Maintenance Management Technology Training Through Case Study Approach

NEVILLE A. PARKER, ESSAM RADWAN, AND MERRON L. LATTA

A maintenance management case study approach has been developed for the International Road Federation executive conferences on road management, for senior professional engineers, and for administrators of highway agencies. A case is structured and presented as a continuing exercise that affords the conference delegates the opportunity to simulate planning, programming, budgeting, and scheduling of maintenance activities for a hypothetical network, through the practical application of real data. Delegates, working in regional groups, develop their cases, beginning with the definition of unique sets of environments that describe traffic flow, climate, roadway cross section, technology, and economic and financial characteristics. Presented with a roadway condition survey, each group then develops a first-year maintenance plan, program, and budget, imbedded in a 5-year projection designed to minimize the total cost of maintenance and vehicle operation. In the process, delegates deepen their understanding of the language and principles of road management and, at the end of the exercise, present and defend their budget requests before a simulated budget committee. Experience to date has shown that appropriately designed case studies can be effective instruments of technology transfer and training. By setting the maintenance management situation in environments defined by the delegates themselves and by providing a medium for the exchange of views and approaches to maintenance management problem-solving through group work, unique case studies can be developed that mirror reality closely and give delegates a feeling of confidence in an enhanced ability to effect meaningful change in their regions' maintenance management procedures.

The maintenance management problem is cast in the context of the interactions between surface deterioration and maintenance and vehicle operation as shown in Figure 1. Surface deterioration is a function of climate, road type, traffic, and maintenance. Road roughness, as a measure of riding surface quality, is a major link between maintenance and operating costs, because of its effect on speed and speed changes (and hence fuel consumption), as well as on vehicle wear and tear. Maintenance costs depend both on needs and strategies, whereas vehicle operation costs depend on speed and road geometry, as well as on road roughness. The cyclic interactions of surface deterioration, road roughness, and maintenance illustrate the cause-and-effect relationship between them and focuses on the strategic part of the problem. Surface deterioration is monitored or predicted, and the measure of riding surface quality determines the maintenance requirements necessary to arrest any further deterioration or to restore the surface to previous higher standards. The maintenance management problem has been fully developed in the developing country context by Gichaga and Parker (*1*). The maintenance management cycle of activities is shown in Figure 2 and described in the following paragraphs.

Good management begins with good planning, and good planning depends on relevant, timely, and accurate data. Planning in this context means the following:

- Determining the maintenance activities to be carried out on both a fiscal year and long-term basis; and
- Estimating the resources necessary to carry out the activities (i.e. labor, equipment, and materials).

Proper planning establishes defensible budgetary requirements. However, budgeting is itself a political process, which is only initiated by the budgetary requirements. The budgetary allocations are therefore more likely to be less than the requirements. As such, therefore, it is the job of management to determine which of the planned projects should be executed to maximize the social benefits, which is expenditure budgeting, and then to revise and update the plan for subsequent years. Management is held accountable for cost-effective use of budgeted funds.

