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Photogrammetry as a Tool for National Development

Applications are presented on the basis of a literature review.

Abstract: *A review of the current literature describing the capabilities of photogrammetry for cadastral and geodetic surveying is presented. Some photogrammetric applications in engineering, environmental studies, biostereometics, police, and military work are discussed. Photogrammetry is also presented as a powerful tool in scientific research. Examples are shown to demonstrate the potential of both conventional and non-topographic photogrammetry as an aid to national development.*

Introduction

Since its advent as a metric tool, photogrammetry has been principally applied for the production of topographic maps. This "topographic" application of photogrammetry (which inevitably replaced traditional ground survey methods of planetabling and tacheometry) in many countries has led to the establishment of a fast, economic, and efficient system for topographic mapping. The availability of topographic maps at various scales provides a tool for exploration, exploitation, and effective management of a country's natural resources, particularly in rapidly developing countries. According to Mr. T. E. Rowland,[118] the aerial survey industry in Canada "has a massive impact upon the economy and touches upon almost every aspect of the country's development". In Nigeria the introduction of photogrammetrically produced topographic maps has made it possible to cover about 80 percent of this vast country (1,000,000 sq.km) with 1:50,000 topographic series in about two decades (even without the application of the latest modern automatic photogrammetric and cartographic equipment). Photogrammetry is now used on a routine basis world wide for producing topographic maps, and its impact on development is therefore often taken for granted. Photogrammetry has also been applied in cadastral mapping with outstanding economic advantages in countries such as The Netherlands, Switzerlands, Italy, Germany, and Brazil. Another notable application of photogrammetry is in the densification of horizontal control using special techniques which provide surprising cost advantages over conventional methods. Guzman *et al.*[109] have reported on the role which orthophoto maps played in agrarian reform *vis-a-vis* the economic development of El Salvador.

In the past decade the photogrammetric world has witnessed an unprecedented growth of "non-topographic" applications in various fields such as engineering, environmental studies, biostereometrics, and many branches of science. This phenomenal development in non-topographic photogrammetry has been made possible because of special equipment manufactured for these applications. Examples of such equipment are stereometric cameras, phototheodolites, special plotters (e.g., the Wild A40 and Zeiss Terragraph), universal plotters (e.g., the Wild A-7, Wild A10, and Zeiss C8), and analytical plotters.

In recent years there has been an increased trend in the use of non-metric cameras such as television, X-ray, holography, electron microscope, and 35-mm amateur cameras for "non-topographic" applications. This paper will discuss a few "topographic" and "non-topographic" applications of photogrammetry which can be used as a tool for national development.

Cadastral Applications

The application of photogrammetry to cadastral mapping was first reported in Italy in 1931 and later in Switzerland, The Netherlands, and Germany

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(Dale).[7] In these early days the methods of photogrammetry were found to be more cost effective and rapid than conventional ground survey method. For example, in The Netherlands (Beltrum project) the photogrammetric method yielded a 50 percent savings while in Germany (Vogelsberg Project) a 33 per cent reduction in the cost of cadastral mapping was recorded (Ghosh[9]). In these two countries the reduction in the time taken to complete the projects was on the order of 18 percent and 12 percent, respectively. In 1972, Lafferty[12] executed 24 analytical photogrammetric cadastral projects in California and obtained an accuracy-cost-efficiency ratio (E) between photogrammetric and ground survey methods of 1.21 (a ratio greater than 1.0 is in favor of photogrammetry). Aston[2] has reported on the effort made by the Queensland Department of Mapping and Surveying to reduce the high cost of cadastral surveys of low value grazing lands by the application of photogrammetric methods.

This author has recently reported on a modest effort in photogrammetric application to cadastral mapping at Lagos University (Ayeni[4] and Ekpete[8] in which analog photogrammetry produced slightly poorer accuracy than the ground survey method, but the latter cost three times more and required three times more time to execute. Accuracies comparable to those of ground survey have been reported by Ackerman[1] and Brown[6] in their experience with photogrammetric applications to cadastral surveying. Beasley[5] has also highlighted the uniqueness of photogrammetry and the savings in time and money in his survey of Honeymoon Island in United States. The difficulty of this survey resulted from the fact that the perimeter constantly changes due to tidal levels.

