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PHOTOLOGGING: A CLOSE RANGE PHOTOGRAMMETRY TOOL FOR HIGHWAY ENGINEERS

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ABSTRACT

Photologging is a technique whereby 35mm photographs are taken of the roadway and its environment at periodic distance increments as a vehicle transporting the camera moves at highway speeds. The resultant photographs, each of which also displays digital information such as mile-point, gradient and degree of curvature, is edited into reels of from 100 feet to 400 feet, and used on stop-motion projectors. Approximately 40 States in the United States use Photologging in a wide variety of applications and it is found to be very cost-effective. This paper summarizes the state-of-the-art of Photologging and addresses the many applications of the technique.

I. INTRODUCTION

For many years, highway engineers have used conventional photographic techniques to document and preserve particular highway conditions on film. In some instances, still photographs, as well as motion pictures, were taken through the windshield as the vehicle moved down the highway. While these photographic records have been used in many ways, the systematic photographing of an entire highway system was very difficult because of the limitations of the cameras and the projectors employed to view the film.

Users of photographic equipment can be generally classified into three areas--hobbyist, commercial and instrumentation. The hobbyist utilizes equipment that is readily available from a variety of retail stores and sold at all prices. His applications can range from family snapshots to serious bird photography utilizing special telephoto lenses.

The commercial photographer may be employed by a newspaper or a television station, he may be a free lance photo-journalist, or he may own a portrait studio. In most cases, his equipment can be obtained from retail stores that specialize in the sale of photographic equipment.

The user of photographic instrumentation specializes in highly technical or scientific work and utilizes equipment that is not usually obtained from the normal sources of photographic supplies (i.e., camera shops, department stores, etc.). His applications might include the photographic tracking of a missile launch or the high speed filming of a vehicle that is being crash tested. Photologging is considered to be an application of photographic instrumentation equipment. The sources for this very specialized equipment are a number of relatively small manufacturers who produce rugged, versatile equipment that is adaptable to many highly specialized uses.

Photographic instrumentation is being used in transportation related areas, for example, in the form of closed circuit video as a freeway surveillance tool, time-lapse photography, vehicle detection and identification and Photologging. Of the many applications of photographic instrumentation, none has been so extensively employed nor impacted the routine operational procedures of so many elements of highway agencies as has Photologging.

Definition. Photologging is a technique whereby photographs of the highway, its environment and specific data about the highway are obtained from a moving vehicle as the vehicle travels down the highway. A Photolog should not be confused with a motion picture of the highway in that motion pictures are normally taken at frame rates of 18 to 24 frames per second, whereas rural Photologs are obtained by filming at frame rates of about 2 per second when the vehicle is traveling at 55 miles per hour.

Picture Interval. Photolog pictures are not taken on a time basis as are the photographs obtained from time-lapse photography applications. Rather, Photolog pictures are normally taken every one-hundredth mile in rural areas and one-two hundredths mile in urban areas as a result of a pulse

from an electronic odometer actuating the camera shutter. In this way, Photolog vehicles can travel at any speed and still maintain an accurate relationship between distance traveled and the actual milepoint at a particular point on the highway.

Film Formats. Two film formats, 35mm and 16mm, can be used for Photologging although the 35mm format is by far the most common in the United States. Film travel for a conventional 35mm camera is in the horizontal direction and the picture size is 24mm X 36mm. Since the magazines on Photolog cameras move film in the vertical direction, the frame size can be reduced by one-half, (24mm X 18mm), thereby producing twice as many pictures per unit length as full-frame photography. The resultant half-frame format is still large enough that excellent picture detal is possible, even when the images are enlarged for viewing.

Cameras. The camera systems that are used in Photologging are manufactured by companies that traditionally provided high quality photographic instrumentation in response to contract work for the U.S. Government. This equipment was basically modular in concept and therefore was readily adaptable to Photologging type applications. In addition, it was designed to withstand hard use under a variety of stringent environmental situations.

A typical Photolog camera incorporates a dual lens system. The primary lens produces that portion of the picture area that approximates what the vehicle driver observes while a secondary lens system captures data such as milepoint, route number, date and direction.

