

Use of Photogrammetry for Highway Land Acquisition Purposes

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● THE current accelerated highway program has been accompanied by a greatly increased use of photogrammetry for highway purposes. Such use of photogrammetry and aerial surveys for highway location and design purposes has proved to be a great time as well as money saver compared to conventional methods. Among other uses, photogrammetry has been used quite economically and efficiently for highway and pipeline surveys. The greatest savings have been noticed when it is used for reconnaissance of an area in which a route location is to be established, reconnaissance of alternate routes to determine the best route, preliminary surveys of the approved route, design, and preparation of construction plans. When photogrammetry is used for location and design purposes, it can also be economically and advantageously applied to the land acquisition process.

FUNDAMENTALS OF PHOTOGRAMMETRY

Photogrammetry is the science of art of obtaining reliable quantitative measurements from aerial photographs. The most widely used type of photograph is the vertical, so called because the picture is taken from the air with the optical axis of the camera lens set vertically. Other types of photos are oblique, horizontal, convergent, and continuous strip.

Stereoscopic Model

When each portion of a ground area appears on two photographs, a three-dimensional view or stereoscopic model may be created. A stereoscopic model or relief model of an area common to two photographs may be viewed by a person using both eyes, with the aid of a simple lens stereoscope or mirror stereoscope (Figure 1), after a little practice. Photographs may also be viewed stereoscopically with the unaided eyes or color separation, but several hours of training are required by most individuals before mastering the art of stereoscopic vision by the unaided eyes.

Stereoscopic pairs of photographs may be viewed for the ultimate purpose of determining land use, property lines, land value, landscaping and roadside development, soils, geology, drainage characteristics, stream crossing, erosion, recreational facilities, for scenic, historical, or archaeological interest, and for taking approximate measurements. Studying shape, size, form, color tone, texture, pattern, and shadow on aerial photographs aids a photo-interpreter. The photo-interpreter must have a knowledge of the purpose for which he is interpreting the photographs, which would also be a requirement if the interpreter were to make an actual site investigation. It may also help the interpreter to be somewhat familiar with the general area and to know the climate of the area shown on the photographs as well as the season of year and time of day.

Mosaics

Photographic coverage of a strip of land is obtained by taking photographs from an airplane as it flies along a straight level line called a flight line. Photographic coverage of a larger area is obtained by a series of these strips, called flight strips, having some overlap along the adjacent sides. By assembling the photographs of an area along the