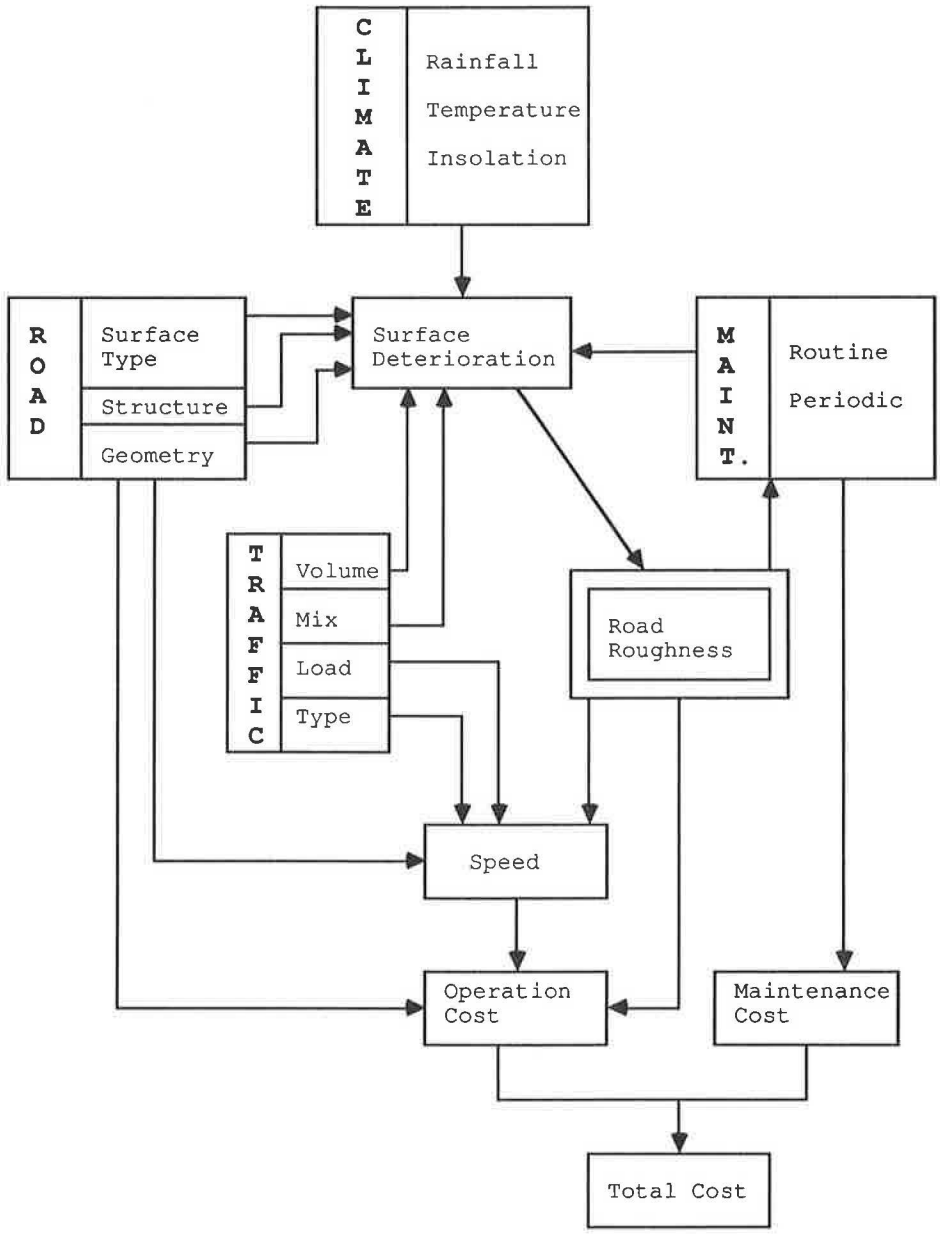
Planning is a macrolevel activity that provides a framework for measuring performance. Programming is the microlevel activity that determines the schedule of work and the detailed allocation of resources necessary to achieve the plan. It includes set up of work camps, dispatching of transport, distribution of labor and materials, scheduling of equipment, and control of finance.

To execute maintenance operations is to supervise and control them in order to ensure that the programmed activities are carried out within budget and time, and at the required standard of performance.

INTERNATIONAL ROAD FEDERATION EXECUTIVE CONFERENCE ON ROAD MANAGEMENT

The International Road Federation (IRF) executive conferences on road management are organized in cooperation with Arizona State University, and held once per year. For two

N. A. Parker, Institute for Transportation Systems, The City University of New York, The City College, Convent Avenue and 135th Street, New York, N.Y. 10031. E. Radwan, Civil and Environmental Department, University of Central Florida, 4000 Central Florida Blvd., Orlando, Fla. 32816–0450. M. L. Latta, International Road Federation, Washington, D.C. 20024.