Lenses. Since the half-frame format is used, primary lenses of a shorter than normal focal length are utilized. For example, a 50mm lens represents the "normal" focal length for full-frame 35mm photography; that is, with a 50mm lens and a picture image of 24mm X 36mm, normal depth perception will result in a photograph. On the other hand, the half-frame format of 24mm X 18mm requires a "normal" lens of about 38mm to produce normal depth perception. Thus, if it is desired to obtain wide-angle photographic coverage in an effort to include more of the roadside in the picture, then lenses in the 24 to 28mm range would provide moderate wide angle coverage.

Film Magazines. The 400 foot film magazine is the most common in the United States; however, several States utilize 1000 foot magazines. Normally, two or more magazines are loaded in a changing bag prior to a day's run. A 400 foot film magazine contains sufficient film for photographing approximately 64 miles of highway at 100 pictures per mile; or, one picture every 52.8 feet.

Control Unit. Another necessary component of the camera system is the control unit. The control unit provides for operator interface and allows manual control of the camera and data display on each picture frame. Operator controls, system displays and alarms are included in the unit which also serves as a junction box for the system's cables.

Exposure Control. Opinion varies as to the need for automatic exposure control. Where exposure is constant and not broken by areas of deep shade due to trees or structures, automatic exposure control can be a significant aid, relieving the operator of one more task. Most highway agencies get excellent results with automatic exposure control; however, in heavily

forested, mountainous terrain, the use of a hand held light meter often results in better pictures. Since hand held light meters are relatively inexpensive, including one as a backup can prove to be a good investment.

Camera Mount and Bracket. Because the camera, as well as the control unit, may be removed at the conclusion of each workday for security and/or maintenance purposes, a camera mount with the ability to adjust the camera angle both in the horizontal and vertical axes is necessary. The camera mount also provides for quick removal and together with a camera bracket minimizes the modification to the interior of the vehicle during installation of the system. Most Photologging is done with the camera angled slightly to the right of the roadway centerline since there is more of interest in the way of roadside hardware and traffic control devices on this side of the travelled direction.

Film Type. With minor exception, Kodak Type 5247 color negative film is used for Photologging. Since most agencies obtain several copies of each Photolog, the color negative original permits each copy to be of equal quality. The color negative original is stored for historical purposes or for use when newly Photologged sections of highway are spliced onto the original. Where multiple copies are not required, a transparency film such as Koday Type 7256 color positive film can be used.

Viewing Equipment. Equipment used to view Photolog films can be generally divided into two categories: (1) micro-film viewers and (2) stop-motion projectors.

Micro-film viewers are relatively inexpensive ($800-$1200) and can be used to view Photologs at one frame at a time. Since these viewers are designed to essentially provide a mechanism for reading or studying printed material that has been reduced on 35mm or 16mm film, they do not permit the sequential viewing of a series of photographs that might approximate, for example, a motorist's view of the highway environment as he drives through an intersection. Micro-film viewers can provide good quality viewing of any particular photograph and are often used by agencies such as a highway district office that does not require extensive use of Photologs.

Stop-motion projectors, although considerably more expensive ($5000-$9000), utilize either a shutter mechanism or a quick frame pull-down technique to present Photolog pictures in a way that approximates a motion picture. In fact, when Photologs are displayed at high projector speeds, the resultant action is quite smooth, even though vehicular speeds appear to be very high. This ability to present a sequence of pictures without distracting interruption can often provide an engineer with a "feel" for how it is to drive on a particular section of highway.

Since available projectors and viewers can be operated at variable speeds both in forward and in reverse, it is possible to approximate an actual driving speed so that the observer can make rough judgments, for example, of the rate at which signing information is presented to a motorist. However, the use of wide angle lenses together with the higher than normal eye height that the Photolog is taken from preclude any highly accurate judgments being made.

Most stop-motion projectors that are being used for Photologging have both rear screen and wall screen viewing capability. Wall screen

projection is normally used in darkened areas for larger groups of observers, whereas the rear screen capability is used under normal interior lighting conditions by usually one or two observers. Also, depending on the manufacturer and model, the projector may have provision for a grid overlay or a digitizer for automatically determining coordinates of points on the rear screen. Work is underway to develop a computer program to solve the photogrammetric problem of converting measurements on Photologs to useful real-space dimensions. A user's manual will be developed to document the program, it's applications, limitations and equipment requirements.