A recent photogrammetric application in cadastral surveying was undertaken by the Department of Natural Resources in the State of Washington. In his report of this application, Karns[10] described a new operational cadastral survey procedure which uses photogrammetric techniques and thereby reduces the cost of retracement, identification, and restoration of the original GLO (General Land Office) surveys. These photogrammetric techniques were also employed to establish a third-order control network. It is Karn's opinion that this new procedure will convince all surveyors to seriously consider the photogrammetric technique as an alternative and to supplement conventional ground methods to reduce costs and strengthen the legal position of the survey.

Norman[13] and King[11] have enumerated the advantages of photogrammetry in cadastral surveying. Norman advocates the application of photogrammetry for cadastral mapping in developing countries where the cadastral system is still in its infancy. This author has proposed the use of photo or orthophoto maps for cadastral mapping in Nigeria to meet urgent mapping needs in rural areas where existing maps are inadequate (Ayeni[3]). Photomaps can also be used to supplement existing outdated large-scale maps in urban areas. The main advantage is that photomaps, though of lower accuracy, can be produced at relatively faster and cheaper rates than cadastral or topographic maps. It is rather unfortunate that most developing countries are not taking advantage of the benefits provided by photomaps. Such maps can serve as interim maps which provide a comprehensive historic record of both rural and urban development for a specific period. Visser[14] has described the role of large-scale orthophoto maps in cadastral surveys of rural and urban development projects. He has given examples of applications in West Germany, Belgium, the United Kingdom, and Australia.

Photogrammetry as a Geodetic Tool

Early in the 60's reseachers demonstrated theoretically the potential of photogrammetry as a geodetic tool (Brown[18] and Panel[24]). One of the problems that has interested photogrammetrists over the past two decades is the question of what optimum accuracy is attainable by photogrammetically establishing ground coordinates. Many investigations have been conducted into the theoretical accuracy of a photogrammetric block adjustment (Ackermann[15]). It has been shown that the main obstacle is the elimination of small residual systematic errors which preclude obtaining geodetic accuracy in photogrammetric block adjustment. Many approaches have been adopted in solving this problem so that photogrammetry could be used as a geodetic tool for densification of triangulation networks.

Ackermann[16] in his Appenweier trigonometric net densification Project used least-squares collocation to control and adjust residual systematic deformations after block adjustment with independent models. He achieved a densification of a third-order trigonometric net into a fourth-order net with a planimetric accuracy of 5.3 cm (root-mean-square discrepancy at 77 check points). Brown[19] has adopted the method of additional parameters with self calibration in a photogrammetric densification of an urban geodetic (first-order) new work. In this project 18 first order traverse points used as check points were determined with a root-mean-square of discrepancies of 7 cm. Using the same technique, Brown[19] also performed the densification of a first-order triangulation network in the state of Vermont. In Finland, Halonen and Noukka[21] have determined geodetic control by analytical photogrammetry for large-scale mapping at 1:500. Good results have also been obtained by Hvidegaard[22], Lucas[23], Tegeler[25], and Verdin[26] in their control densification projects using photogrammetry.

One of the highest accuracy results reported recently in the literature is credited to Grün[20]. He employed a combination of the self-calibration method with orthogonal bivariate polynomials as additional parameters. In addition, a sophisticated gross error detection strategy (with bundle block adjustment) was made; Grün was able to attain accuracies of 1.0 cm in planimetry and 1.8 cm in height with minimum of effort. According to Grün, these accuracies which agree with theoretical expectations "carry analytical photogrammetry to new fields of application such as network densification, cadastral surveying, and many other subjects dealing with the provision of coordinates to ground points in rural and urban areas."

It should be noted that in all these projects photogrammetry provided more economic and faster alternatives to traditional ground survey methods. There are many developing countries, including Nigeria, in which the existing triangulation network of control is not sufficiently dense. This led to the establishment of local coordinate systems. These local systems create significant problems in coordinating surveys within the same country. The photogrammetric approach to densification of an existing triangulation network offers a solution to this problem. It should also be remembered that the photography used for such a densification can also be used for other purposes such as (1) topographic and or photo mapping, (2) land-use mapping, and (3) irrigation, ecological, geological, agricultural, transportation, and settlement studies Ayeni[3].

