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GUIDELINES FOR THE USE OF TIME-LAPSE PHOTOGRAPHY IN TRANSPORTATION RESEARCH

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Final Report

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16. Abstract

The purpose of this report was to develop guidelines for the operational traffic engineer and the transportation researcher to determine when, where and how to use time-lapse photography.

This technique permits the large scale sampling of specific events where: the level of detail required, the cost involved, the elimination of data bias due to the presence or interpretations of field data collectors, negates the use of observers or mechanical/electrical devices. Recommendations are made for data collection, data reduction and record keeping associated with both efforts.

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PREFACE

This report is intended to acquaint the traffic researcher with the basic information needed to use time-lapse photography. Additionally, we have tried to help the novice decide if time-lapse is appropriate for his purpose. Neither the design of actual time-lapse studies, nor recommendations of trade name equipment is included in this report.

The use of time-lapse photography can be a useful and cost effective method of data collection for traffic studies when the user is aware of the limitations and capabilities of the technique. We hope this report will provide that foundation.

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CHAPTER 1

SELECTION OF A DATA COLLECTION SYSTEM

Types of Transportation Data

Permanent visual records are a necessary or desirable adjunct to many transportation studies. Time-lapse systems are used to provide a visual record of the occurrence of some events of interest. Time-lapse may also be used to capture static conditions, e.g., queue length at specific times, or specific events can trigger the system such as an accident occurrence. Generally, however, time-lapse systems are used to collect data on the movement characteristics of a particular set of targets. These targets can be vehicles, trucks, buses, pedestrians, etc.

Time-lapse photography as used in this handbook refers to a visual sampling technique. Through the use of an automatic exposure system, events in the field of view of a camera are photographed at regular intervals. The sample intervals depend on the rate of change of the scene being photographed and the amount of total time to be sampled. Time-lapse may be used to expand the time base of a brief event, such as the impact of a projectile, as well as to contract the time base of a slow event such as the construction of a building. We will address the technique of time contraction of long term events.

Time contraction by time-lapse photography implies viewing as a motion picture. It also implies a large number of samples or frames in the total record. Motion picture film is frequently the most cost-effective means for collection of long term samples, particularly when color is a desirable feature. Short term events, which do not require color and which are not to be retained, may be effectively collected with video tape systems since the reuse of the tape can reduce costs. The initial investment for videotape systems over that of a photography system is substantial. A potential video tape user is advised to gain experience with film before attempting videotape. We will therefore be primarily concerned with film systems in this report.

There are several reasons for selecting time-lapse as a data collection procedure. The user must first, however, be convinced that the required data could not be obtained in a more cost-effective manner. Reducing the collected visual records must be included in the cost estimation for time-lapse procedures. For instance, the required data may be obtainable through on-the-scene manual coding. Does the manual method provide the sensitivity and reliability desired? If so, then time-lapse procedures might be inappropriate. Alternately, mechanical/electrical devices (such as traffic counters) may provide a more cost-effective and, in fact, more sensitive procedure for collecting the required data. The potential user of time-lapse procedures must clearly determine the data needs and then explore the procedures available for gathering the data. A study conducted by the U.S. Forest Service demonstrates the prerequisite logic necessary for decision making.* Exhibit 1 is adapted from a report of that study.

Exhibit 1

Data Collection Technique Alternatives

Alternative	Effects	
	Positive	Negative
1. Full time manual counting and classifying.	Reliable; High accuracy to classify events (resolution)	Expensive — approximately $23,000 annual cost; Non-availability of personnel; Adjusted work weeks required.
2. Mechanical counting and sampling scheme for classifying.	Less expensive than #1; Approximately $7,000 annual cost.	Variable and unpredictable traffic; Adjusted work weeks required.
3. Mechanical counting and photographic-detection system for classifying.	Least expensive; Approximately $4,000 annual cost.	Unknown system; Unpredictable reliability.

The report goes on to state that "Although it was not a proven system, alternative number three was selected following consideration of financial, economic, and manpower situations. If satisfactory results were not obtained, the option to use one of the other alternatives would be available."

The moral of this story is that costs and reliability must be carefully weighed before selecting a data collection procedure. The selected procedure should be neither excessively sensitive nor insensitive for the job at hand. Both extremes lead to a waste of resources (in the latter situation, the error may be nonrecoverable).

Four general types of transportation information amenable to collection via time-lapse systems are:

a. Instructional objective – demonstration of a process or its effects.

b. Identifying extreme or classic cases – examples of a particular behavior or situation of interest.

*Murphy, G.L. The use of a photographic detection system for counting and classifying vehicles on forest service roads. U.S. Forest Service, In *Proceedings of the Society of Photo-Optical Instrumentation Engineers,* Vol. 37, April 1973, pp. 15-27.

c. Analyzing particular cases – specifying/defining particular types of behavior or situations.

d. Characterizing a situation – identifying the frequency and types of behaviors exhibited in a particular situation.

Types a and b are most often used for purposes other than "scientific;" that is, their aim is to present a striking visual record designed to make a considerable impact on the viewer (Public Relations films also fall into this category). Types c and d are often used in conjunction, especially in those studies that are exploring new behaviors or situations. Most traffic studies using time-lapse procedures are aimed at analyzing a situation in order to obtain information on its operating characteristics (type d). Most of our discussion will be centered on these last two uses of time-lapse systems.

Characteristics of Time-Lapse Systems

The camera and film portion of most time-lapse systems can be described in terms of the following characteristics:

1. Exposure frequency (e.g., frames per second)
2. Focal length (e.g., wide angle, telephoto)
3. Film size (e.g., 16 mm)
4. Shutter speed (film exposure in seconds)
5. Focal distance (e.g., feet to infinity, depth of field)
6. Film speed (ASA rating)
7. Light meter (automatic, manual setting)
8. Film capacity acceptance (roll size, e.g., 50 feet)
9. Film packaging requirements (e.g., cartridge, roll)
10. Film triggering (e.g., remote triggering, sound actuated)
11. Film color (i.e., black and white versus color)
12. Lens speed (F rating)
13. Power source (e.g., batteries, AC)

Each of these features impacts on the capability and flexibility of the system. A brief statement concerning the desirability of each feature is in order. The reader should understand, however, that the discussion is based upon the most frequent transportation uses of time-lapse systems and, as such, may not apply to one's particular situation. Additionally, no attempt is made to tradeoff one feature against another. The following paragraphs are merely offered as a nontechnical orientation of the process of selecting a time-lapse system.

1. Exposure frequency is the single most important defining element of a time-lapse system. The number of frames taken per unit time will impact on the cost and convenience of operating the system (film and manning), the ability to reveal events to the desired detail, the flexibility of using the system in other than stationary positions, and the ease of scoring the film. The exposure control device for nonstandard exposure rates (e.g., other than 8, 12, and 18 fps) is generally called an intervalometer. Some intervalometers are housed in the camera, while others are external. Exposure frequency of 1, 2, 4, 8, 12, 18 (standard), 32, and 50 frames per second plus manual single framing are desirable in a time-lapse system.

2. Focal length determines how "close" your photographic subject appears (magnification) and how large the field of view is. The closer or larger you wish your subject to be, the smaller is the area included in your field of view. For example, if you adjusted your focal length in order to get a clear picture of pedestrian head movements, you would not be able to include the entire intersection in the field of view. Thus, the focal length selected will impact on the placement of the camera, the size of the area recorded, the detail available on each film record, and the ease of scoring. Focal length is measured in millimeters with the larger values indicating more telescopic (closer) pictures and a smaller area included in the field of view. Some cameras permit interchangeable lenses which differ in focal length, while other time-lapse systems have a variable or zoom lens. The more focal lengths available, the more flexible the system. A zoom lens system is usually less costly and cumbersome for general purpose use than acquiring an inventory of fixed focal length lenses. A zoom lens with a 10:1 ratio from around 8 to 80 millimeters is appropriate for most transportation uses. Motor-driven zoom lenses are usually an avoidable expense.

