

The Application of Aerophotogrammetric Method  
in the Reconnaissance Survey and Design of  
Railway

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#### Abstract

The aerophotogrammetric method has been widely used in the railway reconnaissance survey and design in China. The paper gives a brief account of its application, operation procedure, working content, method, technical requirements and characteristics etc.

#### Introduction

Construction of new railway lines and reconstruction of existing ones are being carried out in China on a large scale. To achieve this the first important task faced is doing the survey and design work well. The practice of using aerophotogrammetry in railway survey and design makes us believe that it is a very effective way towards high quality and efficiency and that it is the direction for future development.

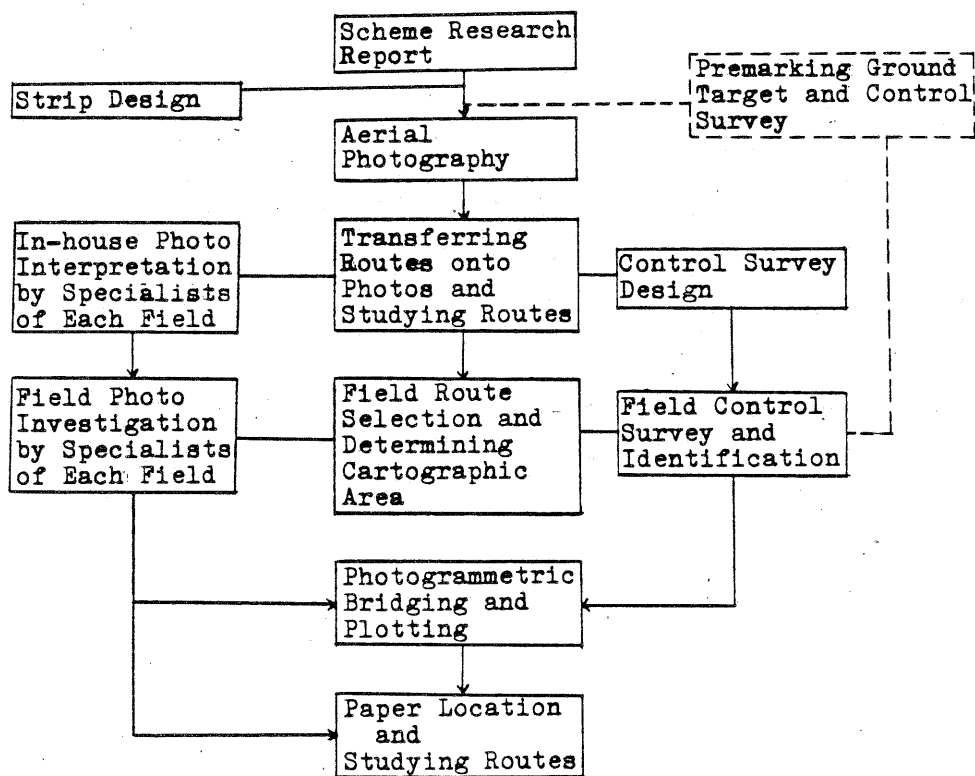
Railway survey is composed of two kinds of work, economic investigation and technical survey. The technical survey covers mainly the exploration, drilling, surveying and mapping of the earth, so that all data (e.g. the data of topography, geology, hydrology, water resources and building material) needed in designing of the lines and single project concerned can be obtained. Most of technical survey can be fulfilled by either conventional ground survey method or aerial survey. An aerial photo which keeps a good record of ground information can be acquired in no time. Not only can topographic maps of all scales be made from it but also the variety of data required for design of railway can be provided by it. For surveying our new lines, especially in difficult mountain areas, aerial survey has been used for the most part.

There is something in common between railway aerial survey and the general one as far as method, procedure and equipment is concerned, but owing to the different needs there is also something different. The paper describes mostly the working content, requirements and results of the railway aerial survey.

The Key to railway survey and design is the route selection. In the route selection, one must follow "from principle to concrete" and "from whole to part". For example, as a rule, the range of the routes is determined "from area to corridor and then from corridor to line"; the accuracy requirement is met according to "from low to high" and the scale according to "from small to large". Division of survey and design into stages is also necessary for progressive approach to the best route. With the help of aerial survey all these requirements can be properly met. Aerial photogrammetry is used to a different extent in all stages such as scheme research report, preliminary survey, preliminary design,

Location survey and technical design in China. Though at all stages everything done belongs to the field of technical survey, the survey and design stages are different from each other, at least in method and requirement. To show it clearly, a diagram is provided below for the stage of preliminary survey before running into details.