Engineering Applications

HIGHWAY AND TRANSPORTATION ENGINEERING

This section is devoted to three types of engineering applications of photogrammetry: highway and transportation, structural (deformation) measurement, and construction engineering. The development of photogrammetric applications to highway/railway location and design started in the early 50's. Since the first attempts to employ new photogrammetric system for highway engineering by the Ohio State Department of Highways, many experiments and studies have been carried out in various countries such as Switzerland (Kasper[33]), Sweden (Adoltssor[27]), Germany and Britain (ISP[30]), and Canada (Zarzycki[45]) which have contributed significantly to the application of photogrammetry in highway design. As a result of these efforts, photogrammetric applications were established in the 60's as a cost effective and efficient innovation in highway engineering. It can now be asserted that the gigantic and impressive highway program of the 50's and 60's in the United States could not have been carried out satisfactorily (in terms of cost and time) without using photogrammetry.

The application of photogrammetry in highway engineering may be divided into three phases: route location, preliminary design, and final design. In the route location stage the main directions of the highways network must be defined. This can be achieved by undertaking photogrammetrically assisted terrain analysis using aerial photographs obtained at flying heights between 3000 m and 5000 m. The route location with alternative center lines is made by the engineer based on studies compiled by geological/geotechnical specialists. Aerial photography taken from 1500 to 2000-m flying height is needed for the preliminary design stage. At this stage, the final center line within the cooridor is chosen and the horizontal and vertical alignment of this line is fitted to the terrain. This is accomplished with the help of photogrammetrically and ground-survey derived longitudinal and transverse profiles. The final design stage uses large-scale photos or maps (1:500 or 1:1000) for producing the detailed design of intersections, interchanges, and bridges. This also includes numerical measurements of longitudinal and transverse profiles and development of digital terrain models.

Different systems of Digital Terrain models (DTMs) have been used in the second and third stages. The main purpose of a DTM is to increase the number of alternative horizontal and vertical alignments that can be investigated without collecting new terrain data. DTMs also provide an efficient data bank for computing earthwork quantities, thereby promoting the integration of digital photogrammetry and electronic computation devices with highway design (Zarzycki[45], Ternyd[41], Smith[40], and Ruiz[39]).

The role of orthophotomaps in highway design has been discussed recently in the literature. According to Blaschke[28], orthophoto maps are ideal (1) for preliminary planning and location of centerline at scales of 1:5000 or 1:10,000, (2) for final design of the highway at scales of 1:1,000 or 1:2,000, (3) for establishment of highway data bank, and (4) as inventory and maintenance maps at scales of 1:500, 1:1000, or 1:2000. Details of these may be obtained from Hallert[29], Johnson[31], Karki[32], Koberlin[34], Ruiz[31], Maruyasu and Nakamura[35], Murai[36], Padilla[37], and Pryor[38]. Some of the papers listed under the reference section show that photogrammetric methods used for highway projects are capable of reducing the cost, time, and labor normally expended on ground survey methods by about 50 percent. It is sad to note that many developing countries (rich or poor) do not take advantage of the benefits offered by photogrammetry in the planning, design, and construction of highways and railways in their development program.

STRUCTURAL MEASUREMENTS

For over two decades, photogrammetry has been used as a tool for obtaining precise structural deformation measurements of various types of engineering structures such as radio reflectors, radio antennas, radio telescopes, satellite station antennas, solar collectors, power dams, and roof and wall structures. The advent of close-range photogrammetry has made this development possible. Kenefick[51] described how DBA systems Inc. had performed contour measurements of about 50 parabolic antennas with high accuracies. He reported that the following precautions were taken: (1) use of a long focal length, narrow angle camera with glass plates, (2) highly convergent photographs, (3) redundant but independent measurements, (4) precise close-range camera calibration, and (5) sophisticated/specialized software for data processing. Structural deformation of antennas causes significant problems in communication (radio and satellite). The use of photogrammetry has assisted in detecting structural deformations in antennas and has made a significant contribution to the development of the science of communication. The same is true for solar collectors, which can be calibrated by photogrammetric methods to detect structural deformations (Ghosh[50] and Ockert[53]).

Photogrammetry has also made a notable contribution to engineering by providing vital maps necessary for designing, construction, and maintenance of power dams. Even after construction, such dams are subject to displacement or deformation due to soil creep, landslides, and erosion, thereby necessitating periodic checks. Photogrammetric methods for monitoring the stability of power dams have been found to be more economical, faster, and more efficient than conventional ground survey method (Brandenberger[48]).

Photogrammetry has also been used to monitor structural movements or deformations of walls and roofs (Atkinson[46], Borchers[47], Preuss[55], and Veress *et al.*[56]). For other examples of structural measurements using photogrammetry, see Ethrong[49], Qshima[54], and Yu[51].

