Pavement Management System for Provinces in Developing Countries: Implementation in Fayoum, Egypt

SAFWAN A. KHEDR AND IBRAHIM A. EL DIMEERY

Almost every road agency is faced with a difficult formula: maintaining its road network to meet the expectations of a minimum level of service, at escalating costs, with ever-constrained budgets. If they are well designed and implemented, suitable pavement management techniques constitute the main answer to this problem. Road agencies of provinces in developing countries are no different; they face even more stringent constraints and limited resources. These agencies also confront social and developmental concerns that may not be of prime concern in other countries. A pavement management system for provinces in developing countries (PMSPDC) geared toward the needs and concerns of these agencies is developed. It features the main development stages of compiling available information, setting the agency's goals, data collection, basic priority criteria, data base design and analysis, execution plans, and determination of the needed resources. A modified pavement condition rating was adopted for paved roads. A developed unpaved road condition rating was used for unpaved roads. The priority factors considered are road condition, population distribution, economic development, regional development, traffic growth, and another factor that was left open for a suitable concern, for example, tourism attraction. PMSPDC is simple, provincial, flexible, and objective. It reflects local values and concerns. It is not a goal in itself, but it is an effective tool that keeps the agency on top of the action and ahead in performance and communication with higher authorities and the general public and that is able to stand firm against unjustified pressures. PMSPDC was successfully implemented in the province of Fayoum, which is a semi-oasis located 105 km southwest of Cairo, Egypt. Analysis of the data in view of PMSPDC priority criteria revealed that the factors considered are mostly independent and significant. The system and the derived justified objective execution plans were well perceived and understood both by the agency's official and by high-ranking officials in the province. Ensuring the optimal nature of these plans made it easier to secure reasonable budgets for road network maintenance and upgrading.

"Local government managers responsible for low-volume roads in the United States are facing a dilemma. On the one hand, there is growing pressure to repair roads and provide an improved level of service. On the other hand, there is public pressure to reduce taxes" (*1*). This dilemma is not confined to the United States; it exists almost everywhere. In addition to the demand for better service with constrained budgets, other factors add to this dilemma in provinces in developing countries. Examples are poor record-keeping on projects, outdated maintenance procedures, lack of quality control facilities and practices, and poorly coordinated decisions regarding network planning. Quite often, these decisions are taken as responses to emergency needs, political pressures, or the complete deterioration of some roads.

S. A. Khedr, Department of Engineering, American University in Cairo, Cairo, Egypt. I.A. El Dimeery, Ain Shams University, Cairo, Egypt.

A pavement management system for provinces in developing countries (PMSPDC) was established in the work described here to meet the urgent need for a tool that is effective and efficient in directing the activities involved in providing and sustaining pavements in an acceptable condition at the lowest possible cost. In the United States several pavement management systems for municipalities and agencies with low-volume roadway networks have been developed, for example, MicroPAVER (*2*) and MTC-PMS (*3*). However, in developing countries upgrading of roadway networks not only should seek optimal use of the budget as the primary criterion but also should consider the economic, social, and regional developments of the influence area served by the network. The PMSPDC can be used as part of the transportation planning process.

Most governorates (provinces) in Egypt have short-term plans for maintaining their road networks. Recently they have recognized the significance of establishing pavement management systems for their road networks with the main objectives of putting a priority program according to their available annual budgets and maximizing the positive impacts on the communities and their development. The PMSPDC was developed for that purpose and was implemented in the province (governorate) of Fayoum in Egypt. Presented in this paper are the essence of PMSPDC and the preliminary results of its implementation in Fayoum.

OBJECTIVES

The main objectives of PMSPDC are to

1. Help the province set its goals and improve and upgrade its local road network.
2. Encourage decentralization and the development of local capabilities.
3. Set up an information management system that can aid the decision-making process in assigning investment priorities within the capabilities of the available resources.
4. Develop a general plan for the road network in the province. The plan should
   - –Provide a program for construction, maintenance, and improvement of the existing network;
   - –Determine if new road links are required to respond to local development needs;
   - –Include both paved and unpaved roads;
   - –Develop priority criteria to be used in the selection of individual road segments for upgrading; and
   - –Initially cover a period of 10 years.
5. Study, assess, and evaluate the existing status of the road agency and road network in a province.

6. Review the plan developed in Objective 4 with various elements of the road agency to achieve an execution program and to determine the resources required to implement it (budget, manpower, equipment, and materials).
7. Identify problematic conditions of roads and review design and construction parameters and considerations on the project level.