Photolog Vehicle. The van type of vehicle is used by almost all agencies involved with Photologging. Since the technique of Photologging requires extensive amounts of driving and attention to the onboard equipment, the vehicle should be equipped with conveniences such as air conditioning, bucket seats, large engine and power-steering so that driver fatigue can be minimized. In addition, an inverter is necessary so that the 12-V DC power system in the van can be stepped up to the 24-V required for the type of cameras used in Photologging.

II. FIRST GENERATION VS. SECOND GENERATION

The preceding discussion dealt with and addressed the technique as it is most commonly known today. "First generation" Photologging might be a more descriptive term since more sophisticated equipment is now available that is being referred to as "second generation" and which greatly expands the data gathering and data reduction capabilities of the technique. Thus, a careful distinction should be drawn between the two because of the higher cost and level of complexity of the new equipment.

First Generation. In first generation Photologging, the primary task is to expose pictures of the roadway, its environment and certain data about the highway including as a minimum, the milepoint, route number and direction. The Photolog vehicle acts as little more than a conveyance for the camera system with the exception of the milepoint information provided by the vehicle odometer. Data other than milepoint is preset manually, prior to filming, through the thumbwheel switches on the control unit or by means of grease pencil notation on the removable data slate in the camera.

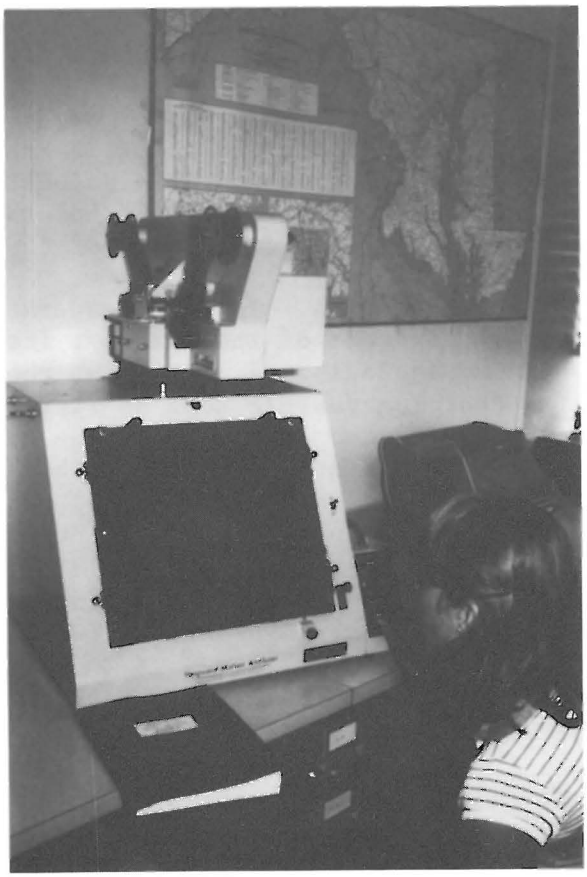
Since Photolog film is a sequential recording medium where all of the gathered data is confined to the film itself, data reduction is sequential and must be accomplished by manually searching the record for either known milepoint locations or for visually detectable information such as highway signs or structures.

Second Generation. In addition to pictures of the roadway, its environment and certain minimal data about the highway, second generation Photologging records other data items on film and on magnetic tape that are the results of measurements obtained by special instrumentation in the vehicle. In other words, first generation Photologging has the single function of recording pictures, whereas, second generation Photologging has the two additional functions of taking measurements and recording information on magnetic tape.

