*Highway Engineering Influence on Aerial Surveys**

WILLIAM T. PRYOR,
Chief, Aerial Surveys Branch,
Highway Standards and Design Div., Bureau of Public Roads,
U. S. Dept. of Commerce, Washington, D. C.

ABSTRACT: *For solution of the numerous and complex engineering and other problems encountered during the past few decades, essential information and specific data requirements in planning, surveying, designing, and constructing highways have increased to an extent previously unimagined. While aerial surveys—the combined use of photographic interpretation and photogrammetry—have been employed by highway engineers as an effective and economic aid in accomplishing such work, highway engineering requirements have profoundly affected the utilization of and expectations from aerial surveys.*

Among the significant effects of the influence of highway engineering on aerial surveys are:

Rapidly and greatly increasing the number and variety of uses and users of aerial surveys.

Compiling maps to scales larger than previously considered feasible or required for most other uses.

Emphasizing the essentiality of positive identification and precise use of accurate basic and supplemental control.

Broadening the need for and contributing to expansion of the national network of basic horizontal and vertical control surveys.

Revealing inconsistencies and lack of overall accuracy in the usual surveys made on the ground.

Greatly expanding the effectiveness and use of digitization of photogrammetrically made measurements in X, Y, and Z coordinates.

Speeding the improvement of instruments and development of finite point measuring and automatic digital recording devices.

Bringing into focus benefits to be gained by the combined cooperative efforts of photogrammetric and highway engineers.

INTRODUCTION

FOR highway engineering users, aerial surveys comprise the taking and feasible use of aerial photographs in the solution of engineering and other problems, and in the demonstration of particular problems and their solutions. In such uses, photographic interpretation and photogrammetry are employed either separately or together as necessary.

Only within the past 25 years have aerial surveys been substantially influenced by highway engineering. Most of the influence occurred within the last 15 years. The influence was greatly accelerated by the Federal-Aid Highway Act of 1956. Passage of the Act inaugurated a program of rapid expansion and improvement of our highway systems for motor vehicle transportation among places of abode and business, work, industry, and recreation—coordinated with rail, water, and air transportation systems. This Act is the first Federal law which specifically provided for establishing temporary and permanent geodetic markers for use in highway location, design, and construction (both present and future); and for the use of photogrammetric methods in mapping. The effects of this Act go far beyond initiating a program to provide needed highways and giving impetus to the exacting and extensive use of aerial surveys. The effects are so far-reaching in the aerial

* Paper presented at the Semiannual Meeting of the American Society of Photogrammetry, September 12–14, 1963, Wellesley Island, N. Y., and also at the Annual Meeting in Washington, D. C., March 15–21, 1964.

surveys field that only what currently appear to be the most significant influences can be presented.

Engineering Photogrammetry

SCALE COMPARISONS

Before photogrammetric methods were employed to compile large-scale, small-contour interval, topographic maps for highway location and design, most, if not all, of the use of such methods was for compiling maps of small to very small scale from the viewpoint of highway engineers. Topographic and other maps at scales of 200 feet per inch (1/2,400) and larger scales, are required by highway engineers of routes, and structure and interchange sites for highway location and design; and of property ownership parcels for procurement of highway rights-of-way. To highway engineers these are large-scale maps. Maps smaller in scale than 1/2,400 to the maps as small in scale as 1/12,000 (1,000 feet per inch) are used for comparing route alternatives and selecting a route for each new highway. To highway engineers, such maps are small-scale; maps smaller in scale than 1/12,000, as 1/20,000, 1/24,000, and 1/50,000 are very small-scale. The very small-scale maps are invaluable, however, in making reconnaissance surveys to determine feasible route alternatives for highways. Map scale, therefore, is one of the significant aspects, and is established by the major use to be made of the maps in each successive engineering stage.