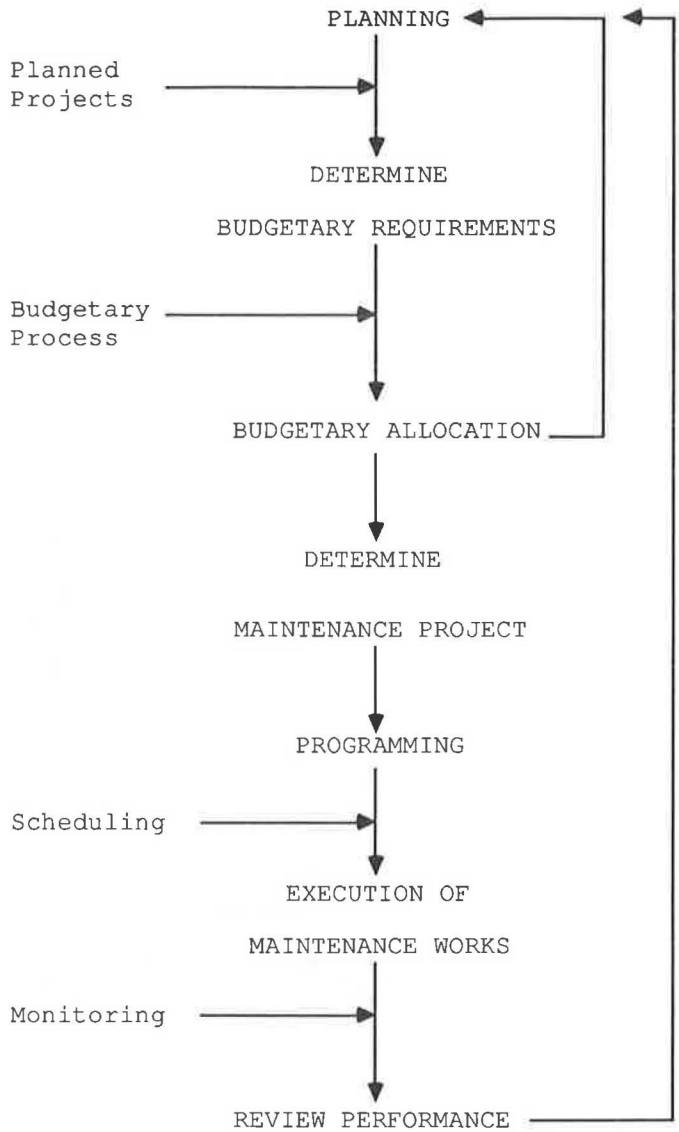
Source: Essentials of Highway Engineering (Ref. 1)

FIGURE 1 Interactions between surface deterioration and maintenance and vehicle operation costs.

weeks, delegates discuss and work together as a group and in teams, to develop solutions to the most critical problems facing road managers today. Delegates return home equipped to define their problems more precisely and make decisions more effectively. Through this educational process, the various highway agencies that the delegates represent will ultimately become more efficient.

The program features lectures, demonstrations, and structured discussion on maintenance management, pavement management, equipment management, technology transfer, and training of the work force. Site visits are made to observe each of the management operations. A maintenance management case study parallels the lectures and serves as the medium for focusing and exercising the management concepts. The typical conference is shown in Figure 3. All sessions are presented by experts from the public and private sectors and from academia. Four coordinators are in residence with the delegates to provide continuity and ensure effective technology transfer and training by providing a continuous and on-demand consultative resource. Coordinators also lecture.

The program is designed for a maximum of 30 senior professional engineers and administrators in public works and communications ministries and highway agencies, who can influence management policies and operations. Sponsoring agencies are encouraged to send multiple delegates who would work together as a team during the conference. Preference is given



Source: Essentials of Highway Engineering (ref. 1)

FIGURE 2 Maintenance management cycle.

to developing nations; highway professionals at appropriate levels in the private sector are also invited.

Delegates receive a permanent record of the conference including an abstract of each lecture, a copy of the case study manual, a copy of the reference text (*1*), as well as various monographs. In addition, each delegate is made a professional affiliate of the IRF for a period of 1 year on a complimentary basis. Professional affiliates are kept informed regularly of the latest developments in roads, and have the opportunity to subscribe to the IRF's literature on technology transfer at significant cost savings.

MAINTENANCE MANAGEMENT CASE STUDY

The case study is an exercise in decision making. It presents the delegates with a hypothetical but realistic maintenance management situation involving three major classes of urban and rural roads: namely, asphaltic premix, bituminous surface dressing, and engineered gravel. With the exception of the road geometry and condition survey, all other environmental conditions are determined by the delegates working in regional groups of three to five, though they are free to accept the default environmental conditions presented in the case handbook (*2*). After setting the case in the appropriate environments, delegates then simulate various stages of the maintenance management cycle (Figure 2), which terminates in the determination of a budget. In the process, delegates develop an enhanced appreciation for the importance of determining priorities, evaluating the consequences of alternative solutions, and making maintenance decisions that take account of both short- and long-term effects on user costs. The alternatives analysis and the exchange of views that occur within

