This study explored the use of digital close-range photogrammetry for routine bridge inspection and historic bridge documentation. The major objective of the research was to evaluate the feasibility of photogrammetry for these two bridge engineering applications. Results of the study indicated that photogrammetry provides sufficient accuracy and is a non-contact, inexpensive, and practical measurement option.

The research was divided into two photogrammetry projects. In the first project, photogrammetry techniques were employed in the geometry measurement of a simple-span prestressed concrete bridge. The bridge was measured and evaluated according to routine bridge inspection guidelines. PhotoModeler, a consumer-grade photogrammetry software program, was used to process the images for measurements of vertical clearance, lateral clearance, deck width, and structure length. The comparison between photogrammetric and hand measurements showed minor differences with the percentage error ranging from 0.06% to 1.43%.

In the second project, a historic non-composite, steel girder bridge was selected for documentation. Three-dimensional models of the bridge in elevation and of the pier were developed using PhotoModeler. Dimensions obtained from the models were compared with the design drawings which showed that the photogrammetry measurements differed by 0.23% to 8.00%. Two-dimensional, orthographic photographs (ortho-photos) were also developed in PhotoModeler and edited with AutoCAD to provide scaled elevation drawings of the bridge.
PHOTOGRAMMETRY APPLICATIONS IN ROUTINE BRIDGE INSPECTION AND
HISTORIC BRIDGE DOCUMENTATION

by

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PREFACE

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ABSTRACT

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# METRIC CONVERSION FACTORS PAGE

## APPROXIMATE CONVERSIONS TO SI UNITS

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INTRODUCTION

ROUTINE BRIDGE INSPECTION

Bridges require regular inspections during their service life in order to assess current structural conditions, anticipate future problems, and identify needed maintenance. During a routine inspection, field measurements and visual observations are made by a qualified bridge inspector to evaluate the physical condition of bridge elements including the deck, superstructure, and substructure (referred to as the condition rating). Bridge dimensions commonly measured by the inspector include the maximum span length; overall structure length; curb or sidewalk width; roadway width; deck width; minimum vertical clearance; and minimum lateral clearance (1).

As shown in Figure 1(a), vertical clearances are measured from two or more locations under the superstructure; in this case, multiple measurements are needed due to the curvature of the roadway and the vertical alignment of the bridge. The smallest measurement is considered the minimum vertical clearance. Figure 1(b) shows the horizontal clearances measured during a routine inspection. The horizontal clearance is the perpendicular distance from the shoulder to the abutment, pier, riprap, or retaining wall. Similar to vertical clearance, the smallest measurements on both sides of the roadway are considered the minimum lateral clearances.

HISTORIC BRIDGE DOCUMENTATION

Evaluating the historical significance of a bridge considers a variety of characteristics. In general, the bridge should prove to be “a particularly unique example of the history of engineering or associated with a historical property in an area” (2).
Organizations including governmental agencies, preservation groups, and historical societies are particularly interested in historic bridge documentation. Federal regulations require the proper recording of historic bridges including properties such as overall geometry and physical deterioration (2).

Historic bridge documentation usually consists of measured drawings, photographs, and written data that provide a detailed record which reflects the property’s significant features (3). Figure 2 shows an example of a measured drawing of a historic arch bridge. It includes five basic parts: a title; a plan drawing; an elevation drawing; a scale and compass; and
The title gives the bridge name, year, and location. The plan and elevation drawings provide geometric information of the bridge and the topography of the surrounding area. The orientation and dimensions can be determined by referring to the scale and compass on the drawing. The written data section provides a general description including the location, the construction materials, and structure type.

**Figure 2** Example measured drawing of a historic bridge (2).

**RESEARCH OBJECTIVE AND ORGANIZATION**

The major objective of this paper is to evaluate the capability of close-range terrestrial photogrammetry as an auxiliary measurement tool for routine bridge inspection and historic bridge documentation using off-the-shelf digital cameras and photogrammetry software. Two studies have previously been conducted with a similar aim (4, 5); however, over 20 years have passed since those investigations which utilized neither digital cameras nor softcopy software.

