PRINCIPLES OF APPLICATION OF PHOTO-INTERPRETATION TO ENGINEER INTELLIGENCE*

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THE mission of the Engineer Strategic Intelligence Division of the Army Map Service is to provide the Chief of Engineers, and through him the General Staff of the Army, and other elements of the Department of Defense, with up-to-date information on all foreign countries, for the subjects within the field of Engineer Intelligence. These include railroads, highways, inland waterways, airfields, electric power, towns, pipelines, construction materials, terrain, and foreign combat engineer tactics, training and equipment. In the course of this work, involving the daily use of photo-interpretation, a number of developments in method have taken place. It is my purpose to explain several important principles that have been established and that should be of particular interest to the Members of the American Society of Photogrammetry.

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A seemingly, simple detail for the cartographer, such as the trace of a highway in an aerial photograph, requires for Engineer Intelligence a fully rounded definition of all its construction aspects, such as road surface and width, base and subbase grades and curvature, drainage, trafficability and carrying capacity, vulnerable points and roadside facilities, as well as a complete analysis of its bridges, fords, ferries, and tunnels and the strategic and economic implications of the road.

Basically, the task is one of compiling and maintaining a complete file of up-to-date information on the many ramifications of these subjects. This involves the assembly of fact structures on each of these subjects, for every foreign country, by piecemeal accumulation from the mass of available reference works, technical publications, maps, intelligence documents and photography.

However, while we have an enormous amount of accumulated and organized intelligence, it is not possible to receive completely current information at all times, on all subjects, in every area. It therefore becomes necessary to devise the means to develop this intelligence from material already at hand. One of the most fruitful means has been by the use of the aerial photograph. Proceeding from the premise that man's every act leaves some trace on the face of the earth, which can be identified by appropriate methods for "reading" the terrain, a methodology is gradually evolving and a number of principles have already been established which are developing photographic interpretation into a science in its own right.

Before World War II, much of what had been written on photo-interpretation was limited to collections of annotated photographs on such topics as types of vegetation, industrial organizations, or airfields, and so on, without much of

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an attempt at organizing these collections of data under any systematic set of principles of photo-interpretation.

By the end of World War II, several important advances in method had been made, especially in such fields as the analysis of geologic formations, landforms, beaches, subsoils, groundwater, and notably that remarkable technique by Williams of Cambridge University of studying offshore water depths by analysis of wave action. What all these advances mainly involve, however, is an understanding of particular elements in the natural environment.

On the other hand, the field of engineer intelligence has required a different approach, and only now is a simple systematized method beginning to take root.

This approach is one of appreciating the relationships of various engineering features to the terrain. These relationships can be recognized, evaluated, and measured, and it is by the analysis of these terrain relationships from aerial photographs, that a great deal of military engineer intelligence is amassed.

Features of engineer interest, being largely man-made, stem from particular, cultural and economic patterns. Within those patterns, they have specific design and construction standards and limitations. When these engineering standards, or criteria, are understood in their broad relations to the terrain and climate, the photographic identification of individual details become a simple matter.

We proceed, therefore, to establish reference standards or criteria, from information on file, on those aspects of engineer intelligence, which can be identified easily on aerial photographs. Based upon these criteria, we have developed a system of photo study which we call comparative analysis. The distinguishing feature of this analysis is that it is based primarily on the recognition of detail, and only secondarily on the measurement of detail. Many dimensions can be ascribed as much from the knowledge of these elements, and often more accurately, than from actual measurement of the detail by reference to the scale of the photograph.

Discrimination between an 18-foot $1\frac{1}{2}$-lane road and a 22-foot 2-lane road does not need to depend upon measuring the 4 feet of difference between the two roads. At a photo scale of 1:20,000, this difference amounts to two 10-thousandths of a foot, an almost impossibly precise unit to work with. Yet the distinction becomes simple when the design difference between the two types of road and their different structural relationships to the terrain are understood.

In practice, working from a combination of measurement and recognition, we have found it possible to proceed regardless of whether the available photography is vertical or oblique, high or low altitude, day or night flown, seriously tipped or tilted, and regardless of the type of camera or type of film. This has become especially important since decisions rely upon our rapid accumulation and evaluation of detailed information.

Comparative analysis has two aspects. First, the establishment and classification of the elements of the criteria, and secondly, an analysis of the deviations from these normal criteria.

Criteria are as varied as the nature of the subject under study. For example, the navigable depths of streams in southeast Asia, can be determined from aerial photographs by recognition of the types of native craft which ply those streams. In another case, concealment for ground troops in a given area, groundwater, and the nature of the soil, can all be studied from a comparison of the growth levels formed by each species of vegetation. In every case, the criteria established must focus upon those elements which reveal the pattern and which can be recognized on the photography.

