maintenance budget for a network of that size is approximately $4 570 000. Therefore, the annual cost of operation of PAVER would be less than 0.5 percent of the total budget. When this cost is compared with an expected annual cost avoidance of 10 percent of the total budget (based on estimates made by pavement engineers who currently use the system), the estimated return on investment is considerably high.

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The views presented in this paper are ours and do not necessarily reflect the views of the Department of the Army or the U.S. Department of Defense.

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Photologging and Roadway Information System

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Photologging was used as the data collection tool for developing a computerized roadway information system for Ann Arbor, Michigan. The study included the development of serviceability characteristics for all roadway segments in the city by use of various condition factors that have an impact on the service life of highways. A weighting scheme was also used to aggregate the serviceability characteristics. The entire data file has been computerized in such a way as to be capable of aggregating and summarizing various roadway characteristics. The data system is capable of being updated as required so that it is kept current at all times. The information system can be used for prioritizing roadway improvement works and in planning and budgetary decision making.

Knowledge of roadway conditions and geometric information are essential if municipal engineers are to perform rational operation and maintenance work in a community. Road maintenance work is often done as a result of routine inspection and public complaint and not on the basis of planned maintenance work. This, coupled with budget constraints, often leads to inadequate work and ultimately to deterioration of highways.

A highway needs study requires a careful assessment of the condition of the roadway for purposes of determining both short- and long-range highway improvement programs. In most communities, data for needs studies are based on visual inspection of roadways and subjective assessment of deficiencies. If roadway condition data are continuously collected and maintained, engineers will be able to prepare realistic short- and long-range improvement plans, develop optimal maintenance programs and schedules, and maintain highways in better condition. The traditional visual inspection of roadways requires significant time and labor but may still produce inaccurate data as a result of subjective assessments, changing personnel, and distractions in the field.

Photologging and extraction of data under a controlled environment thus emerge as an alternative tool (1). This process involves photographing roadways from an instrumented vehicle with a 35-mm cine/pulse camera by using predetermined increments of distance for each picture frame. Each frame of the movie film has the street name, mileage (because units of measurement included in the process are formulated in U.S. customary units, no SI equivalents are given for generic terms), direction of travel, and a 10-digit auxiliary data display that is optically transmitted to the camera and superimposed on the bottom of each frame. The 10-digit display includes (a) the date, (b) the time of day, (c) resolution, and (d) major street, state street, or local street code. To establish footage in addition to mileage, a grid overlay is used during the data extraction process. This allows the viewer to establish a distance between frames and thus provides greater accuracy.

This paper describes the use of photologging as a data collection tool in the development of a roadway information system for a project in Michigan.

STUDY AREA

The study area was the city of Ann Arbor, Michigan. This community is located approximately 83.33 km (50 miles) west of Detroit and has a population of 105 000. Ann Arbor has approximately 450 km (270 miles) of roadway within its city limits; of these, 25.37 km (15.22 miles) are freeways and state routes, 110.67 km (66.40 miles) are designated city major roadways, and 317.02 km (190.21 miles) are local roadways.

DATA COLLECTION AND REDUCTION

All roads in Ann Arbor were filmed once in each direction to obtain a better coverage of the roadway and its environs. The camera was aimed slightly downward and to the right. It is important to note that the purpose of photologging in Ann Arbor was to obtain a set of photographic records from which various data, such as those on the roadway, roadside obstacles, and traffic control devices, could be extracted and transformed into a computerized information system. Photologs provided an excellent data base for multipurpose use. The advantages of photologs over manual data mainly involve the ability to go back to the filing as and when necessary at very little cost (2).

The collection of roadway data involved viewing the photologs frame by frame through a photoviewer and coding the necessary data for each block of roadway or each section of roadway that demonstrated a change in physical characteristics. The coded data were then typed into a computer terminal by means of an interactive software system that prompts the analyst to input the appropriate data. The following categories of data are extracted from the photologs and keyed into a computer to build the roadway information data files:

1. Name of street,
2. Street code (state, major, or local),
3. Direction of travel (north, south, east, west),
4. Identification of beginning point of the roadway (usually the center of a cross street),
5. Location of the beginning point of a block or roadway segment from the reference starting point,
6. Identification of the end point of the roadway segment (this may be either the next cross street or a change in roadway geometries such as a change in street width),
7. Location of the end point,
8. Number of through lanes on the roadway segment,
9. Number of turn lanes on the roadway segment,
10. Type of surface,
11. Type of curb,
12. Type of sidewalk,
13. Measurements of street width,
14. Date of filming, and
15. Serviceability factor.

The data extraction and coding were done in a form that does not require searching for a specific numeric code and can thus be performed by analysts who are not proficient in computer coding and keyboard operating (Figure 1). Similarly, the person or persons who input the data through interactive software by means of a cathode ray tube (CRT) terminal do not have to be proficient in analyzing roadway characteristics. The elimination of the data coding step in computer form and keypunching resulted in a significant reduction of both data errors and the hours of work necessary to complete a project.

