TABLE II.

Vertical Angle.	Maximum slope distance : feet.
2 deg. 30 min.	1,200
5 deg,	800
10 deg.	550
20 deg.	300

Except in very hilly country, few shots will have to be taken which are outside the limiting combinations given in Table II, but when these do arise additional precautions become necessary to maintain the standard of accuracy. These may be as follows :—

(1) Measurement of the vertical angle on both faces.
(2) When reading on the second face, the vertical angle should be varied slightly so that the stadia intercept is measured on a different part of the staff. Horizontal distance and vertical height should be calculated from the readings on both faces individually and the mean of the results taken.
(3) Additional care in ensuring verticality of the staff. This is best achieved by another member of the party assisting the staff-man, the latter holding the staff to face the instrument and the former concentrating on obtaining verticality by one or more of the means at his disposal. On a windy day, the staff should be propped with a ranging-rod.

Of all the sources of error, that most likely to give rise to the greatest and most frequent errors is divergence from verticality of the staff. This varies directly (approximately) as the vertical angle when the slope distance and error in verticality are constant. Within the limiting combinations, the greatest error from this source occurs in a shot with a slope-distance of 250 feet and a vertical angle of 20 degrees, when it amounts to 1·19 foot, or 43 per cent. of the total vertical error. Outside the limited range, the error in a shot of 1,000 feet slope-distance and 20 degrees vertical angle is 4·77 feet, or 66 per cent. of the total vertical error. The necessity for the utmost care in ensuring verticality of the staff when the vertical angle is 10 degrees or greater cannot be too greatly stressed.

The next most important source of error is inaccurate measurement of the stadia intercept. No large error should arise if a staff reading is taken at the centre horizontal line in addition to the stadia lines, and if the theodolite is fitted with a satisfactory telescope.

(iii) *Accuracy of Contours.*

It has been pointed out that the contours should depict the general topography of the survey area and should not be concerned with unimportant details. Their accuracy must, in the main, depend on the accuracy of the spot-levels which, as shown above, should rarely be outside the range of $\pm$ 1 foot 6 inches. If the spot-levels are sited with care and judgement and the Engineer's field notes are fully used in drafting contours, a section plotted from the latter, whilst being rather more regular than the actual section of the ground, should rarely diverge from it by more than 2–3 feet, nor be continuously above or below it for any considerable distance.

Discussion.

Mr. J. E. Cardell introduced the Paper, with the aid of a series of lantern slides.

He observed that certain views expressed in the first part of it were open to question, and he wished to make it clear that nothing in the Paper should be taken as authoritative ; but he thought that they should be ventilated and discussed, so that as far as possible a compromise might be

reached between the railway and even " super-railway " practice advocated in some quarters on the one hand, and an undue conformity with minor features of the landscape on the other.

The main thesis of the second part of the Paper was that it was not sufficient to site a length of road in such a way as to be merely reasonably satisfactory, and that, having regard to the importance of the matter, one should always aim at the very best line obtainable, and not be satisfied with anything less. It was suggested that the only way to achieve that was to start with the clearest possible conception of the function or functions to be served by the road and then to consider every reasonable possibility in the way of alignment and, by the process of examination, comparison and elimination, eventually to arrive at the selected line, and finally to locate that line in detail.

Such a procedure seemed, indeed, so eminently reasonable as to be hardly worth mentioning, and yet it was a fact that it was not by any means always followed. Many members would be aware of cases where a road had been surveyed and located in detail, and even constructional plans prepared, and eventually had been abandoned by reason of some consideration which ought to have been taken into account before the survey party was ever sent out on the ground. There had been in the past too great a tendency to deal with location by rules of thumb and by what was called personal judgement; but judgement, to be worthy of the name, should be based on a solid foundation of ascertained fact, failing which it was better described as opinion.

The methods and procedure had been set out with a view to arriving at the best line, and also with a view to setting out the results in such a way that higher authority could readily judge of those results, and to enable answers to be given to such questions as " What would happen if the line were swung this way or that on this or that side of a hill or valley ? " Prompt and reliable answers to such questions were a satisfaction to all concerned, and they bred confidence; like the quality of mercy, they blessed him that gave as well as him that received.

Appendices III and IV and the Plates were devised with a view to setting out the work in that way. The grid not only enabled levels and gradients, cuts and fills, to be assessed, but also formed the basis for the very rapid method of plotting and of computing cut and fill referred to in Appendices IV and V.

The Paper had been written more than twelve months earlier, and the Ministry of Transport had since issued pamphlets on road design and location which gave instructions for setting out certain typical profiles for cuttings and embankments. The profile for the embankment corresponded to the German profile, whilst the profile for the cutting differed from it, having a larger spread, and entailed more excavation; but actually both profiles were seen in Nature.

The Chairman observed that he would like to see the large-scale model

(Appendix I) brought into effect, and he hoped it might be possible to induce some body of high authority to look into the matter.

Mr. E. C. Boyce observed that the Paper gave evidence of considerable thought and care and a great deal of hard work. A considerable amount of road location work was being undertaken in the county of Gloucester. It was necessary to keep a perfectly clear mind and to decide where location ended and where design started; and in his opinion the finesse of the adjustments suggested in the relationship between horizontal and vertical curvature was a matter of detailed design and was not required in the location stage, which was merely a question of landscape selection and not a question of landscaping the road. He had felt very strongly for many years that the aesthetics of road design were very important, and he was glad to find that authorities were paying more attention to the subject than they did 20 or 25 years ago.

He did not believe that the selection or location of a road line was an exact science, but regarded it rather as an art, which would inevitably express to some extent the personality of the engineer engaged. If six engineers were sent out over the same country they would probably produce five or six separate lines, of which perhaps three or four would be as good as one another. The location of a road might be compared to the creation of a house by an architect. All houses needed a roof, walls, and drainage; nevertheless, if every house was to be designed in precisely the same way as its neighbours, the result would be a monotonous standard of uniformity, which was the criticism usually levelled against the "council house." An architect could design a house having the same capacity and the same number of rooms as its neighbours, but which would express his own personality and be his own design. In the same way, an engineer could design a road to fulfil its purposes, but it need not necessarily be on the same line as and exactly similar to another road. Some latitude should be given to the engineer to design the road as he saw it.

But the location of the road should be related to the country through which it had to pass, and therefore standardization could not be obtained. He did not agree with the German system of three separate standards for different classes of country, but considered that the location of a road should be decided on its merits in each case.

