects as severe ('disturbance with windows shut' has been excluded as it was asked of only portion of the sample). Three reported three effects as

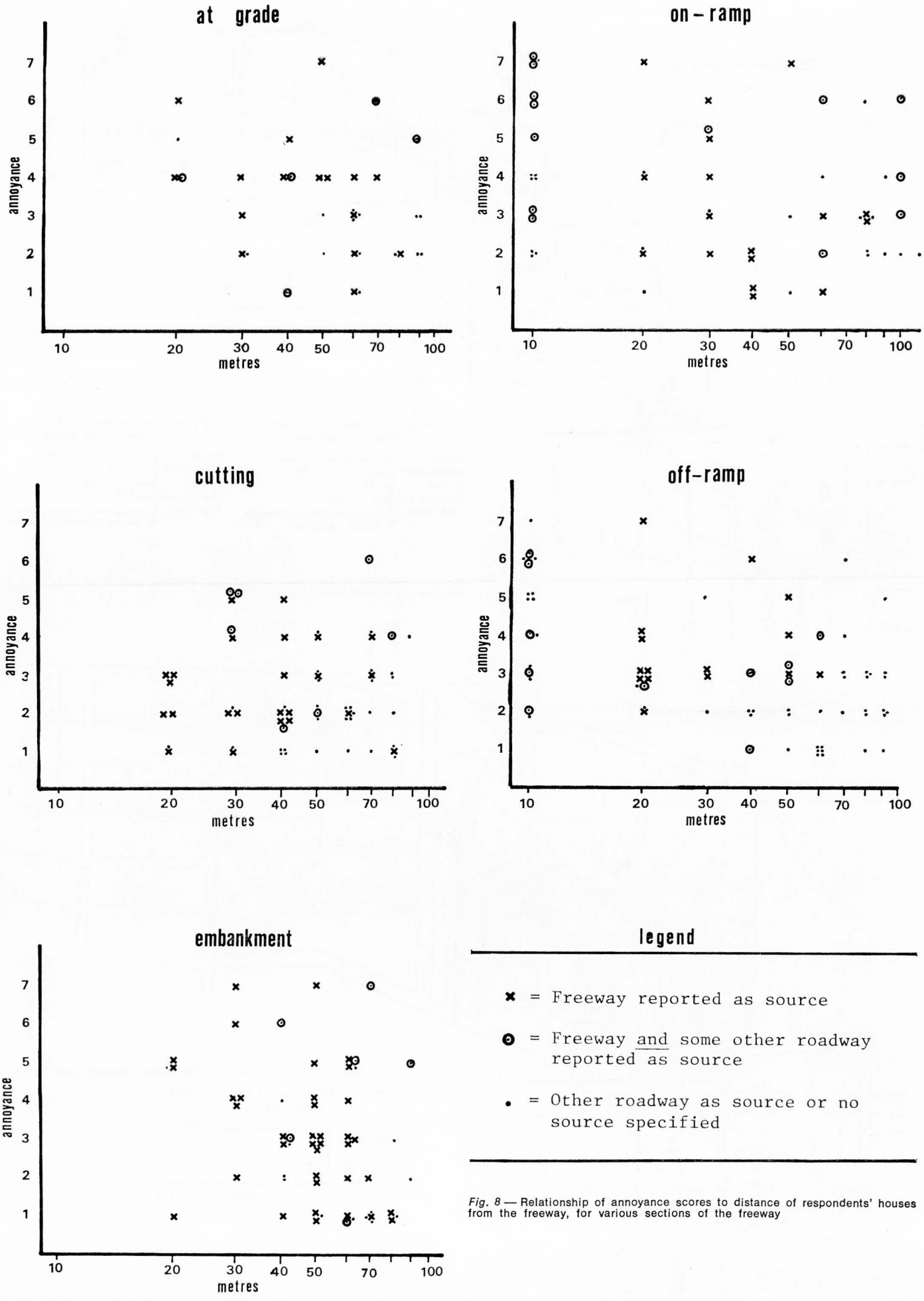

Fig. 8 — Relationship of annoyance scores to distance of respondents' houses from the freeway, for various sections of the freeway

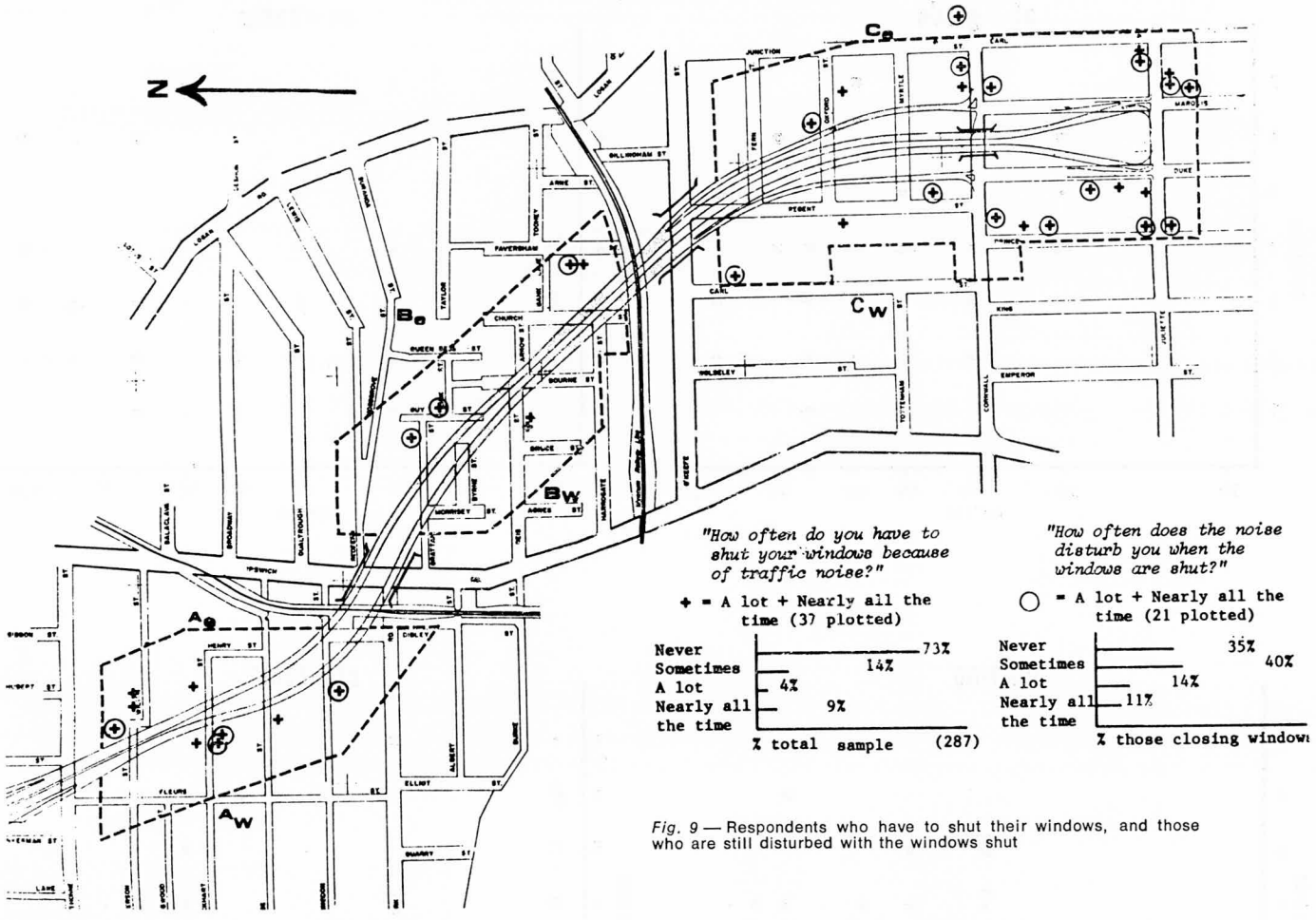

Fig. 9 — Respondents who have to shut their windows, and those who are still disturbed with the windows shut

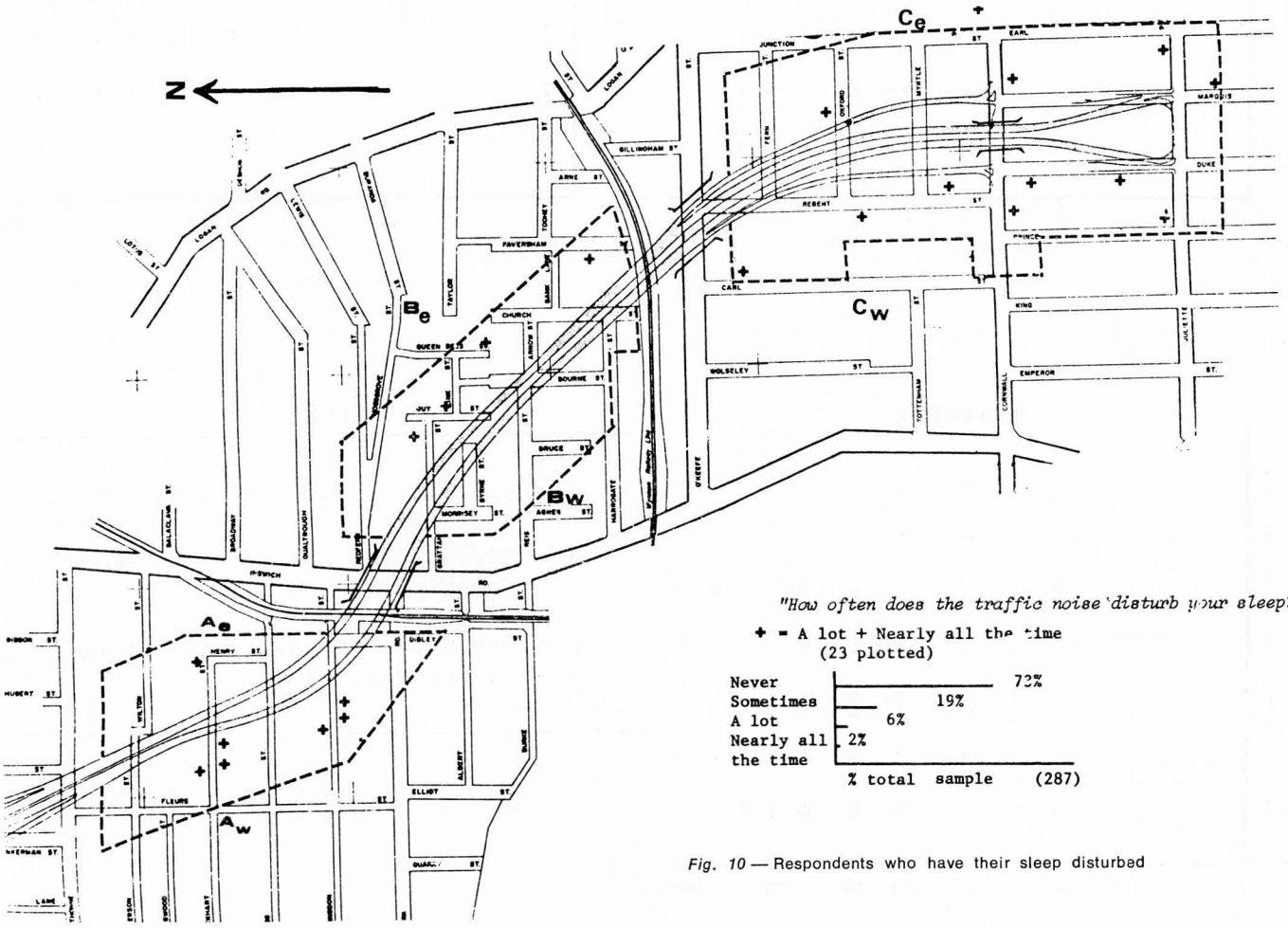

Fig. 10 — Respondents who have their sleep disturbed

severe, twenty reported two effects, and twenty-five reported only one effect as severe. 235 respondents (82 per cent of the sample) reported no effect as severe.