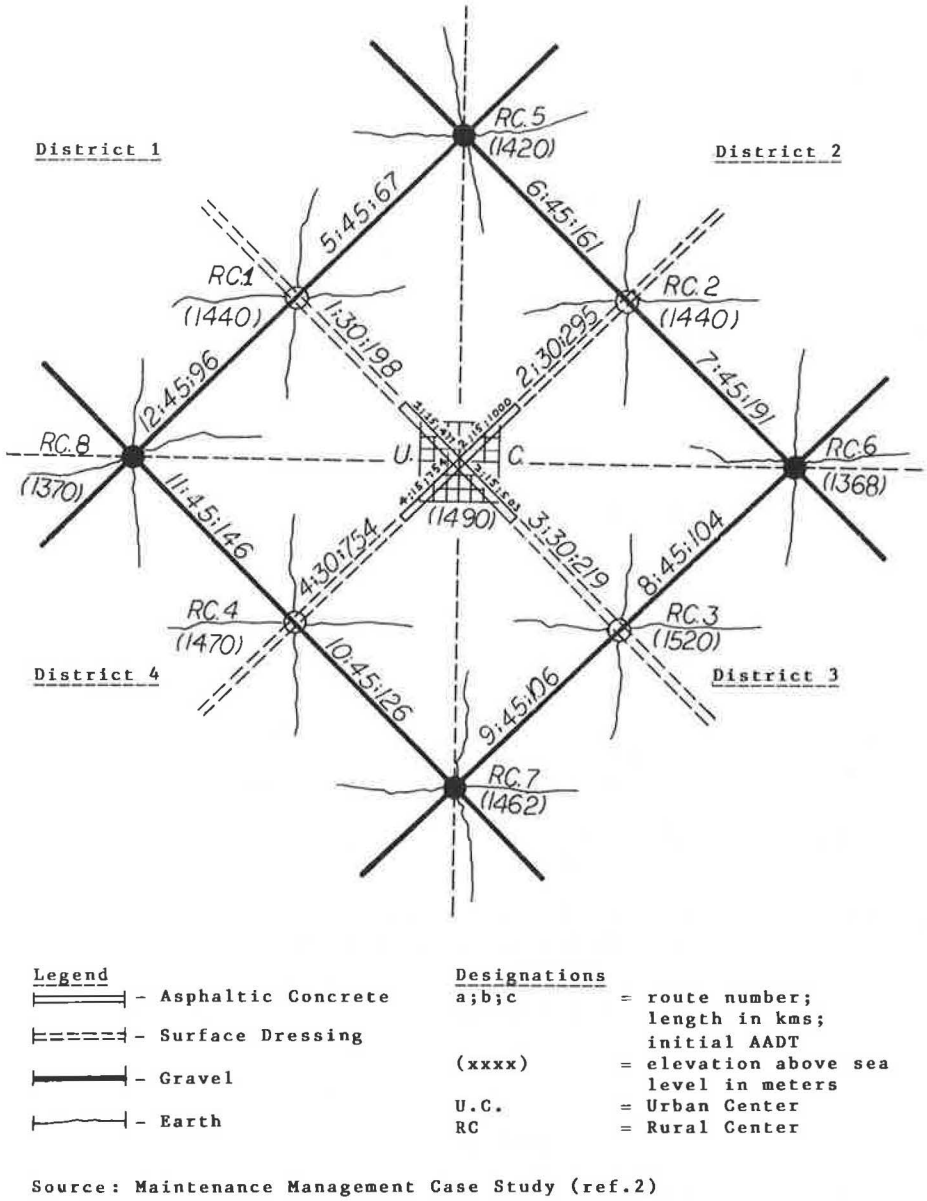
DAY		PROGRAM
1 Sun		Arrival in Phoenix Orientation, Welcome, and Reception
2 Mon	AM :	Road Deterioration Problem (World Bank)
	PM :	Programming and Budgeting for Maintenance (World Bank)
3 Tues	AM :	Principles of MMS
	PM :	Microcomputers Software & Hardware
4 Wed	AM :	Principles of MMS (cont.)
	PM :	Case Study (Part I)
5 Thu	AM :	Principles of PMS
	PM :	Case Study (Part II)
6 Fri	AM :	Principles of PMS (cont.)
	PM :	Demos and Possible Hands-on for RTIM II and HDM III
7 Sat	AM :	Case Study (Part III)
	PM :	FREE Time
8 Sun	FREE TIME	
9 Mon	AM :	Equipment Management Systems
	PM :	Visit a local agency to review their Equipment Management System
10 Tues	AM :	Tutorials on Equipment Management
	PM :	Case Study (Part IV)
11 Wed	AM :	ADOT Field Trip
	PM :	Drive to Grand Canyon
12 Thu	AM :	Strategic Role of Training Case Study
	PM :	IRF Training Tapes and Technology Transfer in Practice
13 Fri	AM :	Case Study Presentations
	PM :	Conference Conclusion
14 Sat	RETURN TO PHOENIX	
15 Sun	DEPART FROM PHOENIX	

FIGURE 3 Typical IRF executive conference program.

and between groups throughout the exercise are bolstered by the use of computer-aided algorithms based on the Road Transport Investment Model (RTIM2) (*3*), and the Highway Design and Maintenance Model (HDM–III) (*4*).

