An Aerial Photographic Technique for Presenting Displacement Data

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The modern serial aerial camera with electronic intervalometer and photographic record of the instant of exposure is a scientific apparatus for the study of moving or displaced subject matter. A novel method of using photographs of vehicular traffic to present a graphic envelope of vehicle trajectory curves is described.

•THE measurement of points in three dimensions is a routine problem of stereoscopic photogrammetry. That the method also provides a fourth dimension, time, is not so often recognized.

Time is not all important to most fixed point plotting; however, we date all maps or state the date of mapping photographs because we instinctively know that our culture and even our terrain is subject to change.

Another class of data, however, is most dependent on time—objects undergoing displacement. It will be recognized that the position of projectiles, rockets, satellites and all vehicles are dependent on their time coordinate.

Photography has long been used to study complex motion by time lapse and multiple exposure techniques. Open-shutter photography also provides a method of recording the path of a lighted moving object against a background of low illumination, but to record time requires an elaborate coding of the transmitted light.

It is not generally appreciated that the modern serial aerial camera with electronic intervalometer and photographic record of the instant of exposure is a scientific apparatus for motion study.

In recent traffic studies conducted with the use of specialized equipment for the Ohio Department of Highways, it became apparent that the precision mapping camera was a tool that could be used without modification for investigating many displacement problems. For instance the minimum 2-sec cycling time available is more than adequate to demonstrate all but the micro-relations involved in traffic flow theory.

For presenting the data from many aerial photographs for direct comparison of traffic situations, a new technique was evolved which can be of use for making other investigations involving displacement.

The data are from special photography taken by the Ohio Department of Highways for a department-sponsored study conducted by Joseph Treiterer of the Ohio State University. The techniques employed were described by James I. Taylor (1) and in an abbreviated form by Treiterer and Taylor (2).

In brief, a fast cycling 70-mm camera was transported by a helicopter at a fixed height and in synchronization with a moving platoon of cars. Panchromatic, Ektachrome, and Infrared Ektachrome film were used to record the moving traffic patterns and a traverse of targeted ground control points.

Nine frames at a time were placed on the stage plate of the analytical plotter AP/C and the plate coordinates for interior orientation, the ground control points, and an identical point on each vehicle together with a complete identification of each point was printed out. The probable error of the pointing on the moving vehicle proved to be less

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than 10μ. The data were then processed in an electronic computer using an analytic program to obtain map coordinates for the traffic analysis.

Much tedious scientific effort, as well as equipment that might not be available to other investigations, was employed.

The largest effort was spent in reducing the data to coordinates, processing, and then replotting the adjusted coordinates for graphical presentation. A technique for reducing this effort follows:

1. Only the pertinent photographic data are printed, striped, or cut from the photographs.
2. A suitable coordinate system of position and time is selected.
3. The photographic strips are fitted on the correct time axis and fixed points fitted to position coordinates to form bar charts.
4. A set of symbols for identification of similar events is adopted.
5. By photographic interpretation, unique displaced objects are connected by identifying "trajectory" curves. Less easily identified points are then joined.
6. Each trajectory is numbered for identification.
7. Contours or grade and alignment data are plotted on one or more straight-line position bar charts.

