paper such narrower letters will be legible for a shorter distance than the wider Series E letters used in our study. Thus, the claimed advantage would not be valid. The use of tall and wider capitals immediately involves a longer sign and greater area than required for the lower case, and therefore is not a fair comparison. Thus, the question of how to compare the two forms of letter is much more complex than it may appear at first glance.

PHOTOGRAMMETRY AND ITS USES IN HIGHWAY PLANNING AND DESIGN

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SYNOPSIS

Photogrammetry might be described as the process of converting photographs into contoured topographic maps. Formerly ground survey methods were considered the only reliable means of obtaining accurate topographic information. It is now possible to develop topographic maps of specified accuracy by means of aerial photographs which are then subjected to a series of photogrammetric processes so that maps may be drawn at scales useful in highway location and design.

For location planning studies, Connecticut uses the Geological Survey topographic maps for the selection of the narrowest band containing all alternate routes considered for a highway relocation. If the alternative routes require a band one mile wide, photogrammetric maps to a scale of 1 in. = 200 ft. showing 5-ft. contours would be specified. Such maps produced on tracing cloth in sheets of 3 by 5 or 6 ft. provide the Location Planning Engineer with sufficiently precise information for the refinement of line and grade, the estimating of construction quantities and the determination of number of structures and acreage of land needed for right of way. The careful pricing of these quantities on the various alternatives will produce costs for comparison with the benefits each alternate line would produce. Study of the photogrammetric maps and the photographs permit evaluation in sufficient detail so that only one line need be surveyed for design purposes.

If all the alternates needing appraisal fall within a 2000-ft. band, Connecticut would specify that the photogrammetric maps be at a scale of 1 in. = 100 ft. showing 2-ft. contours. This scale permits more refinement in the selection of the location to be constructed.

The photogrammetric processes applied so convincingly at the 200 and 100 ft. to the inch scales in our location planning have recently been extended to the more detailed surveying used in the development of construction plans, namely, 40 ft. to the inch with 1-ft. contours. Such maps would have a maximum width of 1000 ft. but if the line determination on previous larger scale maps permits, a narrower width can be specified.

The accuracy of these photogrammetric maps is almost unbelievable. For planimetric detail on 40 ft. to the inch maps it has been found that buildings, fences and virtually everything which can be seen from the sky can be plotted at 40 ft. to the inch within the accuracy normally obtained by ground survey methods. Ninety percent of the contours will be accurate within one-half contour interval and the other 10 percent will be within a whole contour. In areas covered with evergreens or brush accuracy within double these tolerances is obtainable. Such accuracies have been obtained by the Connecticut State Highway Department on photogrammetric work in three contracts through the past three years. Advantages are the ability to supplement existing survey personnel, the shorter time required to obtain maps useful for design and costs no greater than slower ground surveys.

The place for photogrammetry in the operation of the Connecticut State Highway Department has been evolved through the past few years to meet the need for maps of sufficient detail to permit better prosecution of the tasks at hand. In the planning operation the need was for up-to-date topographic maps of a scale which would permit the appraisal of alternate lines to meet a traffic desire. In the design operation the need was for a means of supplementing and accelerating the field survey operations in a period when State salaries were unattractive to the field survey engineers. To show how both of these needs have been met by the use of photogrammetry is the purpose of this paper.

USES IN HIGHWAY PLANNING

The sequence of operations in Connecticut highway developments might be briefly described as: first, to determine deficient roadway sections based on Planning Survey data —inventory, traffic and critical features; and second, special traffic surveys to ascertain the use being made of the deficient road. This information is usually obtained by origin and destination techniques which may be accompanied by central business district parking studies. Analysis of this information permits a determination of the traffic desires. Then a study of existing topographic maps will locate the general alternate routings for a facility to accommodate the traffic desires. Existing topographic maps of Connecticut are of 2 or 2½ in. to the mile scale and show either 10- or 20-ft. contours. Maps of such scales provide the basis for defining the highway relocation problem within the limits set by the major traffic desires. Each relocation alternate should be long enough to by-pass the deficiencies of the existing route and reasonably direct between the major origins and destinations. Study of such a map will probably indicate alternative routings for a highway to serve that traffic.

