Applications Of Remote Sensing Imagery Interpretation In Railway Surveying

Zhuo Baoxi
The Professional Design Institute of
The Railway Ministry, Beijing,
China
Commision VII

(ABSTRACT) This paper described briefly the applications of remote sensing technique to railway surveying in China. Typical examples were cited and our experiences on the work were highlit.

1. General Situation

Since 1950's, China has used aerial photographs for geological interpretation in railway surveying. Experiences gathered in the past three decades have shown that remote sensing imagery interpretation is an efficient mean for railway surveying. The technique is widely welcomed by the mass of surveyors in the Country. This paper briefed the application of aerial photographs and satellite imagery in China.

In railway surveying, aerial photographs have been mainly used for thematic interpretation such as geology, hydrology, tunnel site selection, construction detours and site and etc.in addition to topographic mapping at various scales. Results of geological and hydrological interpretation are especially good.

In the field of engineering geological survey, remote sensing imagery can be used for interpretation of geomorphology, lithological characters, geological structure, ill-geological phenomena, spring cropping, engineering geological zoning and sand and stone-field and so on. Among these the interpretation results for geomorphology and for ill-geological phenomena are most desirable.

In hydrological survey, remote sensing data has been used mainly in bridge site and hydrological profile selection. Besides, it is also used for interpretation of characteristics of drainage area, ancient river channels, flooding outline, special hydrological problems and hydrological engineering structures and so on. To provide hydrological surveying data, aerial photographs are also useful.

In different phases of railway surveying, remote sensing imagery interpretation can be used, but it is found that most extensive and effective applications are in the phases of feasibility study and preliminary survey. Remote sensing data has been used widely in railway planning. To do so, Landsat imagery and 1:50,000 aerial photographs are usually used for geological and hydrological interpretation in feasibility study. In the phase of preliminary survey, large scale aerial photos(1:10,000--15,000) are usually necessary for the interpretation of geology, hydrology, sand field, working road selection and workingsite selection. currently, we have also used aerial photos and satellite imagery in interpretation for railway reconstruction, engineering disease investigation and dynamic change detection.

In addition to visual interpretation technique, other remote sensing data and image processing technique have been studied. Preliminary work in digital image processing has shown great potentials in our field. We have so far collected quite amount of aerial photographs concerning typical geological and hydrological phenomenon and a " Collection of Aerial Photograph For Engineering Geology " was compiled. A number of papers and reports on remote sensing applications have been published. A monograph titled " The Principles of Remote Sensing and Imagery Interpretation for Engineering Geology " was finished jointly by The University of Traffic of South- West of China and The Professional Design Institute of Railway Ministry, in which the experiences on remote sensing applications in railway surveying in the country have been summaried.

Presently, many institutions in the railway system have applied remote sensing technique and some special organizations have been established to popularize remote sensing applications.

2. The Role of Remote Sensing Technique In Railway Surveying

The general advantages of remote sensing technique can be found in many monographs and papers, cited below are only those most significant recognitions in the field of railway surveying.

(1). It is useful in large scale geological and hydrological surveying and mapping and railway planning study as well.

The span of 1:50,000 / 200,000 engineering geological map prepared for railway surveying is about 2km, while the span of a strip geological map provided in the preliminary survey is approximately 400 to 1,000m. It is evident that maps with such spans can hardly reflect the characteristics of geological structure in a region and thus can hardly be used for evaluation, with sufficient accuracy, on engineering geological condition of an area in which a railway in planned. Using aerial photographs or satellite imagery, one can map an area with spans greater than 10 to 20km and 1.5km for the above mentioned scales. Such maps are desirable for evaluation on engineering geological conditions and for selection of different planning schemes.

(2). It is time-efficient and it can turn passive situation in conventional geological surveying into active.

When the approximate location of a planed railway is known, one can start interpretation and charting by using aerial photographs , making geological surveying much active as such work is conventionally done after a topographic map is prepared.

During the preliminary surveying phase, when a planning scheme passing through mountainous area, grand rivers and large scale ill-geological zones, one can already be sent out for geological charting before a map is prepared in order to provide ground truth data for plan evaluation. In some cases, even drilling work can be arranged in advance.

(3). It can improve working condition by saving certain amount of field surveying task.