39. From this examination it is to be expected that cross-tabulation of the frequency of reporting of different behavioural effects should show that, while obvious trends do exist, the frequency of the reporting of different effects is not strongly correlated. The cross-tabulations are shown in *Table VII*. From the table it can be seen that most respondents who report some interference 'a lot' or 'nearly all the time' take action to reduce the interference by shutting their windows more often than 'sometimes'. There is a noticeably low correlation between the reporting of frequencies of sleep disturbance and radio/television interference, even though the numbers of respondents reporting each disturbance are similar.

Other Effects of Traffic Noise

40. Responses to questions in this category are shown in *Figs 13* to *15*. *Fig. 13,* those respondents who were considering moving or intended to move away because of noise, may be a very useful indicator of significant noise problem areas. It is probable that there was over-reporting to this question as intentions of moving residence may in many cases have been based on more factors than just noise annoyance. But at the same time one could postulate a compensating mechanism, in that some respondents may have had such strong roots in the area that they could not consider moving under any circumstances. Those respondents considering moving or intending to move also reported high annoyance scores as can be seen from *Table VIII*.

41. This correlation of high annoyance scores and 'threats' of moving has important ramifications. Taking the extreme example of all these 'threats' being carried out (32 in number, 11 per cent of the study area sample), the study area would lose 6 of the 11 respondents (55 per cent) with an annoyance score of seven, 11 of the 17 respondents (65 per cent) with an annoyance score of six, and 9 of the 26 respondents (35 per cent) with an annoyance score of five. If the outgoing group of residents was replaced by a group whose sensitivity to noise was lower (incoming residents have the opportunity to be aware of noise conditions before moving in), then the noise annoyance throughout the study area would, in effect, be reduced. In this context it is to be noted that the freeway had been opened for 18 months at the time of the survey, but 24 per cent of respondents in the study area had been living there for less than 12 months. There had been adequate opportunity for highly annoyed residents to move out. The present study provides no evidence that such a process has occurred or is occurring around the freeway, but it does indicate the mechanism by which it could take place (not to be confused with habituation).

42. 'Visitors mentioning traffic noise' *(Fig. 14)* is a phenomenon presumably lower in the scale of noise intrusiveness measures, and the more numerous reporting of its occurrence reflects this. The question is interesting

TABLE V

REPORTED FREQUENCY OF BEHAVIOURAL EFFECTS

N = 288	*Shutting Windows*	*Disturbances With Windows Shut*[1]	*Sleep Disturbance*	*TV or Radio Interference*	*Conversation Interference*
Never	209	29	209	198	241
Sometimes	41	33	55	61	37
A lot	12	13	16	15	7
Nearly all the time	25	10	7	11	1
Don't know	1	0	1	3	2
Total	288	85	288	288	288

[1] Asked only of those respondents who 'shut windows'

TABLE VI

NUMBERS OF RESPONDENTS REPORTING BEHAVIOURAL EFFECTS OCCURRING EITHER 'A LOT' OR 'NEARLY ALL THE TIME'

Four Effects: shutting windows
sleep disturbance
conversation interference
radio/TV interference

		Number Of Effects Which Respondents Reported As Occurring 'A Lot'					
		0 effect	*1 effect*	*2 effects*	*3 effects*	*4 effects*	
Number Of Effects Which Respondents Reported As Occurring 'All The Time'	*0 effect*	235	16	5	0	1	257
	1 effect	9	8	1	0	—	18
	2 effects	7	2	4	—	—	13
	3 effects	0	0	—	—	—	0
	4 effects	0	—	—	—	—	0
		251	26	10	0	1	288

