Management of Irrigation Systems Maintenance: Desirable Levels, Estimated Cost, and Institutional Requirements Based on a Case Study in Sri Lanka

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INTRODUCTION

SRI LANKA IS an island nation situated in the Indian Ocean between 6° and 10° north of the equator with a gross land area of about 25,000 square miles. The island receives most of its rainfall from the northeast and southwest monsoons. Due to the characteristics of the topography and the monsoons nearly two thirds of the land called the dry zone receives an average annual rainfall ranging from 35 to 75 inches. The rest of the land located in the southwest of the island receives an average annual rainfall in excess of 75 inches and is referred to as the wet zone.

The lack of significant mineral resources makes it necessary for Sri Lanka to depend primarily on its agriculture for the sustenance of the population of about 15.6 million. Great emphasis is placed on the increased production of rice, which forms the staple diet of the population. The wet zone produces most of the exportable agricultural crops. The distribution of rainfall being inadequate, irrigation is necessary for the cultivation of rice in the dry zone.

Sri Lanka's ancient history records a civilization based on a highly developed irrigation system. From early historic times -- 6th century B.C. until the 13th century -- the social, political, and economic activities of the island were located in the dry zone. The large number of ancient reservoirs, diversion weirs, and extensive irrigation canal systems bear testimony to the thriving economy of an agrarian society. The subsequent interference by external forces caused these systems to collapse and allowed the jungle to take over.

During ancient times the maintenance of the irrigation schemes was given very high priority by the kings. The management system insured the active participation of the farmers in all

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operation and maintenance (O&M) activities. Equitable distribution of the available water to all farmers helped to achieve adequate production of rice to sustain the population. The ancient rock inscription at Kondawattawan stipulated the fines that would be levied on farmers who neglected their responsibilities in the farming activities. This helped to sustain an actively participating farming community in the locality.

In the 1930s the high demand for land in the wet zone, due to increasing population, created a need to go back to the dry zone. Restoration of abandoned ancient irrigation works for new settlements was started at this time, to shift the excess population in the wet zone to the dry zone. This is the birth of the modern era of irrigation development in Sri Lanka.

The approximate extent of land cultivated under rice at present is about 1,850,000 acres of which approximately 865,000 acres are covered by major irrigation schemes while about 430,000 acres are being fed by minor irrigation schemes. Out of the total land area under irrigation at present, about 740,000 acres are managed by the Irrigation Department (ID) of Sri Lanka while 125,000 acres are managed by the Mahaweli Authority of Sri Lanka (MASL) and 430,000 acres in minor irrigation schemes (each less than 200 acres of irrigable area) by the Department of Agrarian Services (DAS). The ID manages all schemes irrigating over 200 acres up to a maximum of 110,000 acres except those falling within the area of authority of the Mahaweli Authority of Sri Lanka (MASL).

In order to improve and sustain the living standards of the people in Sri Lanka, the government lays great emphasis on the development of rice cultivation under irrigation. Hence, the agencies managing irrigation schemes have as their main objective the achievement of increased production.

In order to increase production further which is essential due to the growth in population there are two possibilities, namely,

* increasing production from existing irrigation schemes, and
* developing new lands under irrigation.

Since most of the land and water resources available for irrigated agriculture are already developed the feasibility of developing economically viable new irrigation schemes is rather limited. Therefore, the present policy of the government is to emphasize the need to increase production from the existing systems. Considering all relevant facts this is a more attractive and economically viable proposition. However, the achievement in this direction depends on the rehabilitation of most of the irrigation schemes to a level where it becomes possible for the farmers to obtain the best possible production from their lands and then the adaptation of adequate O&M measures to sustain the level of production.

Most of the infrastructure in irrigation schemes has deteriorated gradually over the past years due to inadequate maintenance. This has been due mainly to the lack of adequate funds, poor management of resources, and inadequate cooperation of the farmers.

The major part of the lands in the irrigation schemes is state-owned and the size of a farm is about 2.5 acres. The irrigation distribution system has to provide the required irrigation water to each of these farms individually and therefore the network of canals in many schemes is very long and intricate. The efficient O&M of the canal network is an essential task which needs a highly efficient management system to optimize the use of limited available resources. Undoubtedly,

this is a perquisite for Sri Lanka to achieve the objective of increasing production of rice to meet the increasing demands under existing resource constraints.