Once the interpretation keys for an area have been established, one can outline massive geological boundaries under laboratory condition, making work much comfortable. Aerial photo interpretation can discover some ill-geological phonomenon without extensive field work, providing preliminary evaluation on engineering geological conditions. Sometimes, decision can also be made based on the results. The field work is thus very much reduced.

(4). It can overcome limitations in ground observation and improve quality of geological charting.

The macro study on aerial photos in combination with micro observation on the ground has the advantage for understanding mutual restrictive relationship between different geological phenomenon, making conclusions much thorough and reliable.

(5). It can enhance predictability for field surveying work and improve surveying efficiency.

Aerial photo interpretation can help one in getting better understanding of the engineering geological and hydrological situation as well as the latest dynamic changes along the route area, playing a guide role for field work and making its more purposive. Almost none of large scale ill-geological phenomenon can be overlooked during the interpretation. Sometimes, it is possible to detect latent troubles in slope area and predict possible diseases.

In summary, aerial photo interpretation has advantage for saving field work of geological and hydrological surveying. Though it can not, at present, provide quantitative data for designing purpose, nor can it replace drilling and experimental work, aerial photographs will continue to be made sufficient uses when one has got a correct knowledge of its merits and limitations. In order to illustrate the applications of remote sensing as it applied to railway surveying in China, some examples have been shown hereafter.

A. Applications in reconnaissance survey

a. Aerial photos and satellite images were used for geological interpretation in reconnaissance survey of a railway in southwest of China. This railway passes through an area where has complicated geological, bad climate and poor traffic conditions. The conventional survey could hardly be carried out in the area. To overcome this, Landsat imagery and aerial photos at 1:60,000 scale were used in the planning phase. The interpretation result was reflected in a regional geological prognostic map of 1:100,000 and intensively used thereafter.

A statistics made within 650km along the route, we found that only 280 ill-geological conditions were labeled at 1:50,000--100,000 engineering geological maps prepared by ground survey technique. Whereas, more than 600 places were marked on a 1:100,000 engineering geological map compiled by using results of aerial photo interpretation(See Table1). According to field check, the interpretation result for ill-geological phenomenon is comparatively better, with an accuracy between 75-90%. The interpretation results for mud flow and devolution were excellent, with an accuracy better than 90%.

Table 1 Comparison of results between aerial photo interpretation map and engineering geological sketch map

No.	Section / Comparison / Item	WD-XL (100Km)		MY-JL (193Km)		YW-GL (200Km)		MB-JL (164Km)		SUM (657Km)	
		Pre. in. map	Sketch	Pre. in. map	Sketch	Pre. in. map	Sketch	Pre. in. map	Sketch	Pre. in. map	Sketch
1	devolution	2		18	2	29	8	36			
2	slacktip	2	4	13	13	6	12	24	21	130	60
3	landslip	7	1	6	5	12		14	15	39	21
4	displacement	8	9	9	8	51	22	13	13	81	52
5	mud flow	2	3	3		1	3	10		16	6
6	gulch		2	21	9	10	2	35		66	13
7	slope wash					13		34		47	
8	alluvial	7	28	3		15	38				
9	glacial cone			8				3		92	83
10	diluvial fan	12	1	11	4	24	1	14	11		
11	rock accumulatioh	4	5	10	2	71	30	25	8		
12	scree slope			3			1	12		125	46
13	spring			4	4	1	7	4	8	9	14
14	avalanche			6		13		6		25	
15	fault	21	4	57	48	73	5	63	34	214	91

Pre. in.map = preliminary interpretation

b. In a northern area, a railway in plan passes through a varied river section, where the river bed is wide and shallow with lots of sand banks. The current is unstable and espacially so during swollen periods. The complete appearence of the river course was difficult to be located from the ground. Aerial photos taken after flood season were used for selection of bridge sites, as the course and the distribution of sand banks along with sheet flood and traces of ancient river courses could be clearly interpreted from the photos(See Fig.1)

During the planning phase, four bridge sites were considered and evaluated according to photo interpretation:

. Profile A(a highway bridge) As it is a diffusive reach, more bridges would be required. The river banks are incomplete owing to the rush of the current and the hydrological condition is relatively poor.

. Profile B Here bridges would still be at the sheet flood section. More brides and protecting engineering work are necessary.

Moreover, the river banks here will be unavoidably influenced by the rush of the current.

.Profile C Though it is the concourse of the main branches, there is still a 6km sheet flood section along the right bank. The hydrological condition is rather poor.

