Use of Field Data in Calculating Cost of Earth Road Maintenance

MAGDY ABDELRAHMAN AND ESSAM SHARAF

Earth roads will continue to form an important portion of the local road network in Egypt. The objective of the proposed study was to provide an index for road assessment and to develop a cost model in which associated repair costs could be determined. Decision making at the network level is concerned with the selection of individual sections of roads for maintenance in accordance with the availability of funds and, therefore, a matter of the assignment of priorities related to needs. For an effective maintenance program, a specified data element about the road conditions is required. Information that can be directly used in maintenance management systems must be provided. The most important step, however, is operation of its own condition assessment subsystem. The cost of periodic and routine maintenance required to renew road sections was calculated. The relation between road condition and repair cost was quantified. Also, the results indicated that environmental factors had a significant effect on road condition and, consequently, on maintenance and repair costs.

A unique aspect of pavement engineering in developing countries that has no parallel in most industrial countries is the extent to which earth roads contribute to the national road network. As a developing country, Egypt operates a road network consisting of about 19,000 km of paved roads and about 14,000 km of earth roads.

In Egypt, earth roads play a vital role in the economic and social life. The development of agriculture, the provision of health services, and many forms of communication in rural agricultural regions, all heavily depend on transport facilities. Although rail and water facilities may play important roles in certain areas, a dominant need is for a road system that can provide a reliable and yet relatively inexpensive means for the movement of people and goods, and that is what earth roads can do.

A pavement management system involves managing pavements using a maintenance managment subsystem. The prime purpose of the maintenance phase in a pavement management system is to determine the costs associated with providing various levels of serviceability for any given pavement. For effective maintenance cost determination, specific data about road conditions are required. It is important that the information provided can be directly used in a maintenance management system. For the earth road, the most important step is to develop a unique condition assessment subsystem.

The earth road condition index (ERCI) is not a new idea. In fact, it was designed to draw on past experience, through maintenance management concepts, about how roads perform and what is observed to analyze these conditions. In this work, the Sharkia Governorate earth road network was selected and the methodology described later was applied on it. The part of the network considered in this study consists of about 190 km (118 mi) covering different environmental conditions.

The development of the ERCI system and its associated distresses are described elsewhere (*1*) with slight modification. The included distresses are mainly selected to express the actual maintenance needs on these roads. An example of a distress is Road Surface Occupancy. Farmers frequently use the roadway to store and prepare imported soil, seeds, and other related materials and equipment. When they do not remove their occupancy in a complete way, it affects the road surface and requires some maintenance work, so it is a distress. The same concept was applied to all other distresses.

METHOD

The method for rating the condition of earth roads and estimating maintenance costs includes the following steps (*1*,*2*):

- Divide the road network into sections and samples,
- Inspect the sections,
- Calculate ratings, and
- Apply the maintenance cost model on the inspected sections.

Dividing the Road Network Into Sections and Samples

Before a road network is inspected, it must be divided into branches, sections, and sample units. A complete road length may be considered as a branch and may be divided into homogenous sections. A homogenous section consists of a number of similar samples (*3*). The process is completed by passing the road links before the condition survey.

Sampling

Inspection of every sample unit in a road section may be necessary if exact quantities are needed for contracting. However, such inspection requires considerable effort, specially if the section is large. Because of the time and effort involved, frequent surveys of a large number of deteriorated sections may be beyond available manpower, funds, and time. However, sampling plans can reduce inspection funds and time considerably and still provide the accuracy required.

M. Abdelrahman, Zagazig University, Zagazig, Egypt. E. Sharaf, Cairo University, Giza, Egypt. Current affiliation: Department of Civil Engineering, Faculty of Engineering, King Saud University, P.O. Box 800, Riyadh 11421, Saudi Arabia.