The research reported herein is broken down into three major sections. The first section provides a detailed description of the photogrammetric measurement system. Hardware
information (including camera models, wide-angle lenses, and camera settings) along with photogrammetry software features and the calibration of the camera-lens system are described. The second section describes a case study using photogrammetry techniques for routine bridge inspection. Span length, deck width, and minimum vertical and horizontal clearances of a 4-year old, prestressed concrete bridge are measured using photogrammetry and compared with those obtained by hand. The third section provides a second case study which focuses on historic bridge documentation of a 68-year old, non-composite steel girder bridge utilizing photogrammetry. Three-dimensional (3-D) models and ortho-photos are developed and bridge dimensions measured by photogrammetry are compared with design values.
PHOTOGRAMMETRIC MEASUREMENT SYSTEM

DIGITAL CAMERA, IMAGE SENSOR, AND WIDE-ANGLE LENS

The camera is the most important instrument in the photogrammetric measurement system. Kodak has developed a series of professional-grade digital cameras which are suitable for close-range terrestrial photogrammetry. The two camera models used in this research included a DCS660 (6) and Pro SLR/n (7). The former model was used for the vertical and horizontal clearance measurements in the routine bridge inspection study while the latter model was used for the deck measurements. The historic bridge documentation study was performed exclusively with the DCS660.

The Kodak DCS660 digital camera has a solid state CCD (charged coupled device) image sensor with a 6.1 megapixel (3048 x 2008 pixels) resolution; the Kodak Pro SLR/n features a RGB CMOS (complementary metal oxide semiconductor) sensor with a resolution of 13.7 megapixels (4536 x 3024 pixels). An important difference between the CCD and CMOS sensors is that the CCD processes pixels in sequence, while the CMOS transforms light into electrons simultaneously in the picture elements (i.e., pixels). As a result, the CMOS consumes less power and operates at a higher speed than the CCD sensor. However, CMOS sensors are considered more susceptible to noise resulting in lower quality images than CCD sensors which produce high-quality, low-distortion images (8).

The two cameras were both equipped with a Nikon 20-mm f2.8D AF wide-angle lens. A wide-angle lens is one having a focal length less than 35 mm. This type of lens provides a broad area of coverage and thus, fewer images are needed to capture the measured object. At times, a flash was used in the field when there was insufficient natural light. For the DCS660, a SUNPAK NE-1AF ring flash was used; a Nikon SB28DX speedlight was used for the Pro...
SLR/n. Other main features and settings of the cameras included the focus (manual set at \(\infty\)); white balance (automatic); ISO rating (100 for the DCS660 and 200 for the Pro SLR/n); drive mode (single); exposure mode (automatic); picture quality (best); flash (automatic); and image format (TIFF for the DCS660 and RAW for the Pro SLR/n).

**TARGETS, SCALE BARS, AND HORIZONTAL PLANE SETUP**

Both natural and artificial targets were used to identify specific points on or near the bridge in the photographs. Examples of natural targets that were utilized include the sharp corners on the retaining walls, piers, and rails; discolored patches on the concrete and steel surfaces; and bolts on the girder webs. The artificial target design consisted of a black paper circle, with a diameter of 108 mm (4.25 in), placed in the center of a 254 x 254 mm (10 x 10 in) white card board to provide high contrast. The target size is based primarily on the camera-to-object distance and should provide at least 8 pixels across the target in the images. Artificial targets are necessary when there are not enough natural targets on the object.

Dimensions of objects in the photographs cannot be determined without a real-world coordinate system with scale. To establish the measurement scale, horizontal and vertical bars of known dimensions were used. The scale bars consisted of wood planks with dimensions of 1.83 m x 88.9 mm x 19.05 mm (72 in x 3.5 in x 0.75 in); three artificial targets were attached at the ends and the middle of each bar. A horizontal plane was also setup to establish the vertical Z-axis which was needed particularly for clearance measurements. This was done at the bridge site by mounting three reference targets on tripods and adjusting the targets to the same elevation with a level. The X- and Y-axis are defined to lie in the horizontal plane and the Z-axis is taken perpendicular to the plane.
PHOTOGRAMMETRY SOFTWARE

A photogrammetric software package may include some or all of the following basic characteristics (9): handling of image display; determination of orientation; transformation of coordinates; image processing functions; measurement tools; and ortho-image production and visualization. The theory of photogrammetry is not discussed in this report but is available in other references (10, 11). PhotoModeler Pro (12), a Windows based photogrammetry software developed by Eos System Inc., was selected for this research due to its user-friendliness, powerful modeling and measurement features, and inexpensive price. This low-cost software has been used in a broad range of engineering and non-engineering applications and provides non-photogrammetrists the means by which to accurately model and measure a physical object from digital images.