.Profile D is the place the river is narrowed up and there is no sheet flood any more. It is the optimum location for building a bridge.

During the field checking, it was verified that the above mentioned interpretation and evaluation were absolutely correct.

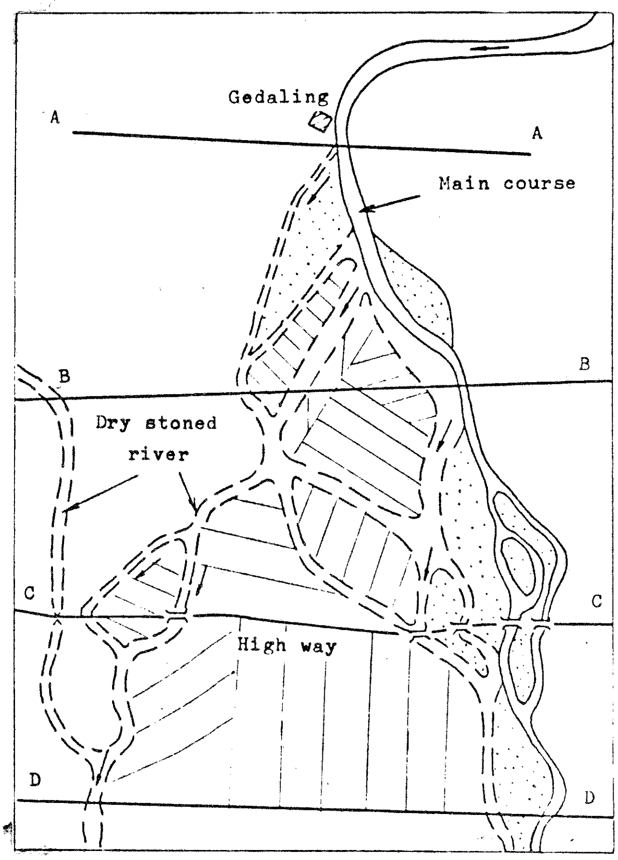


Fig. 1a Aerial photograph   Fig. 1b Interpretation map

B. Applications in detecting diseases in existing railways

The Baoji--Chengdu railway was built in 1950's. It crosses the Qingling mountainous area where the landform and geological conditions are very much complicated. Due to the backward survey technique and lack of experiences in building railways at such environment by then, the diseases caused by ill-geological problems such as landslip, devolution, mud flow are very serious after its completion. This is espacially so at the northern section along the Jialin river, where more than 100 spots suffered from landslip and devolution within a distance of a little more than 100km. The reasons could be varied whereas the influence of geological structure is the predominant factor.

In order to investigate the relationship between deseases and the geological structure, massive work has to be done in the field conventionally. Although certain reasons could be found it is in fact time consuming and cost inefficient.

Landsat images have been used in investigating such problems in the past few years. Normally, Landsat images are radiometrically enhanced and then interpreted visually in order to analize regional geological structure. During Landsat image interpretation, existing geological data should be used . The is followed by local detailed interpretation using aerial photos at the scale about 1:60,000. The final evaluation can be done with very limited field work.

Fig.2 is part of a Landsat image in which linear geological structure and tectonic blocks are shown clearly. The fault structures are sometime shown in different tone or river patterns or in banded structure with certain widths and directional arrangement. Besides, many NS distributed hackly drainage systems are seen perpendicular to them, showing a tension fracture. At the meantime, the NE and NW torsion fracture are also well relected in the picture. These structural forms combined each other and reflect thoroughly the patterns of latitudinal flaser structure.