Note: reporting of 'sometimes' ignored in the table

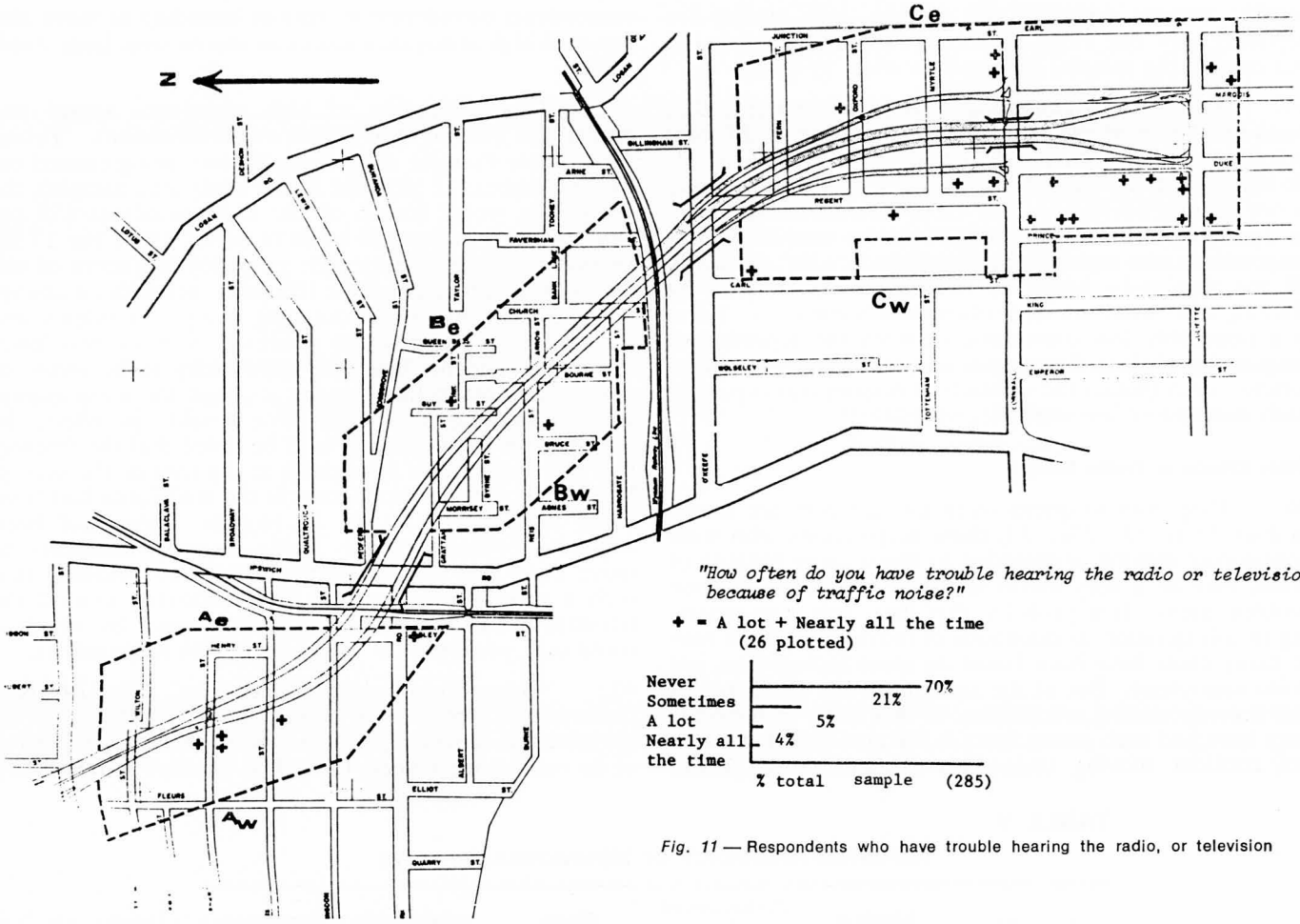

Fig. 11 — Respondents who have trouble hearing the radio, or television

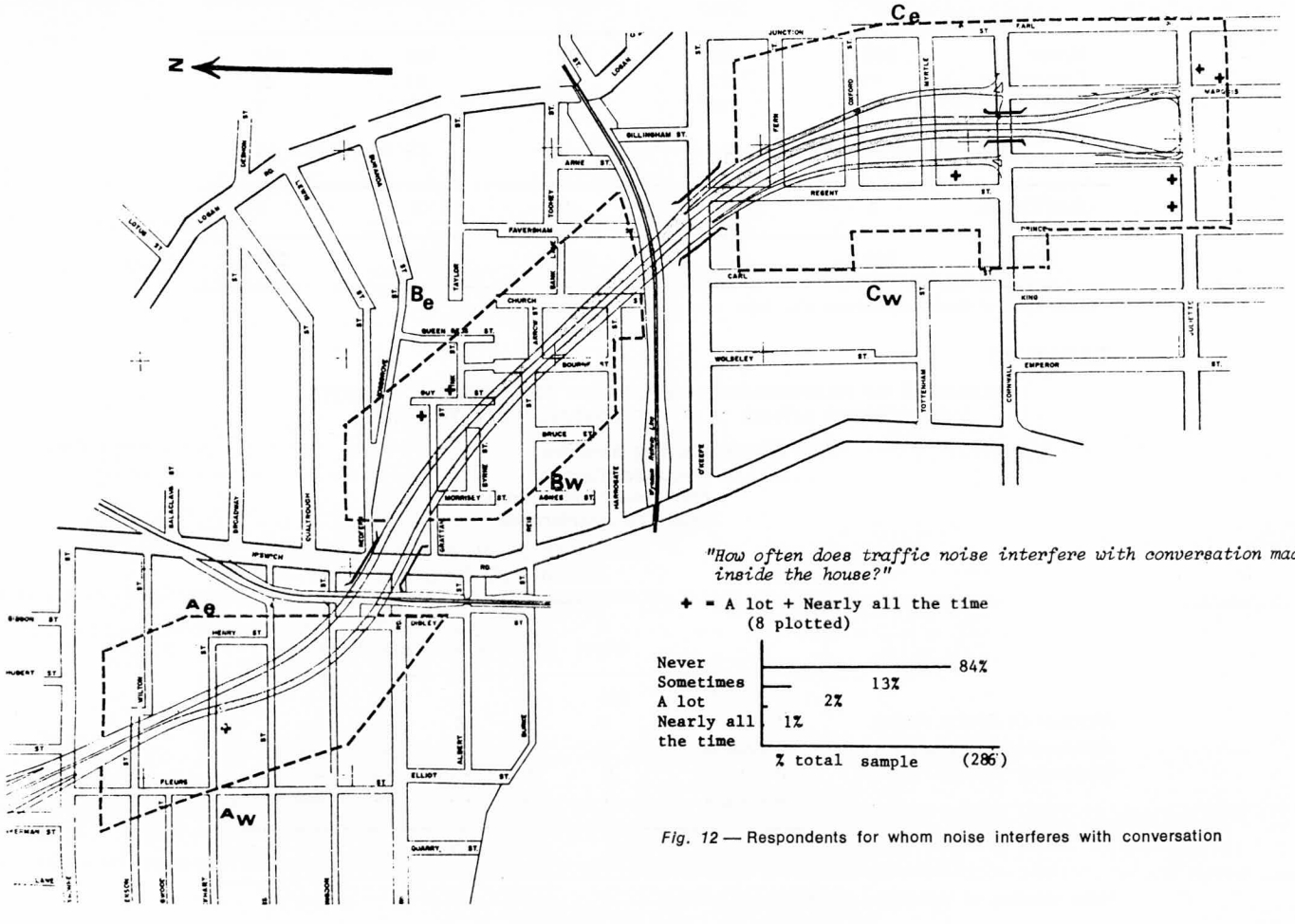

Fig. 12 — Respondents for whom noise interferes with conversation

TABLE VII

CROSS-TABULATIONS OF BEHAVIOURAL EFFECTS
Number of respondents in each cell

		*Still Disturbed With Windows Shut**					*Sleep Disturbance*					*Radio/TV Interference*					*Conversation Interference*				
		1	2	3	4		1	2	3	4		1	2	3	4		1	2	3	4	
Shut windows	1	8	0	0	0	8	175	30	2	2	209	172	34	1	1	208	195	13	0	0	208
	2	18	20	2	1	41	23	13	5	0	41	18	18	4	0	40	31	10	0	0	41
	3	1	5	5	1	12	3	5	3	1	12	3	2	4	3	12	6	4	2	0	12
	4	2	8	6	8	24	8	7	6	4	25	6	7	5	7	25	10	9	5	1	25
		29	33	13	10	85	209	55	16	7	287	199	61	14	11	285	242	36	7	1	286
Still disturbed with windows shut*	1	21	8	0	0	25	15	11	2	0	28	26	3	0	0	29					
	2	16	11	5	1	33	13	11	6	3	33	21	11	1	0	33					
	3	3	4	4	2	13	3	4	3	3	13	3	6	4	0	13					
	4	2	2	5	1	10	2	2	2	4	10	3	4	2	1	10					
		42	25	14	4	85	33	28	13	10	84	53	24	7	1	85					
Sleep disturbance	1	162	34	6	6	208	193	15	1	0	209										
	2	26	21	6	2	55	39	15	1	0	55										
	3	7	5	2	2	16	8	4	3	1	16										
	4	4	1	1	1	7	2	3	2	0	7										
		199	61	15	11	286	242	37	7	1	287										
Radio/TV interference	1	188	11	0	0	199															
	2	46	12	1	1	60															
	3	4	9	2	0	15															
	4	2	5	4	0	11															
		240	37	7	1	285															

* asked only of respondents who shut windows
1 = never
2 = sometimes
3 = a lot
4 = nearly all the time

TABLE VIII

ANNOYANCE SCORES OF RESPONDENTS WHO HAD CONSIDERED MOVING AWAY BECAUSE OF TRAFFIC NOISE

'Have you ever thought or done anything about trying to move away because of the traffic noise?'

N = 288	*Annoyance Score* 1	2	3	4	5	6	7	
No	47	67	71	43	17	6	5	256
Thought only	0	0	3	1	1	4	1	10
Talked amongst family	0	0	0	2	5	4	4	15
Consulted estate agent or tried to sell	0	0	0	0	3	3	1	7
	47	67	74	46	26	17	11	288

TABLE IX

REASONS WHY FREEWAY WAS THOUGHT TO HAVE IMPROVED OR DETRACTED FROM VALUE OF PROPERTY

	Better Access	*Better Lighting*	*Attractive*	*More Trees etc.*	*Less Local Traffic*	*Noise*	*Fumes*	*Cut Off From Neighbours*	*Glare*	*Poor Appear-ance*	*Fear of Accidents*
Improved	76	2	31	12	22	2	0	0	0	0	0
Detracted	2	0	0	0	0	35	4	7	4	7	3
A bit of each	6	0	0	1	1	5	2	1	0	0	0

Note: multiple answers were allowed
responses were not prompted

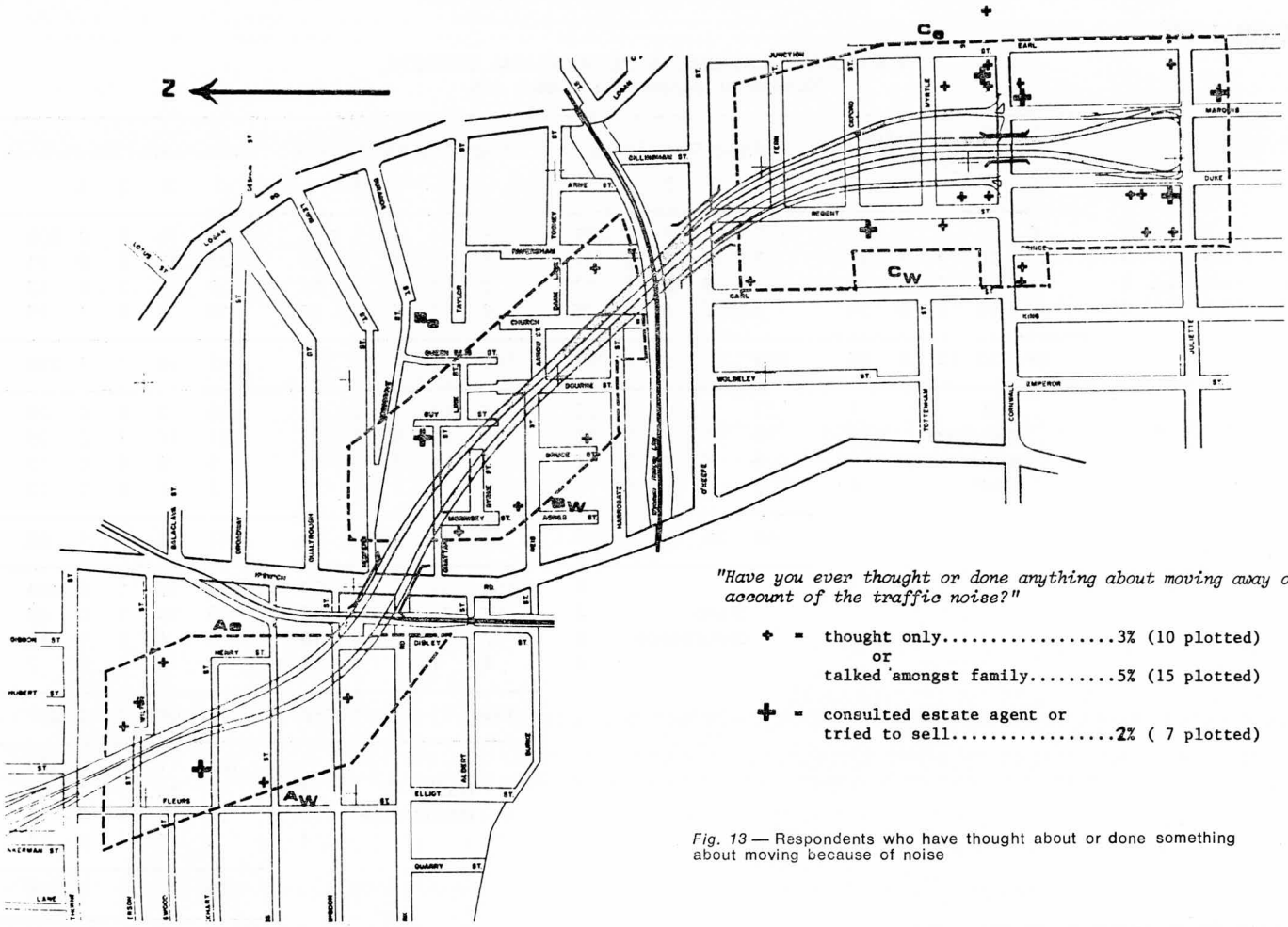

Fig. 13 — Respondents who have thought about or done something about moving because of noise

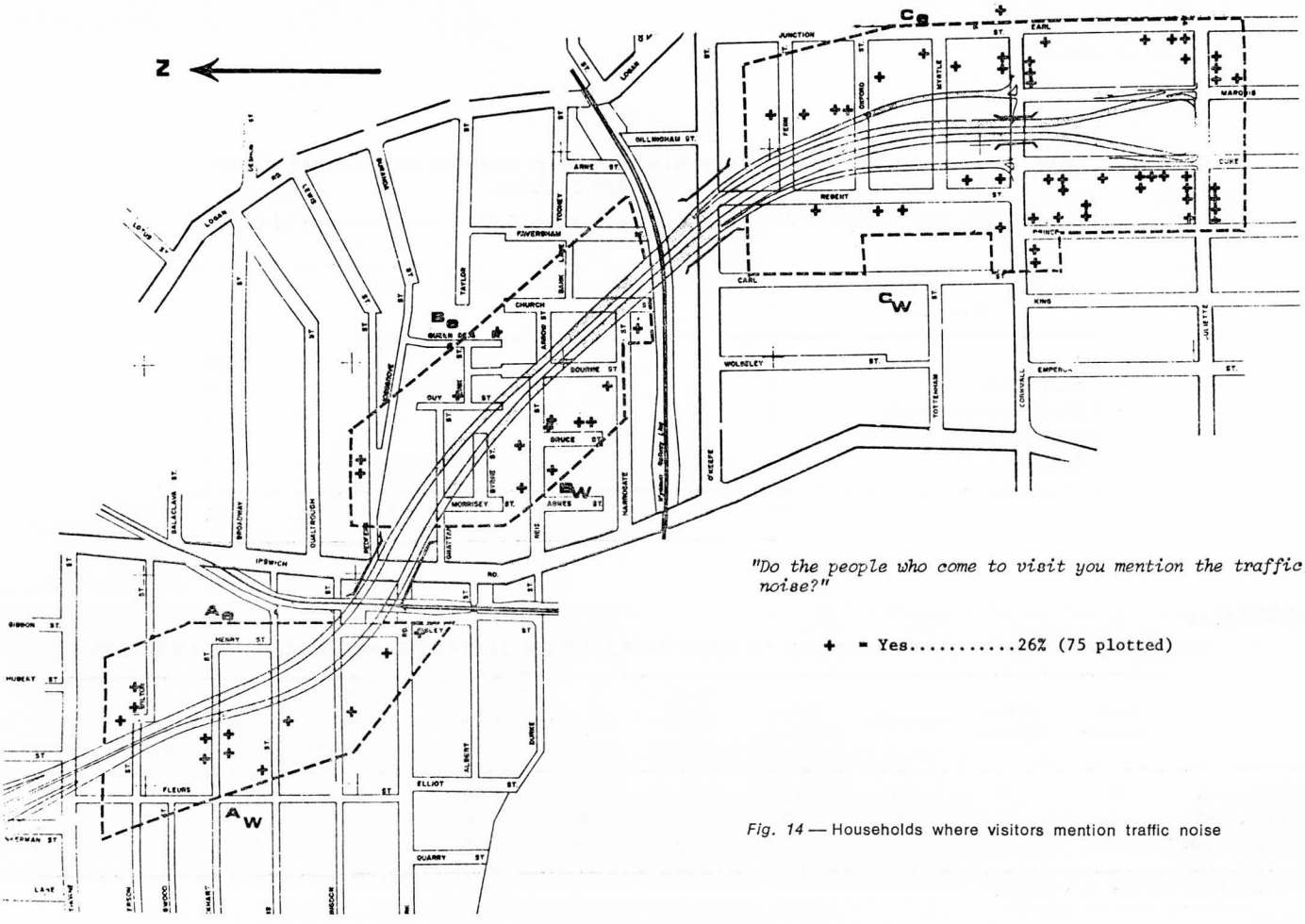

Fig. 14 — Households where visitors mention traffic noise

TABLE X

CROSS-TABULATION OF ANNOYANCE SCORES WITH OPINION ON CHANGE IN PROPERTY VALUE

		Noise Annoyance Score							
		1	2	3	4	5	6	7	
Improved	n = 126	19%	26%	27%	17%	5%	3%	3%	100%
Detracted	n = 66	6%	15%	23%	18%	15%	14%	9%	100%
A bit of each	n = 9	0%	12%	22%	22%	22%	22%	0%	100%
No effect	n = 27	40%	15%	19%	19%	7%	0%	0%	100%
Don't know	n = 60	14%	32%	29%	10%	10%	3%	2%	100%