The Hypothetical Network

The hypothetical network of paved and unpaved roads is shown in Figure 4. It comprises four premix links, each 15 km long; four surface-dressed links, each 30 km long; and eight gravel links, each 45 km long. The paved roads connect the urban center to four major rural centers, which are in turn connected to four minor rural centers by the gravel roads. The rural earth roads shown are not included in the exercise. A detailed survey of the roadside and roadway condition of each paved link is given in the format presented in Table 1. Roughness (mm/km), looseness (mm), rut depth (mm), and gravel thickness (mm) are given for unpaved links. Additional data include classified annual daily traffic (ADT) with growth rates, roadway cross section designs, maintenance criteria, road deterioration relationships, vehicle operating relationships, unit cost items and prices, and sample outputs from RTIM2 and HDM–III to guide the organization of information. However, delegates are not constrained to accept the additional data, if in their judgment the defaults do not adequately reflect their own environmental realities. The network is divided into four districts, as shown in Figure 4.



Source: Maintenance Management Case Study (ref.2)

FIGURE 4 Hypothetical trunk road network.

Conduct of the Case

The case develops along the lines of the maintenance management cycle, in four exercises, as follows:

- Exercise 1: Setting environments and initialization.
- Exercise 2: Determination of maintenance requirements.
- Exercise 3: Estimation of resource and budget requirements.
- Exercise 4: Balancing maintenance requirements with budget allocations.

The relationship of the exercises to the maintenance management cycle is shown in Figure 5.

Each group is assigned a district network for which it analyzes the conditions and sets forth a program both for restoration and maintenance thereafter. Exercise 1, which emphasizes the importance of inventory, condition assessment, and data base initialization, includes the following:

- Determination of rise and fall of each link;
- Road roughness values;
- Rainfall, temperature, and duration of the rainy seasons;
- Roadway cross sections, CBR values, and structural numbers;
- Maintenance criteria and performance standards;
- Traffic distribution by vehicle type;
- Unit costs of labor, equipment and material, as well as tasks; and
- Overhead costs.

Exercises 2 and 3 emphasize the concept that the objective of maintenance is to minimize the sum of maintenance agency and user costs. This requires an optimization procedure, even

TABLE 1 TYPICAL ROADWAY CONDITION SURVEY

PAVED ROAD - ROUTE 1

KM	LEFT SIDE					PAVEMENT				RIGHT SIDE				
	DITCH		SHOULDER			Pot-	Crack-	Rut	Rough-		SHOULDER		DITCH	
	Type	Cond.	Type	Cond.	EDGE	Holes	ing	Depth	ness	EDGE	Type	Cond.	Type	Cond.
0 - 5	Gr	P	E	F	F	N	S	N	F	F	E	F	Gr	P
5 - 10	Gr	P	B	F	F	N	S	N	F	F	E	P	Gr	P
10 - 15	-	-	B	F	F	S	S	S	F	F	E	P	E	P
15 - 20	-	-	B	P	P	S	S	S	F	P	B	P	-	-
20 - 25	Gr	P	B/E	P	F	S	M/X	N	F	F	B	P	E	F
25 - 30	Gr	P	B	P	F	S	P	N	F	F	B	P	Gr	P
30 - 35	Gr	P	B	P	P	N	N	N	F	F	B	P	-	-
35 - 40	-	-	B/E	F/P	F	S	M/X	S/M	F	F	B/E	F/P	-	-
40 - 45	-	-	B	F	F	M	S	N	F	F/P	B	F	-	-

Source: Maintenance Management Case Study (ref. 2)

Legend:

Type: Gr = grass; E = earth; GV = gravel; B = bituminous; Dash (-) = non-existent

Condition: X = extensive; M = much / many; N = none; S = some

Roughness: G = good; F = fair; P = poor

if it is a heuristic one, as in the case where Exercises 2 and 3 are iterated. Exercise 2, determination of maintenance requirements, consists of two parts: restoration works (based on initial physical condition) and normal maintenance requirements (based on the interaction of vehicle usage and roadway characteristics). Exercise 2 includes estimates of the following:

- Restoration works, e.g., pothole filling and ditch lining;
- Routine maintenance requirements for Year 1 and subsequent years up to a 5-year projection;
- Increase in roughness for different maintenance strategies, e.g., 100 percent patching;
- Roughness progression of unpaved roads;
- Extent of periodic maintenance required, i.e., surface dressing, overlay, or regraveling;
- Vehicle operating costs for different levels of maintenance.