The vehicles used for second generation Photologging must be modified to some extent by the Photolog equipment manufacturer. So that information

Typical Second Generation Photolog Frame Showing Data Display Area (Half-frame format, 28mm lens)

Second Generation 35mm Photolog Camera with Control Unit, 400 ft Magazine, Camera Mount and Camera Bracket



Stop-Motion Projector with 35mm Film Transport and Rear-Screen Base

such as bearing, degree of curvature and gradient can be obtained, both horizontal and vertical gyroscopes are included in the system. The following features are desirable for most second generation systems and are usually specified when the vehicle is ordered:

- long wheel base (e.g. 138 inches for Ford Van)
- large engine (e.g. 351 cubic inch V-8 for Ford Van)
- 100 amp alternator
- radial tires
- heavy duty shocks or adjustable air shocks
- high capacity air conditioning
- power brakes
- power steering
- automatic transmission
- swivel captain's chairs
- second battery on line
- spare wheel and tire
- sliding cargo door and hinged rear doors
- windows with privacy glass (except windshield)
- carpeting and added insulation

A first generation vehicle would be similarly equipped with the possible exception of the special shocks and the second battery.

Before a highway agency purchases a second generation system, there are three considerations that should be addressed: (1) a larger agency commitment; (2) need for operator experience in electronics; and (3) cost.

Because of the more sophisticated on-board electronic equipment (especially the magnetic tape recorder), an agency contemplating the purchase of second generation Photologging must be willing to commit computer systems personnel so that software edit programs and other file sorting and processing programs can be prepared. In addition, there may be the need for electronics maintenance personnel to track down problems with certain components such as circuit boards. The need to Photolog as much as possible during the warm weather months dictates that as much maintenance and trouble shooting as possible be done by the highway agency rather than the manufacturer.

The nature of the electronics also requires that electronics servicing should be available in the field either through operator expertise or highway district office technicians so that lengthy trips back to a headquarters facility can be avoided.* Ideally, an operator should at least know how to identify and repair or replace faulty circuit boards. In addition, equipment calibration at the beginning of each day is more complex and the normal operation of the equipment requires closer monitoring than first-generation Photologging.

The following approximate costs are typical of what an agency would incur for a standard system:

*Some second generation users feel that a complete second set of circuit boards should be purchased in an effort to minimize equipment down time.

First Generation

Vehicle _____ $ 8,500.00

Camera system (including a 10 to 15 digit recording display with removable data slate, 35mm camera with variable shutter, camera mount and bracket, lens, automatic exposure control, 400 foot film magazine, operator's control unit with external data entry, power inverter, electronic odometer, installation and testing) _____ $24,000.00

Second Generation

Vehicle _____ $ 9,000.00

Camera system (including instruments for typical second generation data display, 35mm camera with variable shutter, camera mount and bracket, lens, auto exposure control, 400 foot magazine, operator's control unit with external access, display unit, instrumentation unit, magnetic tape recorder, power inverter, electronic odometer, installation and testing) _____ $66,000.00

Items that are common to both systems are listed below:

Projector (stop motion) with cart	$ 5,900
35mm camera and attachment for still photos for use on projector	1,650
Viewer (micro-film)	800
Color negative film (Kodak Type 5247)	128 per 400 ft roll
Negative processing	.0609 per ft
Print processing and print film	.1150 per ft
Two micro-film storage cabinets (18" wide X 58" high X 28" deep) with a total of 8 drawers	1,600
Cold tape film splicer	550
12 rolls of splicing tape	133
Two 2000 ft negative rewinds	350
Two 1000 ft split reels	30
Two 400 ft split reels	25
Film bin for editing	50
1000 storage boxes	80
1000 - 100 ft plastic reels	160
100 - 2 inch plastic cores	10
One dozen white cotton gloves	36
1000 feet of film leader	50
Changing bag (36" X 45")	45
Editing table with light box	210

The above prices, for the most part, represent what is being paid by several highway agencies for these items. Similar products from other suppliers may cost more or less depending on specific features and/or quantities purchased. Also, some agencies may not need, for example, micro-film viewers and projectors; therefore, simply totalling the prices of the items shown may not be indicative of the real costs that a particular agency may incur.

Typical Photolog Van with Sliding Side Entry and Privacy Glass

Film Storage Cabinet Containing Approximately 9000 Miles of Photologged Highways

Second generation systems also require additional costs for equipment maintenance and computer time and programming. The costs shown above are approximate and reflect pricing only at the time this paper was prepared.