Note: row percentages shown

TABLE XI

BIVARIATE CORRELATIONS BETWEEN TANGIBLE EFFECT PREDICTORS AND EACH OF THE ANNOYANCE INDICES

Tangible Effect	*Scale A*	*Scale B*	*Average*
Complain to member of household	0.4670	0.5246	0.5278
Visitors mention noise	0.3870	0.4182	0.4163
Shut windows	0.5716	0.6815	0.6680
Sleep disturbed	0.4383	0.5478	0.5008
Radio/TV interference	0.5440	0.5864	0.5938
Conversation interference	0.3650	0.4301	0.4121
Considered moving	0.4541	0.4957	0.5039

TABLE XII

BETA WEIGHTS AND MULTIPLE CORRELATIONS

Tangible Effect	*Scale A*	*Scale B*	*Average*
Complain to member of household	0.1614	0.1787	0.1912
Visitors mention noise	0.0781	0.0645	0.0675
Shut windows	0.2305	0.3254	0.3193
Sleep disturbed	0.1239	0.2045	0.1389
Radio/TV interference	0.2381	0.2068	0.2215
Conversation interference	0.0207	—0.0059	—0.0167
Considered moving	0.1409	0.1067	0.1414
Multiple correlation	0.6911	0.7913	0.7796
Squared multiple correlation	0.4776	0.6261	0.6077

in that it removes the factors of resident habituation and, in part, individual sensitivity to noise, from the assessment of noise annoyance.

43. Official complaints against freeway noise had been lodged by only four respondents. The authors' opinion, based on conversation with some residents in the study area, is that this low frequency of official complaints is mostly related to a lack of confidence that anything can be done to abate the noise. Respondents were also asked if they ever complained to a member of their household about traffic noise and the responses are shown in *Fig. 15*. This question neglects those respondents who live alone.

Other Relevant Opinions

44. Respondents' opinions as to whether their area was quieter or noisier than other areas are shown in *Fig. 16*.

45. The question on changes in the valuation of property was the only attempt to gain information on householders' opinions of the effect of the freeway on valuation. The question was general, and not specifically related to noise. There were several limitations inherent in the question. Sixty-two per cent of the residences were owner occupied, but in the other 38 per cent, tenants may not have been particularly interested in the economic effect of the freeway, and answered the question indifferently, or in ignorance. Further, owners may have been reluctant to answer honestly, particularly if they thought their home had lost value. Respondents' reasons for the changes in valuation are shown in *Table IX* and the relationship of respondents' opinions to their noise annoyance scores are shown in *Table X*. The distribution of those who considered the freeway detracted from the value of the property and those who thought the freeway improved their property are given separately in *Figs 17* and *18*. The pattern of opinions is far from consistent, but the following generalisations are possible. Respondents who reported a high annoyance with noise were more likely to indicate a fall in value, while those little annoyed by noise indicated an improvement. This would appear to account for the distribution of property value opinions in study

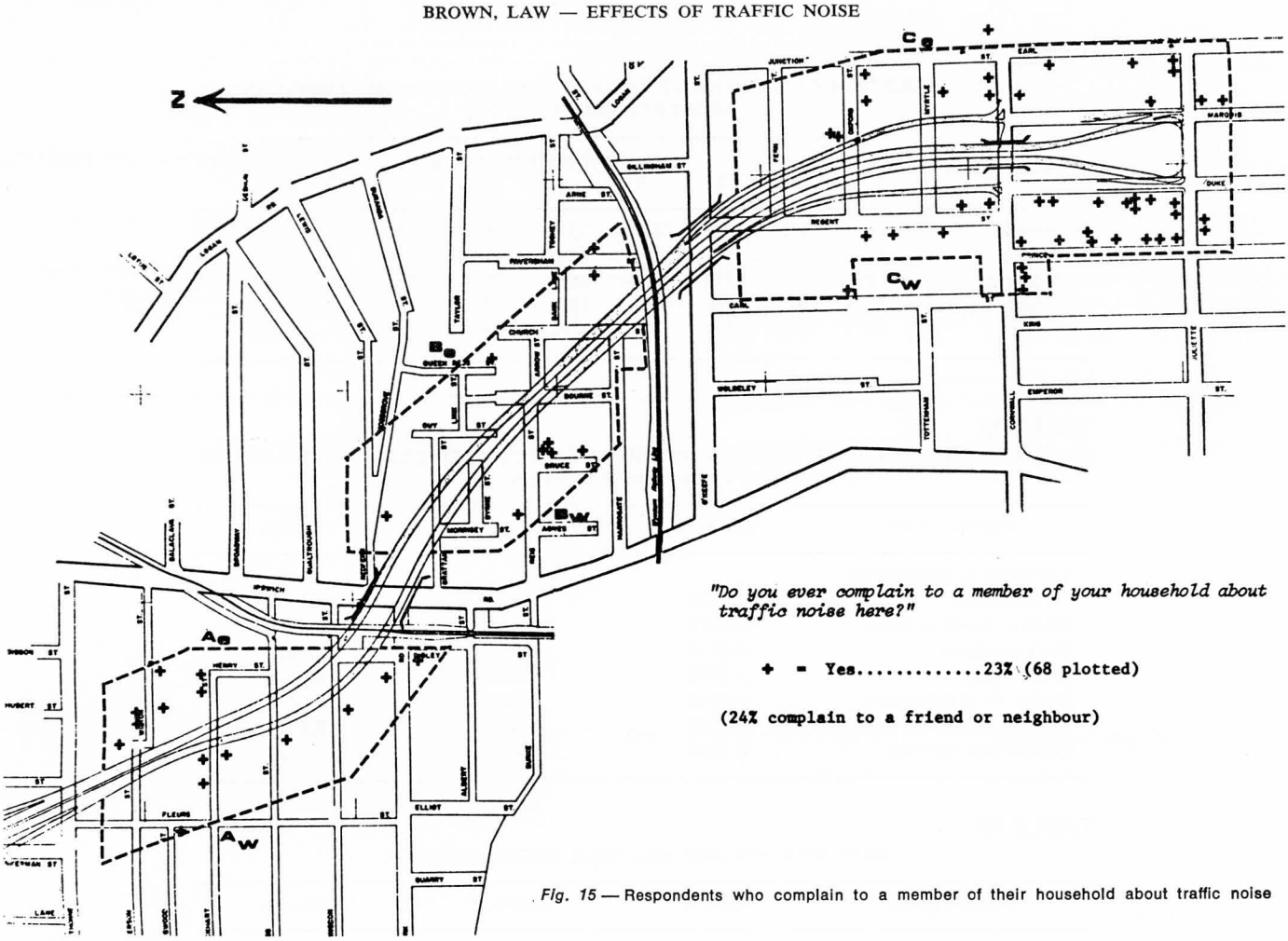

Fig. 15 — Respondents who complain to a member of their household about traffic noise

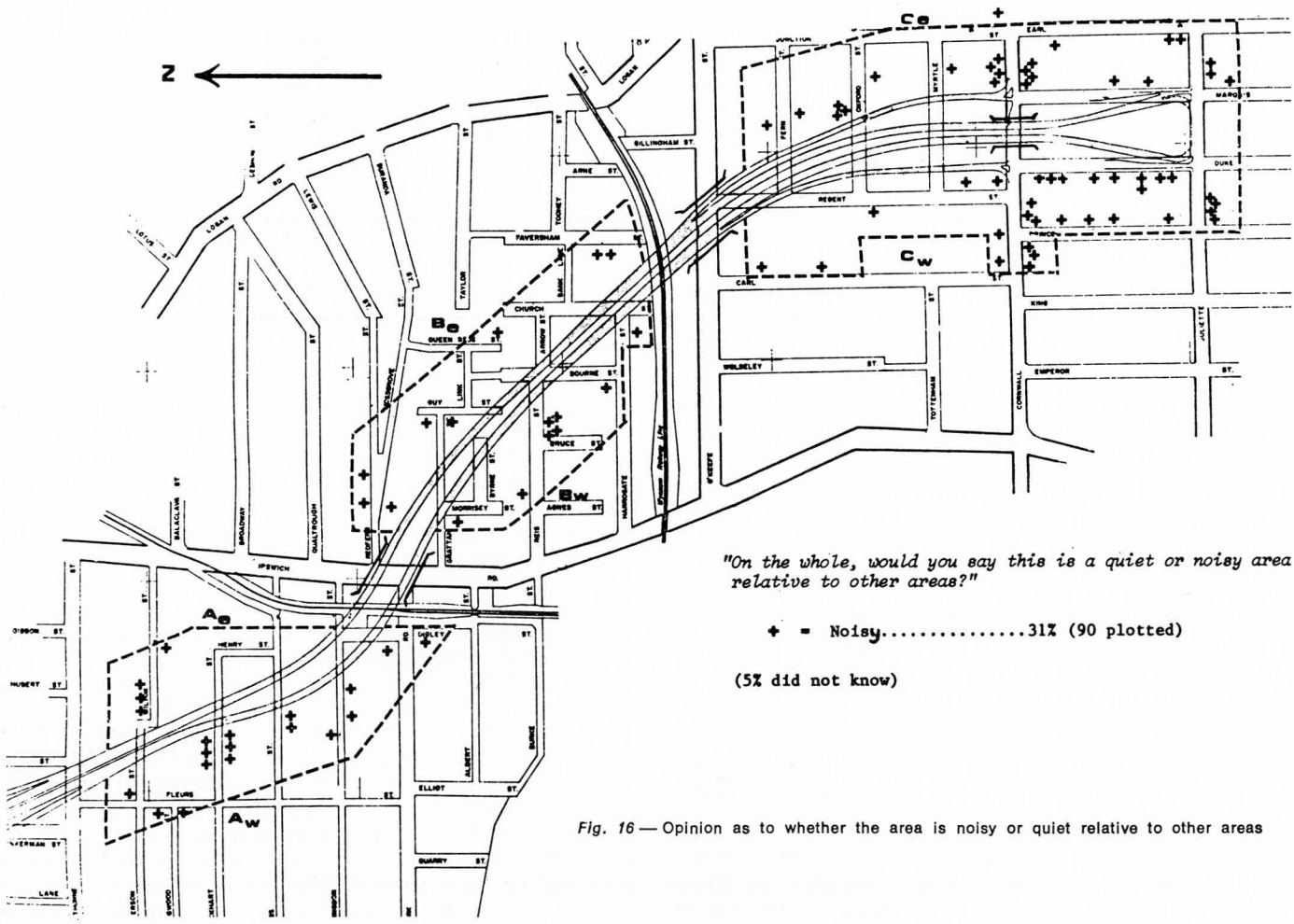

Fig. 16 — Opinion as to whether the area is noisy or quiet relative to other areas