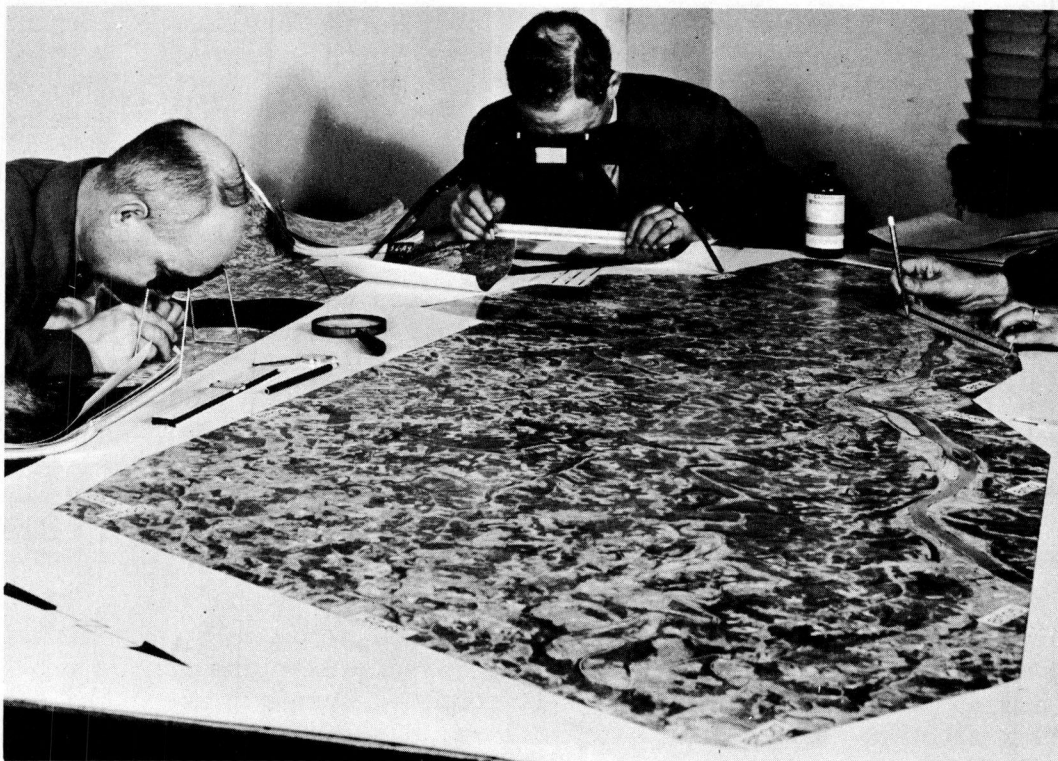


Figure 1. Viewing photographs through a lens stereoscope (left) and a mirror stereoscope (center), with an aerial photographic mosaic in foreground.

flight line of each strip and by matching conjugate images along the edges of the strips of photographs, an uncontrolled photographic mosaic is made (Fig. 2). A controlled photographic mosaic is assembled according to control points established on the ground, and the more exact need that it fulfills is not ordinarily encountered in highway location and design work. For illustrative purposes, the uncontrolled photographic mosaic is better and has been useful to right-of-way divisions of state highway departments.

Map Compilation

Topographic and planimetric maps are compiled from aerial photographs placed in a stereoscopic plotting instrument. Stereoscopic vision of photographs in a photogrammetric plotting instrument of the double-projection type (Fig. 3) is accomplished by color separation. The photographs are oriented in the instrument to make corrections for any amount the camera axis may have been tilted from vertical at the time the photographs were taken. This orientation produces a three-dimensional view of the topography in which the relative position of features are more accurate than the photograph positions. More accurate and detailed maps can thus be compiled by photogrammetric methods in less time than by other conventional methods. Some ground control points are needed to compile maps by photogrammetric methods, and the accuracy of the maps depends on the accuracy of the ground control surveys. The scale of the maps, and the minimum contour interval that can be measured and plotted thereon, depend on the altitude of the airplane at the time the photographs were taken and the photogrammetric plotting instrument being used to compile the map. Contours can be plotted more accurately and with less difficulty if the photographs of some areas are taken at a certain time of year when the snow or the foliage of deciduous trees is at a minimum.

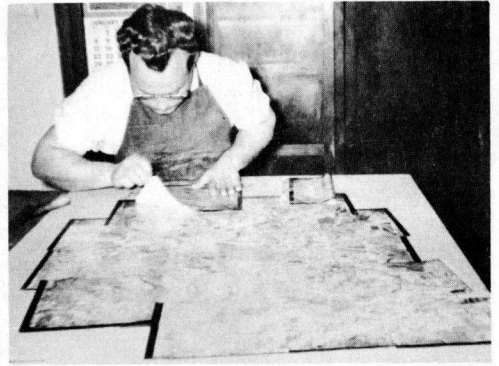
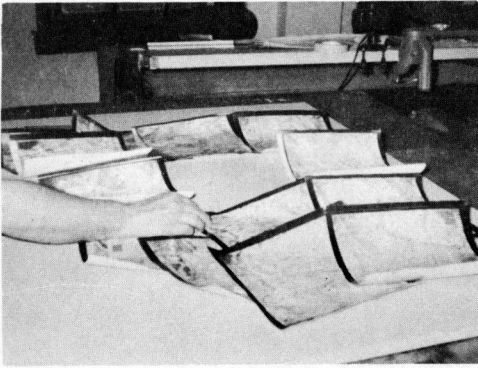


Figure 2. Preparing an aerial photographic mosaic (Courtesy of Texas Highway Department).

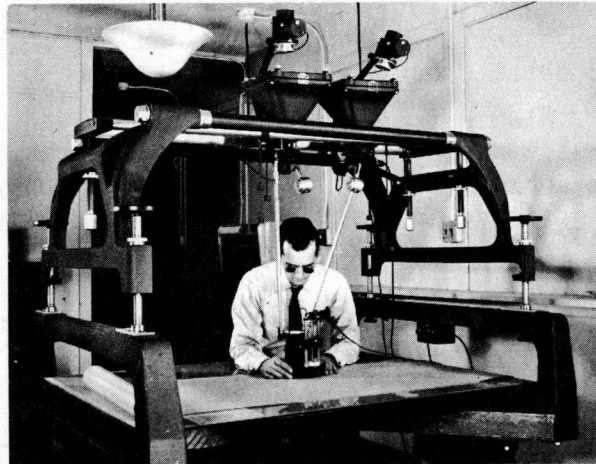


Figure 3. Operator at a Kelsh plotting instrument.