III. APPLICATIONS OF PHOTOLOGGING

It may be beneficial at this point to discuss, broadly, the wide range of uses of Photologging so that the technique can be placed in perspective. Among the most common applications are those related to safety and planning activities such as the review of hazardous intersections, traffic control device inventories, roadside safety inventories and planning inventories. Photologging is also being used in urban areas as a base for computerized inventory systems where traffic control device and safety information is extracted from Photolog film and used to build computer files for system management purposes. For example, the computer can access an inventory file to determine how many STOP signs must be budgeted for in the preparation of a more realistic budget.

Probably one of the most obvious applications of Photologging is in those particular uses which result in eliminating or minimizing trips to the field. While the review of Photolog film is not always a suitable substitute for a field trip, there are many occasions when a trip can be eliminated or made more productive by first viewing the subject location on film. Several State agencies, when threatened with the curtailed availability of official vehicles, used this as one of the justifications for developing a Photolog system.

Photolog film can be a significant aid in communicating with the public, especially when the film is used to respond in writing to public inquiries regarding signing or other physical features of the highway. It can also be a valuable aid in public hearings where viewers can be shown explicitly what changes are proposed.

Legal applications are a growing area of use that reflect the rise in tort liability litigation and the increased awareness on the part of the public that government agencies are responsible for knowing the locations of hazardous sections of highway. It is common practice to use the Photolog to locate particular photographs that are subsequently duplicated in hard copy form and used as evidence in the courtroom. Several State Highway agencies reported that Photolog evidence contributed significantly to legal judgments in favor of the States, resulting in savings beyond the cost of the entire Photolog program.

While there are many highway maintenance applications of Photologs, this use is dependent on how frequently the highway system is re-photographed. A 3-year cycle (i.e. re-photographing approximately one-third of the system each year) is being employed by most States. Maintenance uses include using the Photolog to select sample sites for pavement life studies, previewing draining problem areas, determining areas that require consistent brush control and establishing traffic control for maintenance operations.

Photologging has provided a means for conducting research and traffic studies that heretofore were too manpower intensive and costly to perform. For example, obtaining data regarding the application of traffic control devices at narrow bridges is relatively easy to accomplish by reviewing

Photolog film. Another example might be the extraction of data from film on guardrail applications at fixed roadside objects in an effort to determine current practice.

Since Photologging is still a relatively new tool, its value as a historical record has yet to be proven. There have been some instances where existing Photologs were utilized to estimate damage from severe floods or other natural disasters.

Other applications outside of the highway engineering areas include the following:

- Railroad track and crossing inspection
- Driver education
- Fire and police personnel reviews of streets and highways
- Airport runway inspection
- Large vehicle tracking on narrow roads

IV. STATUS OF PHOTOLOGGING

By far, the majority of Photologging in the United States has been accomplished by highway agencies that have purchased equipment and performed the work with their own personnel. Only two consultants, Goodell, Grivas, Inc., Southfield, Michigan, and Techwest Enterprises, Ltd., Vancouver, British Columbia, Canada, actively offer contract Photologging. Much of the Photolog contract work in the United States has involved the development of computer inventory systems for cities and counties where the inventory data is extracted from Photologs. A detailed description of the computer inventory system is described in a paper by Dr. Tapan Datta in the compendium of technical papers of the 47th Annual Meeting of the Institute of Transportation Engineers.

The most recent technical meeting of Photologging was a one-day seminar in conjunction with the Institute of Transportation Engineers Annual Meeting in September 1979 in Toronto, Canada. This seminar was intended primarily for city and county personnel and enabled those in attendance to hear technical papers, to meet industry representatives and to observe equipment demonstrations. A seminar notebook which includes copies of the technical papers is available from the Institute of Transportation Engineers, Inc., 525 School Street, SW., Suite 410, Washington, D.C. 20024.

A survey of the known highway agencies and the industry representatives indicate that there are 41 States, at least five major cities and one county in the United States that have purchased equipment and developed their own Photologging programs. In addition, 24 cities, five counties, one toll road, 7 Canadian highway agencies, and the U.S. Park Service have contracted the Photologging effort to outside consultants. While these totals probably reflect the vast majority of all Photologging efforts, there may be a few agencies not included in this report--especially if the work was done by a State for a city or county in that State.