In PhotoModeler, a 3-D object model consists primarily of a set of spatial points, edges, and/or curves. Surfaces and textures can later be conveniently added to the basic wire frame model to create a realistic solid model. Measurements of distances between two points, lines and points, points and surfaces, etc. can be made using the measurement tool. Another important feature of PhotoModeler is its capability to export ortho-photos. Ortho-photos are defined as “images which have been remapped to remove the effect of surface variations and camera position from a normal perspective photograph” (12). Furthermore, 3-D models can be exported in DXF format to AutoCAD or VRML format to Cosmo and Cortona players.

CALIBRATION OF CAMERA-LENS SYSTEM

Photogrammetric measurement cannot be accurately performed without knowing the interior characteristics of the camera. The process of determining the optical and geometric characteristics of a camera is called calibration. In general, camera calibration may serve to
evaluate the performance or stability of a lens and to determine the parameters of a lens or camera-lens system or image collection process.

A simple procedure is used in PhotoModeler to carry out a camera calibration by analyzing a grid of targets projected onto a flat wall. Figure 3 shows the target grid and required camera stations; a total of eight images are needed for calibration purposes. Processing of the eight photographs in PhotoModeler produces the following camera parameters: principal point coordinates (the intersection of the optical axis with the image sensor); principal distance (the distance from the center of the lens to the principal point); lens distortion characteristics (radial and tangential); and sensor format size (pixel size and number of pixels). Calibration results are saved and later used for photogrammetric analysis. Self-calibration of the camera can also be performed in PhotoModeler, which can possibly provide higher measurement accuracy. In a self-calibration, camera parameters are determined based on points measured on the actual object; however, self-calibration was not used in this research since much more artificial targets are needed.

![Figure 3 Camera calibration setup used by PhotoModeler](image-url)
ROUTINE BRIDGE INSPECTION STUDY

The bridge selected for the routine inspection study is the Las Alturas Bridge, a single-span, simple-supported prestressed concrete bridge built in 2000 and located in Las Cruces, New Mexico. Based on the design plans, the bridge has a span length of 32.15 m (105.5 ft). The minimum design clearance of the bridge is 4.64 m (15.24 ft) in the vertical direction and the horizontal clearance between the retaining walls is 29.58 m (97.0 ft).

TARGET AND SCALE BAR LAYOUT

For the underclearance bridge measurements, nine artificial targets (labeled G1 to G9) were positioned on the roadway as shown in Figure 4(a). A plumb line was used to set the roadway targets exactly under the centerline of the girders. Two targets were also attached to the eastern edge of the exterior girder and the retaining walls to increase the target coverage (labeled E1 to E4). To measure the vertical bridge clearance, a horizontal plane was setup to pass through three targets (labeled L1 to L3) which were adjusted to the same elevation as discussed earlier; the vertical axis was taken to be perpendicular to this horizontal plane. Four scale bars (two in the horizontal and two in the vertical direction) were placed on each side of the roadway (labeled S1 to S4).

Figure 4(b) shows the targets (labeled G1 to G4 and E1 to E5) and scale bars (labeled S1 and S2) positioned on the eastern barrier. For the deck measurement, targets were also placed on the western barrier (labeled G5 to G9, E6, and E7). The two targets mounted at the end of the eastern barrier (i.e., E1 and E5) were used to measure the length of the bridge.
CAMERA STATIONS AND ORIENTATIONS

For the underclearance bridge measurements, three groups of camera stations (designated as Group I, II, and III) were employed as shown in Figure 5. In Group I, eleven pictures from five camera stations were taken to obtain close-up images of the bridge. Another five camera stations (with eleven pictures) were applied in Group II. In Group III, three pictures from three camera stations were taken 12 m (39.4 ft) from the bridge to capture the entire bridge and all targets in a single shot.
In Group IV, two camera stations were placed on the east side of the retaining walls. The camera was oriented down towards the roadway from these two stations to provide four additional images from an elevated level. These images (taken from a height of about 5.67 m (18.6 ft) from the roadway) provided sufficient coverage of the roadway targets such that elevated images in Group I, II, or III were not needed.
For the deck measurement, images were taken from six camera stations (three stations along the south abutment and three stations along the western barrier). With the exception of one camera station, images were taken from two elevations, 1.68 m (5.5 ft) and 2.36 m (7.75 ft).