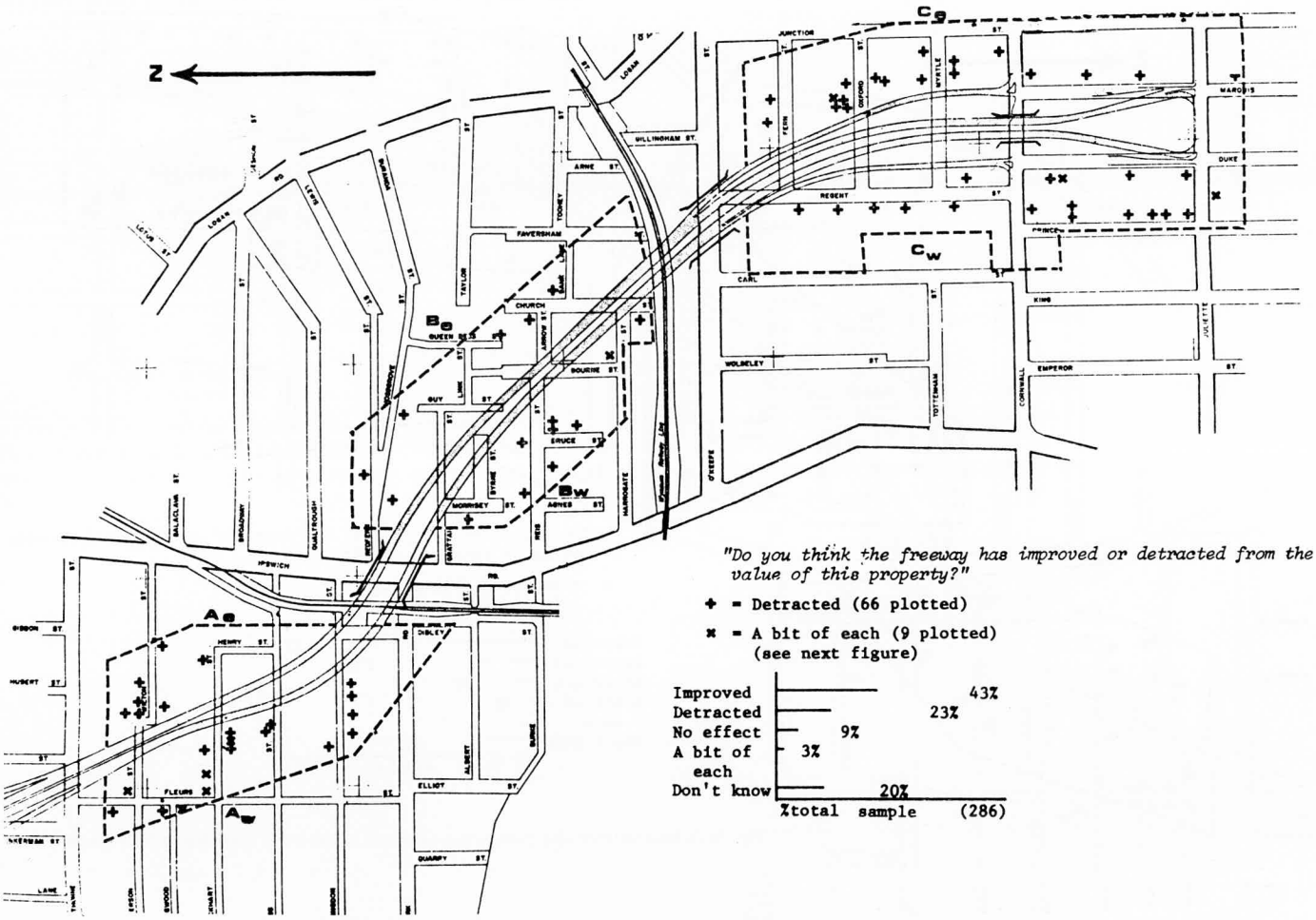

Fig. 17 — Respondents who thought the freeway had detracted from the value of their property

area A, though there are many inconsistencies. The distribution in study area B is completely incongruous. In areas A and B, the effect of increased accessibility to the city is likely to have been minimal in shaping respondents' opinions, as these areas did not have ready access to the freeway. In study area C, opinions on property values would appear to have been based on a trade-off between increased accessibility to the city, and deleterious environmental effects. The increased accessibility appears more important to some respondents, as several reported high annoyance, yet regarded their property value as improved. In area C, those who thought their property value decreased, generally lived closer to the freeway than those who thought their property values had increased.

SUMMARY OF DISTRIBUTION OF TANGIBLE EFFECTS OF FREEWAY NOISE

46. To summarise the distribution of effects in *Figs 9* to *16,* broad-pen generalisations of the areas of maximum reporting of tangible effects are shown in *Fig. 19* and described below. A detailed description of the distribution of the tangible effects is not necessary, as the distributions generally conform to the distribution of annoyance described in paras 22-26.

(a) Study area A

One group of houses in A_e, and several groups in A_w reported most effects as severe. These areas were adjacent to the freeway, and noticeably occurred mainly where the freeway was at grade, rather than on the embankment.

(b) Study area B

Several groups of houses where the shielding of the cutting was not fully effective reported most effects. The group in area B_w is shown queried because the source of disturbance was predominantly Ipswich Road.

(c) Study area C

Most houses fronting Juliette and Cornwall Streets, and those close to the on-ramps reported most effects, as well as several isolated pockets adjacent to the freeway beside the Cornwall Street on- and off-ramps.

RELATIONSHIP OF THE TANGIBLE EFFECTS OF FREEWAY NOISE TO REPORTED ANNOYANCE

47. As indicated earlier, acceptance of the self-report indices of annoyance is contingent upon their correlation with the tangible effects of freeway noise. To establish the extent of this correlation, three multiple correlation analyses were carried out in which each of the indices of annoyance (Scale A, Scale B, and the Average Annoyance Score), in turn were used as a criterion, and seven tangible indices of noise disturbance were used as predictors. The results of bivariate correlations between each of the predictor variables and each of the annoyance criteria in turn are shown in *Table XI* and the results of the three multiple regression analyses are shown in *Table XII.*

48. Clearly, Scale B has the highest multiple correlation with the behavioural indices of noise disturbance. While Scale B shares 62.61 per cent of its variance with a linear combination of the predictors, Scale A shares only 47.76 per cent. This is evidence for the superiority of the semantically labelled Scale B as an index of annoyance. The average annoyance rating shares 60.77 per cent of its variance with the predictors and this would seem to

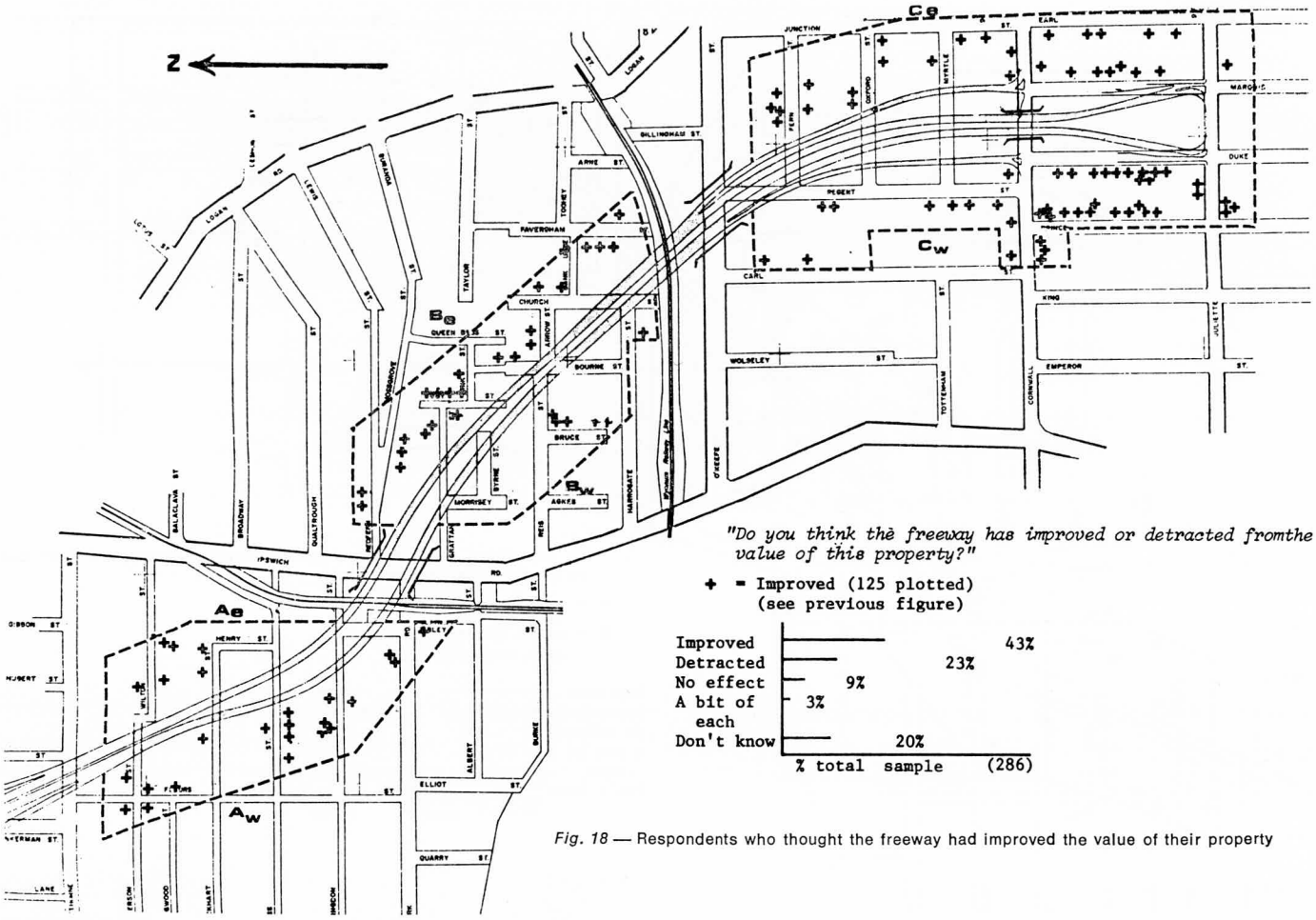

Fig. 18 — Respondents who thought the freeway had improved the value of their property