3. Film size indicates the width of the film image in millimeters. Time-lapse systems are available in several standard sizes such as 8 mm, Super 8, 16 mm, and 35 mm. The detail of the record, known as resolution, is a direct function of the film size. With the larger film area, more detail can be captured. Resolution is particularly important if you are (1) filming under conditions of poor visibility, (2) filming from extreme distances, (3) looking for events that occupy a small portion of the record (e.g., head movements of pedestrians when filming an entire intersection), and (4) enlarging or copying the records. The use of a film size larger than required is very costly since it will impact on the purchase price of the system and the cost of buying and developing the film.

4. Shutter speed refers to the exposure time for a particular frame of film. The length of time in seconds that the shutter is opened determines the amount of light striking the film. This amount of light must be appropriate for the characteristics of the film and the subject being filmed. The faster the shutter speed, the smaller the amount of light entering the camera. Increasing the shutter speed is desirable when the available illumination is above that required by the film (generally the lens aperture or F-stop is the primary adjustment used to compensate for this condition), or when the apparent movement of the subject is great. In the latter case, we expose the film for shorter periods of time in order to avoid capturing the apparent motion of the object on the film and thus

getting a blurred picture (motion effect). The term "apparent" is used because the subject may be stationary and the camera may be moving (such as in logging); in either case, the effects are similar. Also, movement across the field of view requires a faster shutter speed than does movement toward or away from the camera. Most transportation uses of time-lapse photography can be accommodated by a maximum shutter speed of 1/500 of a second. Slower speeds may be useful under conditions of low illumination or in cases where motion effects are desired, such as tracking headlight and taillight streams. Commonly desirable slower speeds include 1/250, 1/125, and 1/50 of a second.

5. The focal distance setting on a camera is used to bring the image into sharp relief on the surface of the film. Filming distant objects requires the camera's lens to be moved closer to the film in order to bring the object into focus. Most camera systems have focal distances indicated in feet and/or meters on the focal ring. All objects beyond the maximum distance indication require a focal distance of infinity (∞).

A very important associated concept is "depth-of-field." The depth-of-field will determine the visible, clear image captured on film. Cameras are available that vary widely in their depth-of-field. Generally, larger depths-of-field are preferred to smaller ones, especially if near and far events are of interest (e.g., vehicle weaving *and* a hand-held watch).

For a given focal length, lens, and focal distance setting, a range of focus exists which is centered about the focus setting. This range increases as the apparent diameter of the lens decreases. The apparent diameter is determined by the F-stop that is required to provide the film with the correct amount of light for the selected shutter speed. In a camera with automatic light metering and a constant shutter speed, a low light level will cause the diaphragm to be opened to the maximum limit; the depth-of-field will then be at a minimum. As the light level increases, the diaphragm is closed, increasing the depth-of-field.

Tables are generally included with a camera permitting the user to predetermine the depth-of-field which will result from any given combination. In general, the required depth-of-field is known from the physical layout of the study site. The tables then indicate the maximum F-stop allowed to produce that range.

Several methods may be used to compensate for a marginal depth-of-field situation. These include using a slower shutter speed or a faster (more sensitive) film.

6. Film speed is a measure of the relative amount of light which is absorbed by the film during a single exposure. Fast films can capture more light on a given exposure than a slower film and are therefore appropriate for use under low illumination levels. A film speed is usually expressed by its

American Standards Association rating (ASA). Faster films, those having higher ASA ratings, obtain their light capturing ability by having larger light sensitive crystals. The presence of these larger crystals presents one of the major drawbacks to the use of high speed film. When developed, the faster films appear "grainier" and thus lose some of their sharpness (resolution). Additionally, the camera lens must have a minimum aperture that is small enough to reduce the light to a level acceptable to the faster films. For most applications, the time-lapse system should, at a minimum, be able to accommodate films with ASA ratings of 40 to 160.

7. Light meters are designed to assess the amount of illumination available for filming. Most meters contain photosensitive minerals which, when struck by light, either transmit or inhibit an electrical current on its way to an indicator gage. The meter reading is then used to determine the lens aperture and the shutter speed appropriate for the filming situation. Light meters can be internal or external to the system. Internal light meters obtaining their measurements through the lens offer the advantage that the light entering the lens, and therefore falling on the film, is being measured. They may also be either automatic (e.g., adjusting the aperture without any manual inputs) or require an operator to make the necessary adjustments. In the former case, it is desirable that the operator be able to override the automatic meter to compensate for unusual exposure situations. For example, if part of the field of view is bright sky and part is a roadway, we may wish to overexpose the sky in order to correctly expose the roadway portion of the scene. Some systems offer an internal "spot meter" which takes the reading from a small area near the center of the field of view. These spot meters may also present problems when filming under difficult exposure conditions since the "spot" area must be pointed at the area of greatest importance. An internal, automatic, "full field" through-the-lens light meter (with or without a spot meter option) with a manual override is suggested for a general capability time-lapse system.

8. Film capacity, as used here, indicates the number of feet of film that can be shot without reloading the camera. The film capacity and exposure frequency are the components that determine the time period the camera can run unattended. When comparing systems of different film size (e.g., Super 8 versus 16 mm), it is more meaningful to characterize a system's film capacity in terms of the number of frames that can be taken without reloading. For instance, Super 8 contains 72 frames per foot, 16 mm contains about 40 frames per foot, and 35 mm contains 16 frames per foot. In general, larger film capacity systems permit more flexible operation. We have found that, in general, a film capacity around 3,600 frames is sufficient for most transportation uses. However, where 35 mm film systems are required, it is difficult to procure equipment that will handle over 1,600 frames – 100 feet. Specially designed 35 mm cameras used in photologging can be purchased in cheaper versions for time-lapse work. They can accept magazines that contain up to 1000 feet of film.

9. Film packaging refers to the type of container that the film is placed in at the factory. In essence, there are two types of film housings: cartridges and rolls. Film in rolls requires threading, whereas cartridge film is self-threading. Cartridge film can generally be removed from the camera without exposing more than a few frames. Cartridge packaging also facilitates in-field operations by reducing the amount of time required to change, label, and store the exposed film. Most Super 8

systems take cartridges, whereas 16 mm and larger systems require the roll-type film. Thus, the type of film packaging used is likely to be determined by the desired film size of the system. In the event that both types of packaging are available, cartridge film is preferable.

10. Film triggering refers to the procedure that is used to initiate the taking of a picture. This procedure can range from manually depressing the standard trigger on the camera to very sophisticated automatic sensing devices. Film triggering methods can be thought of as falling into the following categories:

1. Manual triggering
    a. Using trigger on the camera
    b. Remote triggering
2. Automatic triggering
    a. Mechanical – switch closure
    b. Acoustical sensing
    c. Light sensing
    d. Motion sensing
3. Clock triggering
    a. Fixed intervals
    b. Varied intervals

Most time-lapse systems can be modified to provide triggering by any of the above procedures. The triggering techniques are usually designed to activate the filming process and are independent of the number of frames taken or the exposure frequency. The length of filming is usually regulated by a timing device that is activated by the triggering process, and the exposure frequency is usually regulated by the frequency setting on the camera. If you do not intend to make any equipment modifications, it is appropriate to select a time-lapse system that has a remote triggering capability. Usually this takes the form of an extension cord from the camera's trigger and/or intervalometer. Remote triggering is especially important in situations where the camera's location (e.g., on a utility pole) makes it inconvenient to use the trigger integral to the camera.

Most users of time-lapse equipment eventually find the need for modifications of the triggering system to fit a special application. Of the two types of triggering systems, mechanical and electrical, the most useful by far is the electrical triggering system. Remote or sophisticated triggering schemes may be readily implemented by closing an electrical contact.

11. Film color, as used in this guidebook, refers to the use of color versus black and white film. Color film is desirable in that it facilitates film analysis. The use of color film makes it easier to identify and track vehicles. Color is particularly useful if the traffic density is high, if your exposure

frequency is low, or if you desire to collate film records with notes made at the time of filming. Color film may also make it possible to identify such items as license plate origin. On the other hand, extremely fast films are generally available only in black and white. Thus, black and white films may be required for filming under conditions of poor illumination.