**PHOTOGRAMMETRY ANALYSIS**

The images are initially stored in flash memory in either TIFF (for the DCS 660) or RAW (for the Pro SLR/n) format. Kodak Photo Desk was then used to convert the original photographs into standard TIFF files which is the format read by PhotoModeler.

After photographs are loaded into PhotoModeler, the first step of the photogrammetry analysis is the “marking” of points (i.e., natural or artificial targets) in the images. A helpful, sub-pixel marking tool is provided in PhotoModeler to determine the centroid of circular targets; in general, the point marking is accurate to 0.05 – 1 pixels using this tool (12). In addition, bridge features can be marked using line and edge marking tools. A procedure called “referencing” is then performed to match marked points between images; at least six identical points must appear in two separate images to perform this function (12).

“Processing” is finally performed automatically after the minimum number of points in two separate images are referenced. In this step, PhotoModeler processes the camera calibration and the referencing data and creates spatial point coordinates to produce an accurate 3-D bridge model. Additional images, points, lines and edges can now be added to increase the photogrammetric accuracy. To provide real-world scale to the model, two points on the scale bar are selected and the measured distance between the points (which is tape-measured before the field work) is entered. The X-, Y-, and Z-axis are then defined with reference to the horizontal plane setup described earlier. Figure 6 shows the 3-D
representation (including marked points, lines, edges and surfaces) of the Las Alturas Bridge created in PhotoModeler and displayed in the 3-D viewer. Photogrammetry measurements were subsequently performed with reference to these 3-D elements.

Figure 6 Three-dimensional representation of the Las Alturas Bridge: (a) under and (b) on top

DIMENSION MEASUREMENTS AND COMPARISON

With reference to Figure 6(a), vertical clearances were obtained by measuring the distances from the targets on the roadway (points 217, 55, and 98) to the edge of the eastern girder (edge 213-215) with PhotoModeler. Two additional measurements were made from natural targets on the shoulders (points 296 and 304) to edge 213-215, since there were no artificial
targets at these roadway locations. These five measurements were subsequently converted to vertical clearances by simple geometry (hereafter referred to as vertical clearances A through E). To obtain the horizontal clearance on the south side, the distance from point 14 on the roadway to surface 275-276-277 of the south retaining wall was measured; on the north side, the distance from point 54 to surface 284-285-286 was measured. Surfaces on the retaining walls were defined by marking three natural targets on the walls and fitting a two-dimensional plane through the points in PhotoModeler. On the topside of the bridge (see Figure 6(b)), the deck width was determined by measuring the distance from point 2 on the west barrier to line 29-30 on the east barrier. The bridge length was measured as the distance between points 10 and 98 on the east barrier.

To evaluate the photogrammetry measurements, hand measurements were also made of the required bridge dimensions. Vertical clearance was measured using a plastic measuring pole; the remaining measurements were made using a rolling tape measure. As shown in Table 1, the photogrammetry and hand measurements for vertical clearance differed by 0.06% to 0.49%; for lateral clearance, the percentage difference was 1.38% and 1.43%; for deck width and bridge length, the measurement discrepancy was 0.09% and 0.2%, respectively. These results show a favorable comparison between the photogrammetry and hand measurements.

It is important to note that the two lateral clearance measurements made by photogrammetry are both smaller than those obtained by hand. This is mainly due to the irregular surface of the shoulder. Furthermore, the rolling tape measure was walked from a point on the shoulder in an estimated perpendicular path to the retaining wall.
Table 1 Hand vs. photogrammetry measurements of the Las Alturas Bridge.