Diagram: Working Procedure at Preliminary Survey Stage



## 1. Scheme Research Report

This is the early task in the railway reconnaissance survey and design. Generally it has to make clear about such matters of principle as starting and ending points, running direction, significance, traffic task and construction arrangement of a new line. In addition, suggestion should be made on the cooperation with big reservoir administration, industrial, mining and regional establishments and on the important technical matters of the new line. Therefore, besides economic data, technical data such as topographic, geologic and hydrologic etc. should be collected and used in studying possible routes. Topographic maps at the scale of 1:50,000 are available for most of the areas in China and 1:10,000 ground survey map is no longer made as before, however for difficult mountain areas it is felt that the scale is too small and the accuracy is not good enough. There is close relation between a topographic map and an error of a project because the route length, the earthwork volumes and the number of bridges and tunnels etc. depend on the contour accuracy. As regards map scale, it should facilitate using and normally the scale of 1:10,000 will be advisable in the mountain areas. On such map the horizontal and vertical alignments of the new line can be studied fully. For this we have collected existing 1:50,000 aerial photos which was used in plotting 1:50,000 topographic maps before and plotted 1:10,000 topographic maps for difficult mountain areas. The contours and ground features within the corridor which covers all possible routes have been plotted carefully. Interpretation of regional geology, poor geologic condition, river changes and others can also be done with aerial photos and satellite images. While aerial survey, which can provide as basic data a wide range of topographic, geologic and hydrologic information, is undoubtedly an effective way for comparative selection among many possible routes, plotting with existing aerial photos and control survey data is also of great importance for reducing the cost.

## 2. Aerial Photography

Large scale aerial photography is generally adopted in the preliminary survey. For this, a few possible routes which must be compared in the preliminary survey should be first determined based on the previous scheme research report, and thereby the photographic area will be also determined, then strip design is carried out with reference to map requirement, condition of photographic area, flight requirement and plotting instruments etc..

Strip design is often done on 1:50,000 maps, with photographic area plotted according to the selected routes and photographic scale. Photographic scale is usually 4-7 times smaller than plotting scale.

Aerial photography for railway survey and design is characterized by flying along a route which is composed of many straight lines and curves, To ensure a straight flying, it is necessary to divided an area to be covered into sections. Due to the number of local possible routes, the width of each section may be different from others.

### 3. Work Related to Aerial Survey Done at Preliminary Survey Stage

1) Transferring the selected routes onto photographs, for improvement study of a scheme and determination of cartographic area. This work means that the selected routes on the original maps used at the scheme research report stage will be transferred onto new large scale aerial photos according to ground features, and that main settlements, rivers, mileage and stations on the selected routes and big projects will be also marked on. From the new one reproduction is made as a base of interpretation for each specialized field. By combining office study with field investigation a better scheme is further approached and a cartographic area is determined. To further perfect the scheme for preliminary survey, the field investigation has to be emphasized on important projects e.g. large bridges, long tunnels, important sites and poor geologic sections etc..

2) Comprehensive application of aerial photos in geology and hydrology.

In-house interpretation is often done on the photos with transferred routes before field emphasis check or photo identification. Currently aerial photos are used for interpretation of engineering geology such as geologic structure, boundary of poor geologic land etc., and thereby the engineering geologic maps can be made.

Looking for resources of building material is possible from interpretation of photos on which perhaps outcropping bedrock, river sand and gravel etc. are recorded.

In selecting the locations of large and medium bridges the hydrologic survey is very important. Through photo interpretation, the watershed condition, relief feature, the shape, erosion and deposit of a river and the hydraulic structures etc. can be investigated, so that the bridge locations can be selected correctly. During the investigation of flood level along the river, the flood level points and water face slope points may be marked on the photos. These points later on will be projected and plotted onto a topographic map. on the map, their planimetric positions can be measured, but during the field investigation only their heights are measured.

3) Field control survey and topographic identification.