Use in Highway Engineering

Highway engineering for a new route location is conducted in a series of stages. Reconnaissance of an area in which feasible route alternatives are established is first accomplished by studying small-scale photographs of a broad area taken from a high flight height. Available maps of the area are useful as a supplement to such a reconnaissance survey. Control points located on the ground prior to taking this photography are usually not needed at this stage, as they only become necessary if maps are to be compiled from the photographs. Several alternate routes are thus determined and delineated on the photographs in correspondence with the model seen when the photographs are stereoscopically examined. The routes are also shown on the photographic mosaic. In the next stage, these alternate routes are thoroughly examined and compared to determine the best route. For this determination, several cost estimates and analyses are made, such as amount and cost of right-of-way, including estimates of severance damages, construction and maintenance costs, geometric design standards, and traffic analysis. For the preliminary survey stage, which follows, ground control is established and larger-scale photographs are taken from a low flight height. The necessary ground control (horizontal and vertical) can be established quickly with a minimum of disturbance to the landowners.

A topographic map is compiled from these photographs for use in design and preparation of construction plans and in right-of-way acquisition along the approved route. The remaining stages are the location survey staking of the designed highway on the ground, and highway construction. A prime advantage gained by the use of photogrammetry is the saving in time and the reduction in cost of the first stages of highway engineering. This is more noticeable when establishing a new route location than when an existing highway is to be improved.

APPLICATION OF PHOTOGRAMMETRY TO LAND ACQUISITION

The specific means of applying photogrammetry and the extent of its use by the state highway department for land acquisition purposes vary from one state to another. In some states, all or different pieces of equipment (such as airplane, camera, stereoscopic plotters, and photographic laboratory equipment) are owned by the state; in others, the work is let out by the contracting authority to photogrammetric engineering firms. Some 25 states, and possibly a few others, use photogrammetry to some extent for land acquisition as well as engineering purposes of preliminary and location surveys. They are listed as follows:

Alabama	Georgia	Massachusetts	New York	Utah
Arizona	Florida	Michigan	North Carolina	Virginia
California	Kentucky	Minnesota	North Dakota	Washington
Colorado	Maine	Mississippi	Ohio	Wisconsin
Connecticut	Maryland	Missouri	Texas	Wyoming

How It Can Be Applied

Of great importance is the information security that may be achieved when highways are to be located on new routes. Before low-level photography for mapping the route, land records and legal descriptions can be reviewed and plotted to determine any section corners, property corners, or land locations that should be identified on the photographs. To overcome the difficulty of identifying some ground locations on the photographs, markers or targets can be placed on the ground before photographing. An engineer and a few assistants can, in a short time, without alerting speculators, target ground locations and establish some ground control points before the route is photographed. The route can then be mapped, the highway designed, construction plans prepared, and right-of-way acquired before ground survey crews start to work in the location survey stage, and before land speculation is generated.

After low-level photographs have been obtained along an approved route location and mapping has been completed, the approved centerline can be plotted on the maps and an accurate description of it computed (using plane coordinates), the right-of-way areas may be calculated, and legal descriptions of the parcels to be acquired can be prepared. Map data can be used for calculation of parcel areas by an electronic computer. The accurately compiled planimetric maps showing details such as fences, streams, trees, and crop lines denoting cultivated fields or pastures aid materially in the orientation and plotting of deeds that are abstracted for the properties affected. For ready reference, the grantee, grantor, and page and type of deed can also be recorded on the maps. Of prime significance is the fact that a set of these maps can be made readily available to right-of-way personnel, who in turn can proceed with survey permits and title searching. This results in a substantial saving in time and money by narrowing the usual number of options and abstracts normally secured. It also gives the land acquisition personnel an opportunity to meet with the landowners involved before location survey crews have been in the area.