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<td>0.19</td>
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<tr>
<td>Vertical clearance C</td>
<td>186.0</td>
<td>186.92</td>
<td>0.92</td>
<td>0.49</td>
</tr>
<tr>
<td>Vertical clearance D</td>
<td>188.0</td>
<td>188.83</td>
<td>0.83</td>
<td>0.44</td>
</tr>
<tr>
<td>Vertical clearance E</td>
<td>188.5</td>
<td>188.38</td>
<td>0.12</td>
<td>0.06</td>
</tr>
<tr>
<td>Lateral clearance on right</td>
<td>363.0</td>
<td>358.00</td>
<td>5.00</td>
<td>1.38</td>
</tr>
<tr>
<td>Lateral clearance on left</td>
<td>363.0</td>
<td>357.80</td>
<td>5.20</td>
<td>1.43</td>
</tr>
<tr>
<td>Deck width</td>
<td>526.5</td>
<td>526.00</td>
<td>0.50</td>
<td>0.09</td>
</tr>
<tr>
<td>Bridge length</td>
<td>1499.0</td>
<td>1496.00</td>
<td>3.00</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Without the use of supplemental surveying instruments, it is difficult to follow a perfectly perpendicular path to the retaining wall. In PhotoModeler, the perpendicular direction from the roadway target to the retaining wall is obtained directly in the 3-D viewer. As a result, the measurement obtained by photogrammetry is shorter and more accurate than the distance measured using the tape measure. The situation is similar for the deck width measurement since the roadway has a slope of approximate 0.5% from the centerline to both barriers (for drainage purposes). In this case, the measurement obtained using the tape measure will again be larger than the photogrammetric measurement. In summary, PhotoModeler provides a straight direct measurement between two points over a long distance such as needed to obtain more accurate bridge dimensions.
HISTORIC BRIDGE DOCUMENTATION STUDY

The historic bridge selected for documentation is the Alamosa Canyon Bridge, which is located approximately 10 miles north of Truth or Consequences, New Mexico. The bridge has a total length of 106.7 m (350 ft) consisting of seven simple-supported spans. It was built in 1937 by Hayner and Burn and retired from service in 1967. Historically significant features of the bridge include the reinforced concrete piers; support bearing details; reinforced concrete rails; non-composite construction; CB (Carnegie Brothers & Co., Limited) and ASTM A7 steel beams. This type of bridge construction was once popular in New Mexico in the early 1940’s (13).

TARGET AND SCALE BAR LAYOUT

To create an elevation model, eight targets (labeled G1 to G8) were positioned at ground level on the eastern side of the bridge span as shown in Figure 7(a). The purpose of these ground targets was to provide markable points under the bridge due to the lack of natural targets in this region. In addition, PhotoModeler requires at least six identical points to appear in two adjacent images as mentioned earlier; additional artificial targets were needed to meet this requirement. On the bridge itself, however, natural targets could be used to identify object points. For example, the corners of the rail and the pier as well as the edge of the eastern girder were marked as shown in Figure 7(a). This target arrangement provided a good distribution of points over the bridge elevation from ground level to the concrete rails. Two scale bars (labeled S1 and S2) were also placed under the bridge at approximately one-third the span length.
Figure 7 Target and scale bar layout of the Alamosa Canyon Bridge: (a) span and (b) pier

For the pier model, natural targets were mainly used since points and lines on the pier were easily recognizable and clear in the images from different directions. Figure 7(b) shows the natural targets on the pier and placement of the scale bars; the six targets on the scale bars were also used as artificial targets.
CAMERA STATIONS AND ORIENTATIONS

To model the bridge span in elevation, three groups of camera stations were applied. The groups are similar to Groups I, II, and III described earlier in the routine bridge inspection study. In Group I, images were taken at a distance of 4.0 m (13.1 ft) from the edge of the eastern girder; twenty-two images from eight camera positions were taken at a height of 1.68 m (5.5 ft) above ground level. In Group II, a total of three camera stations were applied 7 m (23.0 ft) from the bridge providing nine images at an elevation of 3.2 m (10.5 ft). In Group III, the camera-to-object distance was 12 m (39.4 ft). Three positions were used to take six images; at each position, images were taken from two elevations, 1.68 m (5.5 ft) and 3.2 m (10.5 ft).

For the pier model, a total of eight camera positions were needed to capture all sides of the pier. At each position, the whole pier could be fit into the image area and natural targets could also be identified clearly. Two sets of images were acquired at each position; one from 1.4 m (4.6 ft) above ground and the other elevated approximately 2.36 m (7.75 ft) to provide adequate coverage of image points in the vertical direction.

PHOTOGRAMMETRY ANALYSIS

The photogrammetry analysis in the historic documentation study followed the same basic procedure as the routine inspection study which included three main steps: marking, referencing, and processing. Following this approach, 3-D models were developed and the real-world scale was established using targeted scale bars as discussed earlier. Figure 8(a) shows the wire frame model of the Alamosa Canyon Bridge (in elevation) created in PhotoModeler. Surface textures were subsequently mapped to the wire frame model to obtain a more realistic representation of the bridge as shown in Figure 8(b).
To create a textured model, surfaces of the wire frame model must first be defined by the “Surface” or “Surface Draw” tool in PhotoModeler.