DISTRESSES	LOW SEVERITY DESCRIPTION
- FAILURE & EROSION OF ROAD EMBANKMENT	WIDTH UP TO 2 M, DEPTH TO 2.5 M.
- FAILURE OF RETAINING WALL	NEED REBUILDING ONLY, NO STONE REPLACEMENT
- SURFACE HEIGHT	SURFACE ELEVATES LESS THAN 50 CM, AND DOWN TO THE GROUND LEVEL.
- CAMBER	DEPTH AT THE MID-POINT LESS THAN 5 CM.
- RUTTING	DEPTH LESS THAN 3 CM.
- POTHOLES	DEPTH LESS THAN 10 CM, ONE POTHOLE/ 10 M^2.
- SURFACE SATURATION	SATURATION DEPTH < 20 CM, LESS THAN HALF THE ROAD WIDTH.
- ILLEGAL IRRIGATION STRUCTURE	EXTENT LESS THAN 1.0 M WIDTH.
- PLANTS ON ROAD SURFACE	EXTENT LESS THAN 1.0 M WIDTH.
- ROAD SURFACE OCCUPANCY	EXTENT LESS THAN 1.0 M WIDTH.

FIGURE 1 Summary of low-severity cases.

Measurement Frequency

As a network level condition assessment, measurement frequency is arranged to reflect network condition. The number of samples are determined according to homogeneity of assessed road sections. Homogenous sections are divided into equal samples of 100 m each. As a rule, at least 0.1 of the entire section length is considered sufficient to represent the section length (*3*). One random sample of 100 m is considered to represent 1 km and 5,300 ft is considered to represent 1 mi (1.61 km = 5,300 ft) of section length. Additional samples are taken at

- Beginning and end of roads,
- Intersection with other roads,
- Inhabited villages, and
- Any significant change in the surrounding environment.

Inspecting the Sections

Each homogeneous section is first passed and the sample locations are determined randomly. It is important that each sample unit be identified concisely, so it can be located for additional inspections, comparison with future inspections, maintenance requirements, and random sampling purposes. Sample inspection includes measuring cross-section dimensions to be used in estimating maintenance costs.

Severity Level

The ERCI system involves two severity levels. The low-severity case (slight case) is shown in Figure 1. Any condition other than low severity will be a severe case.

Extent Weight

Extent weight is defined as the ratio of deteriorated length to the total sample length.

Deduct Value

An important item in the calculation of the ERCI is the deduct value. A deduct value is a number from 0 to 100, with 0 indicating that the distress has no impact on road condition, and 100 indicating an extremely serious distress that causes the pavement to fail. In fact, the case of a deduct value of 100 is a theoretical case, and requires an abnormal road condition. The concept of deduct value for any distress is based on the impact of this distress on road condition.

Calculating Sample Unit ERCI

The procedure for calculating the ERCI for a sample unit involves four steps:

Step 1. Each sample unit is inspected and distress data are recorded on the form, as shown in Figure 2.

Step 2. The deduct values are determined by multiplying distress weight by severity level and extent weight for each recorded distress, as shown in Figure 3.

Step 3. A total deduct value is computed by summing all individual deduct values.

Step 4. The ERCI value is computed using the relation ERCI = 100 − total deduct value.

The ERCI value for the entire road length is the average of sample unit values.

EARTH ROAD INSPECTION SHEET					
ROAD:	DISTRICT:				
SAMPLE UNIT:	SUBDISTRICT:				
DIRECTION FROM TO	DATE:				
INSPECTOR:	O: OCCASIONAL F: FREQUENT E: EXTENSIVE				
DISTRESS	SEVERITY		EXTENT WEIGHT		
FAILURE & EROSION OF EMBANKMENT	Slight	Sever	O	F	E
FAILURE OF RETAINING WALL	Slight	Sever	O	F	E
SURFACE LEVEL	Slight	Sever	O	F	E
CAMBER	Slight	Sever	O	F	E
RUTTING	Slight	Sever	O	F	E
POTHOLES	Slight	Sever	O	F	E
SURFACE SATURATION	Slight	Sever	O	F	E
ILLEGAL IRRIGATION STRUCTURE	Slight	Sever	O	F	E
PLANTS ON ROAD SURFACE	Slight	Sever	O	F	E
ROAD SURFACE OCCUPANCY	Slight	Sever	O	E	E
REMARKS					

FIGURE 2 Earth road inspection sheet.