BACKGROUND TO THE CASE STUDY

Several studies have been done by agencies such as the International Irrigation Management Institute (IIMI) for the purpose of identifying the existing constraints and finding feasible solutions to improve the performance of irrigation schemes. At the same time a number of major irrigation schemes are being rehabilitated with financial assistance from donor countries and international lending agencies.

Donor agencies financing rehabilitation programs are, quite rightly, concerned about continuity of adequate maintenance for sustained performance of the rehabilitated schemes.

Under the Irrigation Systems Management Project (ISMP), financed by USAID, a case study is being done at present by TEAMS (Pvt) Ltd., under the direction of IIMI. The theme of this study is to identify a desirable level of O&M of irrigation schemes in order to sustain their efficient functioning after a program of rehabilitation is implemented.

This study consists of 2 phases. Under Phase I, the O&M activities, management system, farmer participation, and utilization of financial and other resources have been studied in two major irrigation schemes in Sri Lanka, namely Giritale Scheme in Polonnaruwa District and Ridi Bendi Ela Scheme in Kurunegala District. This presentation is primarily based on the findings of Phase I of the study and is supported by the conclusions derived from a previous study carried out by TEAMS (Pvt) Ltd. on Procedures on Collection of O&M Fees.

In a reservoir scheme the headworks consists of an earthen dam across a valley to impound the runoff from the catchment, a spill, and one or two sluices. In a diversion scheme a weir with movable gates constructed across a perennial stream and sluices on either bank constitute the headworks.

In the Giritale scheme the reservoir headworks consists of an earthen dam about 1,600 feet long, a spillway and one sluice. The total area irrigated is 6,192 acres. The Giritale scheme impounds the runoff from its own catchment of 10 square miles and in addition, it is supplemented by water diverted through a feeder canal from Elahera - Minneri Yoda Ela which receives water from the Mahaweli System.

The Giritale scheme constructed in 1954 is a land settlement scheme where each farmer has been allocated a rice allotment of 3 acres, and a highland allotment of 1 acre. The main canal is 11 miles long while the total length of distributary channels and field channels is about 30 miles.

The settlers in this scheme have been selected from various parts of the country and therefore the development of a socially cohesive agricultural community is still continuing. This could be a problem facing the promotion of active farmer participation in the management of the scheme.

In the Ridi Bendi Ela scheme a diversion weir on Deduru Oya diverts water into a feeder canal which supplies water to Magalla wewa. Thus, Magalla wewa impounds the supply from its own catchment of 21 square miles in addition to the supplies diverted from Deduru Oya. The total area irrigated by this scheme is 5,087 acres.

The Ridi Bendi Ela scheme can be described as a village expansion scheme because most of the settlers have been selected from villages located close to the scheme. This would be a positive factor for promoting farmer participation in the management of the scheme.

The distribution system in each scheme consists of main canals, distributary channels and field channels.

NATURE OF OPERATION AND MAINTENANCE OF IRRIGATION SYSTEMS

The objective of good O&M is to insure that the farmers are supplied with adequate irrigation water at the proper time, maintaining equity. Irrigated water distribution among farmers is of paramount importance to insure the farmers' confidence in the irrigation system. This will encourage the farmers to take a positive attitude in their farming activities, by improved inputs such as good seed varieties, fertilizer, weed and pest control methods which would result in increased agricultural production.

In order to insure an efficient distribution system, good maintenance is extremely important. But due to the lack of adequate financial allocations during the past years it had been virtually impossible to insure a good level of maintenance. To some extent this constraint can be reduced by adopting improved management of the available resources. Even in spite of these efforts there could be a gap between actual maintenance effected and the actual maintenance required. Therefore, the only available way to bridge this gap is to mobilize the collective efforts of the beneficiary farmers.

The maintenance activities on the headworks of a reservoir scheme can be identified as follows:

* Clearing of shrubs and weeds on embankments;
* Earthwork for filling minor scours and removal of anthills;
* Repairs to rip-rap protection;
* Cleaning and repairing of toe-filters;
* Repairs to concrete works in spill and sluices;
* Repairs to gates, lifting arrangements, and other timber and metal items in spills and sluices;
* Painting and greasing of metal components; and
* Repairing potholes on the road.