The adjustment of the line lay-out was a matter of feet, not miles, and therefore should come at the design stage. In the location of a road the most important consideration was engineering, combined with economics. Costs could not be disregarded. Amenities were important, but fundamentally the road should be designed for the vehicles that would use it. Consequently the designers of those vehicles should be consulted, to ascertain what they had in mind for the future and, in particular, what they were thinking about in terms of speed. Road engineers were designing the permanent way for a future vehicle about which they knew very little. A railway line was designed for use by various types of locomotive, but

there was not the wide variation in design which the road engineer had to meet. Therefore the closest co-operation should be effected between the road designer and the designers of the vehicles that would use the road.

The factor of speed should be considered in the design of roads, even in the location stage. Sir Malcolm Campbell, when Mr. Boyce had first met him, was a very active member of what was then known as the Safety First Association, yet he was a very fast driver. Fast driving had come to stay, and the speeds might even increase. Mr. Boyce had been told that cars were being prepared which would cruise at 100 miles per hour. If roads were to be located and built for the motor-vehicles of the future, it was necessary to look forward to the time when cars could be driven in safety at such a speed. Therefore the " drivability " of a road was a fundamental quality to which attention should be paid at the location and design stages.

Mr. C. S. Chettoe observed that the extent to which the influence of amenity in location was felt perhaps depended upon the type of country through which the road passed. The Authors had stated that it should be made up of curves which were so disposed in space as to give a pleasing effect; but that would depend on the actual curves and straights used and how they fitted together, whilst the relative widths of verges and carriageways, the separation of carriageways, and relative heights were also involved.

That meant that three dimensions had to be considered, and without some kind of model it was difficult to visualize the road. The model proposed by the Authors seemed rather elaborate in character. Something might be achieved by laying out the part of the road under construction in plan, and building up on the kerb lines the profiles of the actual kerbs. That should give the three-dimensional effect of the road. The road had also to be in harmony with the landscape, and that was more difficult, as the best results could be produced only by having an eye for landscape, walking over the road, and perhaps preparing a model. Regard should be had also to trees and woods, and even to future planting.

If the country was comparatively flat, it might be desirable to have regard to existing features; for example, the road might be aligned on a church or on other existing buildings. It was desirable, if possible, to curve the road when running through a wood, and perhaps to widen the central reservation so as to allow some of the woodland to remain between the carriageways.

The effect a bridge should have upon location was a very controversial question, and the bridge designer and the road designer should work together from the start. Minor bridges should be as unobtrusive as possible. If a bridge crossing was so important that the location of the bridge governed the location of the road, then the bridge was a primary feature and should appear so in the location. Mr. Chettoe wished to plead for a reasonable camber in cases of that kind. In many cases a good camber over a bridge looked right. That did not mean that a small bridge should

have a big camber, because that would be inappropriate; but where the importance of the bridge was sufficient a reasonable camber was justified.

The extent to which the bridge should be noticeable on a road depended largely upon the size of the bridge. For large-span bridges it was necessary to have the road on the straight; in other cases there was no reason why it should not be on a curve.

The relative economy of underpasses and overpasses depended largely on the particular site and the type of bridge. With an open type of reinforced-concrete or steel overpass, the bridge area might be rather more than with an underpass, because it would be necessary to bridge the slopes as well as the actual carriageways and cycle-tracks. Wing walls had to be considered, and possibly spandrel walls with arch bridges. Each case should be considered on its merits. Generally speaking, however, Mr. Chettoe preferred underpasses to overpasses, because too many overbridges tended to be rather monotonous; when dealing with the same type of road and the same conditions much variation of type was unjustified, and therefore it was difficult to avoid monotony. Moreover, too many bridges over tended to interrupt the views of the landscape, whilst approaches carried on banks were subject to settlement, which was less likely to occur where the minor roads were carried down in a cutting and taken under the main road.

In the same way, important junctions might influence the location to some extent. With a flyover roundabout on poor ground the overpass was slightly preferable, as less money would need to be spent on bridges. On the other hand, the half-and-half type (a roundabout carried up to a height of, say, 10 feet, and the road carried down 10 feet) was less obtrusive. All of those factors had an effect upon the location, and all required consideration.

He had been very interested to see the reference in the Paper to the economics of gradients, because some time ago he and a colleague had studied the matter in connexion with a very important river crossing. They had concluded that a high viaduct was unjustifiable from an economic point of view on the data which they had collected; and on consideration he felt doubtful whether, in fact, much economy would be realized by carrying roads on high viaducts, except perhaps in cases where the gradients were steeper than was normal in Great Britain.

Mr. Stanley Mehew observed that he wished to inquire whether the Authors considered that the existing standard width procedure gave sufficient scope for deviation in settling the final line in the detailed design stage, or that something more on the lines of the Parliamentary limits of deviation would be helpful to the designer. Mr. Mehew considered that that would be helpful.

He was very pleased that the Authors had dealt with the subject of amenity on the broad issues. Doubtless the type of fence, the type of kerb, and other details were important; but they were features which

largely harmonized with their surroundings through the softening influence of time. The broader question of the lay-out as affecting amenities was much more important.

He regarded the slackening of gradients on curves as a very desirable feature in the lay-out of a road of the type envisaged by the Authors. Would they consider, from a heavy transport point of view, that advantage on long hills would be derived from slackening grades at intervals, even though the intervening sections might be slightly steeper as a result? From his own experience in a fairly hilly area, he had found that heavy transport seemed to like an occasional slackening in the gradient. That question might with advantage be explored with the transport operators and the Authors' views would be welcomed.

Mr. Mehew could speak with some experience of methods of carrying out location surveys, as he had had the pleasure of working with Mr. Cardell on that class of work, whilst before the war, under his late chief, Mr. Millican, about 18 miles of road had been located by methods very similar to those described in the Paper, at a cost of about £70 per mile in country which could be regarded as difficult.

The model described in Appendix I was very interesting. Mr. Chettoe had emphasized the importance of a road harmonizing with the landscape and taking account of the terrain, and had stressed the essential importance of that being done from an amenity point of view. In considering the results obtained by a model of the type in question, Mr. Mehew could see a possible danger arising from considering the road, as it were, *in vacuo*, and thereby rather losing sight of the effect which the road would have on the landscape.

The adjusted cross-sections were of considerable interest, and doubtless the adjustment of the cross-sections in the way advocated by the Authors would result in the road harmonizing with or sinking into the landscape. But smoothing the cross-section in the way suggested by the Authors might result in loss of the effect of grandeur, hoped for in the construction of roads in certain circumstances, since the extent of the engineering works would probably be largely hidden, and hidden purposely, in order to sink it into the landscape.

