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Letter to the Editor—Fifth International Symposium on the Theory of Traffic Flow and Transportation, University of California, Berkeley, June 16—18, 1971

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Fifth International Symposium on the Theory of Traffic Flow and Transportation

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About 90 papers were submitted for this symposium, the advisory committee selected 30 for presentation. In the review below, reference numbers from 1 to 30 are to the presented papers in the order of presentation; higher numbers are to other references. The complete list of papers follows this review.

Traffic Flow and Vehicle Characteristics

Since the General Motor's car-following work formed the nucleus of the first of these symposia in Detroit in 1959, it was fitting that the opening paper at this symposium, by HERMAN, LAM, AND ROTHERY,[1] was on their latest experiments. The purpose of these experiments was primarily to investigate the starting characteristics of a platoon of vehicles. The wealth of empirical results cannot be summarized in a few lines, but one result that interested me was the finding that the speed of propagation of acceleration waves for small speed changes (2.5 ft/sec) was approximately linearly related to platoon speed. Starting from rest, the wave traveled backwards with respect to a fixed reference point at 25–30 ft/sec, while the wave remained at the same point for platoon speeds of about 45–55 ft/sec.

Most car-following models relate the acceleration of a following vehicle at time t to some function of speeds, relative speeds, and distances at one earlier time, say $t - \Delta$. In a paper by DARROCH AND ROTHERY,[4] it was assumed that a driver uses a weighted average of conditions at all previous times. The form of the weighting function was estimated for a set of freeway data and found to have a very sharp peak with most of the weight between one and two seconds.

A paper by WRIGHT[2] threw new light on the effect of chopping traffic flow data into small time slices. His paper centered on the well-known statistical result that if two variables are linearly related but both are subject to error, then the gradient of the least-squares regression line decreases as the scatter increases. In this case the variables considered were average speed and traffic flow. This effect was demonstrated very strikingly by comparing relations for 6-sec, 30-sec, and 5 min time slices obtained from the same set of data.

Vehicle acceleration characteristics were discussed in a paper by BENDER AND FENTON,[3] It was shown that for a constant throttle level, it is not very satisfactory to assume that the net accelerative force decreases linearly with speed. A vehicle had been instrumented with an electrohydraulic system of control of the throttle to achieve such a linearly decreasing net force.

Assignment, Human Choices, and Optimization

There are many situations in traffic that call for humans to choose between alternatives, and these tend to be modeled in much the same way. Three symposium papers were devoted to this subject. BEILNER AND JACOBS[5] proposed a model for traffic assignment in which drivers always choose what they believe to be the quickest route. Because of errors in drivers' assessments of speeds on alternative routes, or because of different past experience, this leads to a proportional distribution between routes. MITCHELL AND CLARK[6] examined peoples' choice of mode of travel and proposed a new way of estimating the value placed upon time. Gap acceptance was the subject of the paper by MILLER[15] who considered nine estimators of gap acceptance parameters. The models considered in the first two of these three papers were for choices between a number of alternatives. Until now, only two choices have been considered in gap-acceptance analysis, that is of accepting or rejecting a gap. In some situations, a driver can inspect several gaps, and this suggests that the methods of Beilner and Jacobs and Mitchell and Clark may also be applicable to gap-acceptance analysis.

Minimizing economic segregation through transit system changes, does not sound an easy task. This was part of the title of a paper by DICKEY.[7] Using empirical formulas for the effect of transit changes upon land use, he showed how to minimize the sum of absolute differences between zonal and regional proportions of population within four family income ranges.

Three papers related to trip distribution, that is to the pairing of ends of trips. BECKMANN AND GOLOB[8] showed how various versions of gravitational models can be obtained by utility maximization subject to constraints. They argued that utility maximization is more credible than entropy maximization. SASAKI[9] proposed a Markov chain model for the trips made by a person during a day. The transition matrix included absorption states to represent a person returning to his starting base (usually home) at the end of a day's trip. An old problem in trip distribution has been that with most models, if the total numbers of trips from origins were right then the numbers of trips to destinations would not be, and some kind of iterative process was necessary to obtain correct totals for both origins and destinations. POTTS AND LOUBAL[31] were possibly the first to come up with a noniterative method that balanced both totals. Another method was suggested by VAUGHAN[27] who proposed the use of multivariate normal distributions with four variables (two coordinates for each end of a trip).