Once the characteristics of a small section of any area, using all available sources, are fully developed, we can rapidly produce information of similar quality and detail over a wide area by aerial photography alone or in conjunction with piecemeal information.

A hypothetical example, of a typical study of roads in a country in southeast Asia, reveals two aspects—first, the development of criteria for each road type, and secondly the recognition of each type of road from its relationship to the terrain. Through such a study, many conclusions can be drawn, as for example

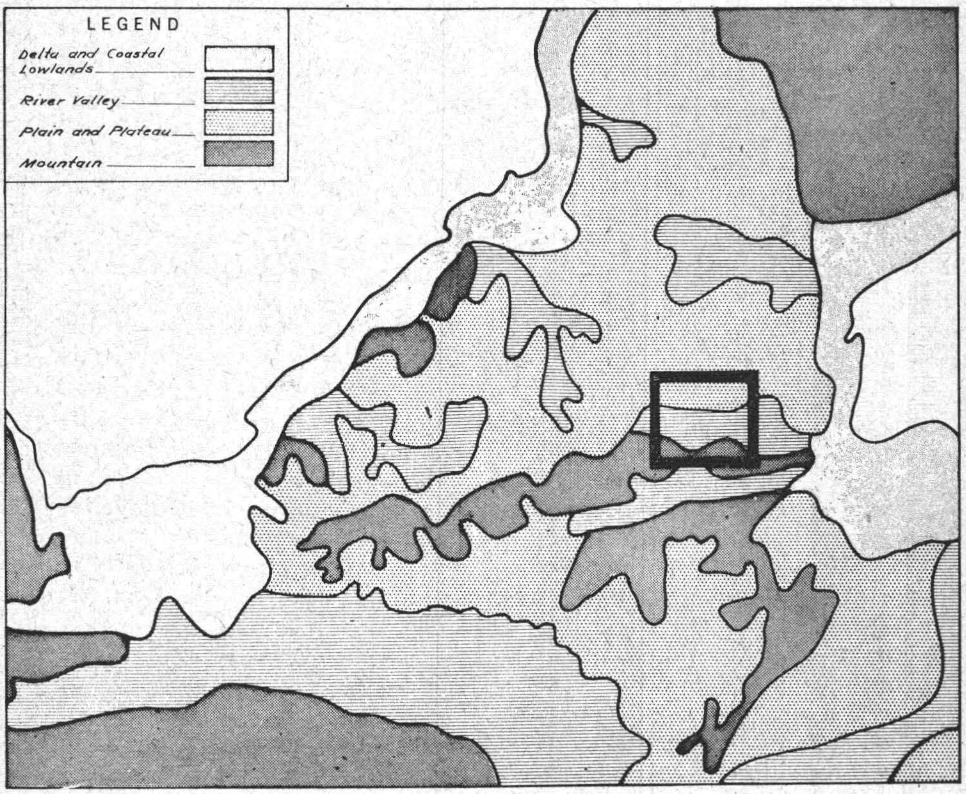

FIG. 1

knowledge of the speed and total carrying capacity of roads and trails in a given area.

The study takes the following form:

First, a terrain classification of the country is made, showing areas having common construction characteristics. These fall into four broad divisions, and, as illustrated in Figure 1, they are:

1. Coastal lowland and delta areas
2. Upland river valleys
3. Plateaus and plains
4. Mountain areas

Each area presents specific problems in road construction, the availability of materials, and the terrain and cultural features that fix the prevailing types of structural design. In this country these areas are characterized generally as follows:

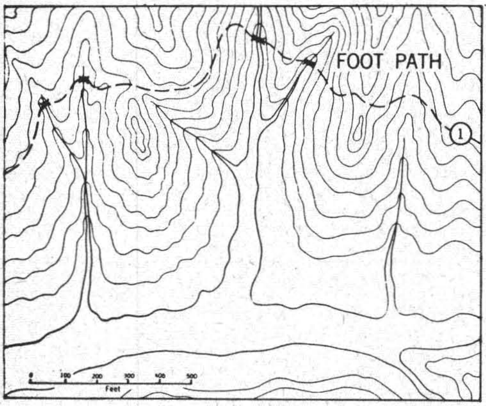

FIG. 2

(1) In the *delta areas*, waterways are the prime transport medium, while the roads are only feeders to local boat landings, and are of secondary construction. Good highways are difficult to build and require expensive bridging.

(2) In the *upland river valleys*, the roads present two distinct patterns. Where roads follow the main axis of drainage, they have many small bridges, many curves, and few grade problems, because they tend to follow contour lines. Where roads cross the main axis of drainage, they have large bridges, frequent passes, deep cuts, and steep grades.