FEATURES OF DEVELOPED SYSTEM (PMSPDC)

A successful pavement management system should be tailored to the circumstances of the agency using it. For the scope of PMSPDC several characteristics are of prime concern. The PMSPDC should be

1. Simple. To ensure success and the continuity of implementation the system should be simple enough so that local officials and engineers are able to understand, implement, update, and employ it in their strategic network-level decisions and project-level assessment and design processes. The system, however, should not sacrifice objectivity and completeness in this process and should minimize subjective judgments. Computer involvement should be kept within the available facilities, for example, microcomputers, and be interactive and simple to use.
2. Provincial. When it is implemented the system should answer the agency's concerns: technical, administrative, social, economic, growth, and even political.
3. Flexible. The system should be modifiable and updatable if strategic changes or new data were to become available. It should have the capability of using feedback information regarding the consequences of decisions.
4. Optimal. An optimal priority assessment technique should be included to ensure the best value for investments.
5. Systematic. Periodic data collection, compilation, and updating should be done systematically so that decisions can be checked and reviewed. Information will then be easily retrievable in a useful format.

COMPONENTS AND ACTIVITIES OF PMSPDC

A schematic flow chart of the proposed activities of the PMSPDC is shown in Figure 1. These activities are detailed in the following paragraphs.

Compiling Available Information

Available information for the area under the influence of the road network is collected. This information includes road network data (types, lengths, and functional class); population distribution; economic activities; the district and township locales served by the network; social data, for example, migration movements and education; the administrative structure, policies, programs, and resources of the road agency; and safety issues on the road network.

Setting Agency's Goals

A clear set of goals should be outlined to set the direction in which the agency is heading and how far it wants to go. In this respect general and stage goals may be defined. The general goals should deal with (*a*) the basic needs of people in urban and rural areas and the minimum levels of these needs and (*b*) upgrading of the network to keep up with the expected expansion of economic activities: industrial, agricultural, and so on. Stage goals are more specific and incorporate the time span over which plans are made. These goals should target (*a*) minimum road condition (level of service), (*b*) the continuity of the transportation network, (*c*) servicing of regions with economic activities, (*d*) the level of social development, (*e*) safety level, and (*f*) the performance and productivities of various divisions within the road agency. These stage goals may be revised in view of the outcome of the PMSPDC within realistic constraints and available resources.

Network Data Collection

The decision-making process and the establishment of a pavement management program will not be valid unless they are based on real, detailed, analyzed information on the road network under consideration. Data collection for PMSPDC includes road inventory, a pavement condition survey, and a traffic count.

Road Inventory

The road inventory should include the following for each link and segment:

- Identification and classification of the link or segment. (A proper coding system for the network may have to be established.)
- Land use and the general topography surrounding the road.
- Elements of road geometry: horizontal and vertical curves; effect on sight distance; cross-section dimensions; side slopes; height of embankments, culverts, and bridges; traffic signs; and lighting facilities.
- Available records on road construction, maintenance, and its itemized costs. It is likely that the system is faced with the obstacle of insufficient records. Interviews with engineers and the personnel in charge will temporarily fill that information gap until the system is implemented. From then on information is collected within the system.

Shown in Figure 2 are the proposed forms for collecting geometric characteristics and road segment records.

At this stage preliminary ideas about potential new roads should be developed and the location should be reviewed. The new roads may connect communities that presently do not have access to the road network, or they may serve new economic or regional development areas.

Pavement Condition Survey

Because of the lack of facilities it is not expected that provinces in developing countries will have access to the equipment capable of testing pavement structure or the pavement surface. Therefore, pavement evaluation for network-level management should be made simple and carried out independently of sophisticated equipment. However, it should encompass all of the problems anticipated to occur in pavements in the province. The results that are obtained