Mr. Mehew wished particularly to congratulate the Authors on their painstaking research on the economics of gradients. In connexion with the general question of the economics of new road construction it seemed very desirable that, before a new road of the character referred to in the Paper was opened to traffic, data should be collected so that the economic value of the new road could be properly assessed. That would not be possible later, because the traffic would take the new road. A proper traffic survey on existing routes designed to show the economic value of the new road should be carried out in advance, and probably the question would then be not "Can we afford new roads?" but "Can we afford to be without them?"

Mr. R. T. Scott observed that, assuming the existence of a master plan, the engineer should have the sheet-anchor of cost to work from, as otherwise all the detailed discussion of amenity in the landscape would never get him anywhere at all. He would be governed by four factors, namely, standards, cost, his own individuality, and the individuality of the countryside. It was impossible to obtain long straight roads in Wales, whereas it was possible to obtain such roads in Lincolnshire.

For field work the engineer should prepare a set of 6-inch plans. By taking any larger scale into the field, he would lose his sense of perception; he could not view the land in sufficient magnitude, and the infinite detail which was picked up would confuse the whole issue. The 6-inch plan should show the boundaries of all farm land, because it was an interesting fact that a well-located road invariably ran along farm boundaries. That reduced the number of accommodation bridges, which in practice averaged out at two per mile if care was taken.

On the 6-inch plan the engineer would be able to set out a number of alternatives in pencil, and generally he could arrive at a strip within which the road would lie. The next stage should be the aerial survey. A typical aerial survey contract would give a contoured plan to 10-foot intervals at a cost of approximately £25 to £40 a mile. Mr. Scott believed that the cost of tacheometry was about £75 per mile. On the contoured plan provided by the aerial survey contract, a fully-revised 1 : 2,500 sheet was obtained, and there was no need for the location engineer to go on the ground again. On that plan he should be able to arrive at the best alternative—be able to demonstrate that it was the only alternative. The engineer should have all that information in the office; he could not go out into the field taking lines of levels all day.

Mr. Scott considered that 1 : 2,500 concertina plan proposed by the Authors was unnecessary at that stage. The practice in Gloucestershire was to trace on standard double-elephant sheet a strip plan in the top half, leaving the bottom half for the profile. The preparation of a standard grid negative to 1 : 2,500 horizontal scale and 1 : 250 vertical savoured also of elaboration, as it was possible to buy from any drawing office supply firm squared paper giving 1 inch to 200 feet horizontal and 1 inch to 20 feet vertical. Slavish adherence to the longitudinal section on the same scale as the plan at that stage seemed unnecessary.

The next stage was to run an accurate instrumental traverse down the strip or down the line of the road, and on that traverse to take all relevant details to within 200 feet from the line. That was then plotted in the office, and the final line was elaborated on that original traverse. He had found that it was necessary to have the original accurate survey to work from. Before the war he had had to prepare a scheme based on the old improvement line plans, and it had caused him a good deal of worry to get the road plan back on the ground.

Thus the details of location were divisible into four basic stages, namely,

the walkover, the rough contour survey, the accurate survey, and the final centre-line run and levelled, and the estimate for the scheme was built on that final centre-line. Amenity fell into its proper position in each case. In the first stage the position in the landscape was obtained; in the second stage the general treatment of the alignment; whilst the third stage included grade separation, the preservation of trees, slopes, and vertical curves. Each stage was watertight, and the scheme could lie dormant at each stage.

The universal road model had considerable merit, but it should come at the construction stage. The location engineer, if competent, should be able by visual checking to tell the merits of the soils at the start, and a complete survey should be taken at the end. The cut and fill could be balanced on the longitudinal section initially. Without elaborate care, the engineer could by eye take out the area on the profile; it was unnecessary to take out volumes, because he would be using a standard section. As the Ministry of Transport standards provided for approximately 3–4 per cent. maximum gradient, they were amply covered by the economics of the gradient.

Mr. A. T. Best observed that location was affected not only by physical features but also by others to which, for want of a better word, he might apply the term "political," in the sense that political geography was distinct from physical geography. The Authors had recognized that by stating that "note should be taken not only of physical features but also of building development and undertakings of all kinds."

The first of those factors that occurred to Mr. Best was the effect of administrative areas, and particularly of county boundaries. One of the alternative lines which it was possible for a road to take, according to the physical features, might lie entirely within a county, whilst the other might dodge to and fro between one county and another Obviously in such a case, that would govern the choice of route; it was desirable for the purpose of uniformity and maintenance that the route which was entirely in one area should have preference over that which was alternately in one area and another.

The location engineer had not an entirely free hand to use his own judgement; he was governed, and rightly so, by many forms of rule and regulation—Acts of Parliament, Statutory Rules and Orders, Ministerial circulars —all of which had to be taken into account.

The title of the Paper showed that the Authors were not concerned with built-up areas; but they seemed to have gone to the other extreme and to have had regard mainly to rural areas, In most cases, however, the ground to be covered was partly of one type and partly of another. That was very important, because valuable properties might be concerned and affected. Even in rural areas the question of severance of farm land arose, and the choice of one route as against another might depend on that, as one route might avoid heavy compensation, whilst another might incur it.

The most important factor was that rival schemes for development existed. Planning was in the air—town planning, planning of large steelworks, of factories for light industries, gas grids, electricity grids, oil lines, and so on. In the location of fifty or sixty miles of roadway in South Wales which Mr. Best's firm had undertaken for the Ministry of Transport, their engineers had been faced with that all the time. So far many of the schemes existed only on paper, and there was nothing to show on the ground; but in reality many interests were involved, and the engineers were continually met with such remarks as "Don't go there, you will upset so-and-so"; "Please don't go there, or we shall have to abandon a dozen houses on our housing estate"; and so on. Account had to be taken of all those things if the jigsaw puzzle was to come out right. The earlier that a road project could be undertaken and the line laid out, the better was its chance of surviving.

The promoters of road improvement schemes had many factors to consider in addition to the purely physical, and possibly those other factors furnished one of the reasons why road improvements took so many years to mature. For example, the Victoria Dock road was proposed in 1902 and opened in 1934. The road by-passing Neath, in South Wales, with which Mr. Best's firm were now concerned, had already a past history when it was first referred to the late Sir Frederick Palmer, Past President, I.C.E., in 1930, and it was hoped to cut the first sod during the present year, 1947!