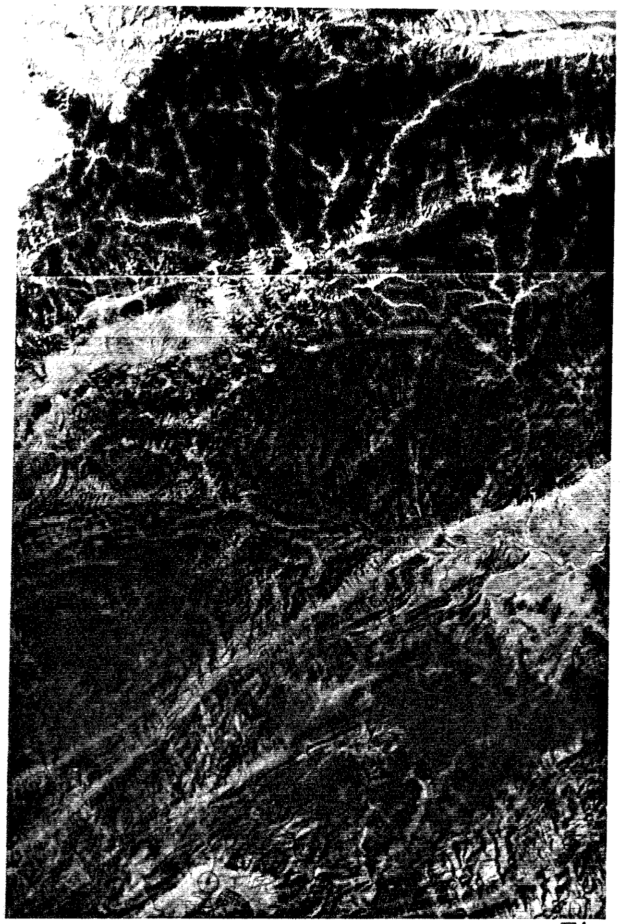
The tectonic blocks are shown in different shapes having diameters some dozens of kilometers. Usually they have clear boundaries and one can easily determine them either as elevated block or as descending block according to their geomorphological appearances.

Studied on Landsat images we found that the places where the deseases of landslip and devolution occured most frequently are all located at the faulted zones or the block boundaries, as these places are the compression loosened zones with very weak structure and low intensity. Perpendicular to both sides of the flaser fractured river valley, the lithological characters of the tension fractured cleuches is very poor, it is the places where the mud flow frequently occurs.

C. Applications in long tunnel surveying

a. Dayaoshan Tunnel Dayaoshan tunnel, the longest one(14300m) in the Country, was the main engineering work during the reconstruction of the Beijing--Guangzhou railway. The tunnel, located at the Yaoshan area in Mount Nanling, crosses the bowstring portion of the bow shaped barranca. Relief difference in this area is approximatly 500m. The area is sparsely populated owing to its dense forest and bad traffic condition. Ground survey data collected in the area were at the expenses of great efforts.

Main strata appeared in the area are Sinian system, epizonal-metamorphism clastic rocks of the Cambrian system and silico-rudite and carbonatite rocks of the Devonian system as well. In view of regional geological structure, it is at the ridge portion of northern Guangdong epsilon type structure. A synclinal vally crosses the mid of the tunnel and coincides with the expansion of the Jiufeng fault, the biggest one in the area.