DETERMINATION OF SERVICEABILITY

Overall serviceability of roadways may include considerations of shoulder condition; median needs; characteristics of drainage, skid resistance, and roughness; surface cracks; cuts and joints on the pavement surface; and curb and gutter and sidewalk condition. However, the criteria used in this study to determine the serviceability of a roadway segment included the following:

1. Roughness characteristics,
2. Roadway surface cracks,
3. Utility cuts on the pavement surfaces,
4. Curb and gutter condition,
5. Sidewalk condition, and
6. Overall impression of the analyst about the roadway segment.

These six criteria were used as the input data to determine the serviceability factor for each segment of roadway. Each of the criteria above was given an appropriate evaluative rating of serviceability from 1 to 5 (Table 1).

The overall serviceability factor, which has been defined as a function of these criteria, involved the following weighting scheme: roughness = 5, cracking = 5, utility cuts = 3, curb and gutter condition = 2, sidewalk condition = 1, and overall impression = 4. The serviceability factor (F_s) was therefore defined as a function of the ratings of serviceability criteria and the corresponding weighting factors; i.e.,

$$F_s = \sum_{i=1}^{n} V_i W_i \quad (1)$$

$$F_s = V_1 W_1 + V_2 W_2 + V_3 W_3 + V_4 W_4 + V_5 W_5 + V_6 W_6 \quad (2)$$

Figure 1. Coding form for roadway data.

DATE ______ ROLL ______ PAGE ______ VIEWER ______

STREET NAME ______ DIRECTION OF TRAVEL ______

BEGIN. POINT	BEGIN. DIST.	END POINT	END DIST	THRU LNS	TURN LNS	SURFACE TYPE	CURB TYPE	WALK TYPE	SERVICEABILITY RATING						1 ST MEAS.	2 ND MEAS	DATE
									ROUGH	CRACK	UTIL. CUTS	CURB GUTTER	SIDE-WALK	OVER-ALL			

Table 1. Roadway serviceability categories.

Criterion	Serviceability Category 5	4	3	2	1
Roughness	Very smooth	Good	Fair	Poor	Very rough
Cracking	None	Few	Moderate	Many	Very serious
Utility cuts	None	Some in good condition	Moderate amount in fair condition	Many with few in fair condition	Many in poor condition
Curb and gutter	New or very good	Good	Fair	Poor in spots or cracking	None or very poor
Sidewalk	New or very good	Good	Fair	Poor	None or very poor
Overall impression	Excellent	Good	Fair	Poor	Very poor

where

V_1 = roughness rating,
V_2 = cracking rating,
V_3 = utility cuts rating,
V_4 = curb and gutter rating,
V_5 = sidewalk rating,
V_6 = overall impression rating, and
$W_1 \ldots W_6$ = corresponding weights (as described earlier).

The higher the serviceability factor is, the better is the condition of the roadway and the longer is the expected service life. The weights used in the project were developed on the basis of a previous highway needs study for the city of Ann Arbor.

RESULTS

When the data have been compiled in the computer, they are run through two programs to produce the final output. The first program computes the location (frame count and grid footage) of the beginning point cross street and ending point cross street to establish the segment length. Next, the location of a change in roadway geometries in the segment (if any) is calculated, and the nearest beginning or ending point from the nearest cross-street location is determined and retained for use in the final output program. The roadway serviceability rating for the segment is then computed and retained for the final output. This program also computes the pavement width of the segment by using the previously input measurements. The method of computation used here is presented by Pryor and Miller (3).

The second program formats the data, sorts them alphabetically according to street name, assigns line numbers, and then prints the final output listing (Figure 2). The final output includes the following items for each roadway segment:

1. Name of street;
2. Direction of travel;
3. Beginning point cross street of the roadway segment;
4. Ending point cross street of the roadway segment;
5. Length of the roadway segment;
6. Roadway characteristic, e.g., type of roadway or geometric change such as addition of a turn lane or change in pavement width (if there is no change in this criterion, this column remains blank);
7. Reference point of the geometric change, if any (the location of the roadway geometric change is referenced by printing the distance, direction, and cross-street name of the beginning point or ending point of the roadway segment that is nearest the change);
8. Number of through lanes on the roadway segment;
9. Number of turn lanes on the roadway segment;
10. Type of surface;
11. Roughness characteristic of the segment;
12. Roadway surface cracking;
13. Utility cuts on the pavement;

Figure 2. Roadway data report.