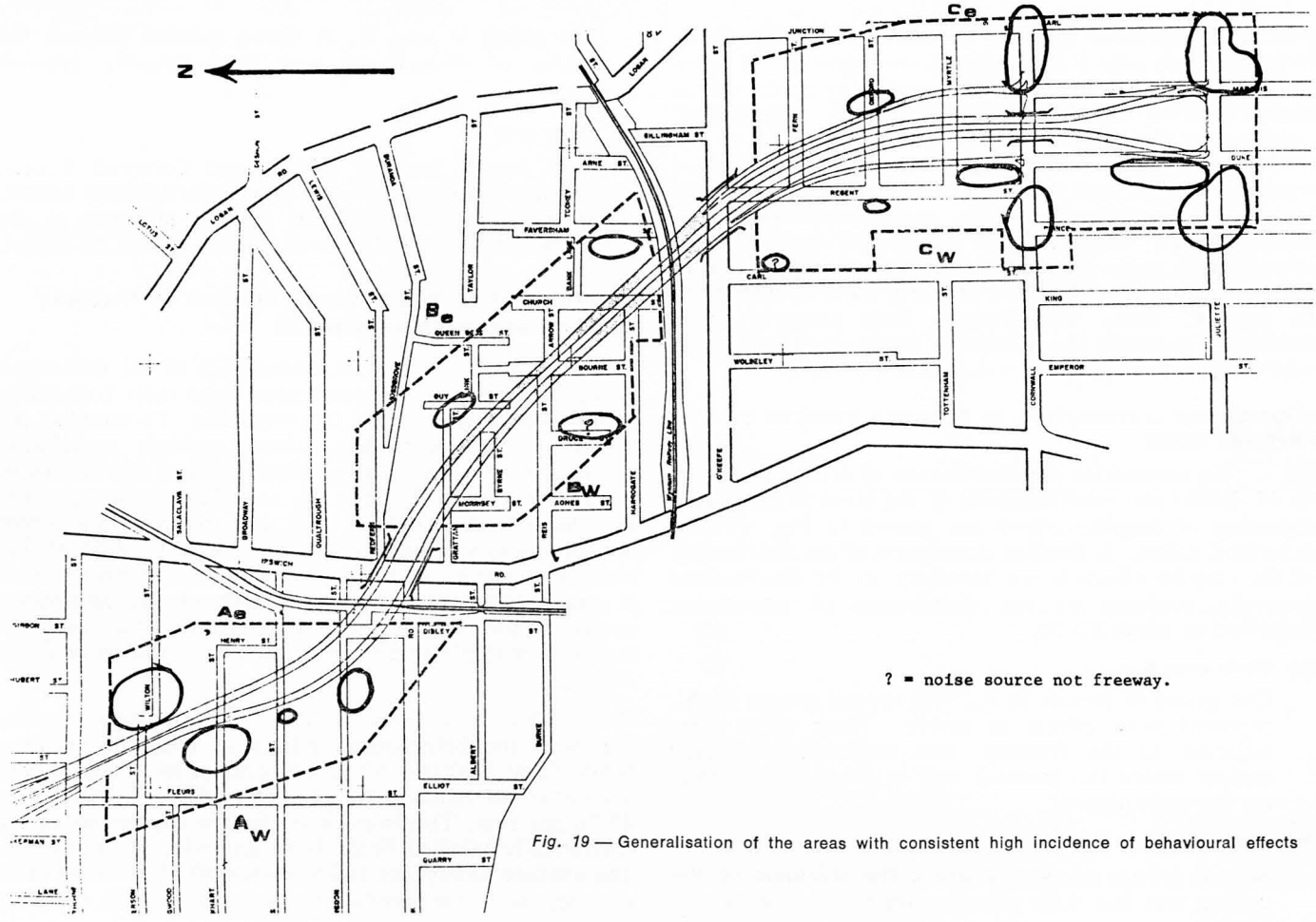

Fig. 19 — Generalisation of the areas with consistent high incidence of behavioural effects

TABLE XIII

CROSS-TABULATION OF ANNOYANCE SCORES WITH EACH TANGIBLE EFFECT
(Row Percentages Shown)

Annoyance Score	Shut Windows				Still Disturbed When Windows Shut[1]				Sleep Disturbed				Radio/TV Interference			
	Never	Some-times	A Lot	Nearly All The Time	Never	Some-times	A Lot	Nearly All The Time	Never	Some-times	A Lot	Nearly All The Time	Never	Some-times	A Lot	Nearly All The Time
1 (n = 47)	100	0	0	0	100	0	0	0	98	2	0	0	100	0	0	0
2 (n = 67)	96	4	0	0	100	0	0	0	91	9	0	0	90	10	0	0
3 (n = 74)	80	20	0	0	65	30	0	5	82	15	0	3	74	26	0	0
4 (n = 46)	63	20	7	10	33	44	23	0	48	41	9	2	50	37	11	2
5 (n = 26)	23	31	27	19	25	50	15	10	38	35	23	4	35	46	15	4
6 (n = 17)	18	29	6	47	8	50	21	21	35	35	24	6	29	24	12	35
7 (n = 11)	10	10	10	70	0	23	33	44	37	27	18	18	18	18	37	27

Annoyance Score	Conversation Interference				Considered Moving				Visitors Mention Noise		Complained to Family		Relative Noisiness Of Area	
	Never	Some-times	A Lot	Nearly All The Time	No	Thought Only	Talked With Family	Tried To Move	No	Yes	No	Yes	Quieter	Noisier
1 (n = 47)	100	0	0	0	100	0	0	0	96	4	100	0	93	7
2 (n = 67)	95	5	0	0	100	0	0	0	89	11	98	2	88	12
3 (n = 74)	90	10	0	0	96	4	0	0	81	19	86	14	76	24
4 (n = 46)	83	15	2	0	94	2	4	0	61	39	56	44	42	58
5 (n = 26)	54	38	4	4	65	4	19	12	50	50	35	65	42	58
6 (n = 17)	47	35	18	0	34	24	24	18	8	92	19	81	19	81
7 (n = 11)	36	46	18	0	45	10	36	9	20	80	30	70	9	91

[1] This question asked only of respondents who shut windows

justify the use of this index as a compromise in the present study.

49. Inspection of *Tables XI* and *XII* shows that the question on window shutting is the most powerful predictor in the set of tangible effect indicators.

50. Although the above correlation analysis does show that an increasing annoyance score parallels increasing intrusion of traffic noise, it does little to aid the interpretation of the significance of a particular annoyance score. What is the difference, for example, between a score of three and a score of six? To assist, however inelegantly, in this interpretation, annoyance scores have been cross-tabulated with each of the tangible effects and these are shown in *Table XIII*. The cell frequencies have been shown as *row percentages*. Considering all respondents with the same annoyance score as sub-samples, the *row percentages* facilitate examination of how differently each sub-sample reported the magnitude of the behavioural effects. For example, 100 per cent of the sub-sample with an annoyance score of one never had to shut their windows, but 70 per cent of the sub-sample who scored seven had to shut their windows all the time. When examining *Table XIII,* it should be noted that the numbers of respondents in each sub-sample vary widely, and in particular the sub-samples with annoyance scores of five, six and seven are small.

51. Respondents with low annoyance scores (one, two) were concentrated, almost exclusively, in the category of never reporting any tangible effect. Sub-samples of respondents with annoyance scores greater than three, reported successively higher average incidence of each tangible effect, but also within each sub-sample the whole range of the effect, from 'never' to 'nearly all the time', was reported. A coarse summary of *Table XIII* is given below:

Annoyance Score = 1 *(n = 47)*
Nearly 100 per cent of respondents with a score of one reported no behavioural effect. None complained about noise to a member of their household. Only 4 per cent of them had visitors who mentioned noise, and only 7 per cent thought their own area noisier than other areas.

Annoyance Score = 2 *(n = 67)*
Most respondents reported no behavioural effects, but up to 10 per cent reported some effects occurring some of the time.

Annoyance Score = 3 *(n = 74)*
Ten to 30 per cent reported behavioural effects occurring some of the time, but there was almost no reporting of effects occurring a lot or nearly all the time. Fourteen per cent complained to a member of their household. Nineteen per cent had visitors who mentioned noise, and 24 per cent thought their area noisier than other areas.

Annoyance Score = 4 *(n = 46)*
Sixty-three per cent never had to close their windows, but 10 per cent had to close them nearly all the time. Over half had their sleep disturbed, and interference with radio and television, some of the time, with 2 per cent all the time, and about 10 per cent a lot. Two per cent had thought about moving and 4 per cent had talked with their family about moving. Fifty-eight per cent thought their area noisier than other areas.

Annoyance Score = 5 *(n = 26)*
Only 23 per cent never had to shut their windows, and 19 per cent had to shut windows all the time. Sixty-two per cent had their sleep disturbed, with 4 per cent disturbed all the time and 23 per cent disturbed a lot. Thirty-five per cent had considered moving and 12 per cent had consulted an estate agent (or similar). Fifty per cent had visitors who mentioned noise. Sixty-five per cent complained to a member of their family.

Annoyance Score = 6 *(n = 17)*
Forty-seven per cent had to shut their windows nearly all the time and 21 per cent of these were still always disturbed even with the windows shut. Thirty-five per cent never had their sleep disturbed, 24 per cent had it disturbed a lot, and 6 per cent nearly all the time. Twenty-nine per cent never had interference with radio/television, but 35 per cent had interference nearly all the time. Over half had interference with conversation, but none all the time. Sixty-five per cent had considered moving and 18 per cent had consulted an estate agent. Ninety-two per cent had visitors who mentioned noise and 81 per cent complained to a member of their household and thought their area noisier than other areas.

Annoyance Score = 7 *(n = 11)*
Seventy per cent shut their windows nearly all the time and 44 per cent of these were still always disturbed even with the windows shut. Eighteen per cent had their sleep disturbed nearly all the time. Otherwise somewhat similar to an annoyance score of 6.

52. There would appear to be a major increase in the frequency of reporting of tangible effects between the sub-sample with an annoyance score of three and the sub-sample with a score of five.

SUMMARY

53. The survey attempted to measure traffic noise annoyance by using self-report scales. The reasonably high correlation of the tangible effects of noise with the annoyance scores gave confidence that the annoyance scores obtained were meaningful. It remains a task for the policy maker to determine what levels of annoyance are to be regarded as acceptable. To assist in this task, a rough 'calibration' of the annoyance scale has been arrived at for the freeway sample by indicating the likely tangible effects for each annoyance score.

54. The distribution of traffic noise annoyance around the freeway has been interpreted in terms of freeway geometry and traffic patterns on the surface streets. Despite a range of scores in most locations, areas where there was significant reporting of adverse effects of traffic noise can be determined from examination of the annoyance score and tangible effects figures. In brief, these areas were located beside the surface streets Juliette Street and Cornwall Street, at close distances to the on-ramps, and beside the at-grade sections where the freeway was in transition from cutting to embankment. A low incidence of the effects of noise was reported beside the sections of the freeway in cutting and on embankment. There was no clear relationship between annoyance scores and distance from the freeway, with some low annoyance scores reported at close distances to the freeway, and vice versa. However, beyond 70 m distance the highest freeway noise annoyance score reported was three, and nearly all respondents reported either other roadways, or no roadways at all, as noise sources.