THE CONTOUR INTERVAL AND ACCURACY

For highway engineering purposes, contour interval and accuracy requirements are related to map-compilation scale; this scale is governed largely by the stereoscopic model scale for double projection instruments, and to ruggedness of the topography. In effect, this means the stereoscopic model scale needed to achieve topographic map compilation scale and specific measurement accuracies desired in profile, cross sections, and cadastral data dominates planning for and accomplishment of most precision photogrammetric work for highway engineering purposes. This contrasts with small-scale topographic mapping in which contour interval usually governs photography scale.

Numerical expressions reflecting the influence of the foregoing may be made in relation to the denominator of the representative fraction expressing map scale. The contour interval in feet should be no smaller than 0.002 multiplied by that denominator. None of the planimetric features on the maps should contain horizontal displacement in feet from true position larger than 0.004 multiplied by that denominator. Moreover, the error in feet vertically for spot elevations and error in feet horizontally from true position for horizontal point measurements should generally not exceed 0.0005 and 0.002, respectively, multiplied by the denominator of the map scale fraction.

AERIAL PHOTOGRAPHY REQUIREMENTS

Measurement and Mapping Photography.—In the reconnaissance survey stages of highway engineering, small-scale aerial photography is usually not seriously affected by ground relief, and seldom by rough air. In these stages, however, it is essential that tilt tolerances be as near zero as can be achieved. Otherwise, contact-printed vertical photographs cannot be used effectively to determine differences in elevation and to locate feasible highway routes on specific gradients by use of parallax measurements, without benefit of ground control.

For large-scale topographic mapping and other precision measuring in the preliminary survey stage, convergent photography is advantageous where obscurations from relief, vegetation, and buildings are not detrimental. Where such obscurations are detrimental, vertical photography is essential to obtain alleviation therefrom. The vertical photography may contain tilts not exceeding limitations set by the photogrammetric measuring and mapping instruments used. Care must be taken, however, to be sure that tilt caused by rough air, frequently existing at low flight heights, does not decrease the stereoscopic endlap, and sidelap of adjacent strips, below the usable minimum.

Wherever topography is rugged, the flight height should be not less than four times the relief height within the stereoscopic coverage of each successive pair of photographs. Consequently, there is a limit within such areas on the maximum scale at which topographic maps may be photogrammetrically compiled. Within slightly rolling to nearly level ground areas, the dominant limitations to obtaining photography for mapping at large scales are aircraft safety at low flight heights, aerial camera cycling and shutter speeds, air turbulence, and image motion.

Vegetation, rugged topography, and tall buildings obscure the ground to a detrimental degree whenever extremely short focal-length camera lenses are used in taking preliminary survey photography. For achieving better results by reducing obscurations, photography of longest feasible focal-length is taken for use in the precision photogrammetric instruments.

Photographic Interpretation Photography.—All panchromatic photography suitable for reconnaissance measurements with engineers' scales and parallax bars, and photography suitable for precision mapping and measurement for highway design are suitable for photographic interpretation in the respective engineering stages for which obtained. Generally, photographic interpretation for highway engineering purposes, which is affected while the photographs are used for measurement, mapping, and highway design, is best achieved when small-scale photography (1/20,000 and smaller) is available to ascertain large configurations and overall relationships, and large-scale photography (about 1/12,000 and larger) is available for determining details and selective distinctions. Types of soil, sources of construction materials, ground conditions, and many of the significant land uses are more easily and effectively ascertained when the panchromatic photography is supplemented by use of color photography and infrared photography. The scale of color photography for such purposes should be not smaller than about 1/12,000, and preferably larger. In addition, there are indications infrared imagery of thermal radiations from the earth will also be a beneficial photographic interpretation supplement to all types of aerial photography.

Certainty in Use of Control.—Precision requirements in maps and other measurements made for highway design demand certainty of identification and use of accurately surveyed control points. This requirement extends beyond map compilation to staking on the ground the designed highway, including its centerline and structures, exactly where position-computed by plane coordinates. The identification and exact position use of control points cannot be achieved consistently unless symmetrical targets of adequate size, proper shape, and color and contrast are placed on the basic control points (both horizontal and vertical) before photography. In addition, such targets must be similarly placed on an adequate number of the supplemental control points used in orienting and scaling each stereoscopic model.