Set up of control points should meet the requirements of analytical aerial triangulation and photogrammetric plotting. With a section as a unit, the points are set up according to a strip. Under normal photographic condition, the number of photo bases between horizontal and vertical control points at each end of a strip section depends on the plotting scale, photo scale, camera focal length and topographic classification etc..

Because the map used for railway design is a zonal map, it is proper to take the measurement of control points in the form of traverse with laser distance measuring instruments and theodolites. Having been started and ended at national geodetic points, the traverse should not have a relative error of closure larger than

1/10,000 for the whole length and an azimuth closure error bigger than  $15''/\sqrt{n}$  ( $n$ = the number of instrument stations); a traverse for height measurement should meet the specification of  $30\sqrt{L}$  mm ( $L$ = length of closed traverse in km).

In addition to the above-mentioned specification, there are some specific requirements for a railway engineering as follows:

- The longitudinal traverse should be as close to the selected route as possible.
- During traversing, 1 or 2 elevation points along the traverse are advised to be sorted out and marked onto each photograph so as to improve the accuracy of photogrammetric plotting.
- Special control points necessary for tie measurement should be proposed by each specialized working group.
- With a view to enabling the layout of the selected routes to be made on the ground in the location survey stage in future, one point every 3-5 km on the traverse nearby the selected main route should be staked and fixed with a appropriate material during the control survey.

#### 4) The office compilation work of the railway aerial survey.

The compilation technique of the railway aerial survey is almost the same as that of general aerial survey. It includes photogrammetric bridging and plotting.

Besides the basic control points needed for stereoplotting, some additional control points such as the points selected on the selected route, geologic and hydrologic points needed for the railway design should be bridged simultaneously based on the ground control points.

There are 2 kinds of aerial survey map used for the railway design: the line map and orthophotomap, with the former used widely. The scale of preliminary survey map is 1:5,000 or 1:2,000 with 1:2,000 more often used, but the map at scale of 1:1,000 has to be made for a few special work sites.

Which kind of plotting instruments and techniques to be used depends on the plotting requirements and aerial survey data.

When the range and accuracy of the 1:2,000 zonal map has met the requirements of the railway technical design, generally plotting is no more needed during the location survey stage.

A lot of maps of the topographic sections and work sites should be made during the location survey stage provided the original aerial data is appropriate and usually all the control points of stereoplotting are measured on the ground, these maps can be plotted with precision stereoplotters.

#### 4. Other Application Aspect

The aerial survey method has also been used for the mapping of an existing railway, e.g. for the operational management which needs the aerial survey maps. In such a case, the characteristics of its application are as follows:

- An existing railway does not cover the route selection problem, only 1:2,000 or 1:1,000 topographic maps are necessarily plotted once and along the railway line and the railway terminals.
- For an existing railway, especially large stations, where objects are thickly located, 1:5,000 photo scale is often adopted.
- To control the positions of the stations and the line, besides making good use of existing objects on the existing railway as targets, the frog centers and station centers will be premarked before aerial photography.
- The field work, in addition to conventional control survey and topographic identification is added by tie measurement of such points mainly as the additional points on a long straight line with one point every one km along the centre line of a railway, both ends of a curve, both ends of a medium or large bridge and some frog centers on large stations, shunting yards, locomotive terminals and goods yards and so on.
- Field topographic identification for an existing railway involves enormous amount of work. Besides general objects to be identified, the emphases are placed on the tracks, switches, signals power lines, platforms, water crane, crossings, bridges and culverts etc.. The purpose of the field identification is mainly a qualitative determination of the objects and the identification method is mostly an investigation. Those that can be interpreted in office will not be trimmed on the photos. Enlarged photos are used for the identification of the stations.
- The mapping accuracy of the existing railway required is very high: horizontally the ground object positions on the map should agree with both their images on the photo and the remeasured ground data (e.g. mileage list, curve list and bridge list); vertically the contours must be rather accurate, otherwise the grades of the existing railway and the flow direction of the river which the slope is very small may be reversed. Therefore during the stereoplotting the main traverse points, levelling points and tie measured points on the existing railway should be fully used for adjusting the stereomodel properly within a permissible accuracy, so that the accuracy of the map nearby the existing railway can be improved.