The difference in cost between black and white and color film is related to the film size. The larger the film size, the greater the differential. In most cases, however, the purposes of the study will dictate the need for color or black and white film. Since most time-lapse systems accommodate both types of film, the above remarks are offered as general guidelines for the use of color versus black and white film.

12. Lens speed refers to the maximum amount of light which can reach the film. This amount of light is determined by the two factors:

$$F = \frac{\text{Focal length of lens}}{\text{Lens aperture}}$$

To permit comparisons and to standardize the use of photographic equipment, the physical characteristics of a lens are expressed in terms of the maximum F-value. Since, under most daylight filming conditions, the amount of light the lens is capable of transmitting would be too great for the film, a diaphragm is included in or behind the lens to reduce the apparent F-stop to that which the film requires. The shutter speed also regulates the total exposure. The correct amount of light may be regulated by appropriate adjustment of the shutter speed, diaphragm or both, and is limited by the slowest shutter speed and lens speed, or maximum diaphragm opening.

Since the use of a fast shutter speed is frequently desirable, more light must be provided by the lens. Faster lenses permit the operation of the system under lower illumination conditions. Fast lenses are those falling into the f/2 to f/1 range. Lenses in this speed range are desirable on a time-lapse system.

13. A reliable power source is required in order to drive the film and shutter and regulate the light setting and exposure frequency. Some time-lapse systems provide separate power sources for the camera operations, the light metering system, and the intervalometer. Changes in the power input to the intervalometer may affect the inter-frame interval and thus complicate film scoring or even make it impossible. A constant exposure frequency is assumed when coding speed and other time-dependent events from the film. The most frequent reason for changes in the power input is related to battery decay. Many time-lapse systems use small, dry cell batteries for their power source. Over extended periods of filming (especially at high exposure rates), the batteries lose their

potency. Severe, cold weather conditions accelerate the decay process. For example, at -10°C a battery may have only ten percent of the 20°C life. Several procedures are available for insuring the reliability of the power supplies. First, some time-lapse systems are equipped with the capability of operating on battery or 110 AC current. Such systems should be given preference if such current will generally be available (e.g., filming from inside buildings, near traffic controller boxes, etc.). Other time-lapse systems provide heavy duty battery packs for prolonged uses, and these should be given preference where bulk and weight are not a serious handicap. Finally, each battery operated system should be thoroughly pretested in the environment in which it is to be operated in order to determine the length of time it can operate reliably. An adequate test consists of filming an electric clock with a sweep second hand for several rolls of film or until the batteries fail. The projected film will then show when the filming rate varied from the initial setting. A schedule for replacing the batteries can then be established.

CHAPTER 2

GETTING STARTED

Learning About the Camera

Before you open your first roll of film, pick up the manual of operation that came with your camera. The manual will at first appear complicated but you must fully understand the function of each knob, dial, and button. In all probability you will later want to write a checklist for the field operator to use to insure successful data collection, and every item or adjustment should be checked. If your camera has an automatic fade feature, for example, it must be checked "off" even though you never intend to use it. Unless you have selected a professional-quality camera intended for time-lapse work, you will find that the manual leaves a great deal for the user to discover.

Discovery

Look upon your first few rolls of film as a scratch pad. The film and processing are the least costly portions of the data collection effort and should be thought of as expendable items. Load and remove the film several times. Look for any problems with threading or cartridge insertion. Cartridge cameras, particularly Super 8, automatically set the correct film speed by sensing cut-out notches in the film cartridge. Find the lever that senses the cartridge and be sure you can insert the film without danger of bending the lever.

Before exposing any film, begin the vital habit of labeling each and every roll. Set the focus to the minimum distance and determine the minimum size of the field of view on which you can focus. Prepare a card or note paper of the determined size with a title describing the expected contents of the roll. Include the type of film and camera, and the date. Set up for proper exposure and shoot a minimum of ten frames of the title.

Confirmation

Field of View

The field of view as seen through the viewfinder almost never corresponds exactly with the image that is recorded on the film. It is necessary to determine what corrections must be made by filming a well-documented test roll. Unfortunately, the field of view correspondence with the film image may also change as the focus and zoom lens settings are changed.

In a well lighted area, with the camera mounted on a sturdy tripod, set the camera adjustments for correct exposure. Focus on a large poster board and mark with black tape the limits of the field of view as shown in the viewfinder. Divide the area inside this border into grid lines and number the inside of the lines.

Make a title card showing the F-stop and focus setting and the lens length being used. Expose the title card, verify that the framing poster border is exactly on the edge of the viewfinder, and expose several frames of the poster. Repeat this test with the full range of lens settings.

Filming Speed

Obtain a large electric clock with a sweep second hand. Using appropriate title cards to indicate the settings, expose a sample of film of the clock for every filming rate that you need or have available. The range of settings for time-lapse work may be substantial, and this test may require two rolls of film. Be sure you are using fresh batteries when you began the test. This test should be repeated at least every six months to detect aging of timing components and the need for recalibration.

Viewing the film exposed in this test should show the second hand of the clock moving from frame to frame at the exposed rate, within the accuracy specified by the manufacturer. For example, if 200 frames exposed at 6 frames per second requires between 32.6 and 34 seconds, the timing is accurate to within 2%. Note that a substantial length of time is required to expose an adequate sample of frames (50 to 200) at slow rates such as one frame per second or less. Be sure the light level remains adequate for the duration of the test.

At the end of the timing test, repeat the first timing speed test. Comparisons of the first and last will give an indication of the short-term changes that may be expected due to battery aging.

Light Metering

The correct setting of the camera's light meter may be confirmed most easily by comparison with another light meter reading known to be correct. It is worthwhile to expose at least one roll of each type of film which you may wish to use under a broad range of light conditions before committing the film to a data collection effort. Suggested conditions include dawn and dusk both toward and away from the sun, scenes which include both deep shade and bright areas, etc. If your camera has a manual override for the light metering system, set the F-stop for a deep shade reading and expose a scene which includes both shaded and well lighted areas. With the meter on automatic, cover the lens, begin filming at 18 frames per second, and rapidly remove the lens cover. When viewing the film, make note of the time the automatic system requires to arrive at a correct setting.

Film Selection

Super 8 has slowly become a medium used by professionals as well as amateurs, and the range of film types available is increasing. Sixteen-millimeter film is available in a range of types nearly as broad as those films which may be obtained in 35mm. For virtually every purpose, however, six films are available which cover the full range of requirements in all formats.

Color:

Kodachrome II – a moderate speed, fine grain film useful for most daylight applications. Processing by Eastman Kodak Co.

Ektachrome 40 -- Similar to Kodachrome II, but processing by commercial laboratories is available.

Ektachrome 160 – A faster color film for use in marginal lighting conditions. Commercial laboratory processing is available.

Black and White:

Kodak Plus-X Reversal -- A moderate speed film for general purpose use. ASA 50

Kodak Tri-X – A very fast film for low light levels. ASA 200

Kodak 4-X – Twice the speed of Tri-X, useful for night photography with minimum of lighting. ASA 400

Other films are available. These are included to give an indication of the range of availability. The characteristics of a film can only be learned by practice under a wide variety of conditions.

Record Keeping for Processing

To insure that the films taken during a project are properly identified, several conventions should be observed. As indicated above, each roll of film should have a photographed label at the beginning which defines the contents. This label should contain a number which refers to a master film logbook entry showing the date, time, camera, purpose, content, and any amplifying remarks. The logbook entry number (label number) will be the primary file reference number for future location of the film. An example of a film processing inventory sheet is shown in Exhibit 2.

In most cases, it is desirable to batch process the film and deal directly with the processor. The likelihood of losing film during the processing is greatly reduced when you deliver 50 rolls of film to the processing laboratory and entrust it to someone you know on a first name basis. However, do not hold test rolls waiting for a greater quantity. A system fault discernible by viewing the test rolls should be identified as soon as possible.

Exhibit 2

Film Processing Inventory

ID #	DATA DESIGNATOR	OUT DATE	MAILED/ CARRIED	RETURNED	VERIFIED

When the film is delivered or mailed to the processor, a record stub provided by the processor must be maintained with the log entry made for the corresponding roll of film until the film is returned. This stub number is the only means by which lost film may be traced. Experience has shown that you may expect to have some difficulty recovering about two percent of the rolls sent for processing in spite of your best efforts at record keeping.