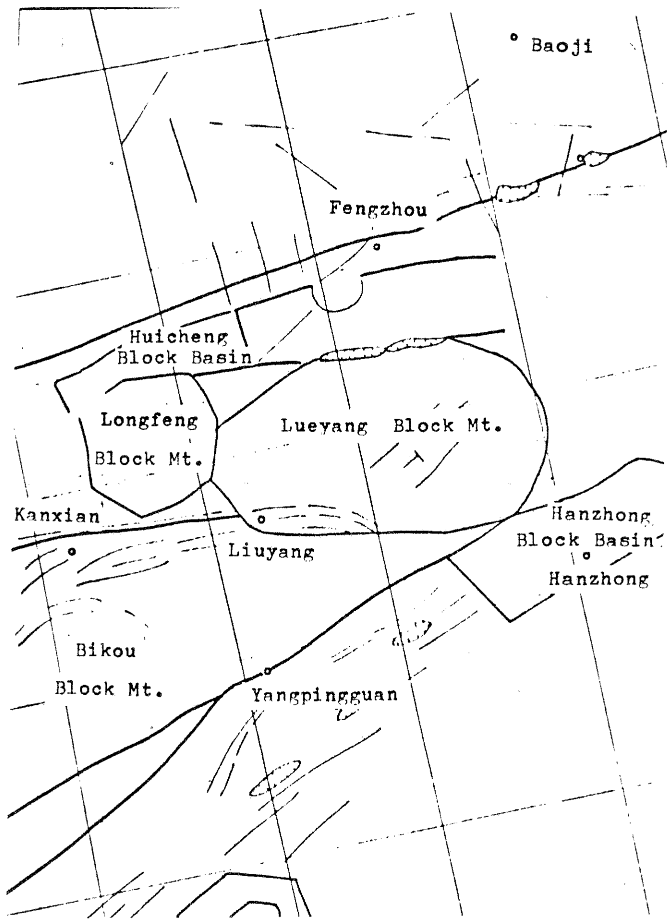


Fig. 2

Landsat image of Fengznou--Lueyang

Interpretation map for the some area

In order to investegate the applicability of remote sensing in railway tunnel exploration in heavy vegetated area in the South, experiments were conducted concurrently during the engineering period. From 1981 to 1983, several aerial remote sensing flights were carried out using different films at scales 1:10,000 to 1:50,000. The experiment covered an area of 450 squared kilometers. The data was interpreted in laboratory before field work. In the laboratory, Landsat images processed on IPOS/101 system were analized in combination with 1:200,000 geological map for the macro geological structure study, which was followed by aerial photo interpretation at smaller scale(1:60,000). In the final stage, conclusion was made from the results of integrated study on various remote sensing data interpretation. Visual interpretation is the main technique being used , which was in some cases aided by digital image processing method. To analize engineering geological and hydrological conditions concerned with the tunnel construction, we made detailed geological interpretation on and comparison between different remote sensing data with a strip of 2.5km along each side of the tunnel. At some critical locations, aerial multispectral scanner data was processed on IPOS/101 system and the result was used to aid visual interpretation. The experiment achieved very good result.

By integrated analysis on various data, more than 300 linear features were outlined within an area of 450 squared kilometers in Wushui barranca, of which more than 40 linears are in the 2.5 kilometer zones and 28 cross through the tunnel. Furthermore, for the 28 linears, 8 had been digged and 4 were proved to be the geological faults. The rest 20 linears need to be verified in the future work.

b. YMG Tunnel The YMG tunnel, 10km in total, is located in northern area in China. Structurally, the area is a part of the NE-SW Xi-type(ξ) structural system. The stratum is composed of metamorphic rock system dominanted by intrusive mass of small scale.

Due to its complicated geological problems and very poor traffic condition, conventional survey met lots of limitation. It was thus decided to use Landsat image in combination with B/W aerial photos(1:50,000 and 1:10,000) during the reconnaissance survey.

The Landsat image and aerial photos were interpreted and a aerial photo map at 1:10,000 scale as well as a 1:10,000 geological interpretation map of remote sensing image were prepared before field work(See Fig.3).

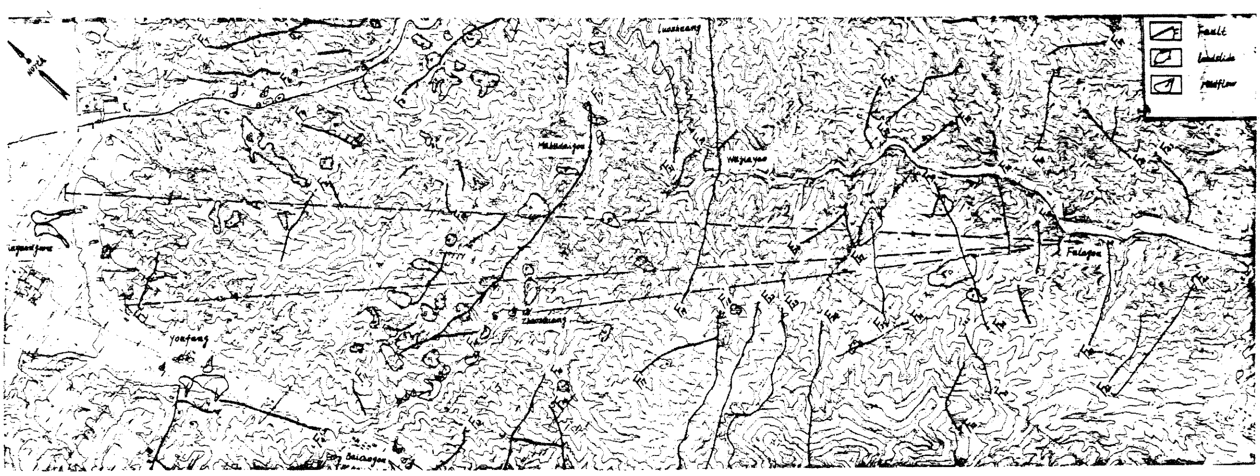


Fig.3 Engineering geological interpretation map of YMG tunnel area, prepared from remote sensing images