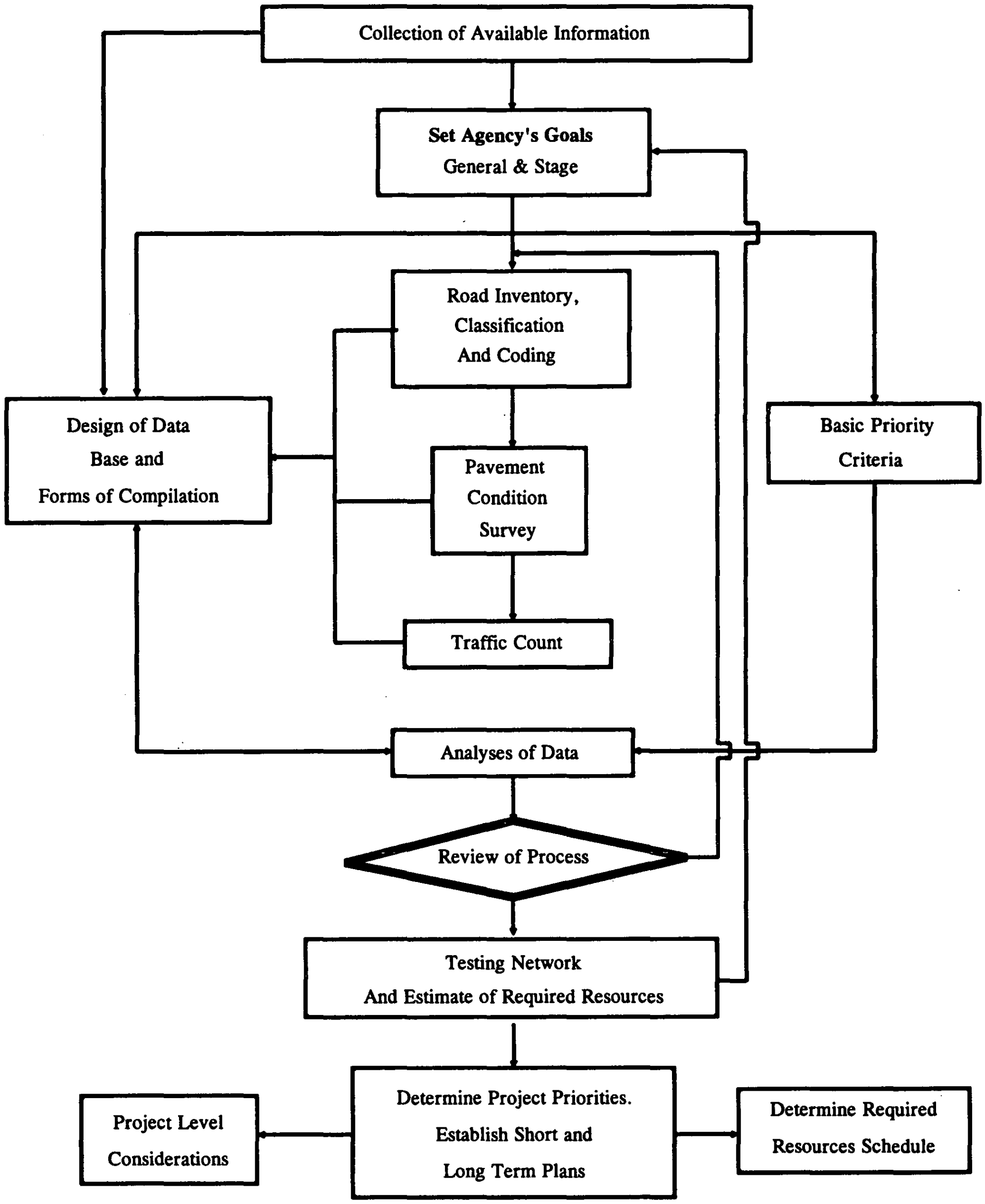

FIGURE 1 PMSPDC development process.

should be reliable and repeatable if evaluation is made by different inspection teams.

Visual inspection of the pavement surface condition is considered the major tool in collecting data for network management. It is important to use uncomplicated, easy-to-understand condition survey methods to ensure consistency and the ability of the agency's personnel to update information for the continuity of PMSPDC. The pavement condition rating (PCR) model (*4*) is adopted and modified to emphasize provincial concerns. A similar evaluation scheme is developed for an unpaved (earth) road condition rating (URCR).

Figure 3 presents the form for survey and calculation of PCR. It is calculated as follows:

$$\text{PCR}\ (\%) = 100 - \sum_{i=1}^{n} w_i t_i d_i$$

where

w_i = relative weight (importance) of distress (i),
t_i = distress severity factor,
d_i = distress extent factor, and
n = number of distresses of concern = 13.

The description of t_i and d_i for the different distresses is given in Table 1. It should be noted that the values for relative weight (w_i) in Figure 3 are set for conditions in which more than two distresses are encountered on the pavement. If only one type of distress exists the corresponding w_i should be doubled. If only two types of distress exist the corresponding w_i should be increased by 50 percent. The emphasis of this rating was placed on cracking because it is believed to be responsible for the fast deterioration of pavements in many regions of the Third World.