Route assignment was the subject of four papers in addition to the one already mentioned by Beilner and Jacobs. Two of these, by JEEVANANTHAM[10] AND NETTER[11] were on the subject of assignment when different road users (e.g., different vehicle types) associate different costs to the same route. Both authors allowed costs to be flow dependant. Jeevanantham showed that the assignments obtained when users choose the cheapest routes converge to an equilibrium solution that can be very different from that obtained using a single cost for each route. Netter went much further including showing that there can be more than one equilibrium solution and that external rules, such as the banning of trucks from certain routes, many be necessary to obtain desirable optimal solutions.

YAGAR[12] compared assignments made using each of WARDROP's principles[32] with the way that traffic was observed to distribute itself in a 3½-mile long corridor through Oakland, Emeryville, and Berkeley, California. The observed results were found to lie between the two assignments. Yagar inferred that drivers were following the first principle, that is that each driver minimizes his own travel time, except for a tendency to avoid the freeway possibly because of the large variability of travel times caused by accidents and breakdowns. HOSHINO[14] reviewed techniques for performing assignments and presented his own combination of these techniques. It was interesting to see that his method for proportional assignment between alternative routes coincided with one found independently by Beilner and Jacobs.

The paper by VIDAKOVIC[13] was based upon data collected from a 1 percent sample of households in Old-South Amsterdam. People were asked to keep detailed diaries of their movements on two consecutive days. The paper gives a summary of some of the statistics obtained on the chains of movements made by people throughout a day.

Delays and Traffic Signals

It was a surprise to find only one paper on the subject of waiting for gaps. This was by MARCUS[16] and was on the delays caused by vehicles that merge on to freeways at very low speeds causing following vehicles also to merge at low speed. The effects of stop signs and "stop here until ramp is clear" signs placed well back from the ramp nose, were analyzed theoretically. The only other paper on the subject of queuing delays was ALLSOP's[17] on delays at fixed-time signals. He looked at the sensitivity of the average delay to vehicles, to errors in measuring arrival, and saturation flows when the signals are set to minimize the delay for the measured flows. He found that, except for almost saturated intersections, the average delay is fairly insensitive to measurement errors.

In recent years a great deal of attention has been given to the problem of determining the optimum offsets for signals in a network, and the main mathematical problems appear to have been solved now. The first major breakthrough was the combination method due to ALLSOP,[33] which substantially reduced the dimensions of the optimization problem; in the example given by GARTNER[19] the method reduces the network from 44 nodes to 10. OKUTANI[20] presented two methods of optimization using the reduced network, namely a discrete version of Pontryagin's principle and the use of dynamic programming. These methods were applied to a simple 3×3 grid but gave two quite different sets of offsets though the overall delay was almost the same for the two solutions. Gartner went further in his paper. He used dynamic programming to obtain the true minimum delay (or any other cost function) for the reduced network and showed how to find the sequence of stages to minimize the computational effort required.

The third paper on the synchronization of signals was by KOSHI[18] and described a method in use in Tokyo for automatically changing relative offsets once every five minutes based upon vehicle counts and the estimated change in delay that can be achieved by varying the offsets. If at the end of a five-minute period it is calculated that a change in offsets is desirable, a change of ±2 per cent of the cycle time is made. Two experiments on a test link showed that the offsets converged upon the optimum values for the link.

Transportation

The sessions on the last morning were headed *Public Transportation* on the program, yet the first paper was concerned with container shipping and the last was on sorting freight trains! PROFESSOR POTTS gave credit for the discovery of containerization to the Greeks (or it may have been the Romans) and produced a slide showing container (public!) transport in France in the 1830's. His paper, jointly with NOBLE,[21] was on the movement of containers between Tilbury and Australia. It provided a neat, well-presented example of the use of programming techniques to solve a two-commodity flow problem.