CONSTRUCTION AND NUCLEAR ENGINEERING

Another branch of engineering in which photogrammetry has been applied is construction engineering. This application generally consists of making periodic measurements by close-range photogrammetry of the object being constructed to ensure that the construction is done to specification. This technique has been applied to the construction of fixed-base offshore platforms as well as to ships (Newton[63], Danko[60], Haggren *et al.*[61], and Smith[65]). The advantages to be gained from the use of photogrammetry are enumerated by Newton[63]. He reported on the reduction in on-site construction time, and the improved accuracy of construction with reference to *a priori* specifications. Abdel-Aziz[58] has reported an interesting result of the application of photogrammetry to the construction of a 30-story precast slab building in Saudi Arabia.

Applications of photogrammetry also abounds in atomic and nuclear engineering. Photogrammetry has been used to study the scatter (the fragments and the new particles which are produced when high-energy particles collide with an atomic nucleus) within the Wilson cloud chamber (Brandner[59] and Seacond[64]). Photogrammetry is also a valuable tool in radar research (Leonards[62]).

ARCHITECTURAL AND MUSEUM APPLICATIONS

During the past few years the tourist industry has become an important source of revenue for both developed and developing countries. The preservation of historical monuments and works of art has therefore assumed greater importance in these countries. Architectural photogrammetry as both a quantitative as well as qualitative tool offers a fast, realistic, and economic approach to the problem of recording, preservation, and restoration of historic monuments. Examples are historic building structures, and facades of buildings, statues, ornaments, paintings, carvings, sculptures, and archaeological finds *in situ* or in museums.

When important sculptures, archaeological finds, paintings, or artifacts are accidentally or otherwise broken, the museum is usually faced with the problem of restoration. The coordinates obtained through close-range photogrammetry can be used to compute distances and angular relationships which, in conjunction with the stereo pair, will be necessary to determine the exact position and correct orientation of the broken part in relation to other parts of the monument. This method can also be applied to the problem of constructing a replica of an historic building which has to be destroyed for economic reasons. In addition, there are many historic sites, buildings, and monuments which cannot be brought to the museum. The permanent and faithful records of such objects in stereo or as a stereogram automatically brings the object closer to the museum with the advantage of a three-dimensional view of such object.

The main advantage of photogrammetry is that three-dimensional measurement takes a relatively short time to accomplish, and it can be carried out at leisure in the office without direct contact with the work of art or monument concerned. It does not therefore constitute a physical hazard to the object being measured (Badekes[66]).

The types of photogrammetric equipment needed and their adaptation for architectural applications are described in Carbonnell[67] and Jachimski[71]. A guidance document for those wishing to make use of photogrammetric techniques for architectural purposes is provided by the CIPA proceedings[70] and Project Quarterly, published under the direction of Dr. J. Kobelin[73] of Miami-Dade Community College in Miami, Florida.

Many examples abound in the literature concerning architectural applications of photogrammetry. Maruyasu *et al.*[74] have reported a unique achievement in monument preservation, in a project which involves the plotting of shapes by contours as well as total mapping of fourteen Buddha statues in Japan. The purpose of the project was to determine inconographic standards that were accepted in ancient Japan so as provide a better understanding of Buddist sculptural styles.

Jeyapalan[72] has also undertaken an architectural application which would have necessitated the removal and preservation of the remains of the historic ship *Niantic* in San Francisco at a cost of $600,000. The delay in excavating the *Niantic* for the construction of a high-rise building was about $15,000 per day. The photogrammetric technique was successfully employed to map the salient features of the historic ship so that a replica could be constructed at a later date. Agnard[66] has described how 36 portals of cathedrals, churches, and abbeys were studied by means of photogrammetry to provide a representative cross-section of French architecture. Carbonnell and Egels[69] gave a vivid description of the current survey of historical monuments by the Institut Geographique National in France through the use of (1) the Matra Traster 77 analytical plotter and (2) the Wild OR stereoplotters. It is interesting to note the contributions which photogrammetry made in saving the legendry San Marco Horses in Venice (Sena and Astori[75]). Equally interesting is the adaptation of orthophotography in architectural photogrammetry (Seeger[76]). In the various countries cited architectural photogrammetry has made an invaluable contribution to sustain the tourist industry.