(3) On the *plateaus and plains*, the roads are built to low standards because of the natural ease of movement; while bridges, although infrequent, are large and well built.

(4) In the mountainous areas, roads are few, but are well built because they lead to strategic areas. They have numerous bridges, passes, and tunnels.

The system of roads is represented by five general types. They are:

1. Footpaths (Figure 2)
2. Village cart roads (Figure 3)
3. District motor roads (Figure 4)
4. Provincial highways (Figure 5)
5. National highways (Figure 6)

For each road type, a criteria data sheet has been prepared by culling our filed information. The selected criteria are those which integrate the geographic, engineering, and cultural information, and which focus on details bearing a direct relationship to the terrain and are thus readily identified on aerial photographs.*

The characteristics of each road type follow specific design standards, and even footpaths have their own special adaptations to the terrain.

The illustrations are for a section along a river valley and show the various adjustments for the different types of road at the same stream crossing.

In these illustrations the various road types are shown as a progression from the footpath to the national highway, but only rarely would all five types actually appear together.

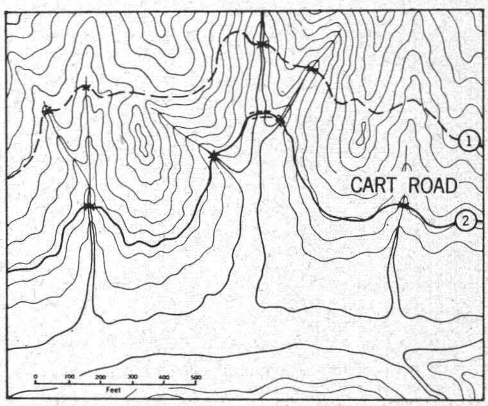

FIG. 3

Figure 2 illustrates a *footpath* (Type 1). It is completely primitive and unmaintained. To stay as dry as possible, it proceeds high on the slope despite steep grades and generally difficult terrain. Stream crossings are natural fords.

A *cart road* (Type 2) is illustrated in Figure 3. It tends to follow each curve

* The criteria data for District Motor Road—one of the five general types—are given in the Appendix.—*Ed.*

in the contour despite long detours and long distance, in order to conserve the pulling strength of the animals. The normal gradient is about 1 in 50; however, since these cart roads are maintained by the villages, and bridges are beyond local resources or ability, a paved ford is all that may be constructed, at a favorable site. Here several steep grades—even up to 20 per cent—might be found. The normal capacity of this road is 15 jeeps and 50 carts per day.

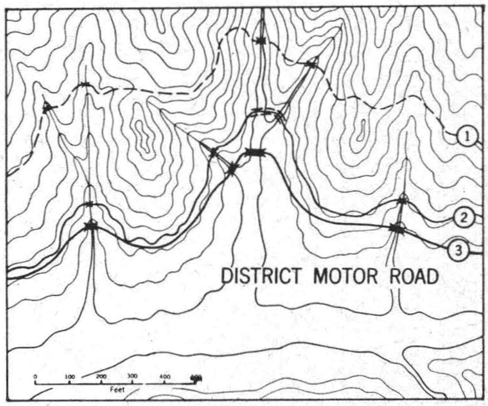

FIG. 4

Motor roads are designed to modify terrain features. Their construction implies a set minimum of traffic for each type, the use of cuts and fills, and reduction in total mileage, gradients, and curvatures. Each case is dependent upon the purpose and nature of the road.

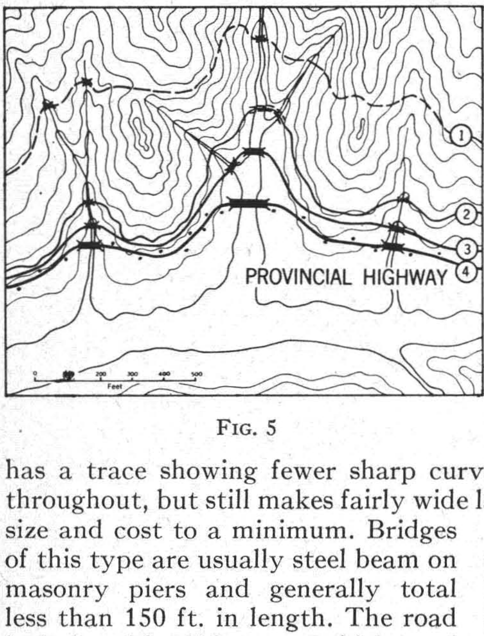

FIG. 5

Type 3 is the *district motor road* (Figure 4). It is one lane wide and gravel surfaced; it serves only local traffic, is designed for slow speeds, has low capacity, is subject to interruption in wet weather and tends to follow the contour. It has small wooden bridges and paved fords. The normal daily capacity is 50 light motor vehicles and 100 carts per day.