APPENDIX A

PHYSICAL PROFILE OF THE STUDY AREA

55. The South-East Freeway was the first significant length of roadway of its type constructed in Brisbane. It is characterised by a high operating speed, 80 km/h, with grade separation from surface streets. A wide median strip separates the carriageways, and in part these are independently aligned. The freeway, with the Riverside Expressway and Captain Cook Bridge, is a radial route from the city centre. The existing stage of the freeway was opened to traffic in early 1973, and the second and third stages are expected to be open in the late 1970's.

56. The first stage of the South-East Freeway terminates abruptly at the southern end (see *Fig. 2*). One set of permanent ramps and one set of temporary ramps connect the freeway to surface streets. These streets, Cornwall Street and Juliette Street, were upgraded residential streets, although Cornwall Street was a through-traffic route before construction of the freeway. These streets distribute the freeway traffic to the major arterials, Logan Road and Ipswich Road. The temporary Juliette Street ramps at the present freeway terminus duplicate the permanent ramps, situated 300 metres away at Cornwall Street. These ramps greatly increase the distances from the freeway carriageway to the first row of houses. Because of the duplicated ramps, 37 per cent of the total length of the freeway in the study area, i.e., 0.75 km in 2.0 km, had houses fronting on to ramps rather than the main carriageway.

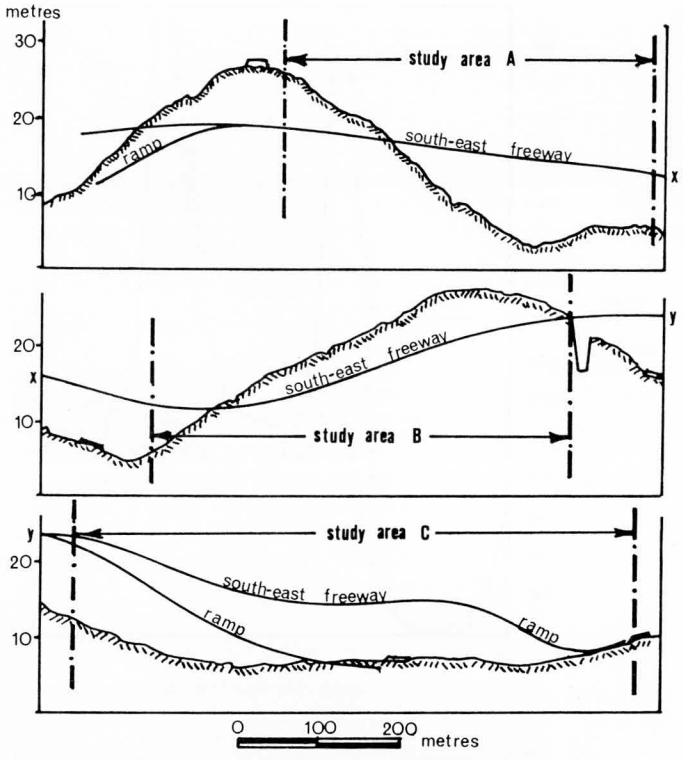

Fig. 20 — Longitudinal section of freeway

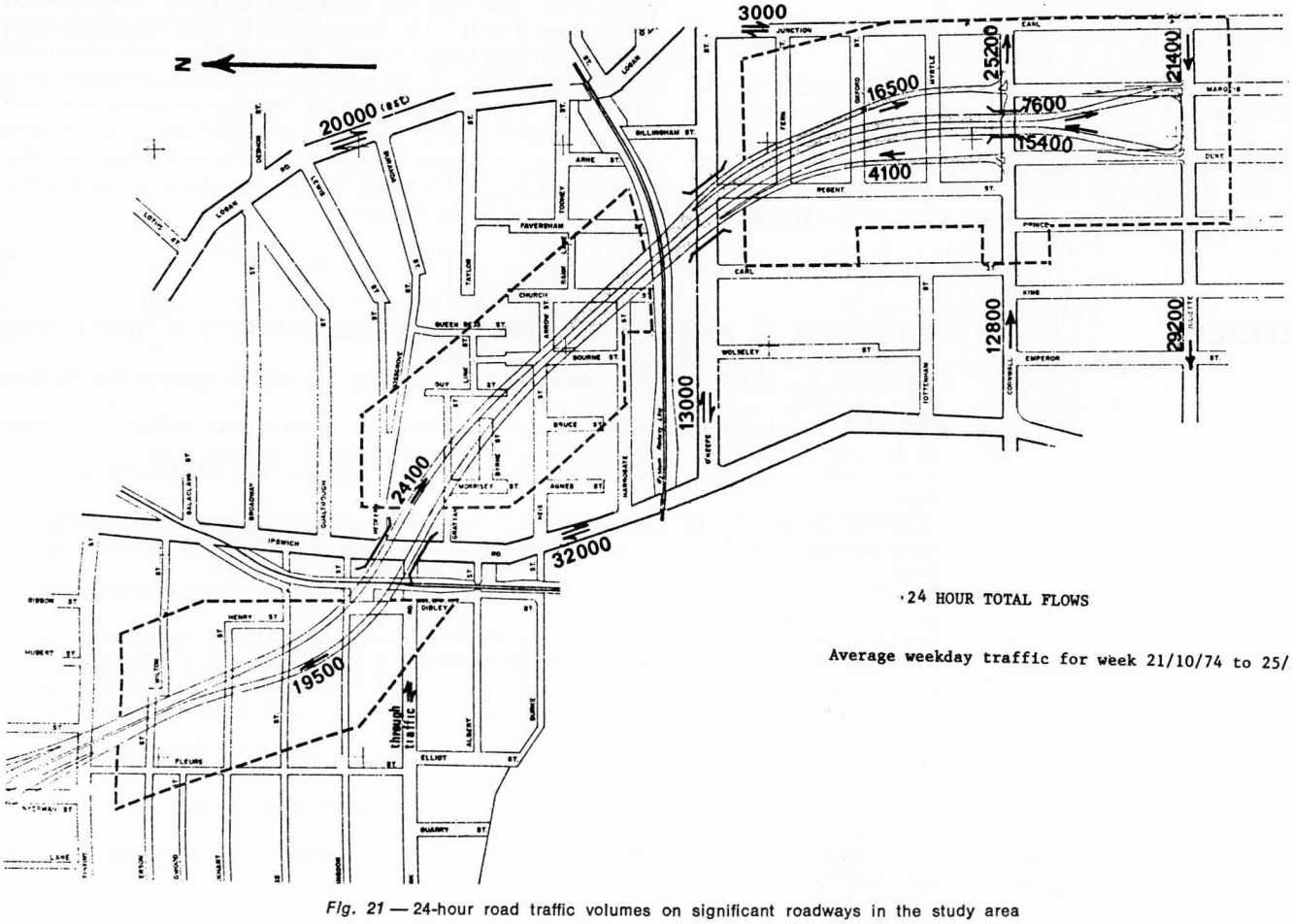

Fig. 21 — 24-hour road traffic volumes on significant roadways in the study area

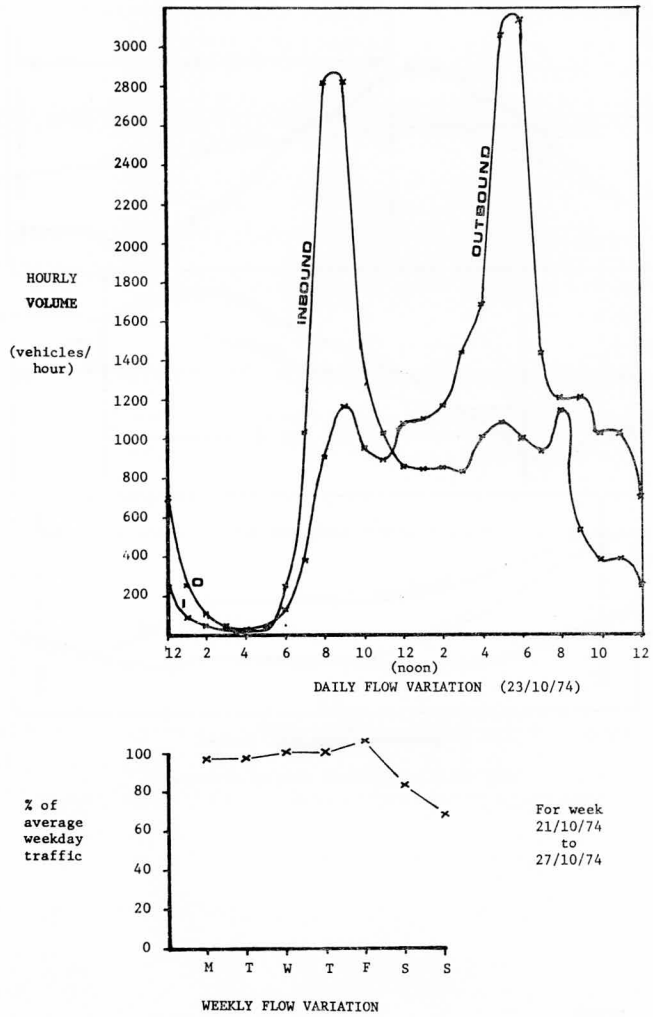

Fig. 22 — Daily and weekly variation in freeway traffic volumes

57. The terrain is undulating, and this, along with the requirements of grade separation with major surface streets, has produced significant cuttings and embankments throughout the length of the freeway. Within the study area (excluding those areas adjacent to Ipswich Road and O'Keefe Street), 35 per cent of the freeway is in cutting (maximum cut 7 metres) and 65 per cent is on embankment (maximum fill — 11 metres). The lengths corresponding to these percentages are 0.61 km and 1.12 km respectively. There are no significant at-grade sections within the study area. These figures apply for the outbound carriageway only and the inbound roadway is slightly different. The longitudinal section along the freeway indicating the relationship of the freeway to the natural surface is shown in *Fig. 20*. Again, only the outbound road profile is shown, but the inbound roadway is not essentially different. The freeway cutting provided effective shielding of nearby houses from the freeway traffic noise, and in some locations the shoulders of the freeway embankment also provided some shielding to adjacent households.

58. Apart from the freeway, Cornwall Street and Juliette Street, other sources of road traffic noise affecting the study area were the major arterials, Ipswich Road and Logan Road, and a cross street, O'Keefe Street. Minor streets in the area, in the main, carried local traffic, though some carried a small amount of through traffic.

59. Automatically monitored traffic volumes were available for the freeway, the ramps, Cornwall and Juliette Streets. Traffic volumes shown for the other surface streets are estimates only as they are extrapolated from short duration counts made by the authors twelve months previously. Twenty-four hour volumes for significant roadways are shown in *Fig. 21*, with the daily and weekly variations in traffic flow in *Fig. 22*. Automatic traffic counting did not provide information on the percentage of heavy vehicles using the freeway, though short term counts by the authors indicated that the percentage is unlikely to have exceeded 5 per cent. The percentage of motorcycles was not noted.

60. The study area was predominantly residential, with commerical and light industrial development along Ipswich and Logan Roads. The households in the study area were unlikely to have been affected by noise from the industrial/commercial areas. A railway line traversed the study area and there were approximately 70 train movements per day on this line. Also, the area was subject to noise from aircraft, but at approximately 10 km from the airport, the study area was well outside the zones where aircraft noise annoyance could be expected.