For appraisal and negotiation purposes, an aerial photographic mosaic can be used on which has been delineated the highway centerline, property lines, and the right-of-way to be acquired (Fig. 4). Both negotiators and landowners are enthusiastic about this method of presenting a picture of a proposed highway. An artist's conception of the future improvement can be superimposed onto the photographs and mosaics. The resulting picture (Fig. 5) can also be helpful in dealing with the landowners. Use of

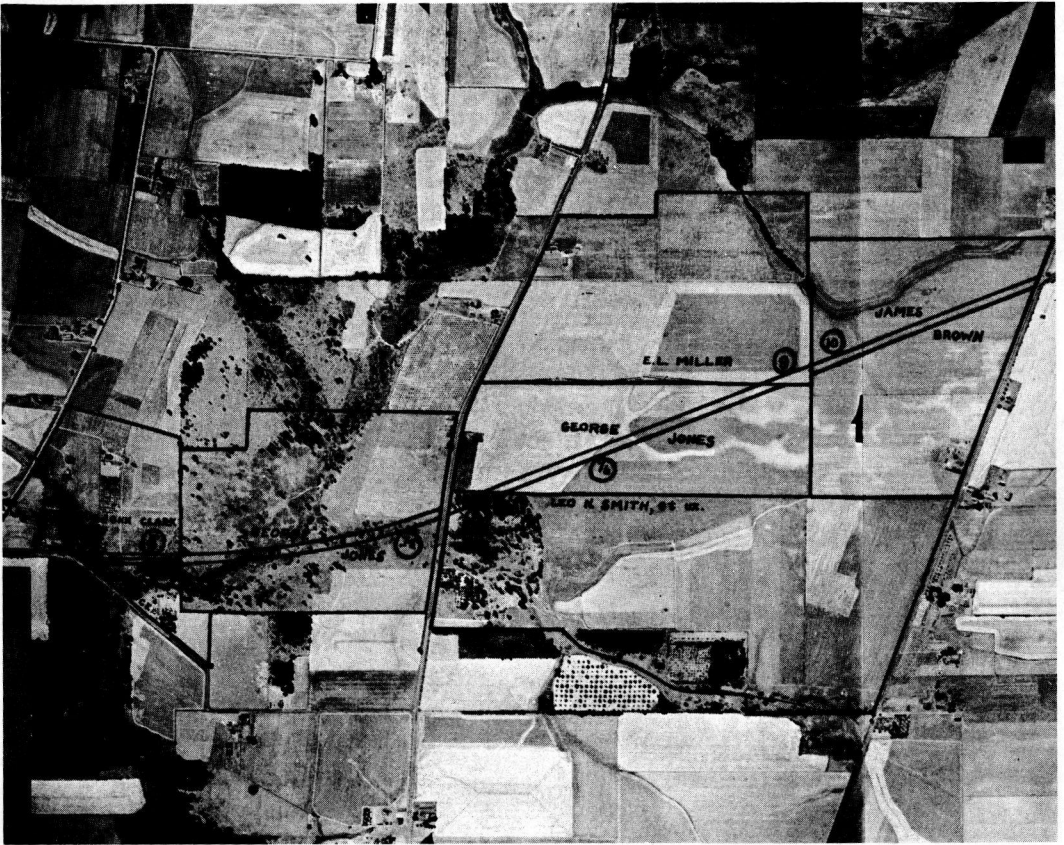


Figure 4. Aerial mosaic showing owners, property lines, and right-of-way to be acquired (one-half size).

a mosaic showing the alternate routes for the purpose of informing or discussing the matter individually with property owners in the early planning stages may lead to unnecessary controversies. However, their use may be helpful at public hearings as a means of securing cooperation.

Property lines of an individual parcel can be delineated on individual photographs or stereoscopic pairs of the photographs for the purpose of appraising, negotiating with the property owner, including in the appraisal report, and even filing with permanent records of right-of-way departments or land offices. Because it is essential to have sufficient photographs of the property in the appraisal report to show the significant features of the appraisal, they are excellent for this purpose.