On the other hand, the maintenance work on main canals and distributary channels can be identified as follows:

* Clearing weeds, shrubs, and minor jungle along the canal banks;
* Removal of water plants and desilting in canals;

* Repairs to scours on canal banks;
* Repairs to stop seepage losses in canal bunds;
* Repairs to minor depressions on canal banks; and
* Repairs to structures on canals, metal work, gates, U/S and D/S protection works.

According to the practices of the recent past, maintenance of field channels irrigating less than 50 acres is the responsibility of the farmers. However, the concrete structures in these canals are being maintained by the Irrigation Department. Thus, the farmers have to attend to any earthwork on the canal bunds, desilting, weeding, and clearing shrubs.

Furthermore, all roads in the scheme except those along field channels have to be maintained by the Irrigation Department. The items of work involved are:

* Filling scours and potholes;
* Periodic graveling; and
* Weeding and clearing shrubs and minor jungle along the road reservation.

Most of the maintenance work is done by manual labor. In exceptional circumstances light machinery and transport vehicles are used. The employment of manual labor could be on force-account or by employment of contractors.

ANALYSIS OF EXISTING LEVELS OF MAINTENANCE

To study the existing levels of maintenance the consultants collected past data from 1985 to 1989, regarding the items of work done and the expenditure incurred in the two schemes.

The data were collected by:

* Interviewing Range Deputy Directors;
* Interviewing Divisional Irrigation Engineers and Technical Assistants;
* Interviewing other staff in the divisions;
* Interviewing farmers and others in the scheme; and
* From votes, ledgers, and other accounting documents.

Furthermore, the procedures related to Financial Allocation and Estimates for O&M were analyzed in depth. It was found that the request for consolidated fund allocations from the General Treasury consists of two parts.

i. Funds for O & M works in major irrigation schemes to meet expenditure on casual labor wages, transport, materials etc., allocated under the Ministry votes.
ii. Funds for the payment of salaries to permanent work supervisors and laborers in the Irrigation Department engaged in O&M works in major irrigation schemes allocated under the Irrigation Department votes.

Table 1. Summary of allocations.

	1985	1986	1987	1988	1989
1. *Operation and maintenance (IMD)*					
Giritale	420,000	443,000	613,900	450,000	542,870
Ridi Bendi Ela	575,000	537,800	569,200	411,445	589,000
2. *Wages and allowances of works supervisors and laborers on O&M (ID)*					
Giritale	214,700	208,400	216,500	199,400	141,750
Ridi Bendi Ela	124,100	173,000	192,000	141,300	130,000
3. *Farmers' collections*					
Giritale	356,819	462,007	292,095	32,116	-
Ridi Bendi Ela	49,500	78,000	-	19,788	-

Table 2. Summary of estimates.

	1985	1986	1987	1988	1989
a. *O&M under IMD funds*					
Giritale					
Full	1,020,000	1,020,000	1,050,000	1,080,000	1,200,000
Appd	420,000	380,000	595,000	460,350	1,200,000
Ridi Bendi Ela					
Full	830,000	850,000	1,000,000	1,000,000	1,130,000
Appd	950,000	561,300	569,200	400,000	870,000
b. Works supervisors and laborers on O&M under ID funds (The estimates are prepared on the basis of funds actually collected).					
Giritale					
Full	196,152	213,912	217,632	297,852	307,440
Actual	199,152	216,672	220,512	288,336	312,480
Ridi Bendi Ela					
Full	182,704	199,224	202,704	277,212	286,560
Actual	117,400	127,920	130,160	177,928	184,080
c. Maintenance with farmers' collections					
Giritale	295,024	361,478	154,383	-	-
Ridi Bendi Ela	34,650	55,560	-	11,410	-

In addition to the above funds, a fee is collected from farmers at the rate of Rs 100 per acre per annum. Hence there are three sources of funding. The allocation of funds for O&M work of Giritale and Ridi Bendi Ela in terms of the above three sources over the past five years can be summarized as per Table 1 (page 94).

The amount indicated above are on the basis of the initial allocations at the beginning of the year and additional allocations made during the course of the year.

The summary of estimates for O&M over the past five years for Giritale and Ridi Bendi Ela are given in Table 2 (page 94).