Mr. H. M. Horrocks observed that he had been very pleased to hear Mr. Boyce's remarks on the scope of the location engineer. In his own less exalted capacity, Mr. Horrocks had found that there was a considerable amount of art in settling just the right place for the road and doing the work in the most economic way. It was difficult to impress assistants with the essential factors to be looked for and the details which should be studied. Many assistants were inclined to waste time in presenting much confusing detail which was difficult to sort out in the office. If they could only visualize their country, pick out the essential points, and deal with those clearly, it would be much easier for the man in the office who had to examine the plans and decide on the best line.

He agreed as to the desirability of some knowledge of agriculture; in dealing with landowners and farmers, if they could be met with some knowledge of their business the negotiations were much easier.

It was not yet certain that the detail supplied by aerial survey companies was sufficient to enable a road to be located without a certain amount of ground work afterwards. Such a proposal would need further careful examination.

Mr. Horrocks wished to plead for a more generous allowance of up-to-date light instruments for the use of survey staffs. The markings of the "Gayer" staff were extraordinarily clear, and misreading was almost eliminated; but he had found on inquiry that the makers had abandoned its production. Whether that was because engineers were so conservative

they they would not change to something fresh he did not know, but the fact that they stuck to the "Sopwith" markings made him wonder.

For approximate work within the limits of accuracy envisaged in the Paper—with which he agreed—he had attempted to find out something about barometric or aneroid surveying. The few details which he had obtained suggested that good use could be made of a pair of very accurate aneroid barometers, Could the Authors furnish any information on that subject? They had advocated all-tacheometrical surveys; but it was very difficult to secure the skilled assistants necessary, and Mr. Horrocks would prefer running a line of levels through the approximate line of the road before starting, and working from those temporary bench-marks and turning them into tacheometrical stations. If an error occurred it was very easy to check back and pick out the series of observations which were incorrect.

The Paper should be very useful to engineers running location surveys, and they would be saved considerable time when instructing new staff in their duties.

Professor F. G. Royal-Dawson observed that the article by Koester covered a good deal of the ground traversed in Professor Royal-Dawson's book published two years earlier,[1] in which, he had dealt with the dangers of monotony on long straight roads and the radii of curves on motorways.

The easing of gradients on curves was not a new idea; it had been the practice on railways for many years. The idea was that on a curve the vehicle had its own resistance which should be added to the ordinary tractive resistance. The allowance made on some railways, which was empirical, was 0·04 per cent. per degree of curvature, and it was applied only to the ruling gradient. If the ruling gradient was 1 in 30 (3·33 per cent.), and the curve was, say, 6 degrees, the allowance would be $6 \times 0{\cdot}04 = 0{\cdot}24$, and 0·24 subtracted from 3·33 gave 3·09 (1 in 32·4) as the reduced gradient. Something could be said for easing a long straight gradient, especially if it were steep, at certain points to relieve the strain. In many cases the question settled itself according to the contour of the country, but such a refinement was not needed on ordinary roads.

The engineer in charge of a project often had little choice of action, being hemmed in by instructions from one side or another. Amenities had been considered in the Paper almost entirely in the artistic sense. If an engineer had no artistic sense, it could not be put into him; but in architecture a fundamental principle was that a structure should be so designed as clearly to indicate its function, and if that condition were fulfilled the actual design was a matter of taste.

The plan and section given by the Authors appeared to be too elaborate for a trial line and not elaborate enough for the finished route. The usual way of plotting surveys was to show only the tangents, with the record of

[1] "Motorways, Flyovers, and Mountain Roads." Spon, London, 1938.

their lengths and the intersection angle of the tangents, and to put in the curves when the final route was selected. An example carried out by a Rumanian engineer had been given in Professor Royal-Dawson's book.[1]

Mr. F. L. Smith observed that in introducing the Paper, Mr. Cardell had remarked that the importance of location was apt to be overshadowed by other aspects. Mr. Smith would go further and add that the engineering aspect was sometimes apt to be overshadowed by other aspects of location to which attention had been drawn by Mr. Best. So many factors had to be taken into consideration that, as a location engineer, Mr. Smith's own approach to the problem was, firstly, to lay down a line which satisfied him on engineering grounds, and then to adapt it just so far as was necessary to meet all the reasonable demands of agriculture, planning, amenity, and the other relevant factors.

Little reference had been made in the Paper to road safety and speed curvature. He agreed that in very difficult country it was not possible to be dogmatic about standards of curvature or maximum gradients, but he considered it to be very important that before the location of any great length of road was undertaken, a reconnaissance of the terrain should be made and certain standards should be fixed, having regard to the difficulties of the terrain, and that those standards should be kept in mind with a view to avoiding sudden changes in the standard of design and location. That appeared necessary more particularly from the point of view of safety, and it implied some standards of minimum radii of curvature. In that connexion it was very important to preserve the corresponding visibility attached to those curves, both horizontal and vertical.

In his book " The Roads and the Problem of their Safety," Sir Malcolm Campbell had complained rather bitterly that ever since the inception of stage coaches on the highways progressive restrictions had been placed upon mechanical vehicles because of the incapacity of the highways to cope with them. The late Mr. A. H. D. Markwick, M.I.C.E., had told Mr. Smith that on the *Reichsautobahnen* he had travelled a distance of 110 miles in a little more than 100 minutes in comfort and without any sign of strain. Mr. Markwick had not said whether he was asleep during that period, so that Mr. Smith could not comment upon the soporific effects of the journey; but it did emphasize that high speeds might have to be dealt with and that in locating roads of the motorway class that fact would have to be borne in mind.

Mr. Smith had been faced with the problem of long maximum gradients in the negotiation of very large escarpments in Gloucestershire, and had often wondered whether it would not be preferable to relax on the maximum gradient and negotiate such steep escarpments in steps. He was pleased that that view had been supported by other speakers.

He had never regarded the use of the " mass-haul diagram " as of great

[1] *Loc. cit.* (pp. 97 and 98).

importance until the design stage was reached. On location the main concern was a balance of cut and fill, and in that respect emphasis should be laid upon the nature of the soils being dealt with. Variability in shrinkage had to be taken into account. The percentage factors of bulkage and shrinkage might be very high.

The contour survey was extremely useful and important; but in dealing with about 60 miles of basic motorway location in Gloucestershire Mr. Smith had had occasion to contour only about half-a-dozen individual sites, three of which were actually on the site of the Severn Bridge. Working in that way was rather more difficult, as it called for something of a *flair* for country. That might be summed up as the ability to think in three dimensions, to visualize the road as it would appear when built, and to have an appreciation of the countryside and of how the road would fit into it. In doing that work, rather as a lone wolf during the war period, he had made use of a 5-inch aneroid barometer, without any base check, and had found it very useful and quick. He had corrected his errors on a time basis, and had found that, by taking suitable days, when there was a steady barometer, he could obtain results, sometimes within 2 feet and generally within 5 feet, which were sufficient for his purpose of preliminary trial profiles.