Maintenance Categories for Earth Roads

Involved distresses are arranged to measure the adequacy of three categories. Routine and recurrent maintenance activities include surface condition repair involving camber (road surface crown), potholes, rutting, mowing of plants on road surfaces, and removal of surface occupancy. Periodic maintenance activities include the repair of embankment failure, surface raising by adding soils, repair of failure of retaining wall, and repair of illegal irrigation structures. Urgent maintenance activities are mainly related to surface saturation caused by rains or damages in irrigation and drainage systems of adjacent fields.

Level of Serviceability Concept for Earth Roads

The concept of earth road level of serviceability is based on two maintenance categories: (a) periodic maintenance applied to repair the generated distresses, and (b) routine maintenance including recurrent activities applied to preserve the surface quality with the desired serviceability. Thus, to provide a certain level of serviceability, two main associated costs are considered, periodic cost and routine maintenance cost. Table 1 indicates the extent that each maintenance category contributes to the total rating scale.

APPLICABLE MAINTENANCE PRACTICES AND COSTS

On the basis of practical measurements, past experiences about earth road maintenance practices, and a literature survey (*4–6*), the associated maintenance activities were determined. These maintenance activities and their associated costs required for repairing the proposed distresses are presented in Table 2. Periodic maintenance activities were determined as the best available repairs for the distress types in either severity level. Periodic maintenance activities repair the combined effects both of load and environmental factors including embankment soil stability, soil type, and surrounding environment. An example of a periodic maintenance distress is the failure and erosion of road embankment, caused both by traffic loads and by the erosion effects of adjacent streams. For an example of low-severity distress, see Figure 4. The associated repair of this distress is to construct a retaining wall for the high-severity case, or to rabble (place cement-treated rip rap on) the failed-embankment, low-severity case, as shown in Figure 5.

DISTRESSES	WEIGHTS	SEVERITY WEIGHTS		EXTENT WEIGHTS			DEDUCT POINTS	RATING
		SLIGHT	SEVER	OCCASIONAL	FREQUENT	EXTENSIVE		
- FAILURE & EROSION OF ROAD EMBANKMENT	20	0.5	1.0	0.4	0.8	1.0		100 VERY GOOD 90
- FAILURE OF RETAINING WALL	12	0.3	1.0	0.4	0.8	1.0		GOOD 80
- SURFACE HEIGHT	15	0.5	1.0	0.4	0.8	1.0		FAIR
- CAMBER	8	0.5	1.0	0.4	0.8	1.0		65
- RUTTING	8	0.5	1.0	0.4	0.8	1.0		
- POTHOLES	8	0.5	1.0	0.4	08	1.0		POOR
- SURFACE SATURATION	8	0.6	1.0	0.4	0.8	1.0		40
- ILLEGAL IRRIGATION STRUCTURE	7	0.4	1.0	0.4	0.8	1.0		
- PLANTS ON ROAD SURFACE	7	0.5	1.0	0.4	0.8	1.0		FAILED
- ROAD SURFACE OCCUPANCY	7	0.4	1.0	0.4	0.8	1.0		ZERO

TOTAL DEDUCT=
ERCI = 100 - TOTAL DEDUCT=

FIGURE 3 ERCI calculations and rating scale.

TABLE 1 MAINTENANCE CATEGORIES

MAINTENANCE CATEGORIES	INVOLVED DISTRESSES	POINTS	TOTAL POINTS
PERIODIC MAINTENANCE	- FAILURE & EROSION OF ROAD EMBANKMENT - FAILURE OF RETAINING WALL - SURFACE HEIGHT - ILLEGAL IRRIGATION STRUCTURE	20 12 15 7	54
ROUTINE MAINTENANCE INCLUDING RECURRENT MAINTENANCE	- CAMBER - RUTTING - POTHOLES - ROAD SURFACE OCCUPANCY - PLANTS ON ROAD SURFACE	8 8 8 7 7	38
URGENT MAINTENANCE	- SURFACE SATURATION	8	8

TOTAL = 100

Routine maintenance activities are determined on the basis of ride quality and associated repairs required to achieve an acceptable ride quality. An example of a routine maintenance activity is surface blading. The frequency of applying this activity depends on how soon the road surface deteriorates after each successive blading. Surface blading frequency reflects traffic level and surface soil characteristics. In fact, not all routine maintenance activities are included in this study, but only those activities that affect the level of serviceability and the associated maintenance level. Examples of these activities are sign repair, bridge guard rail repair, and routine inspection (a fixed item in routine maintenance activities)(*7*).