Finally, when the film is returned, the log book entry numbers should be written both on the film reel and on the film leader.

Special types of processing are available from some laboratories. The most frequent requirements will be for "pushing" the film. This refers to overdevelopment to make up for insufficient light levels when the film was taken. Ektachrome 160 may be exposed at an ASA rating of 400 provided that you have the lab process it for that speed. All black and white films may be pushed to higher ratings, generally with a limit of about three times the intended ASA rating. There will be a considerable reduction in resolution, a loss of color saturation, and an increase in grain size. The cost for special processing is usually greater than for normal development.

General Guidelines

Field of View. When selecting the area which will be filmed, use the lens length which covers the desired area most closely. This is easiest to do if a zoom lens is available since it provides a continuous range of magnification. Areas that are filmed which are outside the field of interest are clearly wasted. The ease with which the film image may be studied increases with the size of the image on the frame. Sky will almost never be important and should be eliminated by tilting the camera down. This will also improve the ability of the metering system to make a correct exposure.

Angle of View. For measurements to be taken from film, the greater the distance on the screen between measurement points, the more accurate will be the data. Traffic motion directly toward or away from the camera is nearly impossible to gain meaning from unless the camera is over 30 degrees above the traffic when the traffic is at the top of the frame (farthest from the camera).

When a large magnification lens is used for traffic filming toward or away from the camera with the camera near the road surface, there is a shortening effect due to the conversion of a screen with depth to a plane surface. When projected, the traffic will appear to be almost stationary.

Tracking. During time-lapse filming, the subject will appear to jump from place to place between frames. For example, at 60 mph, a car moves 44 feet between frames at a 2 frame per second filming rate. For the person viewing the film to be able to understand what is taking place, there must be a reference which does not move. This means the camera's lens may not be moved during filming. If it is necessary to capture special events at a higher frame rate or to get telephoto pictures of a feature which cannot be seen adequately with the time-lapse camera, the only solution is to use a second camera. The events are matched by using a title card before or after the special event is filmed. "Surprise" events require the title card (which may simply be a number) to be exposed by both cameras after the event.

Tracking events of interest during projection may be more easily accomplished with the film run in reverse. For example, if an exit ramp is being filmed and the behavior of exiting traffic is of interest, projecting the film in reverse will allow the exiting vehicles to be seen "backing" down the ramp. The observer does not become involved with watching all the traffic while waiting for an exiting vehicle.

CHAPTER 3

SETTING UP THE TIME-LAPSE SYSTEM

Selection of the Camera Location(s)

The most critical issue in using time-lapse photography for study of transportation behavior is selection of the field of view. This is a function of the focal length of the lens and the camera location. The most desirable location must be determined with the camera centered at the midline of the field of interest.

When movements of vehicles or pedestrians are being observed, it is often desirable to film from an elevated position.* As we get closer to an overhead position, we accomplish several things. First, we decrease the likelihood that the field of view will be partially obscured by moving objects, e.g., large trucks. Secondly, we increase the precision at which we can measure the behaviors of interest. The problems of distortion (parallax) become less severe when we film from a more overhead position. This distortion is a result of attempting to depict a 3-dimensional scene on a 2-dimensional film surface. By going to an overhead filming position, we view the scene as a 2-dimensional object and so avoid this distortion effect.

For some applications, it may be desirable to use two or more cameras in combination. This is particularly true when:

1. The desired field of view is large.
2. Several fields of view (noncontiguous) are desired.
3. All the events of interest cannot be captured by using one camera location.

The following diagrams present some examples of the ways in which cameras could be deployed. Advantages and disadvantages of each strategy are also briefly noted.

The selected location should also result in the camera:

- facing away from the sun.
- being out of physical danger from passing vehicles.
- being out of the path of pedestrians.
- being out of the view of the individuals being filmed.
- being away from places where it might be injured by debris.
- being in a location where it can be easily serviced.

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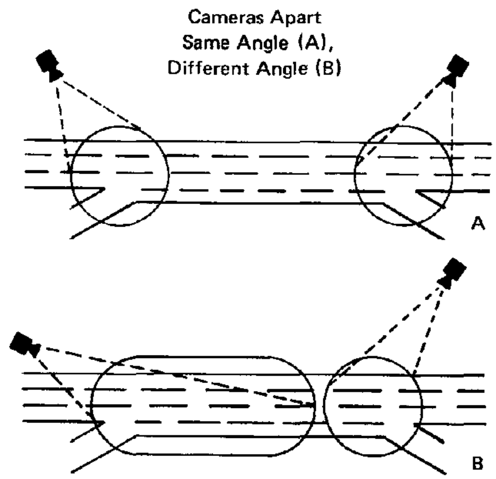
*In some instances (e.g., speed measurements), filming on the same horizontal plane and at right angles to the events of interest provides added detail not otherwise available.

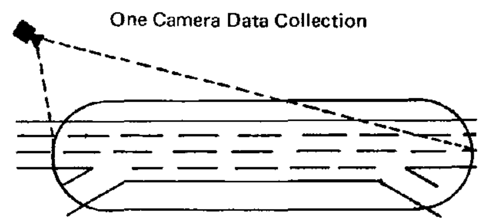


Advantages Over Other Camera Arrangements

1. Permits more flexibility in selection of a field of view.
2. Both cameras can be located directly over or in close proximity to events of interest.
3. Alternative B can be used to capture different types of events.

Disadvantages Over Other Camera Arrangements

1. Requires two camera operators or provision for travel.
2. Possible security problems.
3. Requires two camera locations.

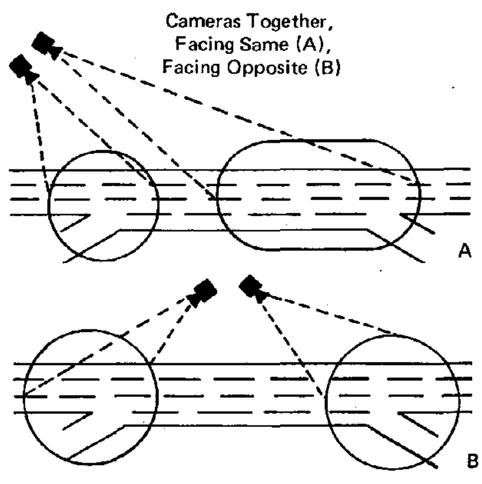


Advantages Over Two Cameras

1. Ease of servicing camera.
2. Only requires one camera location.
3. Minimizes coordination in film scoring.
4. Minimizes in-field personnel costs.
5. Reduced film usage (lower cost than 2 or more cameras).

Disadvantages Relative to Two Cameras

1. May be difficult to locate a single position with the required field of view.
2. Creates scoring problems relative to distortion.
3. Larger fields of view decrease the size (detail) of each of the elements being observed.
4. Film scoring may be more difficult and time consuming (costly).



Advantages Over Other Camera Arrangements

1. Cameras together minimize logistic and security problems and personnel costs.
2. Only requires one camera location.
3. Full film coverage of a contiguous area is often possible.
4. Alternative A results in either a front or rear view of the events of interest from both cameras.*
5. Alternative B results in a front *and* rear view of the events of interest.*

Disadvantages Over Other Camera Arrangements

1. Generally neither camera is located directly over the events of interest.
2. A single location meeting these requirements may be difficult to find.
3. Cameras are required to be at the same height and therefore the type of events that can be observed are similar.

*May be either an advantage or disadvantage depending on the purpose of the study.

You should carefully note the location of each camera, its orientation and the focal length of the lens. These notes are important in order to document the characteristics of the field of view and study area. Additionally, we may need these reference points if it is necessary to collect more data, e.g., before-after studies, etc. In order to have a handy reference as to the previous field of view, it is helpful to print a frame of the exposed film and bring it along when setting up the camera. Checking the scene in the viewfinder against the printed frame is extremely valuable in reestablishing a particular frame of view. Often, spray paint can be extremely helpful in marking the location of the camera or the position of the tripod legs.