Biostereometrics Applications

Biostereometrics has been defined as "the spatial and spatio-temporal analysis of biological form and function based on principles of analytic geometry" (Herron[85]). For the past decade biological and bimedical scientists have found stereophotogrammetry, stereohologrammetry, interferometry, and X-ray photogrammetry valuable tools in conducting their research. Looking back into the early 70's, one may assert that photogrammetry has made some notable contributions to biological and biomedical research and innovations in various developed countries of the world. A few of the contributions made by photogrammetry to the advancement of research will now be described.

Photogrammetry has provided the method for making precise measurements of the volume of the human optic cup in glaucomatous eyes, thereby making it possible for doctors to diagnose and monitor the progress of glaucoma in humans (Currie *et al.*[82]). A stereophotogrammetric analysis of a series of casts of both normal and abnormal palates were carried out by Berkowitz[81] in 1971. These casts include those of Apert's Syndrome and also of unoperated complete unilateral cleft lip and palate children. The results of these biostereometric analyses have provided an "insight into mechanisms by which change in form are produced either through the processes of pathological development or as a result of therapeutic intervention" (Berkowitz[81]).

Pediatricians and surgeons need to assess the early changes in growth rates and volume of premature infants so as to evaluate the proper formula, feeding practices, and effectiveness of medication. This assessment can be accomplished through photogrammetry, which provides anthropometric and volumetric measurements of the whole or any part of the body of the premature infant without any physical contact with the infant (Savara[92]).

X-ray photogrammetry has also made significant contribution to developments in medical research. For example, x-ray photogrammetry has been applied to stereo-radiographs to determine the geometric characteristics of scoliotic deformities (Kratky[89]). Abnormal patellar tracking is known to be a common problem among athletes, which gives rise to incapacitating pain. Treatment of patellar tracking is usually experimental because the tracking patterns are so complex. Treatment failure is also known to lead to patellar-femoral arthritis. X-ray photogrammetry has been employed to quantify patellar motion patterns so that restoration of normal tracking patterns to the knee could be effected quickly without resorting to the painful trial and error method (Lippert *et al.*[90]).

Photogrammetry has made invaluable contributions to the space program, in general, and aerospace medicine in particular. For example, photogrammetry provided the basic maps for lunar exploration and landing. The application of photogrammetry in the field of aerospace medicine has been used to determine cross-sectional area and total and regional volumes of various parts of the spacelab crews after landing. These measurements were used to confirm the loss of fluid and solid tissue in various parts of the body of the crews due to weightlessness during flight, (Hertzberge *et al.*[86] and Keys *et al.*[88]).

There are other biostereometric application such as the determination of the volume of a human blood cell using electron stereomicrography (Ghosh[84]). Photogrammetry has been used to map cows in order to establish genetic relationships (Ayeni[80]). Applications of hologrammetry, Moiré topography, and scanning electron microscopy in biostereometics are discussed in Mikhail[91], Karara[89], and Eick *et al.*[83], respectively. The proceedings of symposia on close-range photogrammetry also contain a good number of articles on biostereometrics (ASP[76], ASP/FIG[78], and ASP/ISP[79].

Police and Military Applications

Forensic photogrammetry as a branch of close-range photogrammetry was used for investigating traffic accidents as early as 1933 and 1935 in Switzerland and Germany, respectively (Ghosh[94]). Since then this branch of close-range photogrammetry has been applied in other parts of Europe, the United States, and Japan. Accidents on heavily traveled streets, highways, and expressways constitute a major problem because of the resulting traffic obstructions which tend to set up chain reaction accidents. Apart from delays, such traffic obstruction may mean loss of money or even loss of life (in case of the critically ill patient being rushed to the hospital) to innocent road users. The police officer is therefore usually under great pressure to record accurately and rapidly the scene of the accident so as to make for speedy restoration of normal traffic flow. Close-range photogrammetry can be used by the police to accomplish this important money saving and life saving task. Lillesand and Clapp,[99] after making a practical comparison between the conventional traffic accident investigation techniques with those of stereometric investigation (based on actual accident site data), arrived at the conclusion that stereometric methods can significantly improve the collection, accuracy, preservation, and presentation of metric accident data.

The initial success obtained in 1967 by the Saitama Prefectural Police Headquarters, Iruma City near Tokyo in using an accident disposal vehicle specially fitted with stereometric cameras has led to the adoption of close-range photogrammetry as a tool for traffic investigation in all police departments in Japan. The photopairs are placed in stereoplotters to make simple stereoplotting and curve analyses necessary in determining the cause of accidents and also for relevant intelligence gathering activities (Ghosh[95]). Apart from the quatitative accident data provided by photogrammetry, the stereopair from the stereometric camera is a faithful record of the accident for "pictures don't lie."