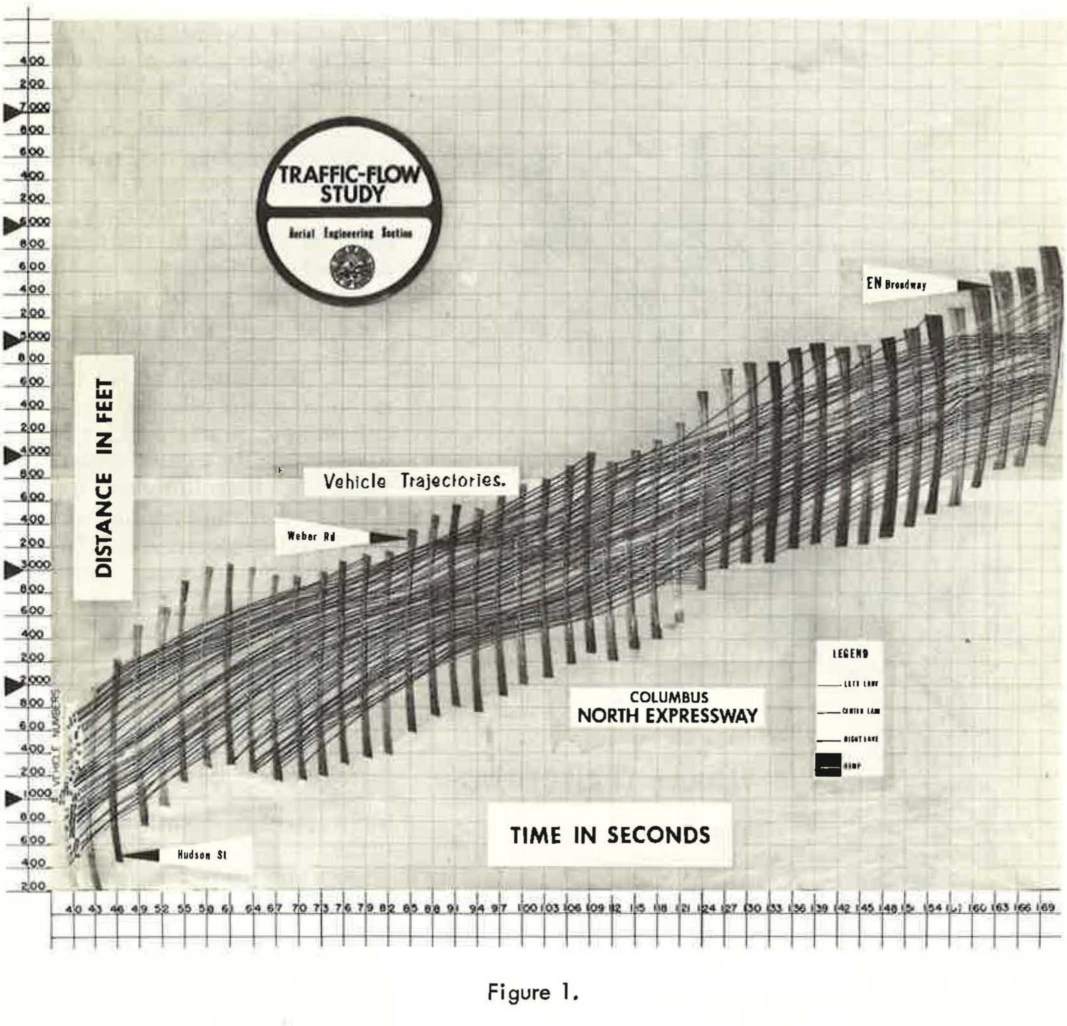

Figure 1.

Traffic data previously described and prepared according to this technique are illustrated in Figures 1 and 2. A further description follows:

1. The vertical axis of the plane coordinate system is displacement. The horizontal axis is time.
2. The photographic bar charts are the northbound lanes with their related ramps of I-71 in Columbus, between Hudson Street and North Broadway.
3. The curve connecting consecutive images of an individual vehicle represents that vehicle's trajectory. The slope of the curve is the vehicle's velocity. Acceleration is indicated by the change in the curve's slope. A horizontal line represents a zero displacement, a fixed point, or a vehicle stopped for a period of time. A vertical line represents an infinite displacement or an instant of time. The scale of the graph is so selected that the legal speed or the average speed trajectory has a slope of approximately 45 deg.
4. The trajectory of a vehicle in a single lane is assigned a distinguishing color or symbol. As soon as it crosses over 50 percent into an adjacent lane it takes on the color assigned to that lane. A trajectory of more than one color represents a weaving vehicle or a vehicle entering or leaving the mainstream of traffic.
5. Individual vehicle trajectories are identified by number.
6. The displacement axis may show contours or gradients.
7. If the bar represents a straight-line diagram the alignment curvature can also be indicated along the displacement axis.

A chart so prepared can be used to study most of the traffic problems of usual interest:

1. Density counts can be made by counting the number of trajectories cut by a vertical line at any desired instant. Not only the number of vehicles in a selected mile can be counted, but also the type of vehicle and the number in each lane can be noted.
2. "Headings" or the distance between vehicles in files can be seen, measured, or compared visually to an arbitrary "assured clear following distance." Average headings in individual platoons can be obtained by comparing totals of displacement and vehicle counts.
3. Volume counts can be made by counting the number of trajectories cut by a horizontal line at any fixed point. Not only the total number of vehicles in a given interval of time can be counted, but also counts of vehicle types in each lane can be made.
4. The path of a vehicle is represented by its trajectory curve.
5. The change of color of a curve represents weaving or lane changing.