Ground-Surveyed Control.—Use of the national network of basic horizontal and vertical control, as origin and closure in the establishment of basic control for highway surveys accomplished by aerial methods, emphasizes the recognized need for extension of the network and placement of control points where they are readily accessible to users.

The marker of each basic control point established for each highway survey must be positioned where it will be usable for accomplishment of supplemental control surveys, and as origin for staking designed highways for construction. Consequently, placement of these survey control points where they will not be disturbed by normal use of the land and will remain a preserved and integral part of the national network of control surveys is essential. Such use of the national network demands highway surveying accuracies greater than formerly achieved in making highway surveys by the usual methods on the ground. Wherever requisite accuracy with the national network is achieved in establishing basic control for highway surveys, continuing convenience and savings in time and money will be realized for all subsequent surveys originating on the new control. Moreover, basic control surveys accomplished for highways, in accordance with standards defined in the 1956 Federal-Aid Highway Act, extend and become part of the national network.

Specifications.—For the engagement of aerial photography and photogrammetric firms by contract to take aerial photographs, to make control surveys, and to compile maps and make other measurements photogrammetrically, specifications are required. Significant purposes of the specifications are to define adequately the needs of highway engineers and to enable the firms to fulfill those needs well and on time by using their professional ability and most progressive and effective methods.

As a consequence, specifications[1] have been prepared, comprising two major divisions. General requirements in the first division pertain to the legal and administrative aspects, which are applicable to awarding contracts, scope of work, legal responsibilities, prosecution and progress, and measurement and payment. Specification details are given in the second division by sections separately applicable to photography, control surveys, mapping and other measurements, and tests of control and maps for accuracy and completeness. These specifications have been

[1] "*Reference Guide Outline—Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways,*" by the Photogrammetry for Highways Committee, jointly representing the American Society of Photogrammetry and the American Congress on Surveying and Mapping.

adopted by highway departments, by engineering consultants, and by others requiring precision work by photogrammetric methods. The adoptions have been without modification in many cases and with some modification in others.

To fulfill particular requirements, procedure in use of the specifications is to define each item of work or result desired in a proposal schedule, relating each item therein by number to the applicable section in the second division of the specifications.

Furthermore, for efficiency and effectiveness, highway engineers must keep in mind the photogrammetric limitations existing in the relationship of map-compilation scale to contour interval. Actually, the compilation scale, in feet to one inch for topographic maps, should not be smaller for double-projection instruments than 40 times the contour interval, or smaller for optical train instruments than 20 times the contour interval. The map scale, however, may be larger, respectively, in relationship to the contour interval for each of the two types of precision instruments.

In addition, wherever topography is rugged, the practical limit on map-compilation and measurement scale set by the relief-height to flight-height ratio which can be accommodated must also be kept in mind and not exceeded. Accordingly, maximum achievable scale of compilation and minimum contour interval are governed by both the map scale to contour interval relationship and the relief-height to flight-height ratio.

Award of Contracts.—A signed contract and a performance bond for the contract are not adequate guarantees that measurements, map compilation, and other essential work fulfilling contract schedules and accuracy requirements will be accomplished. Qualifications demonstrated by reliable performance with adequate equipment appropriately used and by a reputation for integrity are also essential. The advantages gained by negotiation of contracts with qualified and reliable photogrammetric engineering firms have been demonstrated numerous times in highway use of aerial surveys.