The ability to estimate the costs of various maintenance activities is an important element in an effective maintenance management system (MMS). Costing road maintenance is a critical problem, particularly for local authorities. Generally, because periodic maintenance is bid by private contractors, the costs are usually well known. As most routine maintenance activities are done by the local authorities' own force, the ability to estimate the road maintenance costs depends on maintenance cost accounting or management system in operation at the authority. For this study, determination of item costs was based on recent contracts and studies. The concept of the maintenance cost model was based on provid-

TABLE 2 MAINTENANCE PRACTICES COSTING

DISTRESS	MAINTENANCE PRACTICES	ITEMS	UNITS	QUANTITY / L. M.	UNIT COST L.E. [d]	TOTAL COST L.E. / L.M.
FAILURE & EROSION OF ROAD EMBANKMENT: LOW SEVERITY	EMBANKMENT RABBLING	- RABBLING - FILLING UP WITH EARTH	M^3	3.5 3.0 x 1.2[a]	25.0 1.8	94.5
FAILURE & EROSION OF ROAD EMBANKMENT: HIGH SEVERITY	CONSTRUCTION OF RETAINING WALL	- CONSTRUCTION OF RETAINING WALL - FILLING UP WITH EARTH	M^3	8.65 10.25x1.2	25.0 1.8	238.4
FAILURE OF RETAINING WALL: LOW SEVERITY	REBUILDING OF RABBLING	- REBUILDING	M^3	2.25	13.0	29.3
FAILURE OF RETAINING WALL: HIGH SEVERITY	REBUILDING OF RETAINING WALL	- REBUILDING	M^3	6.25	13.0	81.3
SURFACE HEIGHT: LOW SEVERITY	SURFACE RAISING: LOW CASE	- ADDING 3 LAYERS OF COMPACTED SOIL	M^2	ROAD WIDTH (W)	3 x 0.55	1.65 x W
SURFACE HEIGHT: HIGH SEVERITY	SURFACE RAISING: HIGH CASE	- ADDING 5 LAYERS OF COMPACTED SOIL	M^2	ROAD WIDTH (W)	5 x 0.55	2.75 x W
SURFACE DISTRESSES[b] : LOW SEVERITY	BLADING AND SPRINKLING ROAD SURFACE : LOW CASE	- 12 BLADING TIMES ANNUALLY - 60 SPRINKLING TIMES ANNUALLY	M^2	W1[c]	0.016 0.011	0.85 x w1
SURFACE DISTRESSES: HIGH SEVERITY	BLADING AND SPRINKLING ROAD SURFACE : HIGH CASE	- 18 BLADING TIMES ANNUALLY - 90 SPRINKLING TIMES ANNUALLY	M^2	W1	0.016 0.0111	1.27 x W1
ILLEGAL IRRIGATION STRUCTURE: LOW SEVERITY	FILLING UP STRUCTURES	- FILLING UP WITH EARTH	M^3	0.4	5.0	2.0
ILLEGAL IRRIGATION STRUCTURE: LOW SEVERITY	FILLING UP STRUCTURES	- FILLING UP WITH EARTH	M^3	1.4	5.0	7.0
PLANTS ON ROAD SURFACE: LOW SEVERITY	REMOVING PLANTS: LOW CASE	- REMOVING PLANTS OF 1 M OF ROAD WIDTH	L. M.	1.0	0.23	0.23
PLANTS ON ROAD SURFACE: HIGH SEVERITY	REMOVING PLANTS: HIGH CASE	- REMOVING PLANTS OF 3 M OF ROAD WIDTH	L. M.	1.0	0.47	0.47
ROAD SURFACE OCCUPANCY: LOW SEVERITY	REMOVING OCCUPANCY: LOW CASE	- REMOVING OCCUPANCY OF 1 M OF ROAD WIDTH	L. M.	1.0	0.42	0.42
ROAD SURFACE OCCUPANCY: HIGH SEVERITY	REMOVING OCCUPANCY: HIGH CASE	- REMOVING OCCUPANCY OF 2 M OF ROAD WIDTH	L. M.	1.0	0.85	0.85