He wished to emphasize the importance of walking over every yard of the projected route and of following it up, even after a contour survey, with an accurate traverse line.

Mr. A. J. H. Clayton observed that the authors had quite rightly expressed the view that in considering the economic aspects of gradients (Appendix II) the comparison could be based on all-in costs of transport, including time. He supported that view because, after all, roads were built and motor-cars and lorries bought in order to buy time. The private motor-car might be bought for the purpose of taking the owner and his family to the seaside, and that meant that he was buying time at the sea, so that if he had to spend another half-hour on the road he was not getting so much for his money.

The Authors had dealt very completely with the question of gradients from the point of view of fuel-consumption, but not from that of the effect on time. Steep gradients, both up and down, reduced the speed of vehicles: even a powerful car, capable of maintaining a high speed uphill, tended to go slower. In some records of observations made in America, where motor-cars were at least as powerful as in Great Britain, it was found that, whilst with gradients of up to 3 per cent. there was not very much in it, on a 5-per cent. gradient the average of up and down speeds meant $12\frac{1}{2}$ per cent. extra time for cars and 14 per cent. extra for lorries. On a 7-per cent. gradient—which was not normal, but was not impossible—the extra time required amounted to 24 per cent. for cars and 58 per cent. for lorries. The decrease in speed was fairly general over the whole range of speeds which drivers adopted on easy roads free from obstructions.

That meant a substantial loss of time—say 1½ to 2 minutes per mile on a 5-per cent. gradient—and 5-per cent. gradients were nothing out of the ordinary in hilly country. The total loss from that source could be calculated by using the Author's Tables for fuel-consumption costs; for the typical case considered by the Authors in Appendix II, the cost was found to be of the order of £200 per day, in comparison with £300 per day for the cost of fuel.

*** **Mr. C. F. Armstrong** observed that it was unfortunate that neither in the Paper nor in the discussion had more than passing reference been made to the important part which soil surveys should take in road location. Whilst he appreciated that many considerations—not all of an engineering nature—would be involved in the determination of the general location of the line, he considered that it was essential to know with certainty what subsoil conditions would have to be met.

A good location engineer could deduce much useful information about the soil by careful observation and local inquiry. The published geological drift maps and memoirs yielded still further information, which could be supplemented by reference to much unpublished information available in the Geological Survey Offices. A study of that information would reveal a number of sites where difficult soil conditions were likely to be encountered or where the recorded information was not sufficiently definite.

On those sites it was essential to undertake new boring and soil testing as part of the work of location, even though the final formation-levels might not be available as a guide. With the resulting information it should be possible to answer such questions as: "Will soft clays, hillside springs, etc., affect the stability of the cutting slopes? Can bridge sites be slightly offset so as to utilize subsoil of better bearing capacity? Will soft clays or peat be met in crossing valleys?" In each case accurate foreknowledge of that kind was essential, even if the permissible lateral shift of the centre-line was only small.

Although the subsequent detailed soil survey which would be necessary would help to decide on the most suitable construction methods, the preliminary soil survey might indicate the existence of obstacles likely to prove so expensive to overcome as to outweigh some other consideration, such as the demolition of buildings or costly severance.

Mr. H. N. Jenner observed that the highest praise was due to the Authors for their pioneer work. So well and fully had the subject been treated that the Paper might well be taken as a much needed standard.

With the need of such a standard in mind he suggested that the practical usefulness of Part I would be increased if the principles described were summarized in groups in order of importance. Further standardization of the evaluation of each principle would enable a group or groups of

---

*** This and the following contributions were submitted in writing.—SEC. I.C.E.

individuals to locate sections of a route with common priorities and values. That system would enable selection of local alternatives or choice of the whole route to be made on a factual and uniform basis. The values could be given in the form of percentages following standard group headings of principles in the report for each route. The usual descriptive matter would follow and include percentage awards (to a given scale) by which each principle fell short of the ideal for the length of route under consideration.

Mr. Jenner suggested the following Group headings in order of priority, with sub-titles :—

1. *Primary functions.*
   (*a*) Main route A–B.
   (*b*) Connexion M.
   (*c*) etc. Other given connexions.
2. *Permanent Features.*
   (*a*) Curves (excluding 3,000–7,000 feet radius)
   (*b*) Gradients (excluding $2\frac{1}{2}$–$\frac{1}{2}$ per cent.).
   (*c*) Safety (including limitation of access).
   (*d*) Effect of road on landscape.
   (*e*) Scenic value of road.
   (*f*) Use of existing roads.
3. *Cost* : £. *s. d.*
   (*a*) Main route formation.
   (*b*) Junctions.
   (*c*) Bridges.
   (*d*) Earthworks.
   (*e*) Land and accomodation works.
   (*f*) Severance, etc.
   (*g*) Total initial cost.
   (*h*) 20 years' mantenance cost.
4. *Temporary or transient features.*
   (*a*) Private amenities (including severance).
   (*b*) Suitability for artificial landscape treatment.
   (*c*) Suitability for construction by sections.
   (*d*) Existing development.
   (*e*) Planned development, etc.

Mr. Jenner considered that Part II of the paper formed an excellent procedure to adopt for standard practice, with the following minor suggestions and modifications :—

Maps.—One-inch and $\frac{1}{25000}$ Ordnance Survey maps should be added. The 1-inch map should be prepared as a copy of the Master Plan : it was necessary to enable the road (or section of road) to be located visualizing the wide aspects of its function.

The $\frac{1}{25000}$ map was little known, but was an ideal map for study and

trial lines, for recording existing and planned development, geological details, and other features which might be affected or might affect a route. A new edition covering England and Wales had 20-foot contours (10-foot contours in parts), and had proved sufficiently accurate for preliminary investigation of gradients and earthwork. It obviated tacheometric contouring, as in the few places where maximum gradients, junctions, development, etc., necessitated more accurate contours, those would be as well done first as last with the more accurate dumpy level method. Both maps had the national grid, which should be universally adopted for precise reference.

Appearance.—When considering appearance and amenities the use of tapes on the actual site should not be overlooked. Also a more convenient medium was photography; views along and sideways to the route could be used to show the road drawn in its proposed location.

Soil Survey.—A complete soil survey was necessary in border-line areas, or areas where excavation might not be suitable (or economically made suitable) for placing as the core of embankments carrying the road.