In Exercise 3, estimates of resource and budget requirements for the routine and periodic maintenance options identified in Exercise 2 are made. Between Exercises 2 and 3, delegates arrive at an optimum maintenance plan with the lowest total cost of maintenance and vehicle operation. The optimum maintenance plan is the basis for the budgetary request.

Exercise 4, balancing maintenance requirements with budget allocations, introduces the reality of limited budgets, and the effect on maintenance requirements that would yield the lowest user costs. Exercise 4 includes the following:

- Determination of priorities for recurrent and periodic maintenance in which all restorative and routine maintenance is assumed to be carried out;
- Allocation of budgeted funds to minimize the escalation in vehicle operating costs above the optimum; and
- Consideration of a do-something approach on all the maintenance requirements determined in Exercise 2

By assuming that the planned maintenance is carried out, completion of Exercise 4 sets the conditions for the beginning of Exercise 1 in the following years, using appropriate road deterioration relationships as surrogates for inspection and monitoring (Figure 5).

The coordinators work closely with the groups during the conduct of the case, providing individual and customized attention to the delegates, and tutoring when necessary. Computer-aided methodologies are available and their use is encouraged, while the conference lectures, notes, and text (*1*) provide conceptual and contextual reference. Through this close liaison between conference coordinators and delegates, the real technology training and transfer takes place.

Microcomputer Applications

For many delegates, the executive conference offers the first opportunity for hands-on experience with the computer. Computers and their utility as an effective tool in decision making are therefore introduced on the second day of the conference,

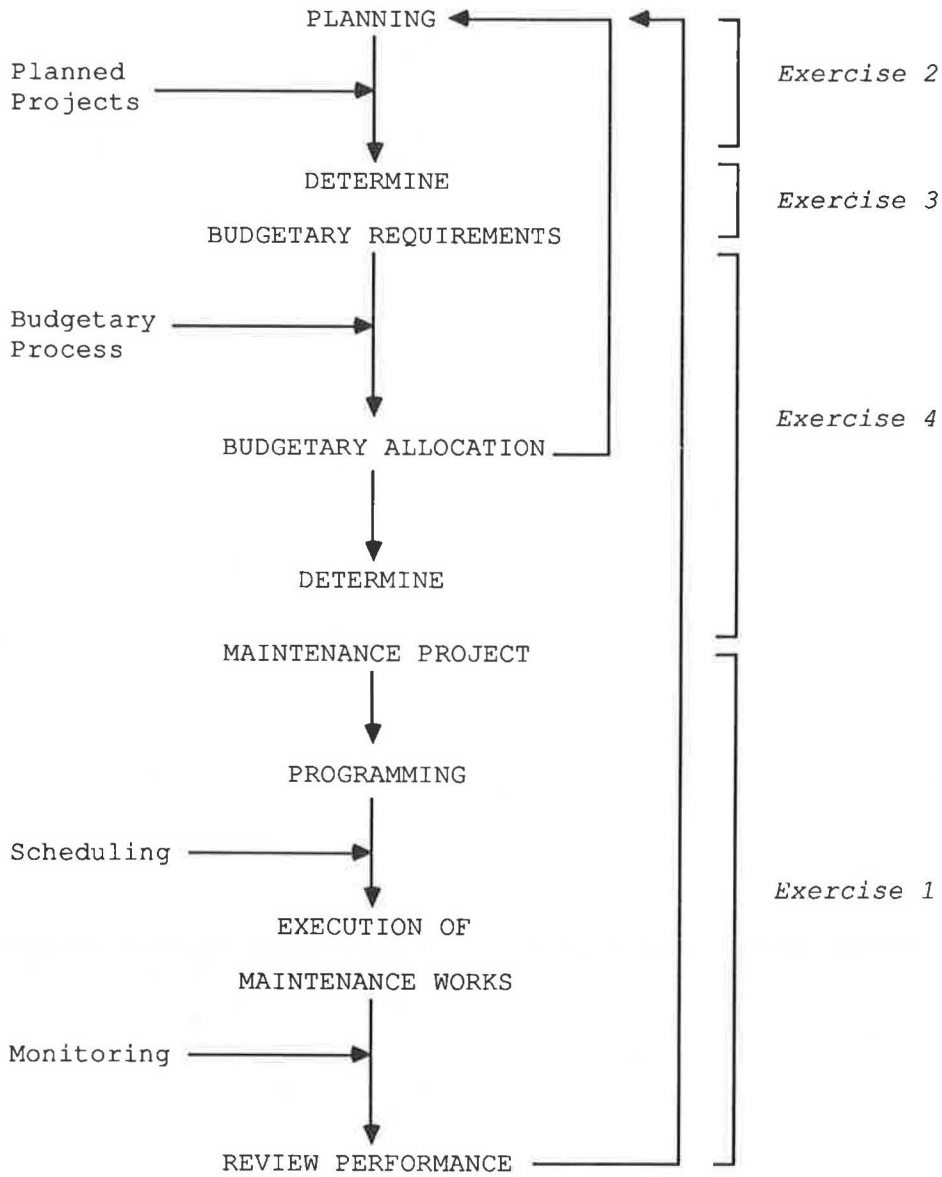


FIGURE 5 Relationship of case study exercises to maintenance management cycle.