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this programme is to provide road designers with data which will enable them to design 'quieter' roads in the future. Of course, such design must be optimised with other parameters such as skid resistance and so on.

To G. E. BETTISON

This would represent a worthwhile study. However, it must be appreciated that reduction of traffic noise is a complex problem that requires the interaction and co-operation between manufacturer, consumer and government. A recent study (TRB 1974) indicated that, based on several criteria, control of traffic noise at the source is the most hopeful avenue for the future. Further, it is likely that requirements for additional reduction in vehicle noise levels will be phased in over a period of years, thereby spreading the cost burden over that time.

To O. G. INGLES

Braking noise is a result of vibrations generated at the shoe/drum or pad/disc interface. It tends to have an intermittent, high frequency tonal spectrum. However, the observed diversity of community opinion as to what sounds are objectionable should be noted in this case. It seems that the discussor is one of those people who finds sounds with such spectra objectionable. Because of its comparatively rare occurrence, braking system noise would represent a traffic noise component of relatively low importance.

To C. TINSLAY

Annoyance is a personal reaction to noise and is dependent not only on the person concerned, but on what activity he is engaged in at the time. Within the community there is a wide diversity of reactions to noise of varying levels. Generally, people tend to object to high frequency tones (or whines) of all levels. For noise with a broadband spectrum, annoyance seems to increase with the overall level. Indeed both the spectral content and the duration of a particular noise are important factors in judging annoyance.

THE EFFECTS OF TRAFFIC NOISE: SOUTH-EAST FREEWAY, BRISBANE

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C. L. FOUVY, Transport Engineer, Planning Division, Ministry of Transport, Victoria

In para. 12 (and *Table II*), the authors compare persons' responses according to two annoyance scales. It is interesting to note that while the majority of respondents who were 'not at all' annoyed by traffic noise found such conditions 'definitely satisfactory', it took 'very little' annoyance by traffic noise to cause respondents to report that conditions were becoming significantly different from completely (or definitely) satisfactory.

In para. 13, the authors indicate that these subjective personal responses need to be related to 'external variables such as behavioural indexes of noise disturbance'. However, they do not seem to clearly specify whether these external variables are tangible effects such as disturbance of sleep or interference with conversation, or objective measurements such as distance from noise source or noise intensity. Would the authors please indicate.

It is difficult to understand how, in a survey such as this, the authors did not take the opportunity to make their research more fully comprehensive by relating the subjective responses of those surveyed with some directly measured objective properties of the traffic noise other than distances between each house and the noise source. Typical properties of the noise would be intensity measurements such as L_{90}, L_{50} and L_{10} and some indication of its duration. In this regard, it would be interesting to know whether the authors had made some objective noise measurements but had not published them.

P. GUNN, Environmental Physicist, Main Roads Department, Western Australia

From this study and your more recent ones have you demonstrated that traffic noise is indeed a widespread problem and area of concern among Australian urban dwellers? How did traffic noise rate among other noise and pollution sources as a cause of complaint or dissatisfaction? Specifically for the study reported, have your results led to any policy decisions being made about the introduction of noise reduction measures on the freeway?

H. HOBBS, Country Roads Board, Victoria

It is noted that the percentage of heavy vehicles in the study was less than 5 per cent of total vehicle volume. As this percentage is considerably lower than the percentage one would normally expect, how does the author see this affecting the reactions of the residents interviewed, i.e. if the percentage had been 10 would the answers have been much different?

T. ten BRUMMELAAR, Senior Lecturer, University of New South Wales

Is the additional noise nuisance reported on the on-ramp as compared with the off ramp, related to vehicles accelerating? If I interpreted the diagrams correctly, the on-ramp is also on an upgrade onto an embankment requiring acceleration while climbing; a typical case of unfortunate design?

AUTHORS' CLOSURE

To C. E. MATHER (see Introductory Remarks)

The more frequent reporting of high annoyance scores by residents living near the on-ramps reflects higher noise levels at these locations. The higher noise levels result mainly from the shorter distances between the houses and the traffic stream than along other sections of the Freeway, but with some contribution by higher emission levels from accelerating cars, and longer on-time of noise from slow moving heavy vehicles. The reactions of startle and fear, which may be evoked in people near the on-ramps by the screeching of tyres as vehicles accelerate through the corner onto the ramps, may also have contributed to the higher annoyance scores.

Alteration in the pattern of shutting of windows during different seasons was not investigated, nor was the effect of decreased ventilation on the respondents' annoyance scores. However, casual observations by the authors of houses in the study area at different seasons indicate that windows on noise affected homes stay shut even in summer.

To G. E. BETTISON (see p. 49)

The effectiveness of the reduction of permissible noise levels of different vehicle types has been modelled by Nelson and Fanstone (1974). They separately considered reduction of car noise levels by 5dB(A), truck noise levels by 10dB(A), and a combination of these reductions. *Table XIV* shows the resulting reduction in the L_{10} level produced by traffic streams of varying flow rates and percentage heavy vehicles.

TABLE XIV

Reductions in L_{10} dB(A) for various flows and percentage lorries when (1) lorries are reduced by 10 dB(A), (2) cars are reduced by 5 dB(A) and (3) lorries are reduced by 10 dB(A) and cars are reduced by 5 dB(A)

Flow, Q, vehicles/h	*Reduction in L_{10} dB(A)*														
	5% lorries			*10% lorries*			*20% lorries*			*40% lorries*			*80% lorries*		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
200	0.7	4.5	5.4	1.4	4.0	5.6	2.5	3.5	6.3	4.5	2.1	7.3	8.4	0.1	9.3
400	0.7	4.5	5.4	1.4	4.0	5.6	2.5	3.1	6.4	5.1	0.6	7.9	8.8	0.1	9.6
600	0.7	4.5	5.4	1.5	4.0	5.8	2.9	2.1	6.7	5.8	0.3	8.6	8.8	0.1	9.8
800	0.7	4.4	5.4	1.5	3.7	5.9	3.1	1.1	7.0	5.9	0.3	8.8	9.0	0.1	9.8
1000	0.7	4.3	5.5	1.6	3.2	6.1	3.5	0.7	7.4	6.0	0.1	8.9	9.0	0.1	9.8
2000	1.1	3.5	5.8	2.4	1.2	6.8	4.2	0.5	7.8	6.3	0.1	9.1	9.0	0.1	9.8

Nelson and Fanstone concluded that a quietening of both cars and trucks is required if any general benefit is to be experienced, but that noise levels will not be reduced until at least 50 per cent of existing vehicles are replaced by quieter vehicles. In order to gauge the effectiveness of the above quietening of vehicles, they indicated that a reduction in L_{10} of about 8dB(A) (as achieved by quietened vehicles with flow rate 2000 veh/h and 20 per cent lorries) could only be achieved with existing vehicles by reducing the traffic flow from 2000 veh/h to 200 veh/h, or by increasing the distance of the observation point from the nearside kerb from 10 m to 40 m.

To T. H. COOKE (see p. 49)

No.

To C. L. FOUVY

The external variables with which the annoyance scores were correlated were the tangible effects of the noise such as shutting of windows, sleep disturbance, etc. The correlation is discussed in paras 47 to 50.

In the two-month period immediately following the conduct of the annoyance survey, noise level measurements were made at 15 sites around the South-East Freeway. Measurements were of 24 hours duration and data collected allowed the computation of all road traffic noise level statistics suggested in the literature to date. The results of the noise level measurement programme, and the correlation of noise levels with the social survey results, will be reported at a later date.

To P. GUNN

In responding to the question 'Do you ever complain to yourself about anything in the area?' 14 per cent of the study area sample volunteered, 'traffic noise'. At that stage in the interview, respondents were unaware that the survey was investigating noise. The next ranking sources of complaint, volunteered by 5 and 3 per cent of the sample respectively, were 'traffic' and 'other people in the area'. Five per cent had complained of dust from the Freeway (specific reports of black dust (rubber or soot?) were registered, but a significant proportion of these complaints were believed to be retrospective complaints of dust at the time of

freeway construction). Three per cent complained of 'fumes', and 2 per cent complained of each of 'appearance of houses', 'poor footpath repair', and 'difficulty of access' because of one way streets and culs-de-sac.

These figures would indicate that traffic noise was the major source of environmental dissatisfaction of residents in the study area. Data are not yet available from a current study of urban surface roadways in some Australian cities. However, estimates available from the United Kingdom (Road Research Laboratory 1970) suggest that between 19 per cent and 46 per cent of the U.K. urban population of 45 million (1970) live on roads where traffic noise levels are likely to be judged undesirable for residential purposes. For 1980 the above estimates increase to the range of 30 to 61 per cent.

The authors are unaware if any policy decisions have been made regarding noise reduction measures on the South-East Freeway. However, it is to be hoped that results from the present study will influence the design of future similar roadways so as to minimise noise annoyance in adjacent communities.

To H. HOBBS

While it is a simple matter to predict the change in noise levels resulting from an increase in the percentage of heavy vehicles using the freeway (about 1dB(A) increase in L_{10} for a change from 5 per cent to 10 per cent heavy vehicles; a 2dB(A) increase for a change from 5 to 20 per cent), the authors have no direct evidence of how such a change would affect the magnitude and distribution of annoyance around the Freeway. However, of those respondents who replied that they 'complained to themselves' about traffic noise (14 per cent of the study area sample) about one-third specifically mentioned the noise from semi-trailers and large trucks.

The authors' opinion is that increases in the percentage of heavy vehicles, to say 10 per cent, would not affect the annoyance scores near the Freeway provided that the percentage increase occurred uniformly throughout the day. But if the increase in the number of trucks was to occur mainly at night or the early morning, it is likely that interference with household activities such as sleep and communications would be more frequent, and annoyance scores higher.

To T. Ten BRUMMELAR

The reply to C. E. Mather answers this discussion also.

To J. TRELOAR (see p. 49)

The Australian Standard 1055 *Noise Assessment in Residential Areas,* may prove useful to local authorities in regulating against noise such as the start-up of heavy vehicles in residential streets. While the standard should not, and in some respects cannot, be used to assess the noise from road traffic, it can be applied to the noise source mentioned. The authors also believe that, with care, the standard can be used to assess community reaction to the noise from a fleet of heavy vehicles passing along an otherwise untrafficked residential street at regular intervals (for example, the use of a residential street as an access road to a quarry).

In the absence of radically quieter heavy vehicles, the banning of heavy vehicles using residential streets as through routes is the only form of noise control available.

Local authorities should be aware of the shortcomings in a response-to-complaint-only method of traffic noise control. It is likely that a proportion of residents living adjacent to roadways carrying any through traffic is affected, or annoyed, by noise from those roadways. There is evidence that such residents do not complain because the generators of noise are usually anonymous and the householders are prone to believe that little can be done to abate the noise problem.

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OBSERVED AND PREDICTED TRAFFIC NOISE LEVELS AROUND ROAD JUNCTIONS IN THE U.K.

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R. R. K. JONES, B.Tech., Department of Civil and Structural Engineering, University of Bradford, U.K.

C. L. FOUVY, Transport Engineer, Planning Division, Ministry of Transport, Victoria

In an otherwise interesting and informative paper, it seems unfortunate that the authors did not actually quote the equations for predicting the single-hour or 18-hour values of L_{10} referred to in para. 8. It would have been interesting to