Record of Road Link

Road Link: No.: Length:

Compiled By: Date:

Segment		Date of Action	Type of Construction or Maintenance	Base Thickness (cm)	Paving Thickness (cm)		Pavement Width (m)	Shoulder Width & Type (m)		Total Initial Cost	Remarks
From	To				Binder	Surface		Right	Left		

(a)

Geometric Elements

Road Link: No: Length:

Inspected By: Date:

Segment		Average Width (m)	Shoulder Width & Type (m)		Topography & Land Use		Sharp Horizontal Curves*	Steep Vertical Curves*	Remarks
From	To		Right	Left	Right	Left			
Schematic Sketch of Link:									

* Do not satisfy proper sight distance

(b)

FIGURE 2 Forms for: (*a*) road record and (*b*) road geometric elements as constructed.

The URCR is calculated in a way similar to that for PCR. For all distress types the extent factor d_i is designated 0.4, 0.8, and 1.0 for scarce, some, and frequent, respectively. Severity is designated low or high (t_i = 1.0). Shown in Table 2 are the values for relative weight and low severity factor for the different types of distress on unpaved roads. Ten types of distress are considered in Table 2. The stability and integrity of the road embankment receive higher weights of importance. Distresses 9 and 10 in Table 2 are related to the improper use of the road's right-of-way, which is not uncommon in developing countries. Also presented in Table 2 is the description of the degree of severity of the distresses. The categories of extent are designated less than 20 percent between 20 and 50 percent, and more than 50 percent for scarce, some, and frequent, respectively, for all distresses except the last two. The improper uses of right-of-way on unpaved roads (Distresses 9 and 10 in Table 2) have scarce, some, and frequent extents if two, two to five, and more than five obstructions are encountered on the road segment, respectively.

The pavement condition survey is performed on every road segment (which normally averages 2 km in length). The survey is done for three randomly sampled sections of 200 m each on the road segment. The pavement condition survey for the network should be performed before every budget planning period.

Traffic Count

The traffic count scheme should be designed so that the average daily traffic is measured or estimated for all road links in the network. This may include 24-, 12-, 6-, and 2-hr counts and classified counts for every group of road links categorized by traffic condition. These measurements or estimates should be adjusted to reflect traffic growth. Traffic growth is mainly attributed to growth in population, changes in standards of living (car ownership), and economic development.

Basic Priority Criteria

On the provincial level in developing countries numerous factors should affect the decision-making process on the network level. Other than the technical evaluation of road condition and perfor-

Pavement Surface Condition Survey

Link:	No.:	Length:
Segment: From	To	Length:
Inspected by:		Date:

Distress	Rel. Wt.	Severity			Extent			Deduction**
		Low	Med	High	Scarce	Some	Freq	
1. Raveling	10	0.3	0.6	1.0	0.5	0.8	1.0	
2. Bleeding	5	0.8	0.8	1.0	0.6	0.9	1.0	
3. Patching & Repair	5	0.3	0.6	1.0	0.6	0.8	1.0	
4. Potholes *	10	0.4	0.7	1.0	0.5	0.8	1.0	
5. Local humps	5	0.3	0.6	1.0	0.5	0.8	1.0	
6. Rutting *	10	0.3	0.7	1.0	0.6	0.8	1.0	
7. Local Depression	10	0.5	0.7	1.0	0.5	0.8	1.0	
8. Corrugation	5	0.4	0.8	1.0	0.5	0.8	1.0	
9. Alligator Cracking *	15	0.4	0.7	1.0	0.5	0.7	1.0	
10. Block & Transverse Cracking	10	0.4	0.7	1.0	0.5	0.7	1.0	
11. Longitudinal Cracks	5	0.4	0.7	1.0	0.5	0.7	1.0	
12. Edge Cracks	5	0.4	0.7	1.0	0.5	0.7	1.0	
13. Other Cracks	5	0.4	0.7	1.0	0.5	0.7	1.0	
**Deduction = Rel. Wt. * Severity * Extent				Total Deduction				
PCR = 100 - Total Deduction				Total Structural Deduction*				

FIGURE 3 PCR survey and calculation.

mance, there are considerations pertaining to regional development, social development, economic activities and development, safety, and political pressure. To simplify the process in the PMSPDC six factors were considered to assign a priority ranking to road segments in the provincial network. Listed in Table 3 are these factors and their relative weights in priority designation. Discussion and the measurement of each factor are presented below.

Road Condition

The relative weight of road condition is the highest among the considered factors; however, it amounts to about one-third of the priority criteria. From a technical point of view this is the only factor that focuses on pavement performance. PCR and URCR are used to reflect pavement condition. The geometric features of the road should be investigated to study the need for road realignment and the effects of these needs on safety. Urgent safety-related geometric problems are either flagged (on the computer program) or reflected in the values of PCR or URCR (by reducing them). Presented in the Table 4 are relative weights for various road conditions. Emphasis is given to paved roads whose condition is between good and failed (or very poor), on which pavement performance deteriorates faster in the case of delayed maintenance actions. Poor and failed paved roads receive a higher priority than unpaved roads with similar rankings. This contemplates the higher expectation versus severe roughness on pavements under such conditions. There is no "excellent" unpaved road, and it warrants greater attention at the "very good" level than paved roads.