and thereafter integrated into the presentation of all subsequent lectures and tutorial exercises. For the case study exercises that parallel the lectures, one laptop microcomputer is made available to each group, with RTIM2 and HDM–III in formats modified for enhanced user friendliness. For example, data input for RTIM2 is organized in frames as a supplement to the tutorial format in which the program is organized; the vehicle operating cost (VOC) submodel and the road deterioration submodel of HDM–III are separately provided and can be used independently, and in many ways more effectively, to solidify the concept of heuristic optimization in Exercises 2 and 3. For both models, the entire network is initialized with a default set of assumptions, some or all of which the delegates may alter to fit their own conditions. Each country delegation receives the HDM–III software and documentation, and many make disk copies of the coded networks and current solutions to continue the exercise on their return home.

The emphasis is on decision making rather than computer dexterity. As such, the case study manual (*2*) contains extensive appendices with mathematized and graphical relationships for road deterioration and VOCs. The exercises can therefore be calculator assisted, and in fact the conduct of the case insists that delegates make their initial calculations this way to develop an intuition about the likely results.

Presentation of Budgets

The case culminates in the presentation and defense of a budget by a representative from each group before a budget committee consisting of the conference coordinators, on the

final day of the conference. Following each presentation, members of the group are invited to append their comments; following all the presentations, the groups are then intensively and extensively questioned by the committee and forced to defend their budgets. It does not take long for this conference session to become serious and at times tense, as the roles are acted out, particularly when differences are pointed out between groups, each of whose districts contain the same types and lengths of road. In the end, each group is allowed to question and comment on the others' presentations, and finally the conference coordinators make their own presentation as just one model, emphasizing organization of information and analysis of alternatives. All presentations are supported by visual aids in the form of overhead transparencies.

Clearly, the case study is very much an exercise in making a case. Delegates come to appreciate the necessity to develop and justify maintenance budgets not just in terms of maintenance per se, but also in terms of the benefits of maintenance and the disbenefits of inadequate or deferred maintenance. The optimization process simulated in the exercise heightens the awareness of the idea that a given maintenance budget yields different levels of user benefits, depending on how and when the funds are expended, and establishes for the delegates the existence of an efficiency frontier (5) for maintenance.

DELEGATES' REACTIONS

In breaking the delegates into groups, two main criteria were used: geographical location where similar environmental conditions about the road network in their home countries exist; and group size that would provide maximum interaction to produce a budget to be presented to the budget committee. For example, at the third conference in 1989, 12 countries were represented by 25 delegates, who were divided into six groups. The first group consisted of the four delegates from Saudi Arabia; the second group included three delegates from Kuwait and one from the Yemen Arab Republic; the third group consisted of the three delegates from Pakistan; the fourth group included two delegates from Indonesia and two delegates from Western Samoa; the fifth group included three delegates from Tanzania and one from Kenya; and the sixth group included three delegates from the Philippines, one from Bolivia, one from El Salvador, and one from Venezuela.

In the first exercise, in which the group members attempt to define the sets of environments that describe traffic flow, climate, and roadway characteristics, the delegates are often inquisitive about how the quantity of rainfall and the duration of the rainy season affect the analysis of gravel road maintenance cycles. They begin to realize, through discussions among themselves and with the coordinators, that the assumptions made are essential for the execution of the case study, and that for the same region, road and traffic characteristics may vary substantially.

In the second and third exercises, the delegates are faced with some tough challenges related to developing a first-year maintenance plan, program, and budget. They relate well to the agency cost component of the budget, but feel that the road user cost component may not be of concern. Their rationale tends to be that budget approvals are political in nature, with decision makers being more influenced by agency immediate out-of-pocket cost. It was logical, at this point, to introduce the concept of cost trade-off between the agency costs (construction and maintenance costs) and the road user costs. The cost maintenance strategy diagram that shows the maintenance cost curve, the road user cost curve, and the total cost curve is shown in Figure 6.