PHOTOGRAMMETRIC INSTRUMENTATION

For highway design and preparation of construction plans, the precision with which measurements must be made and maps compiled of selected corridors challenged photogrammetric instrumentation from the beginning of use of aerial surveys for highway engineering purposes. Initially, a topographic map scale of 1/2,400 with a contour interval of five feet was considered the feasible ultimate in maximum scale and minimum contour interval. It was not long, however, until photogrammetric instrumentation and procedures were improved to achieve topographic mapping at a scale of 1/480 with a contour interval of one foot. Significantly, this influence resulted in increasing the projection ratio of double-projection instruments when used for highway engineering purposes. For precision photography of focal-lengths noted the separate increases in projection ratio were:

(1) 6-inch, from 3.4:1 to 5:1
(2) $8\frac{1}{4}$-inch, from 4:1 to 5:1
(3) 6-inch, from 5:1 to 7:1

In addition, the advantages of using photographic transparencies printed on flat glass plates at film-negative scale became increasingly evident for achieving the largest measurement and mapping scales possible. Since 1956, the use of electronic computers in highway design has greatly influenced the photogrammetric instrument industry. Some significant results are attachments to optical train instruments and auxiliary devices for double projection instruments to digitize profile, cross sections, and other point measurements in *X*, *Y*, and *Z* coordinates.

SMALL-SCALE MAPPING OF LARGE AREAS

As the highway construction programs were intensified, the available highway engineers were pressed for time in the early stages of engineering to determine feasible route alternatives, to compare them, and to select a route for each required highway. Work in these stages demanded obtaining and using adequate information and dimensions throughout each large area of concern, especially wherever route location problems had to be solved and the highway engineers needed topographic maps, soil maps, material sources maps, drainage maps, and land use maps. As the maps were used, they were supplemented by stereoscopic examination of aerial photographs, and by field investigations where necessary. Such needs became an impetus to increasing the rate of topographic mapping on a quadrangle basis, and to utilization of aerial surveys for the compilation of soil maps, material sources maps, drainage maps, and land use maps.

AERIAL SURVEYS UTILIZATION DEVELOPED

Generally, the first elemental use of aerial photographs by each new user for highway purposes, beginning 40 to 35 years ago in some places and much later in others, was limited to pictorial presentation. Gradually, through the succeeding 20 years, use progressed to making parallax measurements for determining differences in elevation and gradients, small-scale topographic mapping, and elemental photographic interpretation. Finally, large-scale mapping and precision measurement of specific points became routine for many highway engineering users of aerial surveys. It is difficult, if not impossible, however, to ascertain the history and to cite the particular time and place that each use in highway work was begun. It is possible to mention briefly only the significant uses which evolved in highway engineering utilization of aerial surveys. No attempt is made to do so chronologically from their beginnings—most of which occurred in the 1940's and later.

Traffic Engineering.—In recent years, the value of aerial photographs as supplements in making traffic surveys and in illustrating many aspects of traffic movement and proposed solutions to traffic problems has been realized. This realization occurred because aerial photographs enable highway engineers to readily recognize traffic congestion zones and their causes, and obstructions to free movement of traffic. Aerial photographs reveal traffic movement characteristics and speed, number of vehicles per lane mile on the highway, and number of vehicles endeavoring to pass through a traffic bottleneck. Thus, each segment where traffic demands are greatest are recognized with certainty and easily demonstrated. In addition, with aerial photographs it is easier than by other means to ascertain the relationship between the floor-area use of buildings within each class of land use and the traffic generated therefrom, for estimating traffic requirements, both present and future.

Drainage and Hydraulic Engineering.—For highway route location and for design and preparation of construction plans, aerial photography is utilized advantageously in determining drainage courses, area and shape of watersheds, ground cover, underlying geologic structure, and soils and their effects on drainage patterns, stream changes, and channel slopes. Also, channel overflow zones, flood damage areas, erosion and sedimentation sections, and seepage zones are easily recognized and studied. Such advantages are most apparent wherever available small-scale topographic maps do not contain sufficient details regarding the drainage courses and watershed boundaries.

Soils and Construction Materials.—The accomplishment of effective highway engineering requires sufficient information regarding soils and their condition, and bedrock, to avoid costly construction and maintenance and at the same time to achieve, insofar as practicable, a balance with all other considerations. In addition, sites of the nearest sources of suitable construction materials must be ascertained.