Population Distribution

The population distribution factor focuses on the distributions of the urban and rural populations in the influence area of the road. A population distribution ratio for a road link is calculated as follows:

$$\text{Population distribution ratio} = \frac{\text{Population served by the road link}}{\text{provincial population}} \times \text{urbanization factor} \times \frac{\text{number of municipal division served by link}}{\text{total number of municipal divisions in province}}$$

TABLE 1 Degrees of Severity and Extent of Distresses for Paved Roads

Distress	Severity			Extent (%)		
	Low	Medium	High	Scarce	Some	Frequent
1. Raveling	Loss of some particles	Noticeable pitting and roughness	Very rough, full of pitting	< 20	20-50	> 50
2. Bleeding	------	Asphalt fill voids between aggregates	Covered with asphalt film	< 10	10-30	> 30
3. Patching	Some deterioration	Partial failure	Needs replacement	< 10	10-30	> 30
4. Potholes	Diameter < 15 cm Depth < 3 cm	Diameter > 15 cm Depth 3-5 cm	Diameter > 15 cm Depth > 5 cm	< 20	20-50	> 50
5. Local Humps	Diameter < 15 cm Height < 3 cm	Diameter > 15 cm Height 3-5 cm	Diameter > 15 cm Height > 5 cm	< 10	10-30	> 30
6. Rutting	< 6 mm	6-25 mm	> 25 mm	< 20	20-50	> 50
7. Local Depression	Some, with negligible effect of driving	Discomfort in controlling vehicle	Difficult to control vehicle	1/km	2-4/km	> 4/km
8. Corrugation	Some, with some discomfort in driving	Discomfortable driving but good control	Severe vibration and reduced speed	< 10	10-30	> 50
9. Alligator Cracks	< 3 mm single or cross cracks	3-6 mm multiple or alligator pattern forming	> 6 mm alligator pattern established	< 20	20-50	> 50
10. Block & Transverse Cracks	< 3 mm	3-25 mm width spalling with less than half length	> 25 mm with common spalling	< 20	20-50	> 50
11. Longitudinal Cracks	< 3 mm single	> 3 mm single or multiple	multiple with spalling	< 20	20-50	> 50
12. Edge Cracks	< 6 mm without spalling	> 6 mm with spalling	multiple with spalling	< 20	20-50	> 50
+13. Other Cracks	< 3 mm without spalling	3-25 mm with spalling	> 25 mm with spalling	< 20	20-50	> 50

TABLE 2 Severity of Distresses on Unpaved Roads

Distress	Rel.Weight	Severity		
		Low		High
1. Failure & Erosion of Embankment	15	Width < 2 m Depth < 5 cm	0.5	Width > 2 m Depth > 5 cm
2. Failure of Side Slopes	15	Does not effect right-of-way	0.3	Reduce right-of-way
3. Corrugation	15	< 3 cm	0.5	> 3 cm
4. Uneven Cross Section	10	Depressions are noticed with not obvious cross slope	0.5	Severe depressions which affect comfort and safety of driving
5. Rutting	10	< 3 cm	0.5	> 3 cm
6. Local Depressions	8	Diameter < 30 cm Depth < 5 cm	0.5	Diameter > 30 cm Depth > 5 cm
7. Intrusion of Irrigation Water	8	Minor with width < 1 m	0.4	Water affects traffic and reduces speed
8. Vegetation of Road Surface	7	Area < 1 m^2	0.5	Area > 1 m^2
9. Obstacles	7	Length < 1 m	0.5	Length > 1 m
10. Illegal Use	5	Length < 1 m	0.4	Length > 1 m

TABLE 3 Relative Weights of Priority Factors

Factor	Relative Weight
Road Condition	35
Population Distribution	20
Regional Development	15
Economic Development	10
Traffic Growth	10
Other (Tourism Attractions)	10
Total	100

The "urbanization factor" depends on the type of residence: 1.2 for urban and 1.0 for rural. The population distribution factor is determined from 5 to 20 in proportion to the population distribution ratio. This relationship will differ from one province to another, depending on the actual population and the number of municipal divisions in the province.

Regional Development

If the road link serves new or developing existing regional or urban developments, it is given a higher priority. The regional development factors for three conditions are provided in Table 5.