Anchoring the Camera

Many times, however, we cannot achieve a filming location that will minimize interference and distortion. Sometimes the object of the study, e.g., license plate typing, driver head movements, brakelight application, are incompatible with an overhead position. In other cases, the available overhead camera location may be of insufficient height to cover the desired field of view. Where ideal conditions are not available, the cameras can be positioned in trees, on lamp poles, on chain link fences, or in the shoulder or median on tripods. Special clamps for attaching the camera to a variety of supports, such as displayed in Exhibit 3, can be inexpensively fabricated.

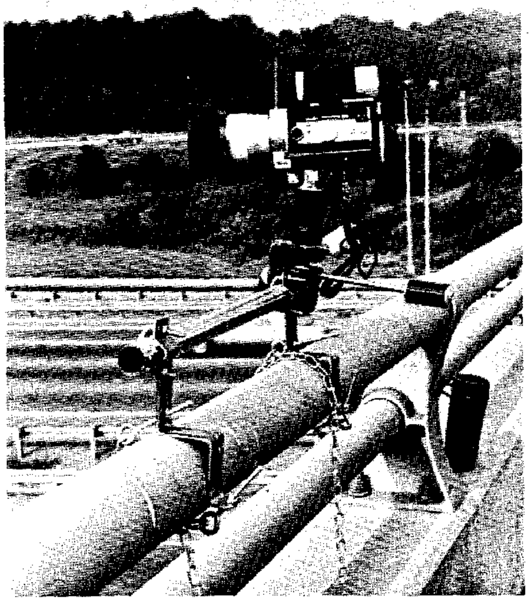
In those cases where the camera is left unattended for any period of time, a theft-proof mount should be used. When leaving the camera, it is also desirable to assure that it is protected from rain and road dirt. In such cases, it is then desirable to house the camera in a portable enclosure. Such housings should be of sturdy construction (e.g., 30mm aluminum plating) and cushion the camera against excessive vibrations.

In the event filming is to be conducted in cold weather (i.e., -10^{o}C), a special heated enclosure may be required. Under such circumstances, it is likely that the lubricant and other characteristics of the camera may require modification. The manufacturer or large camera repair companies may be able to winterize your camera. In any case there is no substitute for a field test to determine reliability.

The designer of mounting equipment should keep in mind that the camera must be accessible for triggering, reloading, and adjusting. The mounting procedures and hardware should be designed so that, when in use, there will be sufficient clearance from fixed structures (e.g., fences, poles) to assure that the camera can be adjusted. Entry points into enclosed housings must be provided for sufficient servicing of the camera (e.g., film and battery changes).

Exhibit 3

Two Field Observation Camera Mounting Procedures



(a) Overpass Rail Mount

(b) Tree Mount

Preparing the Site

Looking through the viewfinder of the camera is not sufficient to assure that you can obtain the data you desire. It is essential to take several rolls of film and attempt to code them for the behaviors of interest. Before collecting data, you may find it necessary to modify the site in order to more precisely observe the events of interest. These modifications can be considered as procedures for:

- eliminating visual obstructions.
- accentuating the occurrence of an event.
- providing appropriate illumination.
- providing a frame of reference for an event.

Eliminating visual barriers can consist of relocating a sign, removing a tree branch, retracting an awning, or rescheduling an ongoing construction project. As in all of the items discussed below, any modification to the site must not affect the behavior that is under study. For instance, the removal of a tree branch may increase site distance and consequently alter driver behavior. Likewise, any modification of a prominent feature of the site may draw attention to the change and thus distort the events.

Accentuating the occurrence of an event may entail attaching small mirrors to a traffic signal so that the signal changes can be observed from a roof top location. Electrically activated devices such as road sensors may also provide useful inputs for identifying specific events. For example, a Tapeswitch[1] located in a gore area may be used to activate a time-lapse system or to provide a visible cue or pulse to the camera.

Having adequate illumination for photographic work may involve the use of artificial lighting. Artificial lighting procedures often entail the use of electrical "triggers" similar to those discussed in the preceding paragraph. When it is necessary to film under conditions of reduced light, two options should be considered in addition to more lighting. One procedure entails the use of light augmentation equipment and especially fast films. A second procedure involves selecting a second site – one where the existing sources of illumination are adequate. These options are worthy of consideration due to the very obtrusive nature of increasing existing illumination.

Providing a frame of reference for certain events of interest is perhaps the most frequent reason for site preparation. Placing markers along side the road or marking the roadway are methods generally used to provide a reference for speed measurements. When deploying such markers, it is important to assure that they are easily identified on the film and, at the same time, not distracting to the

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[1]Trademark, Tapeswitch Corporation of America.

individuals under study. For example, it is often possible to use objects already present at the site for reference points.* At other times, it may be possible to use materials (e.g., soda cans) whose visibility may be enhanced (e.g., use of day-glow paint) on the side facing the camera while still maintaining their "low profile" to the approaching motorist. When placing markers, you should recall the effects of parallax and place reference points on both sides of the field of view; during film coding, these opposed markers make it possible to construct lines that are parallel in the real world.

Operating the Time-Lapse System

Use of Titles and Cueing Procedures

Before data collection begins, it is desirable to develop a procedure for uniquely identifying each roll of film and film segments of particular interest. A well conceived film identification plan can save many hours of accounting and film reviewing.

Each roll of film should begin with a leader that specifies the filming date, a site or location code, and the time of day that roll of film is started. If more than one camera position or filming procedure is being used, each roll should be appropriately labeled. In the event that a variety of behaviors are being observed at different times, the behaviors should be noted on a title card.

The title card can generally be hand-held in front of the camera. The focal distance should be turned all the way down (e.g., 1.5 meter), and the focal length set at its smallest mm reading (widest angle). If large, bold lettering is used on the cards, it may be possible to simply pass them in front of the lens without otherwise interrupting the camera's operation. In either case, at least ten frames of film should then be used to record the title card.

Cue cards can be used within a particular roll of film to provide an indication of:

- a change in the camera's mode of operation.
- a change in the field of view.
- a new time period.
- the occurrence of an event of interest.
- a synchronization with another camera or device.

Preprepared and arranged cue cards (possibly in the form of a ring-bound card deck) facilitate cueing. Cards of varying colors or containing bold geometric designs can, if properly selected, be used as "flash" cards for cueing purposes without the need to change the focus setting.

*When using natural objects, it is important to record the distance between these objects for use during film coding.

Another frequently used method of cueing involves the use of an external log. A written record can be used to augment the information available on the film or to specify where on the film an event occurs. Clocks that are visible to the log keeper and are also in the field of view of the camera provide an excellent means of later locating an event on a roll of film. Less exacting procedures include noting the film footage meter or the time since the last cue or title card was filmed. If a clock is used, the depth-of-field will probably be inadequate to bring it into focus. Excellent results may be achieved as close as two feet from the lens, however, by using a pocket watch with broad black hands on a white face.

Monitoring the Camera's Operation

Like other devices, the time-lapse systems must be periodically checked during their operation. Problems relating to:

- film feeding,
- power supply, and
- intervalometer reliability

are the most common electrical/mechanical failures. The camera's settings and adjustments must also be periodically checked. In particular, the light readings and focus adjustments should be monitored.

A knowledgeable individual should be tasked with checking the camera every time a new roll of film is required. The system check should include:

- listening to the shutter for irregularities in exposure frequencies.
- checking the batteries or power supply.
- checking the footage meter to see if the film is advancing.
- checking the light meter and exposure settings.
- verifying the field of view and focus.
- checking the data collection schedule to make sure that the filming is proceeding as planned.

The attendant should also be alert to conditions that might affect the events under study. For instance, an accident or disabled vehicle upstream may alter the nature of the events captured on film. At the same time, such conditions may be outside the field of view and go unnoticed without the presence of a human observer. The attendant should be prepared to shield the time-lapse system in the event of rain or snow. In most cases, a simple plastic bag with a hole for the lens can serve as an adequate rain cover. If the system is to be left unattended for a long time, a metal housing with the capability of locking the camera to a pole or tree is advised to discourage theft.