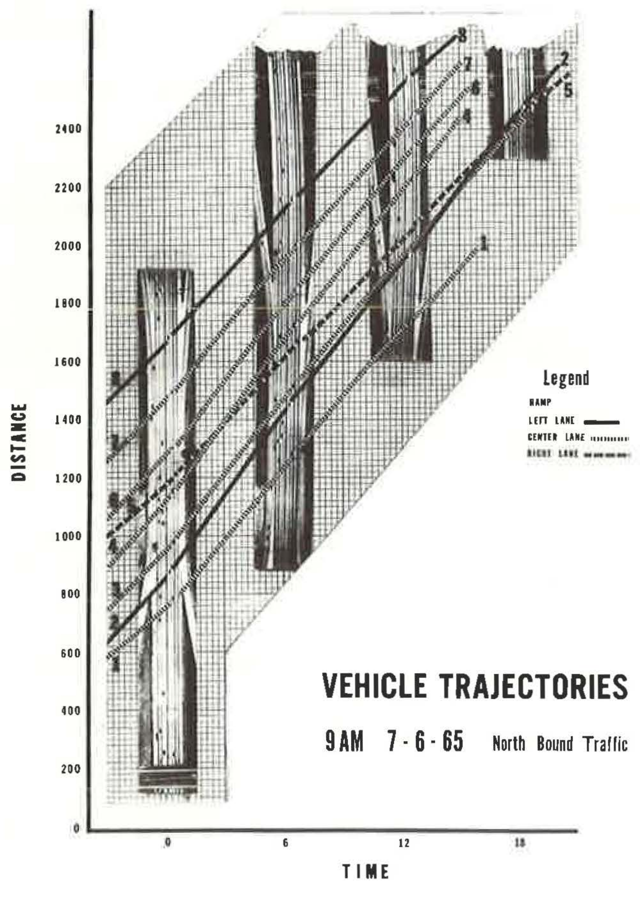

Figure 2.

6. Speed or velocity and acceleration observations are given by the slope of the trajectory curve.

7. A unique vehicle identification system can be used to provide information for comparing the changes in platoon composition.

8. The traffic record can be compared with gradients or alignment to note their effect or, for instance, the need for climbing lanes.

Variations and modification of the illustrated example are possible. For example, only the pertinent portions need be printed from the many negatives involved. The AP/C stereoscopic plotter, with an orthophotographic printing device, seems to offer advantages for implementing this technique by virtue of its versatility. It will be able to print an orthophotographic map of any portion of the negative as well as to print identification and three-dimensional position coordinates. While printing this data, it can also draw the route profile, plot the crossing contours, or compute gradients. Using color materials, this would seem to give the ultimate information except for license numbers and origin and destination. The possibilities of representing curved alignments as straight-line diagrams is limited only by the problem of computer programming.

To study the traffic flow in a network, say within the corporate limit of a small city or the inner city of a metropolis, it is only necessary to expose aerial photographs which will cover the entire network. No attention need be given to securing a suitable stereoscopic base except for a single set of mapping exposures. Problem routes in this network can then be treated as straight-line diagrams and the trajectories plotted.

Parking studies are special cases of vehicles with zero displacements and by stereoscopic examination and photographic interpretation, the identity of vehicles can be determined and counts made.

A further technique of targeting which is being researched by the Ohio Department of Highways may make it practical to premark unique vehicles or targets and pinpoint their location at the instant of exposure. Exposures could perhaps be made at such small scales that the vehicle itself would not be identifiable. The technique is to illuminate a retro-directive prism at the instant of exposure by means of a suitably synchronized and powered electronic flash. Adhesive coated targets could be set on the top of vehicles, and the position and headings, for instance, of all the operating buses in a city transportation system could be pinpointed.

Such investigations could lead to increasing the efficiency of single elements and the entire system.

The importance of traffic flow study is pointed out by an official of the Cleveland Transit System. He estimated that every increase of 1 mph in the average travel speed on that city's streets would produce an annual savings in transit operating costs of about one million dollars.

REFERENCES

1. Taylor, J. I. Photogrammetric Determinations of Traffic Flow Parameters. Ph.D. dissertation, Ohio State Univ., 1965.
2. Treiterer, Joseph, and Taylor, J. I. Traffic Flow Investigations by Photogrammetric Techniques. Highway Research Record 142, p. 1-12, 1966.