Economic Development

The role of highways in economic progress is indisputable. If a road link has a direct impact in serving economic activities, for example, industrial and agricultural activities, it is designated a higher-priority road. Road links in this category are expected to carry traffic with a higher ratio of heavy vehicles. This is used as an indicator. The economic development factors for three activity levels are provided in Table 5.

Traffic Growth

In general, most roads on provincial networks in developing countries can be categorized as low volume. Therefore, traffic volume may not be regarded as a major factor in the priority measure because most traffic volumes on roads will be too low anyway. This factor is given a relative weight of 10 out of 100. It is measured in reference to the average daily traffic, as shown in Table 5.

Other Factors

Provinces may differ somewhat in their consideration of factors that affect ranking of roads in a management scheme. A relative weight of 10 is left to be filled with a factor of particular interest. This factor may regard, for instance, strategic defense or political, environmental, or tourism considerations. In Egypt, for example, tourism attraction is considered important in most provincial activities. The relation of a road link to these activities will be a criterion in deciding its relative priority.

The overall priority index (PI) is the sum of all six criteria factors discussed above. A higher PI for a road segment will place it higher on the construction, rehabilitation, or maintenance list.

Political influence is usually an important issue. It can be handled under one of two different scenarios. First it may be assigned a designated relative weight and given a value decided subjectively in relation to the prevailing political directions. The main advantage of this alternative is that it gives a predecided weight to political pressure and therefore puts it within predetermined limits. On the other hand it may be difficult to get politicians to agree to the limitation and acknowledge the existence of such pressure. The second scenario is to continue with the system and then review the final execution program with the political domain, having the tool to assess the consequences of altering the program.

Data Base Design

Data storage, organization, analyses, and retrieval are done best by using computer facilities. However, on the provincial level this should be made simple and friendly for use by local officials and engineers. In most provinces personal computers have recently become available. In PMSPDC a program is developed to satisfy these requirements in a DBASE IV software environment. Facilities are available to display the user program interaction in the user's native language. This removes major language obstacles in the usage of PMSPDC.

The program handles the following for the road division and road network in the province:

1. Information pertaining to administrative affairs;
2. Construction and maintenance cost items;
3. Information on resources: manpower, equipment, materials, and budget;
4. Road identification, condition, and traffic for every link;
5. Pavement condition for every segment;
6. Priority criteria factors and PI for every link and segment; and
7. Priority list and program alternatives on the provincial and district levels.

TABLE 4 Pavement Condition Priority Factor (PCPF)

PCR	PCPF	Condition	URCR	PCPF
0-20	35	Failed	0-40	30
21-40	30	Poor	41-65	25
41-60	20	Fair	66-80	20
61-75	10	Good	81-90	15
76-90	5	Very Good	91-100	10
91-100	0	Excellent	—	—

TABLE 5 Priority Factors of Regional Development, Economic Development, and Traffic Growth

Purpose of Link	Regional Development Factor	Level of Economic Activities (measured by heavy vehicle traffic)	Economic Development Factor	Average Daily Traffic	Traffic Growth Factor
Evolution of new settlement(s)	15	Heavy traffic loads	10	> 1500	10
Help developing existing communities	10	Medium traffic loads	6	500-1500	5
Connection of existing communities	5	Light traffic loads	2	< 500	2

Analysis and Plans

On the basis of the available information and priority criteria a priority list is compiled in a computer data base for all road segments. Each segment is preliminarily reviewed and initially categorized in one of three stages: routine maintenance, rehabilitation, or construction. A cost estimate is used to provide an estimate of the needed resources in the short and long term. The agency's goals are then reviewed in light of the available information. The goals may be adjusted to be more realistic if they are not.

A weighed average of the PIs over all sections of the road network is called the network index (NI). The NI can be used as an indicator of the overall condition of the network. For the purpose of comparison a lower NI indicates a better condition of the network.

The final year-to-year plans are made in the following steps:

1. Analyze each road segment at the project level to assess the expected performance under alternate actions (usually limited to two to three alternatives).
2. Estimate the initial cost of the action for each segment by using current itemized costs.
3. Provide alternative plans of action for the first year within the constraints of the resources and check the consequences of each plan in the form of expected network performance (NI). Select the plan with the best performance.
4. Assuming that the selected plan in Step 3 is carried out, run the same procedure for the second year, and so on.

A linear pavement performance model was used in this procedure. This is considered a preliminary assumption until adequate data are collected over the years in the province to develop a more realistic model and update the procedure.

It is common practice among provincial road agencies for the budget for routine maintenance to be handled separately from the rehabilitation and construction budget. The sources of each budget may even be different. Therefore a provision is made to provide separate plans for each set of actions.