CHAPTER 4
ANALYZING THE FILM

Operational Definitions of the Events of Interest

Each of the events of interest must be carefully defined *before* the initiation of data collection. Shooting film of a particular location does not insure that you will capture the data you need. Many investigators have assumed that because a permanent visual record was made, they could worry about what they were going to code at some later date. Nothing could be further from the truth!

The investigator must operationally define the events he wishes to measure. An operational definition of the events of interest consists of specifying the observable elements that are necessary to identify the event. A good operational definition does not exist in the mind of the investigator – it is words on paper. Every operational definition must be capable of being conveyed to other individuals via a series of written statements (and illustrations, if appropriate). In theory, a fully automated decision-making machine (computer) should be able to use the operational definition and accurately code the defined events. An example of an operational definition for running used in coding pedestrian behaviors might be as follows: "A pedestrian will be coded as running if he/she crosses an entire traffic lane in three frames or less."*

By carefully reviewing a definition, the investigator can judge whether the filming procedure he is considering will adequately record the necessary elements. For example, a particular deployment of cameras at a gore area may: adequately capture abrupt lane changes; not capture brake applications; and may be insensitive to, or minimally capture changes in acceleration. Additionally, the location of the cameras may preclude the observation of relevant parts of the roadway or relevant vehicles, such as those behind articulated trucks. Similarly, filming restrictions such as ambient lighting conditions may result in a biased or unrepresentative sample. Likewise, film coding limitations such as parallax may make it impossible to obtain some of the desired behavior.

A concise statement of the elements used to define a measure is also invaluable for comparing the results of different studies. Often "contradictory" results can be explained in terms of subtle differences in the operational definition of the events of interest. In this sense, we want to maximize the likelihood that other investigators can verify the results.

*This particular definition assumes that exposure frequency and lane widths remain constant throughout the coding.

Coding Reliability

One of the most difficult aspects of time-lapse photography is film coding. Two general types of film coding schemes are used in conjunction with time-lapse:

- In the first case, the film is viewed in expanded time ("slower than life").
- In the second case, the film is viewed in compressed time ("faster than life").

Expanded time analysis usually is associated with enumeration and classification of events or behaviors. The resulting data is, therefore, quantitative in nature. Compressed time analysis is generally used to obtain judgments as to the overall patterns of behaviors at a location. Qualitative data, such as orderliness of an interchange, usually result from this type of analysis.

Sources of Coding Error

Users of time-lapse often underestimate the cost and time involved in coding the events captured on the film. One reason for this unjustified optimism is the feeling that the film coders will only require limited training. Unfortunately, extensive training is generally required before the results of the film analysis can be trusted. The lack of attention paid to the reliability of the film coding (and, hence, the credibility of the entire study) is reflected by the fact that out of the hundreds of time-lapse studies done every year, only a handful indicate that the film coders achieved an acceptable standard of consistency.

A great number of factors determine the amount of effort required to achieve an acceptable level of coder reliability. Some of the more important of these factors are the:

- conciseness of the operational definitions.
- quality of the film image.
- filming angle and field of view.
- apparent distance from the film coder to the events of interest.
- exposure frequency used during the filming.
- adequacy of coding forms and other job aids to be used in the film coding.
- availability of electromechanical aids such as frame counters or motion detectors.
- motivation and prior experience of the coders.
- amount of practice and feedback given to the film coders.
- amount of continuous coding performed by a coder.

After the development of the operational definition, it is generally necessary to develop a set of coding conventions. These conventions further clarify those ambiguous situations that are bound to occur in the course of film scoring. Examples of appropriate coding often provide the basic technique for documenting the conventions. Coding sessions, comprised of the principal investigator and the coders, are mandatory in order to test the feasibility of coding conventions.

Film coding, by its very nature, is a time consuming and monotonous process. Therefore, it behooves the investigator to develop procedures that facilitate the classification, counting, and recording of the event of interest. These procedures are generally known as "job aids." Some job aids can serve dual purposes. For example, Exhibit 4 represents a paper and pencil frame recording form that was developed around a basic Fortran coding sheet. In this case, both film coding and key punching was facilitated by the choice of this format. An experienced investigator expects to revise his paper and pencil job aids several times before they are finalized. The film coders are the best source of information relative to the shortcomings of a job aid and they should be consulted before and after every modification.

Work-rest cycles also play an important role in determining the reliability of the resulting data. As a general rule, one uninterrupted hour of film is a maximum. A short five- to ten-minute break every hour (that can consist of record keeping activities) can serve to revive interest in the coding and rest blood-shot eyes.

Finally, the selection of motivated and conscientious individuals is a must. Such individuals require less training, provide more useful advice in the design of coding procedures and job aids, and consistently require less supervision and rechecking.

Procedures for Computing Coder Reliability

Many methods can be used to arrive at an index of coder reliability. They all have attempted to characterize to what extent a coder:

- agrees with other coders or the principal investigator in the classification of events, or
- consistently classifies the same events when viewed at different times.

The first type of reliability is known as inter-coder reliability, and the second as intra-coder reliability. Intra-coder reliability is of major concern when:

- only one coder is scoring a particular set of behaviors, or only one coder is involved in the film analysis.
- changes in coding performance are expected to occur over the course of the film analysis.

Inter-coder reliability is of major importance in:

- determining which of several coders require remedial training.
- isolating behaviors that are more difficult to score as evidenced by the coders' lower level of agreement.

Exhibit 4

Coding Sheet

PROGRAM								PUNCHING INSTRUCTIONS	GRAPHIC								PAGE OF
PROGRAMMER						DATE			PUNCH								CARD ELECTRO NUMBER*

SITE	LOC.	COND	REEL	CARD NO.	START THRU RED	START THRU GREEN	START THRU YELLOW	START TURN RED	START TURN GREEN	START TURN YELLOW	COMMENTS	VEH. STOP	VEH. CLEAR	LANE #	EXT. MVT	QUEUE POS.	VEH. DS.	INT. BLKD	PULL DOWN	LARGE VEH	VEH. LGHT	FILM SPEED
1	2	4	6	8 9	11 12 13 14	16 17 18 19	21 22 23 24	26 27 28 29	31 32 33 34	36 37 38 39	41 42 43 44 45 46 47 48 49 50	52 53 54 55	57 58 59 60	62	64	66 67	69	71	73	75	77	79 80

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

*A standard card form, IBM electro 888157, is available for punching statements from this form

**Number of forms per pad may vary slightly

One procedure for determining the reliability of the coding consists of making a simple tally of the times that an event is coded. A comparison between the tallies associated with one coder can then be compared with those obtained by other coders on the same film segment. In a similar fashion, the tallies obtained by a single coder scoring the same film segment at two different times can be compared. If, for instance, we hade three (A, B, & C) events that were to be coded and four (1, 2, 3, & 4) coders were involved in the process, we could proceed as follows:

1. Train all the coders to the point where you believe that film analysis can begin.
2. Obtain 20 segments of film on which the events of interest should occur in at least ten of the film segments. Every segment should contain somewhere between zero to five occurrences of each event.
3. Have the coders each code all of the 20 film segments. The principal investigator should also code the film segments. The coding should be performed as it will be during the actual film analysis. This may mean, for example, that several events are coded during the same viewing of the film, or each behavior requires a separate run through the film, etc.
4. Obtain a tally of the number of times coder 1 observed event A in every film segment. Do the same for coders 2, 3, and 4, and the principal investigator. Now do the same for events B and C.
5. Looking at event A, compute the number of film segments where coder 1 agrees with coders 2, 3, 4, and with the principal investigator. An agreement implies that both coders noted the exact same number of occurrences of A in a particular film segment. Divide the number of agreements by 20 and you have the percentage of agreement. Perform the same calculation between all coders for each event.
6. Note any event that received an average (over all coders) agreement of less than 80%. The definitions of these events probably need to be clarified or revised.
7. Note any coder who consistently showed a low agreement with other coders (and especially the principal investigator's codes) for a particular event. Retraining is usually called for in these cases. In the event that a single coder does poorly across all events, you should consider replacing him with someone else.
8. When all coders achieve over 80% agreement on all the events, then you may consider the coders' reliability to be sufficient to begin the actual film analysis process.