During the course of 5-year budget estimation, the delegates are confronted with the complication and time consumption of road user cost calculations. Furthermore, to simulate a 5-year road deterioration process, one would need several weeks of manual calculations to successfully accomplish this task. The delegates are then provided with microcomputer systems applications for road deterioration and user cost. To their surprise, they discover that they can execute several simulations in a matter of minutes.

Each group presents its budget request, putting forward the assumptions made and its requirements for the first year and the next 5 years. After the presentations, the chairman of the budget committee informs the delegates that because of the budget constraints, their requests cannot be fully met, and they are asked to revise their recommendations to fit a specific budget figure. The group members then go back to the drawing board to come up with their adjusted 5-year programs. This process of deliberation and program adjustment brings the case study to its culmination whereby the delegates hone their understanding of the dimensions of programming and budgeting of road maintenance.

In addition to observations made by the case study coordinators, the delegates provide some remarks on the evaluation forms of the conference. Comments range from the importance of the conference in which they have participated to the usefulness of the information gained and readily applicable in practice. One delegate suggested that implementation of a road management system involving social costs and user costs augured well for the future in his country, while another delegate felt confident that he would now be able to argue effectively for an adequate maintenance budget. Certainly, the question of budget preoccupies managers and it is gratifying to note that delegates have been overwhelming in their

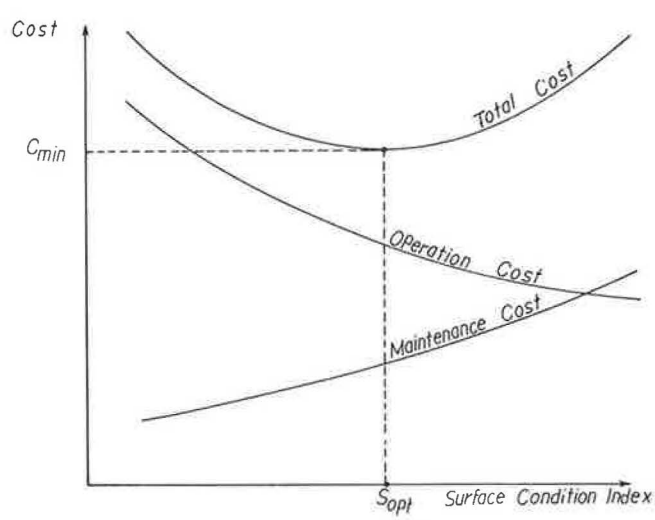


FIGURE 6 Maintenance cost strategy diagram.

expressions of the sentiment that the focus of the case study on budget preparation and defense is both well placed and effectively conducted. This tone is well captured in the following two remarks, among many, by delegates to the Third Executive Conference, which were published in the IRF World Highways newsletter and African Review (*6,7*):

> My job is preparing the annual budgets for the Ministry. Previously, I didn't think maintenance was very important, but now I think it is perhaps more important for us than construction or design. I can now discuss these procedures intelligently and explain to administrators that maintenance budgets can't be cut.
>
> This is one of the most profoundly important conferences that I have been involved in. In almost all countries, the main challenge is getting a better budget. One of my biggest problems is that I don't know what the actual highway user costs and agency operating costs are. When I have submitted proposed budgets, and have been asked what the ramifications are if I don't get the money, I haven't been able to give informed answers. Now, using the models we have developed here, I can tell the budget administrators and legislators just what it will cost the nation if we don't spend the money on maintenance.

CONCLUSION

The exit surveys of delegates to the IRF executive conferences on road management verify that the case study approach is an effective way to train personnel in maintenance management technology. In particular, by conducting the case in groups, it improves teamwork; by emphasizing submission of a budget as a major output, it improves presentation skills and capabilities of the delegates; and by a close and continuous liaison between conference coordinators and delegates, technology transfer is virtually ensured.

An on-the-job survey must still be done to finally and definitively verify the effectiveness of the case study approach. In the meantime, the conferences continue to be well subscribed, with the majority of delegates belonging to multiple delegations, representing countries that have subscribed to the program every year. A telling feature of the conference is that every year since the first one, there have been repeat delegates, a testimony indeed to the continuously evolving dynamism of the program.

Finally, the fact that to date no group has ever accepted the default conditions presented, though this would be the easiest course, is perhaps the most gratifying aspect of the exercise. Not only has it led to unique cases that cause interesting dialog, but it demonstrates how the case study approach can be instrumental in helping delegates to focus on their real problems, and also eases the process of immediate implementation on their return home.

ACKNOWLEDGMENT

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