Before image interpretation, some preliminary ground survey was already done in the area. As the geological structure in the area was not so clear, it is difficult to arrange drilling locations. Engineering geologists, according to a 1:200,000 geological map, required following three problems to be answered by remote sensing imagery analysis: firstly, is it true that there three large faults across the tunnel? secondly, is there really a dike along each side of the tunnel? and thirdly, what is the degree of the development of the groundwater in the mid part of the tunnel? To answer these questions, aerial photo interpretation(at scales 1:50,000 and 1:10,000) was firstly done in laboratories to derive information to guide field work. During the field checking, it was proved that only one fault(F19) crosses through the tunnel and would not cause serieus infuence on it. A fault(F8), in addition to F19, does exist but not cross the tunnel as it was suspected. While the third suspected fault is accually not existing. Instead, a fault(F13) which was not labled on the existing geological map is found lying across the tunnel. This fault has relatively strong influence on the tunnel engineering. As the dikes questioned were disproved after detailed interpretation at large scale aerial photos and field checking. Lastly, no groundwater appearance was found in the questioned area during the interpretation and ground work. The applications of remote sensing image interpretation for tunnel engineering are summarized as following:

. Provide guide information for field geological surveying and make the arrangement of drilling reasonable.

. Prove that the abandonment of a plan for a short tunnel(5km) at the west part of the surveying area was correct for the reason that there are dense active mud flows(Fig.4) at the approach of the entrance

. Make a thorough evaluation on engineering geological conditions of the tunnel:In the southern part, the direction of the stratum is approximately orthogonal to the tunnel and rock body is comparatively complete. The geological condition here is much better as compared to other places(Fig.5). While in the northern part, the occurrence of rocks are disorderly and a lot of ill-geological phenomenon can be found . The engineering geological condition is comparatively poor.

. It is convinced that the conditon of hydrological geology for the tunnel area is fairly good.

The evaluation was based on the image interpretation and field checking only, which has not yet been proved by engineering work.

Fig. 4 Dense active mud flows

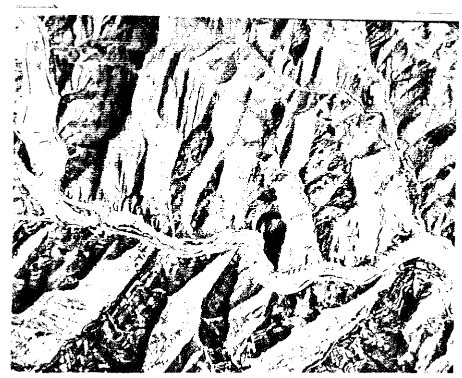


Fig.5 Stratun orthogonal to the tunnel

3. Remarks

A. It is realistic and urgent to popularize remote sensing tecknique in railway surveying in the Country.

By the end of the century, more railways will be constructed yet the survey technique is still based on field working mainly, which would certainly not meet the needs. To fulfil the heavy exploration tasks it is necessary to popularize photogrammetry and modern remote sensing technique. Transportation and traffic is one of the main courses in our economic reconstruction, it is urgent to use remote sensing technique to facilitate railway construction. China has a large territory with complicated landform and geology, it is favorable for development and application of remote sensing technique.

B. Using aerial remote sensing mainly in combination with space remote sensing data is the main mean for the Country.

As railway surveying is mostly banded engineering surveying, it has different requirements as needed by other application fields, in which space remote sensing is required for its macro coverage only and aerial photography is required for micro observation. Whereas railway exploration needs both techniques as one often starts on macro scale and gradually focuses on detailed engineering locations.

C. In view to the present status of remote sensing technique and considering the characteristics of railway surveying in the Country, conventional aerial photo and Landsat image interpretation technique needs to be popularized, as we have already had a full coverage of aerial photos at multiple scales and Landsat image collection. It is much economical to use these data. Other remote sensing data are more or less experimental and expensive,it is thus not suggestible to be popularized immediately.

D. Remote sensing may be applicable to any areas whereas it is most favorable in mountainous areas with complex geological, bad climate and poor traffic conditions. For the reconnaissance survey of long tunnel and its engineering monitoring, the economical effect is evident and especially so in complicated geological zones and mountainous areas.

It would be very difficult to try to summarize all work done in the Country. The author's gratitude goes to all his colleages who have made contributions to the application of remote sensing technique in railway surveying and provided their invaluable materials to be used in this report.