Eight States, one Canadian Province and a foreign university have taken delivery of second generation systems. All but one of the States, (Utah), had previously operated a successful first generation system.

Thus, the considerable additional equipment expense for the second generation systems was apparently assumed with some assurance that it would be cost-effective.

At least five new States have taken the initial steps toward developing a Photolog program while six States that presently have first generation Photologging are seriously considering the purchase of second generation systems. Second generation Photologging is under consideration by two more Canadian Provinces and it is likely that several more counties and cities in the United States will also start up in the near future.

Seven other countries, Tanzania, Nigeria, New Zealand, Greece, West Germany, Argentina and Great Britain, are known to have Photolog equipment; and there have been serious inquiries from South Africa, Saudi Arabia and Yugoslavia. Several Regions of the U.S. Forest Service have employed Photologs of remote access roads while the Federal Highway Administration is under contract to the U.S. Park Service to Photolog the entire Park Service roadway network.

The Connecticut Department of Transportation has purchased a second generation system that is mounted in a hi-rail vehicle for purposes of obtaining railroad inventories. The unit has the standard second generation features and will be used for highway Photologging as well.

Iowa is now utilizing a hi-rail vehicle and on-board computer with a track geometry system that measures degree of curvature, roughness, crosslope and rail gauge. The system includes a 16mm Photolog camera; however, apart from railroad identification, time-of-day and milepoint, the track geometry data is not recorded on film. Photologging is secondary to the track geometry recording function of this system. Iowa also utilizes a separate second generation 16mm system for Photologging their highways.

In total, highway Photologging is being done at all levels of government, as well as the private sector, and interest in the technique is on the increase. It has been estimated that in excess of 500,000 miles of highway has been Photologged in the United States alone.

V. EQUIPMENT MANUFACTURERS/DISTRIBUTORS

Techwest Enterprises Ltd.
3559 Wesbrook Mall
Vancouver, B.C. Canada V6S 2L2_ _ _ _ _ Camera Systems

Instrumentation Marketing Corporation
320 South Mariposa Street
Burbank, California 91506_ _ _ _ _ _ Camera Systems and Projectors

Vanguard Instrument Corporation
1860 Walt Whitman Road
Melville, Long Island, New York 11746_ _Projectors

L-W International
6416 Variel Avenue
Woodland Hills, California 91367_ _ _ _Projectors

Flight Research
Post Office Box 1-F
Richmond, Virginia 23201 _ _ _ _ _ _ _Camera Systems and Projectors

VI. BIBLIOGRAPHY

1. Baker, W. T. and Williams, J. C., "Photologging: A Traffic Engineering Tool", Traffic Engineering, July, 1970.

2. Datta, T. K., "Photologging and Computerized Information System", Compendium of Technical Papers, 47th Annual Meeting, Institute of Transportation Engineers, Mexico City, October, 1977.

3. "New Developments in Optical Instrumentation - A Problem Solving Tool in Highway and Traffic Engineering", Proceedings of the Society of Photo-Optical Instrumentation Engineers, Vol. 37, April, 1973.

4. "Photo-Optical Instrumentation - A Tool for Solving Traffic and Highway Engineering Problems", Proceedings of the Society of Photo-Optical Instrumentation Engineers, Vol. 30, November, 1971.

5. The Transportation Research Board, through the National Cooperative Highway Research Program, is sponsoring the preparation of a synthesis report on highway Photologging. This state-of-the-art document is slated for publication in the Fall of 1980.

6. "Photologging As a Tool for the Transportation Engineer", Notebook of a one-day seminar given at the 49th Annual Meeting of the Institute of Transportation Engineers in Toronto, Canada, September, 1979.

7. The following highway agencies have prepared final reports. While most of the reports are procedural in nature, some include information on evaluation:

Arizona	New Jersey
California	New Mexico
Connecticut	Ohio
Delaware	Oklahoma
Hawaii	Oregon
Idaho	San Antonio, Texas
Indiana	Virginia
Kentucky	Washington
Maryland	Wisconsin
Michigan	Wyoming