The appraisal of the alternatives is difficult on maps of the scale available generally throughout Connecticut. The requirement here is for topographic information in greater detail. The scale selected for this work is 200 ft. = 1 in. with 5-ft. contours. Such maps can be obtained with a single sequence of aerial photographs and cover a band one mile in width. If the extreme spread between the alternates needing appraisal exceeds a mile, it may be necessary to specify parallel photographic sequences to include all the lines to be appraised. Our experience has indicated that only rarely are the two parallel strips necessary. However, if the alternates fall within a one-half mile width band or are in built-up areas, it is desirable to specify maps at 100 ft. = 1 in. scale with 2-ft. contours. In urban areas where intensive land use is usual, it has been found that the 100 ft. = 1 in. maps have much to commend them. A single sequence of photographs for this scale of maps will cover a half mile width.

The photogrammetric maps at either of these scales will show within the accuracy of the drafting table everything which is visible on the photographs. They permit closer determination of the alignment and profile of each alternate. Study of these maps may even suggest possibilities not previously known to exist. The 5-ft. or 2-ft. contours permit determination of the geometry in both plan and profile. They permit the planner to establish the controls for the location and the geometric treatment of intersections and interchanges. Within the standards set for a highway of this type they provide an excellent base for studies to fit the highway to the ground and to make the proposed improvement blend with existing land uses.

At this stage it has been Connecticut practice to make prints of the topographic map tracing on which have been drawn the alternate lines being studied. These prints are distributed to the several divisions of the Department for independent appraisals. Men skilled in estimating construction costs develop such costs while the Right-of-Way Division appraises the costs of land and structures required. At the same time the traffic planners can establish the vehicular usage and the traffic benefits of each alternate line.

At earlier sessions of the Research Board there have been discussions of the various methods of making such determinations. They are usually based on comparison of the running time or the roadway distance on each proposed alternate with that of the existing road. With photogrammetric maps the allocation of vehicles is made easier because the scale of these maps is such that accurate distance is obtained, and with the knowledge of design geometry the time can be determined within

reasonable limits. The traffic benefits are determined by comparison of time and distance costs on the proposed work with the time and distance experienced on the existing facility. The costs of the construction and right-of-way determined by the estimators then is combined with the traffic benefits to produce a benefit-cost ratio. Thus there is developed a factual determination of the alternate yielding the greatest return per dollar of cost.

It is important that the estimates of all alternates be made with the same diligence and exactness so that results may be truly comparable. The methods described above provide a means of reducing the field reconnaissance and field surveys. The only reconnaissance necessary is to determine elements not visible from the photographs—e.g., the value of buildings and the location of sub-surface utilities or soils. However, the type of soil or amount of rock to be encountered in roadway excavation is the subject of another intensive use of air photography. The unknowns that existed in this field a few years ago are rapidly being overcome by the techniques of air photo interpretation being developed in the soils engineering field.

Some of these field explorations can be made by the survey party which has been assigned the task of checking the photogrammetric maps for accuracy of planimetric and contour information. By combining the quantitative and cost appraisals of the various estimators, the highway planner can determine the one line which provides the greatest return to the investing motorist. Then only one line need be surveyed in the field, and that can be done with the assurance that all alternatives have been explored and discarded on the basis of thorough office studies of large scale contour maps taken for the specific purpose and indicating all culture that existed only a few months before these studies were made. There is no question of obsolete information when photogrammetric maps are secured for use in the solution of a problem of this sort.