Resources

According to the developed plans, the resources required for short- and long-term implementation are determined on the basis of the local rates of productivity, techniques, costs, and performance. At this point it is appropriate to review the administrative structure, policies, and practices of maintenance and construction.

IMPLEMENTATION OF PMSPDC IN FAYOUM, EGYPT

Fayoum is a semi-oasis province (governorate) located 105 km southwest of Cairo. In 1986 the province had a population of 1.55 million, and its total area is 4,550 km^2. Administratively it is divided into five districts with five cities, 157 villages, and 1,450 small villages. The province has a mix of rural and urban communities, with the urban area population representing 23.3 percent of the total population. Agriculture is the main economic activity in the province, where 315,000 *fedans* (29 percent of the total area) are cultivated by using canal irrigation systems (*5*).

The roads in Fayoum Province are divided into three categories: national, regional provincial, and local urban. The first is managed by the national Authority of Roads and Bridges of Egypt. The third category is administered by local city or village authorities, sometimes helped by the province. The second category of regional provincial roads is the subject of the present PMSPDC implementation. The total length of this road network in 1992 was 1,099 km, of which 652 km was unpaved (earth) roads. All routine maintenance is executed by the road agency's crews through its five main district offices. Rehabilitation and construction are executed by contractors under the supervision of the agency. The annual budget level in previous years ranged between £E 3 million to 4 million (US$1 = about £E 3.4). The total manpower of the agency is 1,380, of which there are 13 engineers, 252 technicians, 244 administrative staff, and 870 laborers.

The general goals of the province's road agency were stated to emphasize social development by extending road services to every small community, serving developing economic activities, and enhancing road services to tourism activities in the province. The main development activity was identified as the cultivation of new lands in the adjacent desert.

The stage goals were set to maintain road pavements at a performance level of at least "good," complete road sections vital to the continuity of traffic flow, extend road services to at least 25 percent of the communities that did not enjoy them at present, construct new roads to serve tourism and the cultivation of new desert land, improve the safety characteristics of roads, and upgrade the performance levels of various elements in the agency.

A new consistent coding system was developed for the road network. The network was divided into links, with each link subdivided into segments that are similar in character. The average length of the segments was 2.5 km. The new coding system identified 142 roads, divided into 215 links, subdivided into 471 segments. Approximately 100 km was designated candidate new roads that serve the stage goals.

All paved roads were two-lane with an average width of 6.8 m and unpaved shoulders with an average width of 1.25 m. The average width of earth was 4.5 m. Most roads were run in agricultural land, with only 12 percent run in desert surroundings.

The road surface condition survey revealed the results shown in Figure 4. The most common distresses on paved roads were rutting and "other" cracks. On unpaved roads uneven cross sections and illegal use were most commonly found.

The average daily traffic measured and estimated ranged between 200 and 2,800 vehicles per day. The proportion of heavy vehicles ranged between 0 and 25 percent. Slow-moving vehicles constituted 21 to 70 percent of the traffic.

In the implementation of PMSPDC in Fayoum it was decided to adopt tourism attraction as a priority factor in calculating the priority index. The relative weights of 0, 6, and 10 were given to road links that have no, an indirect, and a direct influence on tourism attraction, respectively. The population distribution factor was correlated to the population distribution ratio as shown in Table 6.

Priority factors were calculated or determined for each road segment in the network. Statistical analyses were carried out to study the interrelationship among and the significance of these factors in the case of Fayoum. A sensitivity analysis was performed to assess the effect of excluding any of the factors and its influence on the priority program. The correlation coefficients are shown in Table 7. A relationship was suggested by the correlation coefficient of 0.83 between economic development and traffic growth factors. It was normal to expect heavier traffic where there was stronger economic development. However it was not the only variable that might affect traffic volume and traffic growth. There were lesser significant interrelationships between economic development and tourism attraction factors on the one hand and between traffic growth and population distribution factors on the other. These relationships might suggest that the economic development could be expressed by some of the other factors considered in Fayoum.

The significance of each priority factor was tested by investigating the effect of its absence on the priority list. It was found that the absence of any of the factors significantly affected the priority scheme of the road segments. They ranked from most to least influential as follows: surface condition, tourism attraction, population distribution, traffic growth, and economic development. Regional development had the least effect on the priority scheme. This might be attributed to the more settled nature of Fayoum Province, which is considered an older, more established province with limited potential for new regional development.

The upgrading operations were divided into five categories:

1. Routine maintenance for both paved and unpaved roads.
2. Maintenance of paved roads.
3. Overlay of paved roads.
4. Reconstruction of paved roads.
5. Paving of earth roads and new construction.