Periodic Reliability Check

While collecting this reliability data, it is important that the coders do not discuss their coding activities, nor should the principal investigator intervene in any way. The investigator should also use the reliability data to identify specific events that need clarification. He should review those film segments where agreement was low. He should also determine those instances where the coders disagreed with him. It is not unusual to find that the principal investigator is using operational definitions that differ from the official definitions.

Additional reliability checks should be performed in those instances where coding will be done continuously or sporadically over a period of weeks. This precaution is necessary because coders often change the operational definitions of events by adopting shortcuts or through carelessness.

Equipment for Film Analysis

The nature of equipment that is useful for assisting in film analysis depends on the events of interest. In all cases, however, a projection system and some means of recording the data obtained from the film are required.

Projectors. The projection system used in film reduction may range from "home movie" projectors to special systems designed specifically for data reduction. The novice user of time-lapse photography should carefully investigate renting equipment if his requirements involve the use of professional quantitative measurements, or give consideration to subcontracting this work. The requirements for special purpose equipment to assist the time-lapse user in the reduction probably will not be met by a single manufacturer, although sophisticated devices are appearing on the market, and semiautomatic digitizers for X-Y coordinates are available for use with rear projection screens for both 16mm and Super-8 projectors. Positioned data may be entered directly into a digital processor for correction of parallax and calculation of speeds and distances.

Most projection requirements are not as demanding, but the data reduction can be enhanced with professional equipment. A week of projection which includes frequent film reversals can ruin a projector designed for home use. The successful data reduction effort will require as a minimum, the features noted below:

- Flickerless projection at slow speeds
- Heat removal for film protection when stopped
- Forward and reverse single frame capability
- Slow (6) and fast (18) continuous frame rate
- Bright image with 200-hour projection lamp life

Additional features which will enhance the data reduction effort are:

- Positive, repeatable frame registration
- Automatic focus when single framing
- Consistent frame registration when switching from reverse to forward

- Full remote operation of all projection modes
- Wide angle operation of all projection modes
- Precise timing of continuous motion speeds
- Up-down frame counter, resetable and presetable
- Quiet operation

The projector selected will probably not meet all requirements, although some are excellent. Problem areas which deserve consideration by manufacturers include poor film registration when switching from forward to reverse, and focus changes when switching from continuous motion to single frame. The noise made by projectors can be a severe influence on the reliability of the data reduction. If the image, when single stepping the film, is dimmed by the heat removal system, the room lighting may have to be too low for efficient note taking.

Projector bulbs produce concentrated heat, requiring a constant-speed fan for removal. A machine which changes projection speed by slowing the drive motor requires the addition of a separate fan to cool the bulb. Some projectors are designed so that the bulb is turned off when switching from forward to reverse. A separate switch must be installed to keep the lamp on, or the shock to the filament will greatly reduce the lamp life. When the projector is to be turned off, the fan must be operated for several minutes after the lamp is turned off to completely cool the projector bulb.

Most projectors are designed so that the motor must be on before the film speed or direction switches are changed. If there is no interlock to prevent switching when the motor is off, placards and operator training are indicated, but will probably not be completely successful. Before a final decision is made regarding any equipment purchase, the availability of maintenance should be investigated. Spare parts which are likely to fail, particularly projection bulbs, should be kept in stock.

Projection Screens. Three categories of screen surface are available: matte, glass bead, lenticular. When measurements do not have to be made on the screen, the glass bead or lenticular screen may enhance the image by greatly increasing its brightness.

The matte screen has a smooth, dull white surface. The chief advantage is that you may focus an image on the surface precisely. Since the projection light is scattered to give the broadest viewing angle of the three surfaces, the image may be seen from very close to the screen by an observer out of the way of the projector beam. The main drawback is its dull finish and low reflectivity which cause it to throw a relatively dull image back to the audience.

The glass bead screen has a matte surface covered with a layer of glass beads. The viewing angle is the narrowest of the three and the reflected image is brighter, and not as sharp as the other types of screens.

The lenticular screen has a smooth surface with a series of vertical grooves which scatter the light to a wider viewing angle than the glass bead, but less than the matte. In nearly all respects, this surface lies between the other two.

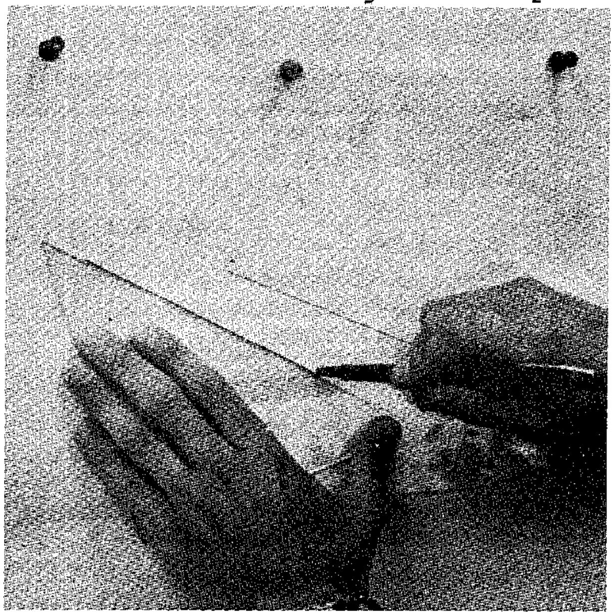
When measurements are to be made on the screen, a much smaller area is preferred to enhance the resolution when viewed closely. A white poster board surface pinned to the wall is suitable and permits lines to be drawn to indicate references. Exhibit 5 illustrates the use of time-lapse for determining speed over a 25-foot segment by extrapolation of vehicle position. Only two frames are required if the frame interval is precise.

In all cases, the screen should be parallel to the film plane to minimize distortion. Tape should be placed on the screen over identifiable objects near all four corners to verify consistent frame registration.

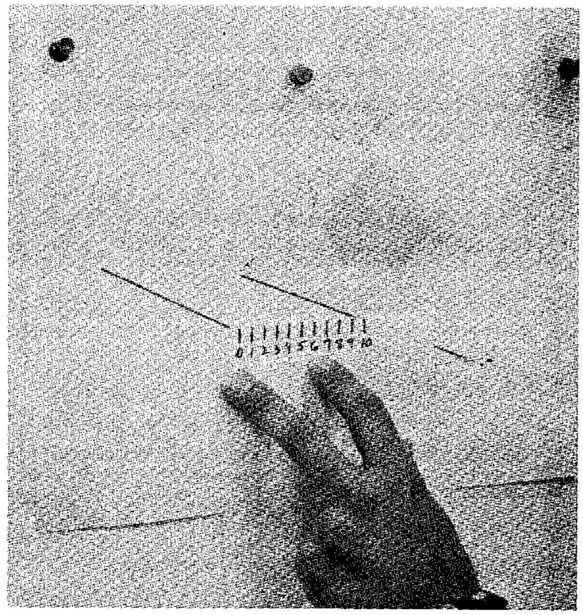
Rear projection is frequently more suitable for analysis since it allows the observer to make measurements on the screen without interference with the scene. The rear projection image must be reversed, and is done by projection into a mirror. The disadvantages are distortion and loss of light due to the translucent screen. The image brightness may appear to fall off rapidly from the center in some rear projection systems and should be examined carefully before selection. The mirror should be protected from dust or readily accessible for frequent cleaning. Most projectors are designed for operation from the right side, and therefore rear screen systems generally place the projector at the left of the screen. Be sure the projector control will be accessible when used with the projection screen.

Screen Size. The size of the projected image depends on the projector lens focal length and the distance of the lens from the screen. For convenience, the projector should be reasonably close to the screen, but the shorter lenses tend to be much more expensive than longer lenses for the same distortion. Less edge distortion will be produced at longer projection distances for flat screens. Under ideal conditions, all points on the screen will be at the same distance from the film. A greater projection distance minimizes the percent difference in distances to various points on the screen. Some projection lenses are designed with a "field flattener," which corrects the projected image when used with flat screens.