USES IN HIGHWAY DESIGN

To the best of our knowledge the use of photogrammetry for highway design is an innovation with the Connecticut Highway Department. It has long been our practice to obtain topographic information by ground survey methods and to plot this information at 40 ft. to the inch. Accompanying each map would be a profile of the base line of the survey. With this information the location engineer established the center line for construction which could not vary from the surveyed base line any great distance because the topographic information was usually restricted to a relatively narrow band. Large adjustments were difficult to make unless the field surveyors anticipated a line shift and secured more than the usual field information. Having established a line and set a rough profile for the construction, the job was sent back to the field for the establishment of the road center line and the securing of cross sections every 50 ft. normal to that center line. The width of the cross sections would be greatest where large cut or fill sections were anticipated. After plotting the ground profile obtained on the highway center line, highway profile adjustments would be made and center line grades established at every section. The ground lines and road templates were plotted for each section so that yardage by the average end area method could be computed.

As you may recognize, this sequence of operations required considerable time both in the field and in the office, and in transmission of material between the groups. Moreover, there are several aspects of our Connecticut climate which hinder the obtaining of field survey information at the time most suitable. We find that construction activities require the use of the great majority of our field personnel throughout the warmer seasons. Only in the cold winter period do we have an adequate staff for field surveying purposes, and then the men are hampered by the weather and by our uncertain quantities of snow. These circumstances delayed the work and increased the cost of field surveys. These conditions had prevailed for years.

In the postwar period the Connecticut Highway Department was further hampered in processing designs on the accumulation of needed highways by a shortage of professionally trained personnel. In the pursuit of alternate methods which might either accelerate the work, save money, or supplement our manpower, the author wondered about the application of photogrammetry to this problem. His researches have led to the awarding of four contracts for photogrammetric maps at a scale of 1 in. = 40 ft., showing 1 ft. con-

tours and covering strips 1,000 ft. wide. These contracts aggregate 20 miles in length and were secured at an average cost of $2,250 per mile. The two most recent contracts have been awarded at prices of $2,000 per mile or less.

The principal information received from the photogrammetry contractors consists of tracing cloth maps 25 in. wide and 60 or 70 in. long showing all planimetric detail visible on the photographs and indicating ground surface relief by one foot contours. All information is referenced to the Connecticut State Coordinate grid shown at 5-in. or 200-ft. intervals. Elevations referred to the established datum are shown for all road intersections, saddles, and summits and hilltops.

Such maps permit the Location Engineer to study all the location possibilities within the 1,000-ft. map width. He is not required to make exhaustive reconnaissance in the field, and his determination of the best highway centerline is not restricted to the 200- or 300-ft. width formerly obtained by ground survey. The ground elevation information is available throughout the map width, not just along a single survey line. This feature of the photogrammetric map is especially valuable in the establishment of interchange or service road layouts, which often spread to considerable distances from expressway centerline.

After marking the detail alignment and grade of the proposed highway on the map tracings, prints are sent to the field survey parties for establishment of the centerline on the ground. At the time this is done, the surveyors check the maps for conformance with specification by running ground profiles and taking measurements to fences, structures, streams and roads. They also determine the size and location of underground utilities, property boundaries, and other elements not visible on the air photos and therefore not plotted on the maps. With this supplemental information for areas adjacent to the proposed facility, the highway designer can complete his detailing for the highway construction plans and cross sections.

A major advantage of these methods is that the field survey work by state forces is confined to only the one line which is to be constructed. Moreover when inquiries from property owners arise as a result of their seeing surveyors at work, their apprehensions can be quickly settled by showing on the plans and on the by-product photographs exactly how their properties will be affected by the proposed construction.