Properly used, aerial photographs of adequate scale enable highway engineers to delineate the boundary between soils of different classifications, to differentiate rock outcrops, to plan effective soil sampling programs, to determine the likely sources of construction materials, and to design highways achieving the economical use of existing soils and available construction materials. Moreover, aerial photographs are examined and interpreted, and are used as the delineation media in the preparation of soil maps for highway engineering purposes.

Rights-of-Way and Cadastral Data.—Some highways requiring improvement and each new highway to be located, designed, and constructed need adequate right-of-way. This cannot be acquired until property ownership boundaries are defined and their exact position ascertained, and the right-of-way boundaries are established. In such work, aerial photographs are used first to ascertain general character of land use and land use boundaries. Second, the aerial photographs are used for general delineation of property ownership boundaries and superimposition of the proposed rights-of-way thereon. Third, the aerial photographs are used in evaluating properties affected and in ascertaining costs of the right-of-way, first by estimation and second by negotiation with the property owners. Aerial photographs used in this manner make it much easier for all parties concerned to visualize the relationship of the proposed highway to the property, to judge its effects thereon, and to agree on just compensation.

Recording of deeds, however, requires the use of specific dimensions regarding size, shape, and position. Heretofore, such cadastral data were obtained by ground surveys. Fortunately such costly methods need not be resorted to for each specific parcel. By placement before photography of photographic targets on carefully selected property corners and boundary lines, and on basic horizontal control points, cadastral data for deed purposes may be measured photogrammetrically to requisite accuracy and more economically than by other methods. Wherever these techniques have been employed, highway engineers have saved both time and money.

Inasmuch as most cadastral laws require occupancy of each property marker when its position is surveyed, occupancy will probably be necessary whenever photogrammetrically made cadastral measurements for highways are challenged by property owners. General acceptance of photogrammetrically made measurements will occur as experience is gained in their use. The logical sequel will be revision of laws so such measurements will be acceptable in the courts.

Measurements for Payment Purposes.—Before payment is made for contract construction, in progress or completed, measurements are made to compute the volume of excavation and of other materials. Exceptions are those cases where specifications stipulate that payment will be made on the basis of quantities determined during design which are itemized in the proposal schedule. Whenever measurements are made by ground survey methods for volume computation purposes, interferences from traffic, and difficulties of climbing excavation and embankment slopes steeper than the original ground add to the cost of making the measurements.

The photogrammetric measurement of profile and cross sections of a constructed highway is easy and economical to accomplish to requisite accuracy. The ease, economy, and accuracy are assured when the aerial photography being used is correlated in horizontal and vertical position with photography initially used in the photogrammetric compilation of topographic maps and the making of other measurements required for design. The correlation is achieved by placement of targets on markers set at control points outside construction limits where they will not be disturbed by normal use of the bordering lands. Then, preceding the taking of photography of the constructed highway, the targets are reset on the same points. This procedure obviates need for additional basic and supplemental control points to orient the stereoscopic models for measurement of the profile and cross sections.

Wherever these techniques have been used and the accuracy of results was checked by survey methods on the ground, differences between the separate measurements have been insignificantly small and the resulting excavation and embankment volumes generally differ by less than one per cent from volumes computed during design. Ordinarily, the differences indicated larger volumes from the photogrammetrically made measurements than from the field-survey made measurements. The reason for this occurrence is that generalizations occur more often in field measurements, whereas few difficulties are encountered in getting true configurations by photogrammetric methods. When such facts are understood, construction contractors readily accept payments based on photogrammetric measurements.

Illustration and Correlation.—Before highways are improved or new highways constructed, all affected and interested citizens have the right to be informed and to express their opinions regarding the proposed facilities. Consequently, conferences and public meetings are held at which pertinent facts are presented. Fortunately, aerial photographs with the feasible routes stereoscopically delineated thereon, and assembled in the form of photographic mosaics, are effective media for such purposes. In addition, perspective delineation on oblique photographs, and stereoscopic imposition on stereograms and anaglyphs make it easy to convey concepts and portray relationships much better than can be accomplished otherwise, except perhaps by the use of physical models constructed to scale. When physical models are necessary, aerial photographs and maps photogrammetrically compiled make their development representative and easier to achieve.