Mr. James E. Lee observed that the Authors had opened a subject covering a wide field and, in their " Principles of Location " had offered a comprehensive appreciation of the requirements of planning in relation to both efficiency and amenity.

Civil engineering location work was dependent upon thorough appreciation of the requirements of the finished work, and that probably explained apparent lack of literature on the subject. The location engineer should have a background of wide experience, which could not be gleaned from books; but he should study the records of current practice and theory in its relation to design and construction in order to keep abreast of progress.

Even on routes outside built-up areas different conditions would need to be observed and, in considering the broad outlines of a proposed route with a view to incorporating the principles embodied in the Paper, two main classifications came to mind, covering respectively routes across virgin country and those partly utilizing existing roads coupled with the breaking of new ground at intervals to avoid existing communities.

The former classification seemed likely to be in the minority, particularly in England and where the new road was intended to relieve traffic loads in industrial areas such as the North, the Midlands, and South Wales.

Similarly, the diversity of the obstacles which so frequently occurred in the form of watercourses, roads, railways, canals, service mains and buildings rendered it doubtful whether the former could apply to any appreciable extent.

Apparently Koester's view was based only upon the construction and operation of *Reichsautobahnen*, and it was debatable whethe rsuch grandiose roads could form a model for British trunk roads to an appreciable extent, particularly in planning. There would appear to be only a limited prospect

of employing long sweeping curves solely for effect, or of the possibility of excess length of straight sections.

Great Britain enjoyed a highly developed control of land drainage and erosion which could have a considerable bearing upon location requirements.

The Authors appeared to incline towards a study of the design of slopes of enbankments and cuttings and, in their scrutiny of the observations of Koester and of traffic requirements generally, they led to the assumption that they visualized a location plan and section as being a finalized line. On the other hand they extenuated the acknowledged approximation of tacheometric contouring, and even suggested delay in levelled sectioning until constructional work was in progress.

Mr. Lee considered that at an early stage definition was required of the limits of accuracy and, in fact, of the true requirement of the survey.

Whilst acknowledging the necessity for a walking reconnaissance and preliminary line, coupled with study of maps and ordnance sheets, the location survey should provide adequate information to enable the designing engineers to proceed without further survey; the land valuers to negotiate for the land and assess compensations; and all parties concerned to be able to formulate their requirements for incorporation in the final constructional drawings. Town Planning requirements were becoming increasingly detailed and increased the need for such a complete survey, apart from the interests of so may Authorities and Departments generally.

That was particularly necessary in dealing with the cases of roads only partially across new ground. If the road broke virgin country, there seemed to be no reason why the use even of percentage gradient to ground-line sections should not be adopted, apart from reduction in the detailed survey work generally.

There could be little doubt that tacheometric contouring was well worth considering, but a broad statement of the errors might be misleading. The British climate was not conducive to long sights with an instrument, particularly in hilly country where rain and mist so often reduced visibility. Moreover, in traversing rough and hilly ground the multiplication of stations was high and produced corresponding danger of error.

Taking into account the fact that 3 inches increased depth of excavation alone over one mile of dual-carriageway road could involve an added expenditure in excess of £800, it was worth while to consider whether the initial expenditure of a further £50 per mile on levelled sectioning would not be economical in the long run, thus providing details sufficient for an accurate lay-out and obviation of constant detailing and adjustment as work proceeds.

With regard to Fig. 3, Plate 1, Mr. Lee found it difficult to understand why so extensive a strip had been contoured. The route shown was straightforward, with no gradient steeper than 1 in 38. It was debatable whether such survey work could be carried out, particularly during winter months, for an expenditure of £120 per mile, as visualized in the Introduction.

A contour plan based upon tacheometric readings could be reasonably accurate when based upon a traverse where the stations had been levelled through. Accordingly it would appear to be necessary to study the alternative value of spending slightly more on the initial survey with a view to providing a levelled section, thus reducing the possibility of extra measurement in the contract, coupled with a definite reduction in the cost of Resident Engineering staff when the work proceeded.

Mr. Lee wished to plead for delay in consultations until after the reconnaissance. There could be no more effective way of reducing the efficiency of a locating engineer than by filling his mind beforehand with a series of doubts and objections. He should proceed with an open mind to secure the best possible line and thus provide for consultation his conception of the best route coupled with an appreciation of any alternatives in debatable cases.

Mr. J. J. Leeming observed that the Authors had rightly stressed the importance of avoiding monotony in road design, but they seemed to have underestimated the importance, in that connexion, of varying the width of the central reservation and the relative levels of the carriageways and, in fact, to have accepted parallel carriageways as the normal. But that certainly tended to monotony, and it was far preferable to have the carriageways at variable distances apart and at different levels. Moreover, that practice made for economy on sidelong ground by reducing the excavation, and helped considerably in reducing dazzle at night.

A possible source of great economy in the planning of new roads, combined with improvement to the amenities, lay in the use of selected stretches of existing road as one of the carriageways, and planning the new carriageway independently of the old one. A standard of curvature which would not be suitable for a two-lane road might be quite unobjectionable on a one-way road, because the restriction due to curvature might be due far more to restriction of vision of oncoming traffic than to the curvature itself. If the oncoming traffic were removed to another road, speed could be virtually unrestricted. In such cases, the other carriageway could be quite a long way from its companion without inconvenience.

The Authors appeared to contemplate 6,000 feet for the maximum rate of curvature, as adopted in Germany. Their statement that " above 10,000 feet a curve gives no advantage over the straight in reduction of headlight glare " was doubtless true, but as an argument for a maximum radius of curvature it was irrelevant. The reduction in headlight glare should be effected in the central reservation, either by planting, if a constant width and level carriageways were unavoidable, or, better still, by separation of the carriageways. On the other hand, the curve offered immense advantages in reduction of monotony, and it would be far better planning to lay down that straight stretches should be reduced to the minimum, and that the curve should be the norm in layout, rather than the straight.

An example of a bold effect in planning, slightly marred by the straight

in the foreground and the parallel lanes, was shown by a photograph taken from a moving bus on the Dresden-Chemnitz *Autobahn* (Fig. 5, Plate 1). The bridge over the *Grosse Striegis* lay in the near valley.

In Appendix II, the fact that running downhill using the engine as a brake meant that a very rich mixture was drawn into the cylinders seemed to have been ignored. Actually the assertion had been made that running downhill in that way used nearly as much petrol as the corresponding climb, as well as causing more damage to the cylinders and bearings.

Mr. D. J. Maclean observed that the Authors seemed to have very seriously underestimated the importance of a soil survey in connexion with both the location of a new road and its design.