Two papers were presented on the operation of buses in urban areas. The first, by WEBSTER AND OLDFIELD,[22] was on the effect of restraining the use of private cars in Central London. It was estimated that an overall saving in community costs of about £10 million per year could be achieved if the number of private cars entering the central area were reduced by 40 per cent. The optimum size of bus would have 40 seats and have a scheduled speed, including stops of 16 km/hr. The other paper on buses was by BYRNE AND VUCHIC[23] who looked at the optimal spacing of bus routes on a rectangular grid and at the optimal frequency of services for a given demand. The methods developed were then applied to an area of South Philadelphia.

There were no papers on 'dial-a-bus' systems but a 'collective taxi system' considered by FARGIER AND COHEN[24] was similar. In this system, taxis are allowed to multiple hire until the taxi is full, but drivers are allowed to refuse fares if their destinations are such that a large detour is necessary either for the passengers already on board or for the new passenger. There is no centralized control of the taxis in the system discussed. The paper is a model example of the use first of an extremely simple model to obtain a broad macroscopic picture of the operation of the system, and then of the use of an efficient simulation to study the finer detail.

Railway hump marshaling yards have been in use around the world for sorting freight trains for many years, and a number of different schemes have been devised for doing this. SIDDIQEE[25] compared four such sorting schemes and found that no one method is the best for all circumstances.

During the symposium one person objected to me that there were no 'simulation' papers. In fact this was not true, there were two such papers. The first of these, by Fargier and Cohen, has already been mentioned, and the other was by TANNER.[26] Instead though of the usual "we did this, here is our list of parameter values and here is our computer output," these authors argued at length for the need either to include or exclude various features from their models, then proceeded as far as possible using exact methods before finally resorting to the use of simulation to tackle the more mathematically intractable parts of their problems. It was a pleasure to see the technique of simulation used intelligently and efficiently instead of as a poor substitute for exact analytical methods. Tanner's paper was on a strategic model for transport planning (all modes) for an urban area.

Minimum Cost Paths and Urban Densities

Two papers considered minimum cost paths. One, by HAUER,[28] took a microscopic approach, while WARDROP[29] treated the problem macroscopically. Hauer looked at the problem of finding the optimum location of one main arterial with feeder links serving a number of destinations. The closer the arterial approaches each destination, the shorter the length of feeder required but the longer the detour of those not wishing to go to that destination. After proving a number of general properties, a graphical algorithm is given and used to solve a simple problem. On the macroscopic scale, Wardrop looked at the problem of finding the minimum cost path between two points given that the cost per unit length is a function of location and direction. A graphical method is given for finding isocost curves.

The last paper, by PEARCE, SIMPSON, AND VENABLES[30] was not on traffic or transport but on urban population densities. Papers on this subject have proliferated in the last few years and yet there are many new ideas in this one. For census purposes in Australia, the boundaries of an urban area are not based upon administrative areas but upon population densities. This has led to the discovery (by R. J. SMEED) of two empirical relations between population densities and urban areas. These relations have been used by Pearce, et al. to derive a new population density model. This model and a large family of other models have been fitted to data for Melbourne, Adelaide, Perth, and Launceston.

* * *

Compared with the previous symposia, this one showed a very marked change in emphasis from traffic theory to transportation. There was a disappointing decline in the amount of experimental work reported, but this is probably an inevitable consequence of the change in subject matter. Many of the papers could be described as examples of good applied mathematics, which showed the understanding to be gained from exploring the properties of simple models incorporating the most important features, rather than from the all-too-frequent mammoth simulations or from throwing vast amounts of data into a computer with a multiple-regression package. The emphasis throughout was on premises, consequences, and applications, with the mathematical gymnastics largely omitted.

The Proceedings of the Fifth Symposium are being published by American Elsevier and are expected sometime later this year.

It was announced that the sixth symposium will be held in Sydney, Australia, in 1974.