PHOTOGRAMMETRY FOR HIGHWAYS COMMITTEE

Twenty years ago, people using photogrammetry were directing their efforts toward the mapping of large areas and the improvement of instruments and techniques for such mapping. As the utility of photogrammetry for engineering purposes became more apparent, thoughts and efforts were directed toward extending the application of photogrammetry into highway engineering. A natural sequel was the establishment of a technical committee, the members of which were especially qualified and interested in utilizing and improving methods and procedures in photogrammetry for highways. Accordingly, the Photogrammetry for Highways Committee was organized by the American Society of Photogrammetry in 1950. The first major accomplishment of this Committee was the preparation and publication of specifications for highway engineering utilization of photogrammetry. Other contributions have included the preparation of technical papers, sponsoring improvements in instruments and techniques, broadening utilization, and pointing to specific expectations by highway engineers from photogrammetry and photographic interpretation.

The initiative and progressiveness of engineers utilizing aerial surveys for highways led to employing innovations in instrumentation, to using color and infrared photography as supplements to panchromatic photography for photographic interpretation and some types of mapping, also to using photographic targets to achieve certainty and accuracy in utilization of control, and the digitization of photogrammetrically made measurements for use in electronic computers. Each innovation has indicated the desirability of further innovations and the need for research.

Unfortunately, it is difficult and sometimes impossible for highway engineer users of aerial surveys to divert their efforts to research. Happily, however, actual utilization ofttimes results in improvements and in new developments, which lead to economies and to greater use.

DISSEMINATION OF INFORMATION

Training.—The most rapid acceptance and expansion in use of aerial surveys has occurred wherever training courses for highway engineers have been conducted—courses in which the principles of aerial surveys and their uses in locating and designing highways are featured. Engineers completing the courses are able stereoscopically to examine aerial photographs, to interpret them, and to ascertain the qualitative information needed, as highway route alternatives are determined and compared, a route is selected, and highway designs are accomplished. The engineers are cognizant of the basic principles of photogrammetry, and the measurements and mapping which can be accomplished photogrammetrically for fulfilling specific needs. Also, understanding and abilities have been sufficiently fortified to enable the engineers to expand and to improve their uses of aerial surveys.

Engineering graduates who enter the highway engineering field usually need functional and operational training before they assume responsibilities for accomplishing and directing highway engineering work. Inasmuch as highways cannot be constructed for use until adequate surveys and designs have been completed, the significant aspects of such training must include surveying, both from the air and on the ground. Until the curricula of engineering educational institutions provide for adequate instruction in fundamental principles, applicable mathematics, and functional procedures and instrumentation, graduating engineers will continue to need essential training in aerial and ground surveying before being placed in responsible charge of the work for which employed.

Pan American Highway Congress.—In the use of aerial surveys for highways, there have been continuing demands for exchange of information. The most beneficial exchanges thus far made (by papers and in oral discussions) pertain to needs and to the applicable principles, techniques, instrumentation, and procedures which will best fulfill the needs. Nevertheless, not all demands have been satisfied. This is a challenge to the American Society of Photogrammetry, as exemplified by a resolution unanimously passed at the Ninth Pan American Highway Congress held in Washington, D. C., May 6–18, 1963. This resolution requested member countries of the Pan American Highway Congress to make information known regarding their experiments and progress in use of aerial photogrammetry and photographic interpretation; recommended that the respective governments and private institutions engaged in highway work expedite training in photogrammetry and photographic interpretation; and recommended curricula of all American engineering universities include optional courses at both graduate and undergraduate levels in photogrammetry and photographic interpretation.