## 5. Practical Effects

After years of practice, the practical effects of aerial survey in China's railway construction may possibly be summarised as below:

- 1) Aerial survey is capable of providing enough information on topographic, geologic and hydrologic conditions, helpful to the

large area route selection and useful to the comparative selection among many and different routes, and can improve the quality of the route selection and save the capital construction investment.

The route selection is the key to the reconnaissance survey and design of railway. To do it well, not only should one consider politics, national defence, economy and other factors, but also have to study again and again all kinds of data concerned, namely topographic, geologic and hydrographic information, so that the optimum route can be approached step by step without missing any possible valuable route. This is very important particularly for the area where topographic and geologic conditions are very complicate.

The aerial photos required can speedily and easily be obtained by the use of aerial photography. With stereoscopes or other photogrammetric instruments, a reduced stereo terrain model can clearly be represented, which is more visual than a topographic map and much broader than viewing in the field. The photo interpretation may take place in office repeatedly according to the office condition. It has created the conditions required for the large area route selection. Through interpretation of the topographic, geologic and hydrologic conditions related and with reference to the topographic maps, the optimum route will be selected, thus improving the quality of the route selection. For example, the statistics for 6 new railways have shown that a sum of more than 100 million Renminbi Yuan in the capital construction investment has been saved due to the large area route selection by use of aerophotogrammetric method as compared with the conventional ground survey method. Therefore, the economic macro-effect of this technique is very apparent.

With the development of electronic computer techniques, a digital terrain model can be obtained by the aerophotogrammetric method and combined with railway design parameters will be calculated by computer so that profiles, cross sections, construction quantity and cost etc. all for the design can be worked out. This would be even more helpful to multi-route comparison and selection, thus improving the quality of the route selection.

2) Reducing the amount of field work, improving working condition aerophotogrammetric method can increase productivity.

The railway reconnaissance survey with a conventional ground method involved enormous amount of field work, high in expense but low in efficiency, whereas with aerophotogrammetric method, only a few of control points are needed to be measured in the field before one sitting in an office with plotting. This assures better working conditions and higher efficiency, particularly for a difficult area. Years ago, we did a new route in a plateau area. As the climate and geologic conditions there was so poor for doing field survey that aerial survey was used instead. With 4 teams half a year spent in the field, it took us altogether only one year to cover the topographic, geologic and hydrologic surveying and mapping work, which should be done at the preliminary survey stage for the main route and main comparative routes which extended about 2,000 kilometers. The time and manpower

consumed would have been more than doubled if field survey method had been used.

In the geologic and hydrologic survey, to interpret photos and sort out the typical sections first in the office and then go and check in the field can reduce the amount of field work.

The work using aerial photos to interpret and investigate the geologic and hydrologic conditions etc. can be done before the route traverse has been connected and before plotting, thus can speed up the reconnaissance survey process. The amount of field investigation work can be reduced also by using the photos in choosing the bridge location, disposing hydrologic profiles and detecting river changes, bank erosion, flood line and watershed condition etc..

3) Aerial survey can improve the quality of the reconnaissance survey data.

An aerial photo objectively and completely reflects the ground. The aerial survey maps plotted through optical stereo models show in detail the ground objects and landforms with remarkable accuracy. Aerial survey has unique advantages in terms of accuracy, completeness and speed, particularly when it is used for a railway terminal area of an existing railway, which is crowded with many facilities, objects and heavy traffic. For example we have checked our aerial survey maps for an existing railway in the field and found that the positions of the ground objects on the maps are within an accuracy of 1 m compared with that on the ground, which is good enough for the railway survey specification.

In engineering geologic survey, the faults, landslip, collapse, alluvial fan, mud-stone flow, karst, dune, marsh etc. poor geologic conditions all can be interpreted from photos with more accurate result.

Aerial photos play a useful role in the investigation of river form, mapping of the water collecting areas, the selection of the bridge location and tunnel opening, and in determination of sandstone producing area, and in the determination of the number of occupied farmland and houses to be dismantled etc..

With broad territory, the energy sources and traffic system, especially the railway construction, are being paid great attention to in China. To speed up the railway construction it is necessary to strengthen the research, development and application of the science and technology. The continuous development and application of electronic computer, calculation technique and remote sensing etc., the railway aerial survey will surely play more and more important role in the reconnaissance survey and design of railway in our country.