Ghosh has shown that photogrammetric application in Japan seems to be cost-effective (apart from expediting the rapid processing of court cases). According to one superintendent at the National Police Headquarter, "there is no road accident—related court case pending anywhere in Japan beyond one week after the accident" (Ghosh[95], p. 332).

Photogrammetry has also been applied to the investigation of collisions at sea. In the spectacular case of the ship collision between the German freighter *Trans-Atlantic* and the Dutch freighter *Hermes* which occurred in 1965, aerial photographs were used to determine the change in positions of the beacon between 1959 and 1964. Photogrammetry provided the evidence used in the Supreme Court to show that the collision was caused by navigation error which in turn was caused by the displacement of the beacon (Brandenberger[93]). Hohle[96] has also described the use of underwater photogrammetry in 1969 to map an ancient shipwreck (*circa* fourth century).

The police department of criminology routinely uses finger prints to identify culprits. The question is whether tooth impressions can also be used in criminal investigation. Photogrammetry equipment (Wild A7) has been used to draw contours and cross-sections of bite marks on a pipe found at an arson site, the bite marks in a similar pipe owned by a suspect, and also of the mold of the suspect's teeth. The data collected from these drawings showed that the bite-marks found at the arson site fitted very well with the mold of the suspect's teeth (Jonason *et al.*[97]). In forensic odontoloy teeth-marks are used to identify an individual. Other forensic applications of photogrammetry are discussed by Quim[100] and Schernhost[102]. Photogrammetry can be used to determine the internal geometry, distances, and angular relationships which are unique within an original art work. The data can be used to verify the authenticity of a stolen or copied art work such as paintings, sculpture, carvings, and archaeological finds (Kobelin[98]).

Military applications of photogrammetry abound in the literature. Precision photogrammetry has been applied in testing and launching missiles (Brown[94] and Rosenfield[101]). Photogrammetry has also been used in deriving flight parameters for rockets (Thomas[103]). Another unique application is exemplified by the use of photogrammetically produced contour maps of soldiers' bodies to design military uniforms and equipment and also to determine the space occupied in military vehicles by soldiers on duty (Walton[104]).

Military reconnaissance probably represents one of the first practical applications of photogrammetry, which is now regarded as a key tool in military science, particularly military intellegence and military strategies. Topographic maps play a great role in movement and deployment of forces, as well as in planning military operations.

Miscellaneous Applications

There are other applications of photogrammetry which time and space will not permit to be discussed in this paper. Such applications include coastal mapping including mapping with underwater photogrammetry (Adekoya[105] and Karara[111]), forestry (Aung[106]), geography and geology (Fang[108] and Savage[119]), astronomy (Heyden[110]), environmental and urban planning (Keating[112], Lauden[115], and Krueger[114]), soil and agricultural studies (Koechley[113]), glacial studies (Blachut[107]), meteorological and space science (Tesche *et al.*[120], Wasko[121], and Norwicki[116]), and marine resources exploration and management (Pollio[117]).

Conclusion

Although its major application is still in topographic mapping, photogrammetry in recent years has made significant contributions to the development of all countries of the world. The main contributions discussed in this paper are in fields of cadastral, geodetic, engineering, architectural, biostereometric, police, and military applications. Reference has also been made to applications of photogrammetry as a tool for research in practically all branches of science, engineering, and technology. Photogrammetry has indeed come a long way.

It is unfortunate to observe that the contribution of photogrammetry is almost entirely restricted to topographical mapping in many of the developing countries of the world. Such countries have yet to witness the full potential of non-topographic applications. This is primarily due to the lack of qualified photogrammetrists and photogrammetric equipment necessary for photogrammetric investigations. Many advanced countries of the world have experienced automation in photogrammetry and cartography while at the same time most developing countries lack the human and material resources to adequately prosecute their conventional topographic mapping programs. It is hoped that the governments of these developing countries will realize that photogrammetry is a key element in national development and will, therefore, take advantage of the potential provided by photogrammetry to accelerate and sustain social infrastructural, economic, and research development in their respective countries.

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ENGINEERING APPLICATIONS

Highway and Transportation Engineering

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