During the past 10 years the Road Research Laboratory had been concerned with soil surveys for several important roads, and in quite a fair number of cases the actual location had been influenced by the results of the survey.

On the other hand, the Authors rather overestimated the value of Geological Survey maps for road location. In general, those maps did not indicate changes in rock or soil type with sufficient accuracy; moreover, it was not possible to judge the engineering properties from the geological type: for example, the Bracklesham beds of the London basin varied from a clay of low mechanical strength to a sandy loam having good mechanical qualities.

Also, it was incorrect to suggest that a sufficient knowledge of subsoil conditions could usually be obtained from an inspection of the surface ground, even when that was coupled with a study of the appropriate geological map. Recently Mr. Maclean had come across a site where a bed of peat was underlying a layer of sand. That was typical of many other cases where it was impossible to judge subsoil conditions except by making the necessary borings.

Apart from its value in connexion with road location, a soil survey could be of inestimable value in obtaining a proper road design. It was possible to design safe slopes for embankments and cuttings; to obtain essential information on cut and fill; to estimate the stability of the foundation of embankments, bridge abutments and other structures; and to design a pavement of sufficient strength to carry the anticipated traffic.

The Authors had stated that the Paper had been written principally with reference to the proposed motor roads to be constructed in Great Britain. Those roads would require much more extensive earthworks than any roads previously constructed, and Mr. Maclean hoped that full recognition would be given to the essential requirement of a soil survey, for both their location and design.

Mr. P. J. Maddicks observed that roads running mainly in an east-west direction should be located sufficiently far from trees on the southerly side, because during the winter months in Great Britain roads which were screened from the sun by trees were always wet, and in addition to being

liable to be covered with ice during cold weather, the road surface suffered more rapid deterioration than did lengths subject to the drying action of the sun.

He considered that more space might have been devoted to gradients, a subject which had been neglected in Great Britain in comparison with horizontal curvature. As indicated in Appendix II, the economics of gradients were worthy of considerable research, especially to determine suitable gradients which could be negotiated in top gear by various classes of vehicles. In laying out a new road, that ruling gradient should be adhered to, and considerable horizontal deviations should be accepted in order to maintain it, even to the extent of constructing properly designed "S" bends. The advantage of maintaining "top-gear" gradients was immediately apparent to anyone travelling on the more important alpine roads on the Continent. If steep gradients had to be constructed, the gradient should be eased off for short lengths, at frequent intervals, to allow vehicles to regain speed. Research was required to determine what those lengths should be.

The Authors had stated (p. 11, *ante*) that often the lower strata in cuttings were stronger than the upper and would therefore permit of steeper slopes, whereas, in quoting the German memorandum No. 1, it was recommended that the lower slopes should be flatter. Observations of existing cuttings disclosed that, as a result of natural agencies, the profile was often nearly vertical for the upper 2 or 3 feet, flattening out considerably at the bottom.

Mr. Maddicks did not consider that the Universal road model described in Appendix I would have very much practical value. Its use would appear to be confined to the study of kerb lines, which were very often influenced by the background of the surrounding country, including sidelong sloping ground and the effect of buildings, etc., which often created optical illusions; those effects were only observable on the ground.

Mr. G. E. Scott observed that the Authors had dealt with the subject mainly from the aspect of road location in the British Isles. In view of the claim of The Institution to be the leading Civil Engineering authority, in the British Empire at least, that limitation did not seem wise. For example, the Authors had stated that the cost of a new major road would run to £120,000 per mile. In the dependencies engineers thought themselves fortunate to be given grants of £1,000 per mile, excluding the cost of land acquisition. The "Burma Road" was originally opened for motor traffic for much less even than that limited sum.

In any road location the first essential was to locate the various points through which it should pass, known as "fixed points." Those might be passes or saddles in ranges of mountains, sites for bridges or ferries over rivers, and towns, villages, or special buildings. For a road to be satisfactorily located in hilly country it was sometimes necessary to decide whether it should follow a ridge or a series of ridges, or a valley line.

Drainage and bridge costs were obviously reduced considerably in the former. In ordinary circumstances economy of construction and subsequent economy of maintenance were of considerable importance, but the Authors seemed to have a remarkable disregard for the interests of the taxpayer.

The Authors had assumed the availability of large-scale Ordnance maps. Often that was not the case, and in heavily-wooded country it was often not possible to carry out even a preliminary ground survey or reconnaissance, so that trial lines had to be opened out, and the first estimate of cost had to include " Survey and Opening out." Aerial surveying afforded a possible solution for that " blind " location, and Mr. Scott believed that it had been employed during the campaign in Burma.

Mr. F. N. Sparkes observed that an intensive effort was required to develop methods of assessing the economics of road location, construction, and usage. The Authors had considered the subject chiefly in relation to gradients, but the study of the economic aspect had a wider field of usefulness in relating the probable life of the road to its costs of construction, usage, and maintenance. Obviously the location influenced the construction costs: it was a matter for individual consideration whether a long shallow gradient was better or worse than a series of steeper but shorter gradients from the point of view of usage. Undoubtedly a good deal could be said for the long shallow gradient, in that it provided, or might provide, a better opportunity for assisting the smooth flow of mixed traffic. If the road were designed to provide a smooth flow from one point to another, then clearly that would best be achieved by arranging gradients so that heavy traffic would not be unduly slowed down. The Americans had studied that problem intensively during the past few years, and every effort was being made there to reduce gradients to the minimum. It had been recommended that gradients should not normally exceed 5 per cent., and steeper gradients were allowed only on short lengths or road in very hilly country. For roads carrying heavy traffic and where steep gradients had to be adopted, consideration might be given to the possibility of increasing the number of lanes over the crest of the hill so that heavily-laden and slow-moving traffic could draw in to one side to allow the faster-moving traffic unrestricted flow. The Authors had expressed the view that a maximum gradient should not be rigidly fixed: but that surely depended upon the main purpose for which the road was constructed. Whilst rigid adherence to a maximum gradient figure might increase the cost of construction in certain circumstances, that should be balanced against the expected saving accruing from the possibly smoother flow of traffic with the shallower gradient.

The effects experienced on the German motor roads in driving at high speeds for a considerable length of time appeared to have been found also in America. On the Pennsylvania Turnpike—a dual-carriageway road approximately 150 miles long, located on the site of a projected railway

which was never completed—the gradients were slight (maximum 3 per cent.) and the curve radii large. When traffic first used that road, considerable trouble was experienced from over-heated engines and from tire-bursts due to the maintenance of high speeds for a long length of time, and it was found necessary to introduce a speed-limit of 50 miles per hour.