Figure 5 illustrates the *provincial highway* (Type 4). This is designed for somewhat heavier traffic, greater speed, and fewer interruptions, is $1\frac{1}{2}$ lanes wide and macadam surfaced. It has a trace showing fewer sharp curves, has less extreme grades, is bridged throughout, but still makes fairly wide lateral sweeps in route to keep the bridge size and cost to a minimum. Bridges of this type are usually steel beam on masonry piers and generally total less than 150 ft. in length. The road is designed for 300 motor vehicles and 250 carts per day with speed from 25 to 40 mph.

The fifth type is the *national highway* (Figure 6). It is designed principally for speed and uninterrupted 2-way traffic, maintains close grade and curvature tolerances, and therefore seeks the floor of the valley as the easiest route. It requires many more and longer bridges of higher load capacity. These bridges are constructed

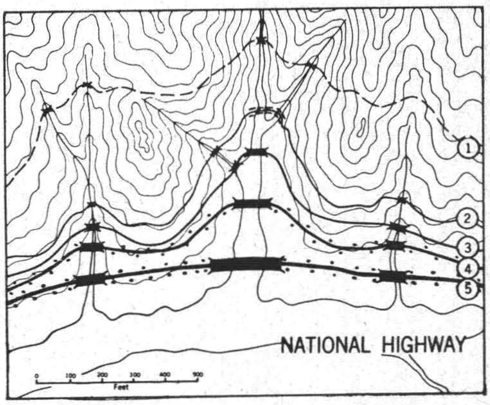

FIG. 6

throughout of concrete, except under those special conditions which our intelligence information will reveal. The designed normal capacity is 1,200 motor vehicles per day at speeds up to 50 mph.

In the case of both the national and provincial highways, which are characteristically bordered by trees, the width from tree center to tree center is 70 feet.

These have been only a few highlights in the analysis possible from the aerial photograph by the use of the criteria sheet.

In conclusion, let me emphasize that the direct effects of the establishment of criteria for each subject in a given area are to integrate the intelligence on each subject, the experience of the area specialist, the engineer, and the geographer, and to make all of these available for use by the photo-interpreter in a simple form, before he begins his delineation, thus providing him with a system of logical search of the photograph.

The result is a simplified means of accumulating reliable information. In the case of Korea, where the road system has many bridges, one photo-interpreter could present accurate data on about 60 bridges per day from a combination of aerial photography and piecemeal intelligence.

In studying Korea, it was found that by using these criteria to summarize our accumulated information and experience, a complete analysis of the highways, railroad, waterways, towns, and power facilities could be made, covering a much wider area than was possible by field reconnaissance; and that the results were more accurate than when done by observers in the field.

Looking forward to the time when tabulated criteria can be made available to photo interpreters in theatres of combat, it is evident that the present need to expose reconnaissance personnel to enemy action can be reduced.

APPENDIX

Photo Interpretation Criteria: Highways

Terrain: Upland River Valley

(1) Type of road: District motor road
(2) Function: Main branches of provincial or national highways and take traffic into interior of each district.
(3) Trafficability: Limited all weather—1 lane
(4) Prevailing type of surface: Water bound macadam
(5) Average width of the travelled way: 12′
(6) Width of right of way: 40′
(7) Maximum grades: 1:8
(8) Minimum radius of curvature: 150
(9) Daily load capacity and traffic: 200–500 tons, with low percentage of motor vehicles.
(10) Designed speed: 20 mph
(11) Prevailing types of structures which in this case are: Timber trestle bridges over main streams.
    1. Major bridges: Timber trestle with occasional steel beam bridges
    2. Minor bridges: Timber trestle
    3. Ferries—Hand operated, capacity 1 vehicle
    4. Fords—Irish bridges over washes
    5. Culverts—Wood trestle—less than 20′ long
    6. Embankments—Road raised where irrigation problems are prevalent plus numerous culverts.
    7. Tunnels—None
(12) The interruption factors:

1. Trestle bridges may wash out during monsoons, usually replaced with hand operated ferry with 1 vehicle capacity.
2. Irish bridges designed to standard of 1 day interruption no more than 6 times per year.

(13) And last those features which bear direct relationships to the terrain:

1. District road allows lateral sweeps to favorable sites for short bridges.
2. Road at base of foothills tends to follow contours, has few cuts but considerable fill to maintain grade and curvature.