[a] SHRINKAGE FACTOR.

[b] THE AVERAGE RATING OF (CAMBER, RUTTING, AND POTHOLES).

[c] BLADING WIDTH IS ASSUMED TO BE 3, 6, OR 9 M.

[d] L. E. : EGYPTIAN POUND, AND L. M. : LINEAR METER.

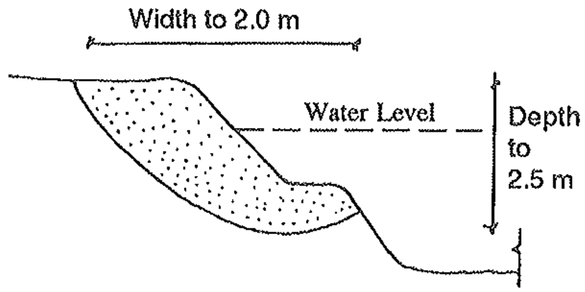

FIGURE 4 Embankment failure, low-severity.

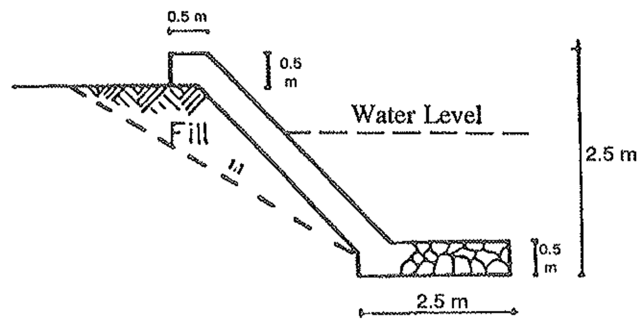

FIGURE 5 Embankment rabbling.

ing more services on roads to achieve the proposed level of serviceability.

COST-SERVICEABILITY RELATION

On the basis of the required periodic maintenance activities and their associated costs of repairing the present distresses, the cost of bringing a section from its current ERCI level to an ERCI level of 100 can be calculated. This was done for all roads included in the sample to indicate the periodic and routine maintenance costs required to completely renew the network (ERCI = 100).

Associated Periodic Maintenance Costs

Figure 6 shows the average ERCI value for each road rating included in the sample along with the associated cost of periodic maintenance required to bring it to an ERCI level of 100. For example, considering a road with an average ERCI value of 40 to 65 (i.e., in the poor range), the cost of bringing this road to its original ERCI of 100, using the appropriate maintenance actions to repair, remove, or eliminate the present distresses, is equal to about 117,000 Egyptian pounds (L.E.) per kilometer (U.S. $60,000/mi). On the other hand, a road with an average ERCI value of 80 to 90 (i.e., in the good range) has a corresponding renewal cost of about 43,784 L.E./km. In order to repair a section with a poor condition (on the basis of the ERCI system), it will cost about 2.5 times the cost of repairing the same section while it is in the good condition, on average. This result compares favorably with the results of several other studies done for paved roads (*8,9*).

Associated Routine Maintenance Costs

As indicated in Table 1, the routine maintenance category contributes about 38 percent to the total rating scale and does not control the ERCI value. However, routine maintenance costs are affected mainly by the blading frequency required for a desired maintenance level. For the same maintenance level, routine maintenance costs should not control the priority scheme, because it is mainly affected by the physical measurements of the road (e.g., width). In addition, the magnitude of routine maintenance costs compared with that of the periodic maintenance is relatively small. Figure 6 justifies this statement.