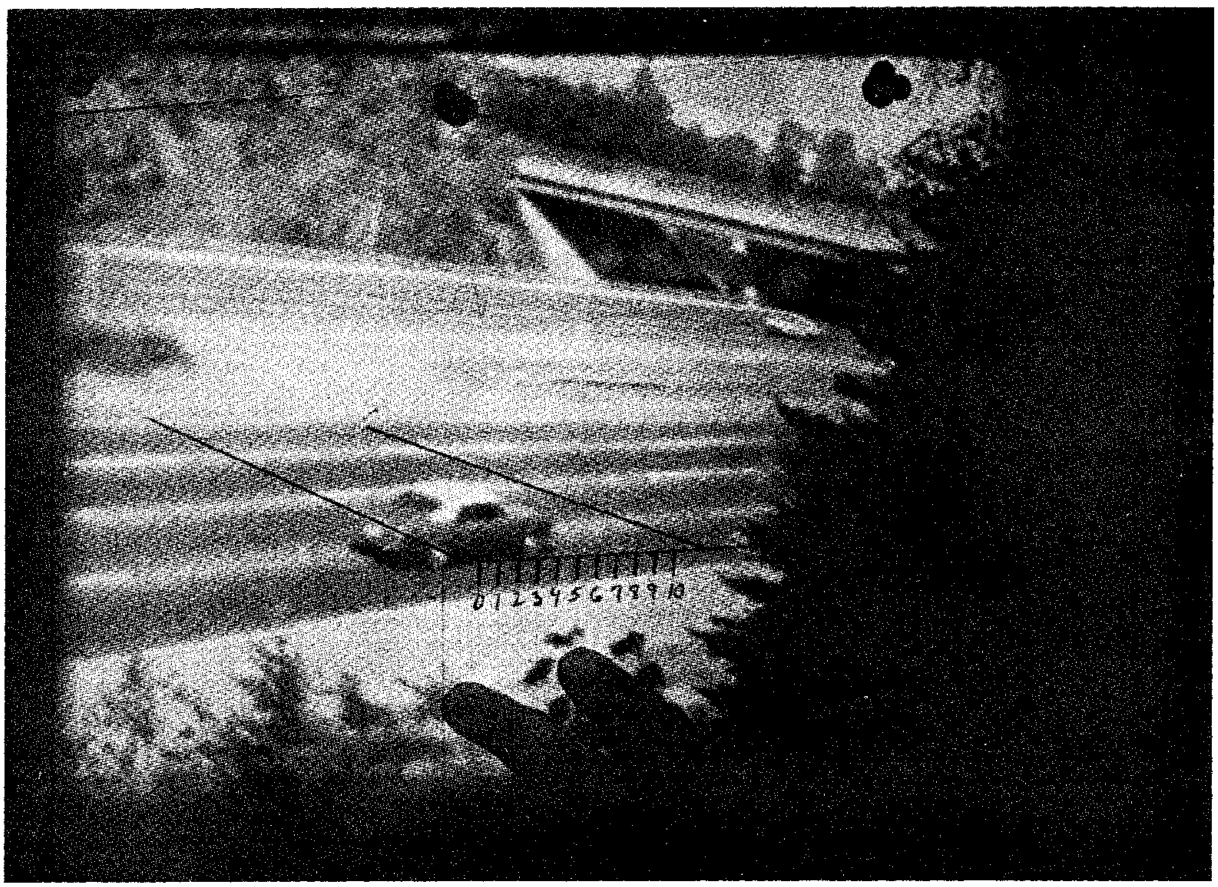
Measuring Vehicle Speed by Extrapolation



Construction Lines Connect Adjacent Roadway Markers.



A Graduated Scale is Used to Estimate Distance Between Markers.

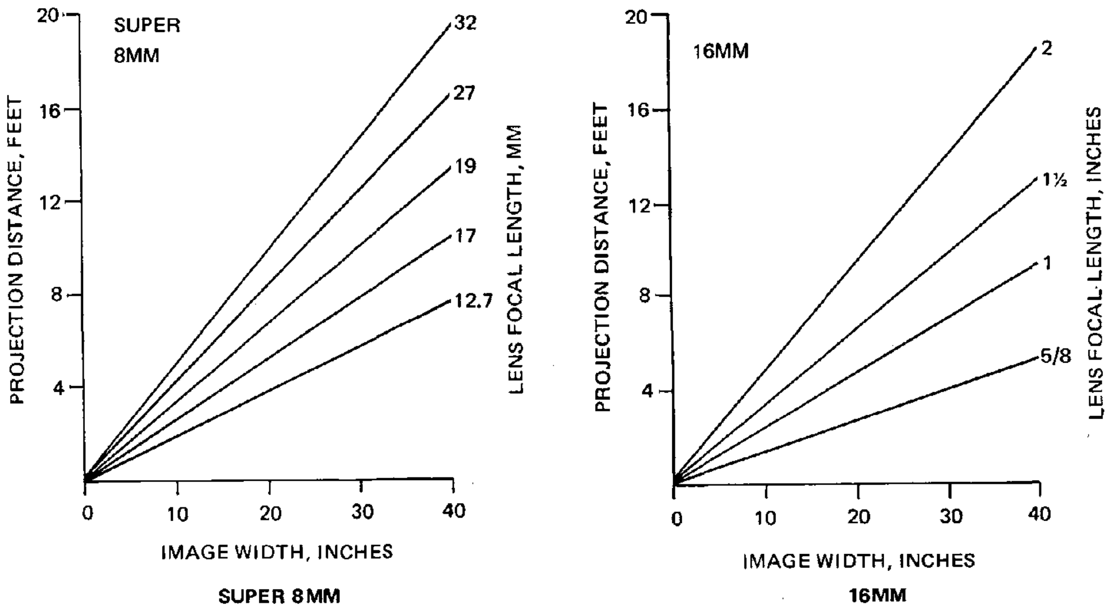


The Projected Image, Marker Spacing Lines, and Graduated Scale.

The distance from the lens to the screen for a given screen size may be found from Exhibit 6.

Exhibit 6

Projected Image Size for Super 8 and 16mm Films



Auxiliary Equipment. Since most data reduction will be done in a low light level, some form of illumination must be provided for the observer to keep records. Ideal sources are small gooseneck lamps which illuminate a small area and which may be easily moved.

The projector should have a frame counter that adds and subtracts as the film direction is changed. The preferred display type is electronic so it can be seen without illumination. Mechanical frame counters are usually limited to less than ten counts per second, preventing rapid advances to the area of interest on the film.

Frame counters are typically triggered by the signal which directs the projector to move to the next frame, rather than by the actual motion of the film. As the projector parts become worn, this signal may not always cause the film to move and will result in counting errors. The preferred type of counter is triggered by the actual motion of the film.

The ideal system is one with multiple counters; a master counter maintains a record of the current position, and resetable slave counters are used to find the numbers of frames between events of interest (yielding time). Some electronic counters increment on a selected number rather than one, permitting direct readings in feet or seconds of real time. That is, if film was taken at a rate of six frames per second, a counting rate of 0.1666 per frame would read time in seconds directly.

Many applications require the number of times an event occurs to be counted. The time required for data reduction can be reduced considerably by using mechanical or electronic counters and a keyboard so that the observer does not have to look away from the screen. Depending on their complexity, an observer may be able to count several different categories of events during one continuous running of the film.

A stopwatch that can be read easily in a darkened room is frequently useful. If a great deal of timing of events is to be done, a camera which records digital time on each frame may be cost effective, particularly for those studies where the camera is only operated when an event of interest occurs. A pocket watch within the field of view may provide sufficient information at lower cost, however.

EPILOGUE

Of all the advice contained in this report, the most important is "Try it – you won't like it." First hand experience is the best, and only, way to make sure that things will turn out the way you expected. The camera position, film, settings, etc. will in all likelihood require considerable fine timing before you are ready to begin taking data. A pilot test is your best assurance of a successful effort. Hopefully, the information in this report will make you more likely to try time-lapse and also make the pilot test a more rewarding experience.