Two 10-year plans were established: one for routine maintenance, handled by the agency's crews, and the other for the other actions, to be handled by contractors under control of the road agency. Budgets were estimated for each plan by using local cost information. The plans were detailed year to year. The plans and budgets were further scheduled for each of the five districts in Fayoum.

On the basis of the 10-year plans, local rates of productivity of the workforce and equipment, and a review of the structure of administration and activities, a schedule of needed resources was organized. The needed budgets were found to be higher than originally allocated by approximately 20 percent. However, the present workforce was much higher than needed, especially in the categories of administrative staff and labor. More engineers were needed to accomplish the target plans. The excess of labor was attributed to the outdated routine maintenance practices, which were labor-intensive with poor efficiency. Surprisingly, the equipment owned by the province was found to be adequate, if it was used efficiently, for routine maintenance. Finally, it was found that there was a risk of an inadequate supply of aggregates that satisfied proper quality standards.

During the course of implementing PMSPDC in Fayoum, a general investigation of common problems that were found to face road engineers on the project level was carried out. Structural failure of pavement under medium truck loads was a main concern.

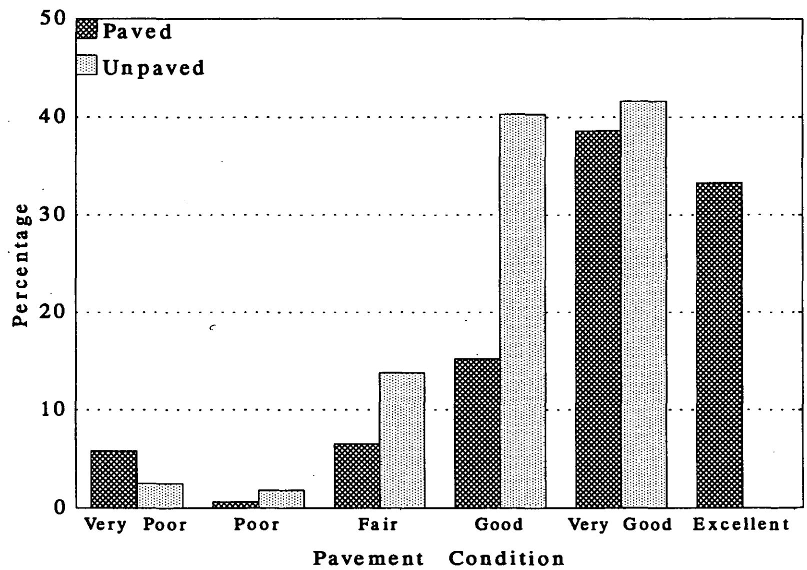

FIGURE 4 General road surface conditions in province of Fayoum.

TABLE 6 Population Distribution Factor for Fayoum

Population Distribution Ratio (10^{-5})	Population Distribution Factor
0-6	5
6-12	10
12-31	15
> 31	20

TABLE 7 Interrelation Correlation Coefficient Among Priority Factors

	f_1	f_2	f_3	f_4	f_5	f_6
Surface Conditions (f_1)	1.0	0.06	0.52	0.16	0.16	0.18
Population Distribution (f_2)		1.0	0.65	0.60	0.71	0.54
Regional Development (f_3)			1.0	0.21	0.66	0.43
Economic Development (f_4)				1.0	0.83	0.76
Traffic Growth (f_5)					1.0	0.6
Tourism Attractions (f_6)						1.0

Narrow pavements, which forced trucks in both directions to take almost the same wheelpath, were found to be responsible for double loading on pavements. This led to early failures of those pavements. The second problem was deep failure of road foundations. This was attributed to the seepage of irrigation water under the road from agricultural fields to water canals. A lack of proper subsurface drainage systems to control water movement was the reason behind the considerable loss of strength of silty soils in road foundations. Finally, slope failures of embankments were found to be caused by water seepage and encroaching agricultural fields, which forced steep side slopes. General guidelines were established to deal with these problems.

CONCLUSIONS

1. A pavement management system geared toward the needs and concerns of provinces in developing countries (PMSPDC) was developed. It is expected to be effective in reducing road maintenance costs and improving road conditions.

2. A simplified scheme for pavement surface condition survey and rating was developed.

3. Priority criteria were established to exemplify the concerns of a province in developing countries.

4. Language represents a great barrier that should be overcome before expecting an adequate response from local officials and engineers. PMSPDC was presented in native languages as a system and computer program.

5. Successful implementation of PMSPDC in Fayoum, Egypt, uncovered important facts and was well received by the road agency's officials and the high-ranking provincial officials.

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