Environmental Impact

The effect of the surrounding environment is shown in Figure 7. In this figure, the average ERCI values and the associated renewal costs (as explained earlier) are shown for groups of sections, sections adjacent to drains, sections adjacent to canals, and sections penetrating the agricultural fields. The figure indicates that the impact of the surrounding environment represented by the adjacent canals or drains is significant to

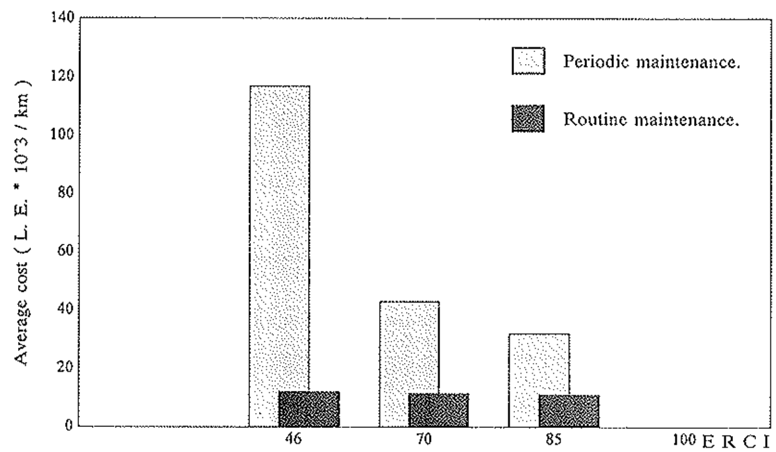

FIGURE 6 Maintenance costs versus road condition.

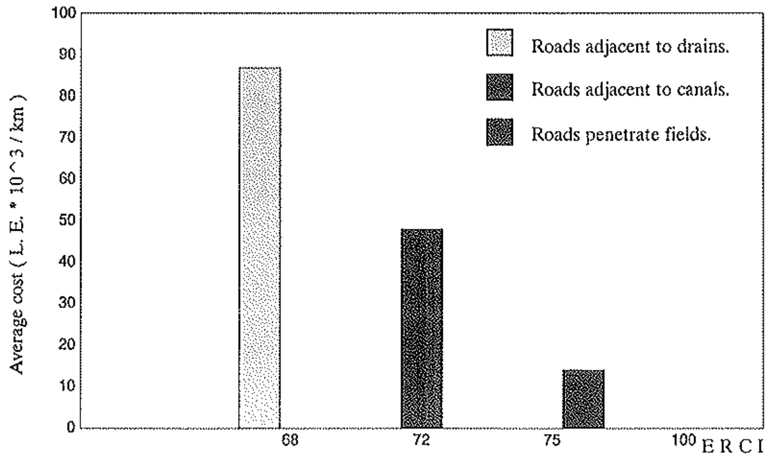

FIGURE 7 Environmental impact on maintenance cost.

the ERCI value and, consequently, to the repair cost. For instance, roads penetrating fields with no adjacent canals or drains have an average ERCI value of about 75 and an average renewal cost of about 12,000 L.E./km; on the other hand, roads with adjacent drains were found to have an average ERCI value of 68 and corresponding renewal costs of about 85,000 L.E./km. This result, in turn, implies that the current priority scheme, which only considers the traffic level, is not entirely correct and that other environmental factors should be considered.

CONCLUSION

The condition assessment subsystem and its associated cost model were developed to provide the necessary information for management decisions, to be as simple and practical as possible, to be used to evaluate the identified road condition, and to provide the decision maker with data needs about maintenance budgeting and priority setting. The information developed through the ERCI system could be used along with information on traffic volume, improvements cost, and so forth, to help in making maintenance decisions.

In studying the effect of surrounding environment, adjacent canals, and drains on maintenance cost of earth roads, consideration both of the earth road and the adjacent stream under the same jurisdiction authority may result in a better maintenance management process.

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Publication of this paper sponsored by Committee on Maintenance and Operations Management.