In considering the functional purpose of the road, the Authors did not seem to have paid sufficient regard to the nature of the traffic which was to use the road. Much information could be obtained by a properly managed and co-ordinated series of traffic-counts in the vicinity of the proposed road. At the same time, observations should be made as to the origin and destination of the traffic in the vicinity, so that an estimate, based upon known fact and not upon intelligent guesswork, could be prepared of the volume of traffic desiring to use the projected road. In so far as the requirements of the traffic influenced location, traffic studies of that kind would appear to be more logical than the " score-table " method suggested by the Authors.

The Paper dealt with conditions in Great Britain, but it was also interesting to consider the application of the methods suggested to roads in the Dominions and Colonies. When a long length of road had to be constructed through barren country as cheaply as possible, the use of aerial survey was of considerable assistance in determining the location. That subject had been carefully studied in the United States, and some work had also been done in Great Britain. In constructing roads over such terrain the precise location of the road, or part of the road, might be determined by the presence or absence of suitable stones and aggregates in the vicinity of the proposed line. Aerial surveys enabled such deposits to be recognized, and a balance could then be struck between the economics of the construction operations and any deviation in the proposed line of the road. The aerial survey might also indicate the presence of unsatisfactory soil, such as peat, and so influence the location.

The Authors, in reply, observed that they were gratified by the interest which the Paper had aroused and by the kindly reception which had been given to it.

Many of the omissions and scant treatments to which attention had been called by the speakers had resulted from the necessity for reducing the length of the Paper to conform with limitations imposed by the paper shortage. As first presented, it had referred to the uses of 1-inch, 1/25,000, and 6-inch Ordnance Survey maps, and the Authors agreed that the 6-inch was in general the most useful and convenient on the ground. The Paper had also itemized the consultations usually found necessary, including that with the Mineral Valuer, which had often saved much waste work. The Authors could not agree with Mr. Lee's deprecation of consultations in the early stages, having knowledge of cases where weeks, or even months, of detailed work had had to be scrapped owing to neglect of that elementary precaution.

Other apparent omissions were accounted for by different conceptions of the scope of a location survey. The Authors considered, for example, that the Origin and Destination Census was a matter which ought already to have been undertaken and the results considered in connexion with the decision in principle to provide the road as a constituent part of the master plan.

It was evident that a similar difference of opinion (namely, as to scope) accounted for the criticism that the work was carried to too much detail and for the suggestion that the relation of horizontal and vertical curves, being a question of design, should be left to be undertaken at the scheme stage. It was difficult to see how any substantial adjustment could be made at the later stage, without varying the location line; Mr. Mehew had, in fact, pleaded for latitude within specified limits of deviation.

As Mr. Best had pointed out, however, there was often a time-lag of years between location and execution, and the Authors had little doubt that that would often be the case in the future. Whilst, therefore, they would agree that a case existed for protection within limits of deviation pending location—provided that the latter was not unduly delayed—it would obviously be neither reasonable nor realistic to expect landowners and Local Authorities to wait indefinitely for reasonably precise information. The Authors felt, therefore, that as a general rule the location line would have to be regarded as final and that location should accordingly be in such detail as might be necessary to ensure the practicability of the ultimate scheme and, in the meantime, to define the land required with reasonable accuracy.

With regard to the suggestion that levelling for contours might be carried out by the aneroid barometer, the difficulty was that even if it were found possible to achieve the same degree of accuracy as by tacheometry, the positions of the numerous spot-levels required would have to be " fixed "—presumably by theodolite. Hence it was felt to be doubtful whether any real saving would result. The Authors agreed, however, that it might be a very useful method for rough work.

Several speakers had referred to the question of slackening gradients at intervals on long hills. The Authors considered that that was desirable and they had, in fact, adopted the expedient in a case giving an average gradient of 4 per cent. over a distance of more than 4 miles. It was doubtful, however, whether vehicle designers or anyone else could give a conclusive opinion on the point, having regard to the very wide range of vehicles and uncertainty as to future trends of design, which last might well depend upon the retention or otherwise of the horse-power tax. The Authors agreed that there was nothing new in easing gradients on curves, which was, in fact, typical of the oldest roads in the country—those which had been located by trial and error. With the advent of the survey and the drawing-board, however, a tendency had arisen to consider horizontal and vertical alignment separately and that eminently reasonable feature had therefore tended to disappear.

The conception of road location as predominantly a matter of judgement, flair, or intuition, still appeared to command a good deal of support. The Authors believed that that was a phase through which all branches of industrial and other activity in Great Britain seemed destined to pass and, unfortunately, it usually required the impact of dire necessity, resulting from foreign competition or a major war, to enforce recognition of the merits of the scientific approach. In that connexion, criticism of the Universal road model had been expressed, on the grounds that it dealt with alignment in isolation from the surrounding landscape. It was of the essence of the scientific approach that the subject should be first analysed or broken down into its constituent parts and each part or aspect examined in isolation. Only when that had been done could the matter be properly considered as a whole.

The view had been expressed in the Paper that the cost of a full-scale reconnaissance and location-survey *need rarely approach* £120 per mile. In the Authors' experience the *all-in* cost, up to and including preparation of final plans, had usually been considerably lower. Figures quoted in respect of aerial survey covered only the preparation of the contoured plans and, in order to establish a fair comparison, allowance would have to be made for the other stages necessary, including walking reconnaissance, drafting of lines and profiles, and preparation of final plans and sections, when it might be found that there was not so much difference as was sometimes thought.

The Authors did not regard it as " slavish " to use section paper adapted to the purpose instead of something which had only the merit of being commercially produced, especially when its use facilitated the very rapid methods of plotting and computation described. Inspection of longitudinal sections could hardly be a reliable guide to balance of cut and fill, having regard to the varying widths at different heights and depths.

Mr. R. T. Scott's suggestion that " a well located road invariably ran along farm boundaries " was interesting, but was not in accord with the Authors' experience, as confirmed by inspection of the occupation maps which had been prepared by the Ministry of Agriculture. On the contrary, they considered that road location had in the past paid far too much respect to boundaries—hence the tortuous alignment of many existing roads. Neither could they agree with Mr. Best as to the overriding necessity of having regard to district boundaries, which regard had, in fact, operated greatly to the disadvantage of many schemes. District boundaries had been altered in the past and would doubtless be altered in the future.

MADE AND PRINTED IN GREAT BRITAIN BY WILLIAM CLOWES AND SONS, LIMITED, LONDON AND BECCLES.