justified, but instead to strike a middle course based on a careful investigation of aircraft performances and trends. That seemed to lead straight to the provision of the minimum which was necessary for safety without incurring expenditure and producing difficulties for which there was no valid reason.

The figure of 94 per cent. for the usability of one NE-SW runway direction in the London area with a maximum cross-wind factor of 15 miles per hour seemed a little high. Similar calculations which the Author had made gave only 88 per cent. which, with the 99 per cent. maximum total usability for a three-runway system which he had obtained, left 5½ per cent. to be catered for by each of two secondary runways. Those figures of 6 per cent. (the time lost according to Wing-Commander Wilkins's calculation) and 5½ per cent. for the use of each secondary runway in the Author's calculation, did not seem high expressed in that way, but they were equivalent to three weeks in every year, and he did not think that such a large aggregate time-loss would be viewed with equanimity by an airline which had to run commercial scheduled services. It seemed that the only way to avoid the use of ground and the expenditure of money involved in providing more than one runway direction, was to make aircraft less sensitive to the effect of cross-winds, whether by the universal adoption of the swivelling or " drift " undercarriage, or otherwise.

He welcomed Wing-Commander Wilkins's suggestion that a Paper on radio and radar as applied to airports should be submitted as soon as possible to The Institution, as those sciences undoubtedly had a considerable bearing on the subject of airport design. So had air traffic control methods, and he hoped that one day members would see a Paper on that subject.

In conclusion, he wished once more to express his appreciation of the kind reception given to the Paper, and of the very interesting discussion, which showed clearly the widespread interest taken in the subject.

Paper No. 5433.

" Traffic Capacity of Roundabouts at Road Intersections."†

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Mr. H. W. S. Husbands observed that the Author's thesis was based on a number of assumptions of doubtful validity, but the general conclusion was that the maximum capacity of a roundabout could scarcely exceed

† J. Instn Civ. Engrs, vol. 23 (1944–45), p. 149 (Jan. 1945).

half the peak capacity of the roads entering the intersection. Firstly, he had assumed that a small four-way roundabout would have the same capacity as a similar signal-controlled junction. That capacity obviously could not exceed half the road capacity, since each road was held up for at least half the time. Similarly, it might be inferred that the capacity of a six-way junction could not exceed one-third of the road capacity, if three equally important arteries crossed there, as each would be held up for at least two-thirds of the time.

Fig. 2 showed fourteen actual counts of traffic at roundabouts (presumably all four-way) of varying traffic-density and a formula was proposed, conforming to diagonal lines for lane-density, converging to a maximum at the top left-hand corner. No details were given for verification, but in the formula the capacity would seem to vary directly with the number of lanes (or density) and size of roundabout, completely ignoring the fact that the interference (cross-traffic or interweaving) increased not directly but as the square of the density or number of lanes per road, as Mr. Husbands had showed ten years ago. Further, it was not clear, but might be inferred, that the formula was intended to apply also to six-way roundabouts, but there again Mr. Husbands had proved that although the increase in traffic over a four-way roundabout, at the same density, was only 50 per cent., the cross-traffic was three or four times as great and fourteen times as much as with a fly-over, and that would certainly reduce the peak load capacity to a much smaller fraction of the road capacity; no allowance for that was visible in the formula. Moreover, the actual instances plotted in *Fig. 2* would seem to belie the formula proposed. Of the nine three-lane and four-lane points, only four were above the half-saturation density line, and only one of the five points of over four-lanes, so tied. Hence, there would seem to be no justification for the four traces converging to A, as shown; in fact the average line for the five points of larger density ran from 400 vehicles per hour on the right to a maximum of about 700 vehicles per hour on the left. In any case Mr. Husbands found it difficult to envisage how the density could exceed the half-saturation of 600 vehicles per hour per lane, unless it was due to a reduction in the cross-traffic by reason of unequal distribution or some very homogenous streams interweaving, or to an unusual proportion of small and light vehicles, giving a higher lane-saturation figure; had not 2,000 vehicles per hour been reached in America?

Taking the most favourable condition at a four-way junction with only one lane entering per road, with traffic running through full pelt both ways on one road, it was clear that no cross-traffic could interweave through those streams, or they would not be at maximum density, but as only one of the roads was running the total was only half the full road capacity. Having further assumed that every alternate vehicle was removed from each lane, there would then be room for interweaving and the abstracted vehicles would suffice to form similar lanes on the other cross road; they

could interweave with the other streams. The capacity of the roundabout was still only half the peak capacity of the roads entering the junction.

The Author, in reply, observed that the assumptions made were based on experience and the first three seemed to be self-evident. The assumption that a small roundabout had the same capacity as signals on four-lane roads was used in the paper for simplicity. It could be confirmed theoretically, on the basis suggested in the last paragraph of Mr. Husband's observations, by methods given in Road Paper No. 3.[1] Although it was true that the capacity of signals was less than half that of the roads controlled in the case of four roads and one-third in the case of six-lane roads there was nothing in the Paper to suggest that the capacity of a roundabout followed a similar rule. On the contrary, the conclusion to be drawn was that roundabouts could be and should be proportioned to carry the potential traffic which could come to them.

Of the densities given on *Fig. 2*, Nos. 1 to 7 related to four-way intersections and the others to six-way intersections. It should be appreciated that they did not represent saturation, for the conditions existing, so that upper limits should be taken. In spite of that (if the special cases of 9 and 10 are omitted) half fell on or above the "half-saturation line." As stated in the Paper, the lines converged at A because for a long one-way street the capacity was proportional to the width. 1,200 vehicles per hour per lane was adopted as a practical working figure although up to 2,000 was possible for light traffic at high speed. As agreed in the Paper, more data were required, but the three-lane and four-lane lines were confirmed by two points each and a seven-lane point lay close to the six-lane line.

Closer examination would show that the formula did not make the capacity vary directly with the number of lanes. On the contrary, for higher values of the weaving angle the number of lanes had little effect, as would be shown by the following Table of the relative capacities :—

Lanes.	Weaving angle: degrees.					
	40	50	60	70	80	90
3	2·3	2·1	1·9	1·7	1·5	1·3
4	2·8	2·5	2·2	1·9	1·6	1·3
5	3·4	3·0	2·5	2·2	1·8	1·3
6	3·9	3·4	2·9	2·4	1·9	1·3

Pending further data, the Author suggested that the method shown gave a useful basis for comparison between different lay-outs. It was intended to apply to any number of roads, as in practice the amount of weaving which took place on one side was about the same for the same total volume of traffic.

[1] A. J. H. Clayton, "Road Traffic Calculations," J. Instn Civ. Engrs, vol 16 (1940–41), p. 247 (June 1941).