CITY OF ANN ARBOR DEPT. OF STREETS, TRAFFIC AND PARKING : ROADWAY DATA REPORT AS OF 09-21-78 PAGE 2

STREET NAME - ROSEDALE STREET TYPE - LOCAL DIRECTION OF TRAVEL - SOUTH

BEGINNING STREET	ENDING STREET	SGMT LEN	ROADWAY CHARACTER	REFERENCE PT DIST	DIR	ST	THR LN	TRN LN	SURF TYPE	CURB TYPE	WALK TYPE	SERVICEABILITY RATINGS RGH	CRK	UTL	CGT	SWK	ALL	SRV IDX	STR WID	DATE	LINE NUMBER
PACKARD	ST AUBIN	50					2	0	BIT	CONC	N/A	3	3	4	3	1	3	61	27	0976	0100000
ST AUBIN	REDWOOD	998					2	0	BIT	CONC	N/A	3	3	4	3	1	3	61	27	0976	0110000
REDWOOD	SHARON	80	END SDWK W	80	S	BEG	2	0	BIT	CONC	CONC	3	3	4	3	3	3	63	27	0976	0120000
REDWOOD	SHARON	121	END SDWK E	121	S	BEG	2	0	BIT	CONC	CONCE	3	3	4	3	3	3	63	27	0976	0130000
REDWOOD	SHARON	226	BEG SDWK W	226	S	BEG	2	0	BIT	CONC	N/A	3	3	4	3	1	3	61	27	0976	0140000
REDWOOD	SHARON	58	END SDWK W	58	S	BEG	2	0	BIT	CONC	CONCW	3	3	4	3	3	3	63	27	0976	0150000
REDWOOD	SHARON	53	BEG SDWK E	53	S	BEG	2	0	BIT	CONC	N/A	3	3	4	3	1	3	61	27	0976	0160000
REDWOOD	SHARON	75	END SDWK E	75	S	BEG	2	0	BIT	CONC	CONCE	3	3	4	3	3	3	63	27	0976	0170000
REDWOOD	SHARON	68	BEG SDWK W	68	S	BEG	2	0	BIT	CONC	N/A	3	3	4	3	1	3	61	27	0976	0180000
REDWOOD	SHARON	111					2	0	BIT	CONC	CONCW	3	3	4	3	3	3	63	27	0976	0190000

TOTAL STREET LENGTH = 1840

14. Condition of curb and gutter;
15. Condition of sidewalk;
16. Overall impression of the roadway segment by the analyst;
17. Total serviceability factor (the calculation of which was printed earlier);
18. Pavement width of the roadway section;
19. Date of filming; and
20. Line number (assigned for updating purposes).

These items are printed for each segment of roadway along every street in the city in an alphabetic listing by street name.

The printing program also has the ability to search the entire file, or any portion of the file, for any variable or combination of variables mentioned above. This capability of the program enables the municipal engineers to determine, for example, all roadway segments in a community that have a serviceability factor of less than 50. The engineer is thus able to use the search function to facilitate city maintenance plans and long-range planning.

When changes in condition of the roadway segment occur in the field (for example, the repaving of a roadway segment) or when the serviceability factor is altered (for example, by frost heave), the inventory must be updated to ensure that the data are accurate. The update process involves completing a form (Figure 3) by using the line numbers in the output, having the data keypunched (or keyed in through CRT), and running the roadway update program.

The program addresses the data by using the line number of the inventory file. It searches the file for the appropriate variable indicated on the update form. When the update procedure is completed, a complete listing of all segments that have been updated is produced to ensure that the data are correct.

CONCLUSIONS

The procedure presented in this paper has proved to be an important highway management and planning tool. Photologging provides a means of data collection that can be more reliable than manual field surveys. Its additional benefits also encourage its use with a computerized roadway information system.

The system is being used in the city of Ann Arbor to identify deficient locations based on serviceability rating and capital improvement programming and budgeting. The information is also expected to be used in the city's future highway needs studies.

The serviceability factor provides a quantifiable means of establishing roadway deficiencies and can ultimately be used for prioritizing roadway improvement works. The rating scheme for serviceability criteria and the respective weights can be established in accordance with an individual highway system and provides a means of maintaining roadway data that can be upgraded and kept current at all times. The system provides municipal engineers with quantitative data that can be used in making budgetary and planning decisions.

Figure 3. Roadway update form.

1.	Command A. Alter / B. Delete / C. Insert	1 – 6
2.	Line Number	7 – 12
3.	Street Name	13 – 24
4.	Street Type A. State / B. Major / C. Local	25 – 30
5.	Direction of Travel / A. North - N / B. East - E / C. South - S / D. West - W	31
6.	Beginning Point	32 – 43
7.	Ending Point	44 – 55
8.	Segment Length	56 – 59
9.	Number of Thru Lanes	60
10.	Number of Turn Lanes	61
11.	Surface Type	62 – 67
12.	Curb Type	68 – 73
13.	Sidewalk Type	74 – 79
14.	Roughness	80
15.	Cracking	81
16.	Utility Cuts	82
17.	Curb and Gutter	83
18.	Sidewalk	84
19.	Overall Impression	85
20.	Serviceability Factor	86 87
21.	Street Width	88 – 90
22.	Date	91 – 94

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