If Federal funds are to be used in the construction of a project, the state highway department is required to submit to the Bureau of Public Roads, at the program stage, an estimate of the cost of rights-of-way to be acquired. Before or at the project agreement stage, the state must submit to the Bureau a right-of-way map for the entire project, showing lands it anticipates will be acquired. Any vouchers, and especially the final vouchers submitted to the Bureau for reimbursement of expenditures, are supported by a copy of a right-of-way map indicating the relation of the parcels acquired to the right-of-way limits of the project, or by reference to a right-of-way map previously submitted. Good right-of-way maps for this purpose can be compiled from aerial photographic mosaics or topographic and planimetric maps that have been compiled by photogrammetric methods. A good way to get an estimate of right-of-way costs and property damages at the program stage without sending out a field survey party and

and possibly disturbing the property owners is to use the aerial photographic mosaics or the photographs individually on which property lines and proposed right-of-way lines have been delineated.

Examples of Its Application

The Michigan State Highway Department has noted that photogrammetry has reduced the cost of reconnaissance surveys about 96 percent over previous methods, with a 95 percent saving in time. They have also applied photogrammetry to right-of-way planning, preliminary surveys, road design, and soils location with respective time savings of 15, 30, 5, and 10 percent.

In addition to expediting location work and protecting the location from land speculators, the Right-of-Way Department of Maryland has used aerial photographic mosaics for land acquisition and as court evidence in condemnation proceedings. They have used aerial photographs to establish property lines on master plats and have used photogrammetrically compiled maps and aerial photographic mosaics for preparing property mosaics. Master plats and property mosaics are not only needed for right-of-way negotiations in Maryland but also used for permanent file reference. They consider that maps compiled photogrammetrically offer the best material for work in preparing property plats, because of the accuracy and detail shown on these maps.

Mississippi has used aerial photographs extensively to make right-of-way estimates, especially in municipal areas. The Right-of-Way Division has used photographic enlargements to estimate property damages on alternate route locations, which is an influencing factor in selection of the best route, without disturbing the property owners.

Maine is one of the more recent additions to the list of states using aerial photographs to aid in land acquisition, especially in rural areas. Appraisers are now furnished with aerial photographs showing the area surrounding the parcels to be taken. This enables the appraisers to visualize more readily the parcel of land being taken in relation to the rest of the tract belonging to the landowner, to visualize the property in relation to neighboring property, to view the problem of access to land cut off from the whole by the taking, and to study the problem of drainage that might be affected by adjacent land.

The Texas Highway Department made a number of studies prior to 1958 to ascertain the feasibility of using data photogrammetrically obtained for the development of right-of-way maps and field notes for deeds. These studies convinced the highway department that photogrammetry would be economically feasible.

A pilot project was then contracted for in 1958 along a section of Interstate 20 in Dallas. The contract called for a photographic mosaic at a scale of 1 in. = 50 ft, and photogrammetrically compiled planimetric and topographic maps, both at a scale of 1 in. = 20 ft. The contractor was required to establish horizontal ground control surveys meeting second-order accuracy and vertical control meeting third-order accuracy before photographing. Notes of these surveys were also furnished on IBM cards for quick checking. The work on this pilot project was carefully checked for accuracy to determine the necessary requirements for such photogrammetric data and to ascertain the feasibility of meeting these requirements. Survey points established by the City of Dallas were used to enable the state highway department to check the resultant planimetric and topographic maps with subdivision maps. The photogrammetrically compiled maps were found to be well within the tolerances of a second-order survey.

Accurate property maps were developed with a speed that allowed the design engineer early consideration of all right-of-way factors. Many delays experienced in the past, while waiting for information from which to make a decision, were avoided. Appraisers were given work sheets consisting of prints of the area of the parcel they were to appraise. The parcel was designated by pencil shading. Copies of these sheets were also made for the property owner. New deed descriptions were prepared, using property survey notes as scaled from the photogrammetrically compiled maps and the previous deed. Should the property owner wish to have a survey of his own made on the ground, it could have affected the right-of-way line a maximum of 6 in.



Figure 5. Aerial view showing artist's conception of an expressway route.

At least 93 percent of the parcels on the pilot project were acquired by negotiation and no major problems developed. Work done under the project was checked by the state highway department. Only minor discrepancies were found and these were attributed to the fact that a field edit was not made. The department has concluded that there should be a field edit of a project of this type and that the expense involved is not extravagant.

With the benefit of this pilot project, the Texas State Highway Department has since contracted for a second project at a cost per mile only 27 percent of that for the pilot project. The specifications for this second project are considered adequate, as the project has received warm approval from the engineers closely associated with it. It is the intention of the highway department to use these specifications as a guide for future projects of this type.