SYMPOSIUM PAPERS

1. R., HERMAN, T. LAM, AND R. W. ROTHERY, *The Starting Characteristics of Automobile Platoons.*
2. C. C. WRIGHT, *Some Properties of the Fundamental Relationships of Traffic Flow.*
3. J. G. BENDER AND R. E. FENTON, *On Vehicle Longitudinal Dynamics.*
4. J. N. DARROCH AND R. W. ROTHERY, *Car Following and Spectral Analysis.*
5. H. BEILNER AND F. JACOBS, *Probabilistic Aspects of Traffic Assignment.*
6. C. G. B. MITCHELL AND J. M. CLARK, *Modal Choice in Urban Areas.*
7. J. W. DICKEY, *Minimizing Economic Segregation through Transit System Changes: a Goal Programming Approach.*

8. M. J. BECKMANN AND T. F. GOLOB, *On the Metaphysical Foundations of Traffic Theory: Entropy Revisited.*
9. T. SASAKI, *Estimation of Person Trip Pattern through Markov Chain.*
10. I. A. JEEVANANTHAM, *A New Look at the Traffic Assignment Problem.*
11. M. NETTER, *Equilibrium and Marginal Cost Pricing on a Road Network with Several Traffic Flow Types.*
12. S. YAGAR, *A Study of the Travel Patterns in a Corridor with Reference to the Assignment Principles of Wardrop.*
13. V. VIDAKOVIC, *A Study of Individual Journey Series: an Integrated Interpretation of the Transportation Process.*
14. T. HOSHINO, *Theory of Traffic Assignment to Road Network.*
15. A. J. MILLER, *Nine Estimators of Gap-Acceptance Parameters.*
16. A. MARCUS, *Theoretical Analysis of Expressway Ramp Merge Controls as Single-Server and Tandem Queues.*
17. R. E. ALLSOP, *Sensitivity of Delay at a Fixed Time Traffic Signal to Small Errors in the Observations Used for Calculating the Signal Settings.*
18. M. KOSHI, *On-Line Feedback Control of Offsets for Area Control of Traffic.*
19. N. GARTNER, *Optimal Synchronization of Traffic Signal Networks by Dynamic Programming.*
20. J. OKUTANI, *Synchronization of Traffic Signals in a Network for Loss Minimizing Offsets.*
21. K. J. NOBLE AND R. B. POTTS, *Network Flow Model of the Australia-Europe Container Service.*
22. F. V. WEBSTER AND R. H. OLDFIELD, *A Theoretical Study of Bus and Car Travel in Central London.*
23. B. F. BYRNE AND V. R. VUCHIC, *Public Transportation Line Positions and Headways for Minimum Cost.*
24. P. H. FARGIER AND M. COHEN, *Study of a Collective Taxi System.*
25. M. W. SIDDIQEE, *Investigation of Sorting and Train Formation Schemes for a Railroad Hump Yard.*
26. J. C. TANNER, *A Strategic Model for Urban Transport Planning.*
27. R. J. VAUGHAN, *Decentralization: a Mathematical Explanation.*
28. E. HAUER, *Optimal Form of a Class of Collection-Distribution Networks.*
29. J. G. WARDROP, *Minimum Cost Paths when the Cost per Unit Length Depends on Location and Direction.*
30. C. PEARCE, P. SIMPSON, AND W. VENABLES, *Urban Density Models.*

ADDITIONAL REFERENCES

31. R. B. POTTS AND P. S. LOUBAL, "A Mathematical Model for Trip Distribution," *Proc. 4th Internat. Symposium on the Theory of Traffic Flow*, Karlsruhe, 1968, published as *Strassenbau and Strassenverkehrstechnik*, heft 86, 190–197, 1969.
32. J. G. WARDROP, "Some Theoretical Aspects of Road Traffic Research," *Proc. Instn. Civ. Engrs.* **1** (2), 325 (1952).
33. J. A. HILLIER, "Appendix to Glasgow's Experiment in Area Traffic Control," *Traff. Engng. & Control* **7**, 569–571 (1966).