**DIMENSION MEASUREMENTS AND COMPARISON**

An ortho-photo of the bridge in elevation (with texture) was exported from PhotoModeler, which is shown in Figure 9(a). This feature provides a scaled drawing from which dimensions can be manually measured; however, PhotoModeler cannot produce ortho-photos without texture. To obtain a wire frame ortho-photo (without texture), the photogrammetry
model was exported in DXF format and loaded in AutoCAD. Drawing tools were then used to add and delete points, lines, and surfaces to and from the original photogrammetry model. After editing the photogrammetry bridge model in AutoCAD, a non-textured ortho-photo with dimensions was produced as shown in Figure 9(b).

![Figure 9](image)

**Figure 9 Ortho-photo representation of the Alamosa Canyon Bridge:**
(a) textured and (b) non-textured.

Similar to the routine bridge inspection study, measurements were obtained from the photogrammetry models for comparison with design values to evaluate the relative difference. Figure 10 shows the selected portions of the bridge which were measured and Table 2 lists the photogrammetry measurements and design dimensions of the bridge components.
Figure 10 Compared dimensions of the Alamosa Canyon Bridge.

Table 2 Design dimensions vs. photogrammetry measurements of the Alamosa Canyon Bridge.

<table>
<thead>
<tr>
<th>Part</th>
<th>Designation</th>
<th>Design Dimension (in)</th>
<th>Photogrammetry Measurement (in)</th>
<th>Difference (in)</th>
<th>Difference (%)</th>
</tr>
</thead>
</table>
For the rail, the absolute difference ranged from 4.8 mm (0.19 in) to 35.1 mm (1.38 in) and the percentage difference was 1.31% to 4.00%; for the pier, the range of absolute difference was 1.0 mm (0.04 in) to 35.1 mm (1.38 in) and the percentage difference was 0.23% to 5.19%. The deck thickness and girder length also compared well. This simple comparison served to demonstrate the use of photogrammetry for checking design data.
CONCLUSIONS AND RECOMMENDATIONS

Based on the results obtained in the two photogrammetry studies presented herein, several observations are made. First, for photogrammetry measurements in routine bridge inspection, the accuracy meets that of traditional hand measurements. Photogrammetry provides the capability to obtain straight and direct measurements between two points, a point and a line, a point and a surface, etc. Second, for photogrammetry documentation of historic bridges, 3-D models and ortho-photos can be efficiently developed using the PhotoModeler software. Third, both studies showed that photogrammetry is capable of providing the measurement information associated with routine bridge inspection and historic bridge documentation, which traditionally has been generated by means of hand measurements and field sketches. Furthermore, photogrammetry measurements were completed by means of site photography with minimal contact of the specific portions of the bridge. All measurement and modeling was performed off-site using a personal computer and the PhotoModeler software. The total cost of the basic photogrammetry system used in this research, including the consumer-level digital camera and non-industrial software, was less than $5000 which is a reasonable price for most bridge inspection agencies.

As with many new technologies, the major obstacle faced in using close-range photogrammetry for routine bridge inspection and historic bridge documentation is the increase in time and money required to make the measurements. Compared to a normal inspection, photogrammetry will require more of a time investment prior to, during, and after the field work. Prior to the inspection, time must be allotted for determining the best positions for the targets, cameras, and scale bars. During the inspection, the installation of artificial targets and scale bars as well as acquiring the necessary photographs will require
extra time. After the inspection, more time will be needed to build the photogrammetry model of the bridge to make the measurements. All these extra activities, as well as the photogrammetry training of personnel, increases the inspection cost. To minimize the increase in the time investment and thus, inspection cost, photogrammetry is recommended most for bridges that are easily accessible and remotely located from heavy traffic. In addition, the use of photogrammetry is advised for bridges with complex geometry where the extra inspection cost can be justified. As shown in this report, photogrammetry is capable of providing more accurate measurements of bridge geometry which can ultimately improve the overall quality of a routine inspection or historic documentation project.
REFERENCES


8. DALSA Corporation Homepage. Waterloo, Ontario, Canada.