Florida has found that aerial photographs often eliminate considerable work that would be necessary for a field crew to disclose certain information. They make a photographic mosaic on which is shown the parent tract and the boundaries of each parcel within the proposed right-of-way. This type of right-of-way delineation has readily indicated property that will be landlocked as a result of the proposed improvement. Fragment parcels that might be isolated from the main body of land can also be detected and included in the acquisition, thus reducing severance damages. In some instances, a means is revealed for providing frontage roads to avoid leaving the owner with residual or isolated parcels on which total severance damage would perhaps have to be paid. Another advantage they have experienced is that frequently the location of property lines as determined by the actual descriptions in the conveyances to the owner do not exactly coincide with the property lines indicated by fences and buildings

as they appear on the aerial photographs and the knowledge of these discrepancies is often of advantage in negotiating a settlement. Aerial photographs are also used by their appraisers and negotiators and for presenting evidence to a jury in condemnation proceedings.

Wyoming reported that aerial photographs are used in property appraisals and public relations work. They are also used by the courts in some legal cases.

On several Wyoming highway projects the land corners and property lines have been pre-marked, before photographing, thus making photogrammetry available for purposes of land ties and measurements.

The Highway Research Board Committee on Photogrammetry and Aerial Surveys is assigned to work under the Department of Design. It is constantly endeavoring to aid highway departments in the adoption and use of photogrammetry in every appropriate manner and in the various stages of highway extension and improvement.

SUMMARY

The possible advantages of the use of photogrammetry in land acquisition as discussed in this report might be summarized as follows:

Precluding Land Speculation.—With the aid of photogrammetry, information and data for designing a highway and obtaining right-of-way can be acquired before the location survey crew starts to work on the site. As a result, land speculation can be averted in the period before a certain route location has been decided on, and before the highway department is prepared to acquire the right-of-way. Proposed highway routes have been rendered economically prohibitive because of the activities of land speculators in the interim period before a definite location has been decided on. Time and money may also be saved by narrowing the options and abstracts normally secured.

Appraising.—There are several applications to appraising. Aerial photographs and mosaics are very helpful in making estimates of right-of-way costs for each of several locations under consideration, an important factor in determining the best route location or in programming Federal funds. They assist the appraiser in making his inspection of the property, locating corners, and classifying the land. They are especially helpful in appraisal studies when only part of the property is taken and the amount of severance damage to the remaining property must be determined. When considerable field work might otherwise be required, an appraiser might readily notice from aerial photographs or a mosaic that certain parcels will be landlocked or that severance damages could be reduced by including certain fragment parcels in the right-of-way. Large-scale aerial photographs, rather than small-scale mosaics or strip maps, readily lend themselves to inclusion in appraisal reports, because photographs of the property are valuable to the report. It has also been discovered that aerial photographs or mosaics may be used as a permanent file reference in right-of-way departments or land offices.

Negotiating.—Both landowners and negotiators are enthusiastic about using aerial mosaics or photographs to show the landowner how the right-of-way passes across his property and how it will affect the remaining land. To show the landowner how the completed improvement is expected to look, an artist's sketch or drawing can be superimposed on the mosaic or photographs.

Preparing Right-of-Way Maps.—Right-of-way personnel who prepare right-of-way maps and plot deeds find aerial photographs helpful for orienting or establishing property lines on a map or mosaic. Property lines, owner, highway centerline data, and right-of-way boundaries are essential to a right-of-way map. The grantee, grantor, page, and type of deed of the parcels might also be recorded on the maps or mosaics for ready reference.

Computing Areas.—Electronic computer programs have been developed to determine areas of right-of-way parcels and information for preparing legal descriptions in the deeds. Data from photogrammetrically compiled maps may be fed into the computer.

Court Evidence.—When it becomes necessary to resort to condemnation, aerial photographs or mosaics may be used to show the court the details of the area to be taken in a form that can be easily understood. A mosaic that shows the parcel boundaries and highway centerline data may be rephotographed and enlarged for this purpose. The photographs may also be enlarged for such illustrative purposes. Frequently certain individual problems affecting a subject parcel (such as local conditions, neighborhood influence, proximity to business areas, slum areas, churches, and schools) can be presented to the jury much more effectively by use of aerial photographs than could be done by an on-the-ground inspection.

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