The American Society of Photogrammetry is fully aware of the realities which make this resolution efficacious. It focuses our attention on the fact that, with respect to aerial surveys for highways, there is need for research, for greater dissemination of information on developments and use, and for more instruction and training of highway engineers in principles, techniques, and applications.

Aerial Surveys Influence

Thus far, we have been considering the influence of highway engineering on aerial surveys. As we all know, there is another side to the coin—the influence of aerial surveys on highway engineering. This influence has extended into nearly every stage and phase of highway engineering, but only what appear to be among the outstanding influences are mentioned.

Aerial surveys, through their "trial by fire," have changed initial concepts. Instead of readily questioning photogrammetrically made measurements when they do not agree with measurements made by survey methods on the ground, the latter are checked first in the process of achieving conciliation. The inadequacies in detail and in scope, and inconsistencies, which are ordinarily reflected by lack of uniformity in accuracy and reliability of surveys made on the ground, were not really known until "tested" by aerial surveys. Coming to such a realization is not license to conclude, however, that surveys were not made accurately and comprehensively on the ground. It merely emphasizes the effects of routines gradually drifted into because of costs, exigencies, haste, and perhaps inattention.

Exactness is essential in transfer to the ground of designed highways for construction from their computed plane-coordinate positions on the photogrammetrically compiled maps. Exactness, however, cannot be achieved unless differences between distances measured on the ground and distances determined from plane coordinates of maps compiled on the datum of the State Plane Coordinate System are ascertained and their effects nullified. This reciprocal influence led to development of a mathematical and easily applied procedure for repositioning the datum of the State Plane Coordinate System. Differences between ground-surveyed distances and distances determined from plane coordinates of maps compiled by use of control positioned on the new (repositioned) datum are insignificantly small. Thus, the highways can be easily staked on the ground in their designed position, because map and ground distances will not differ enough to require any adjustment of the map-determined distances to achieve agreement with distances measured on the ground.

In cases where circumstances brought into direct comparison information and data obtained by ground surveys with that ascertained by aerial surveys, the general economic inability of surveys on the ground to compete with aerial surveys has invariably become evident. This inability largely pertains to details, scope, and overall reliability. Moreover, aerial surveys have made it possible to determine easily the best solution to each problem using facts readily available from the surveys. Such was not always attainable by surveys on the ground merely because making sufficient comparisons to achieve the best solution was thought to be too costly in terms of time and money.

The Future

The engineering and construction of highways are continuing endeavors. Seemingly, incessant increase in the number of motor vehicles and their use make it difficult for highway construction to keep pace. Consequently, the advantages of aerial surveys insure their continued use by highway engineers. As in other fields of aerial surveying, automation in computation will be expanded, and automation in certain aspects of photogrammetric instrument operation will be realized. Photogrammetric measurements will be accepted and become common practice in cadastral surveying. More and more, color and other varieties of photography will be utilized for photographic interpretation, photogrammetric work, and illustration purposes.

The challenge for photographic interpretation and photogrammetric specialists not directly engaged in the engineering and construction of highways to become aware of highway engineering principles and needs will be greater than heretofore. As these specialists increase their knowledge of highway engineering, it will be easier to achieve a mutual understanding. In addition, highway engineers will learn more about aerial photography and photogrammetry, including principles, instrumentation, and techniques of utilization; and will achieve better adaptations and benefits therefrom.

Sequel to the foregoing will be the separate groups of specialists with different technical qualifications further focusing their attention on problems of mutual interest. Research will be undertaken on a cooperative basis and lasting benefits will accrue from the complementary qualifications, interests, and efforts of each group. Thus, improvements will continue and new techniques will be devised. In actuality, it is impossible for imaginative and clear-thinking persons to predict fully how far-reaching and in what direction the improvements and changes will be made. We can all be sure, however, that the movement will be forward and that the benefits accrued to both aerial surveys and highway engineering will become greater in number and scope in the years ahead.

Of a certainty, aerial surveys and highway engineering will continue to grow and to have reciprocal and mutually benefiting influences on each other.