The procedures outlined above greatly reduce the amount and cost of work performed by state personnel. The time between the

TABLE 1
AERIAL TOPOGRAPHIC MAPS DEVELOPED FOR THE CONNECTICUT STATE HIGHWAY DEPARTMENT

Date	Location	Length	Low Bid Price	Cost Per Mile
	Specification: 200-ft. Scale—5-ft. Contours—Mile Wide			
		mi.		
May 1944	Hartford—New Britain	12 9	$9,050	$700
Apr. 1946	New Haven & Bridgeport	18 0	15,900	890
Mar. 1948	Guilford & Old Saybrook	22 0	11,800	540
Dec. 1948	Norwalk & Georgetown	5 5	5,100	930
Dec. 1949	East Haven & Meriden	21.5	13,500	630
Apr. 1950	Greenwich	7.1	4,350	610
Total ...		87 0	$59,700	$690 Avg.
	Specification: 100-ft. Scale—2-ft. Contours—Half-Mile Wide			
Dec. 1949	Newington	3 0	$4,000	$1,300
Apr. 1950	East Hartford & Glastonbury	7.7	7,850	1,000
Total		10 7	$11,850	$1,100 Avg.
	Specification: 40-ft Scale—1-ft. Contours—Thousand Feet Wide			
Dec 1948	Plainville—New Britain	4 0	$12,000	$3,000
Dec. 1949	Seymour	0 5	2,100	4,200
Apr. 1950	Mansfield & No Windham	3 8	7,400	2,000
Dec. 1950	Four Locations	12.2	23,700	1,900
Total .		20 5	$45,200	$2,250 Avg.

definition of the strip to be surveyed and the receipt of unchecked tracings is only six months on our current project. This is considerably less than would be required if the twelve miles of location survey had been added to the other assignments of our personnel.

Costs of Photogrammetric Maps—Table 1 provides information on photogrammetric maps procured for use in Connecticut.

To date the total cost of these operations has not been compared with the cost of obtaining the necessary design data without photogrammetry. However, it is believed that photogrammetric methods permit improved designs to be developed at approximately equal total costs and in considerably less time than previous methods.

Concerning costs, it should be pointed out that the element which is all important is the cost of checking the maps as received from the photogrammetry contractor. The Connecticut specifications detail the information and accuracy required on the final maps. They are not concerned with methods of obtaining that accuracy. What is needed is a product which will stand the accuracy tests imposed by the surveyors and engineers who will use them, and who must be convinced that photogrammetric methods will produce maps equal to or better than those made by conventional methods. Pride in one's work is a creditable trait. Surveyors are reluctant to accept the inexpensive innovation produced by photogrammetric means. Since checking costs can run to extremes and tip the economic balance, the photogrammetric engineering profession must make sure that accuracy specifications are fulfilled on every test.

TRAFFIC REPORT BEFORE AND AFTER IMPROVEMENT AT INTERSECTION OF ROUTES 1 AND 25[1]

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SYNOPSIS

An extremely severe traffic congestion problem at a right angle intersection was solved by a relatively inexpensive re-design. It is believed that this type of design, which might be termed "Directional Channelization", has not been employed before.

The principle of the design is to remove the left turning vehicles from the intersection proper by substituting a left turn off of the approach road before these vehicles reach the main intersection and then providing a left turn onto the exit road at a point beyond the main intersection with a roadway connecting the two. The locations of these points for left turns are selected at such distances that progressively synchronized traffic signals can be operated so that stops are not created in addition to those which would have been necessary without the improvement.

This "Before" and "After" study indicates that it is sometimes possible to increase the number of traffic signalized intersections and speed up traffic. It may be possible to expand this principle to the point where traffic signals combined with design may prove to be a means of temporarily deferring expensive grade separation construction for many years or may even prove to be satisfactory for an indefinite length of time.

At this intersection the re-design resulted in a saving of about one-half minute for the average car of the 45,000 cars per average day entering the intersection. This saving is the direct saving in travel time within the intersection area and does not include the time saved by increase in capacity and resultant elimination of long tie-ups.

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[1] A cooperative project between the Division of Planning, Traffic and Economics of the New Jersey State Highway Department and the Bureau of Public Roads.