It was found that O&M work is generally carried out throughout the year except some special maintenance work that cannot be done during water issues, such as desilting, repairs to structures, etc., which are undertaken during the closed season. Weeding in canal reservations is done, generally, twice a year and priority is given to this item of work particularly within the water-flow section. Desilting, especially at critical locations such as drainage crossings etc., is also carried out on a priority basis. During the course of the year priority maintenance items are identified by the inspecting officials such as the Range Deputy Director, the Irrigation Engineer, the Technical Assistants and the Work Supervisors. Furthermore, on representation received from farmers, directly or through Project Committees, special maintenance works are carried out, depending on the availability of funds. In this manner some of the O&M works are done on a routine basis and some special maintenance is done as priority items during the course of the year. Thus, it would be seen that some O&M works executed are outside the estimates prepared at the beginning of the year.

In the case of maintenance work with farmers' collections, the items to be executed are identified on a priority basis and estimated, and thereafter carried out. When done on force account, there may be some deviations.

The summary of O & M expenditure for Giritale and Ridi Bendi Ela for the last five years can be visualized from Tables 3 and 4.

Table 3. Summary of O&M expenditure.

	1985	1986	1987	1988	1989 (up to June)
Fund					
1. *O&M (IMD)*					
Giritale	466,327	612,634	671,756	467,988	356,223
Ridi Bendi Ela	589,269	586,387	567,562	409,541	312,458
2. *Work supervisors and laborers on O&M (ID)*					
Giritale	199,152	216,672	220,512	288,336	121,680
Ridi Bendi Ela	112,822	154,938	167,983	185,498	98,196
3. *Farmers' collections (maintenance)*					
Giritale	173,536	349,641	191,471		
Ridi Bendi Ela	33,707	47,672	-	4,482	

Table 4. Analysis of expenditure on O&M.

Ridi Bendi Ela (Average expenditure 1985 - 1988)

	ID	*IMD*	*Total*
Operation	100,615 65%	88,893 17%	189,508 27%
Maintenance	-	306,143 57%	306,143 45%
General	54,674 35%	143,153 26%	197,827 28%
	155,289	528,189	693,479

Giritale (Average expenditure 1985 - 1988)

Operation	161,319 70%	15,520 3%	176,829 23%
Maintenance	-	328,866 59%	328,866 42%
General	69,850 30%	210,290 38%	280,140 35%
	236,169	554,676	785,845

From the above it is seen that the Irrigation Department allocation is spent on operation and general charges and IMD allocation is used mainly for maintenance, 59 percent in Giritale and 57 percent in Ridi Bendi Ela. The charging of expenditure between operation and general charges would be rather indistinct. Therefore, if we add up expenditure on operation and general charges this would come to 58 percent in Giritale and 55 percent in Ridi Bendi Ela leaving only 42 percent and 45 percent for maintenance in Giritale and Ridi Bendi Ela, respectively.

The staff employed for O&M under each scheme would be more or less the same in number from 1985 to 1988. However, the expenditure on salaries, traveling etc., would increase due to increased salaries, increments, cost of fuel, vehicle maintenance etc. Therefore, the funds that could be allocated for maintenance would be the balance available after expenditure on operation and general charges. As the allocation got reduced from 1985 to 1988 the expenditure on maintenance has also reduced as seen from Table 5.

This is clearly seen in Ridi Bendi Ela where the expenditure on maintenance has steadily declined in amount as well as in percentage. In 1988, when the allocation was drastically reduced, the steadily increasing operations and general charges had also been reduced. This may be an attempt of the Irrigation Engineer to prune down his O&M staff to try and meet the effects of reduced allocation. But still the main casualty has been maintenance. In the case of Giritale expenditure actually increased from 1985 to 1987 and then in 1988 it went down. But the operation and general costs have steadily increased in amount as well as in percentage. In 1988, the expenditure on maintenance has been drastically reduced.

Table 5. Expenditure on maintenance.

	1985	1986	1987	1988
Giritale				
Total expenditure	665,479	829,306	892,268	756,324
Maintenance	289,987	361,560	406,309	257,608
	44%	44%	45%	35%
Operation and general	375,492	467,746	485,959	498,716
	56%	56%	55%	66%
Ridi Bendi Ela				
	1985	1986	1987	1988
Total expenditure	702,091	741,325	735,455	595,039
Maintenance	380,491	326,396	296,945	220,742
	54%	44%	40%	37%
Operation and general charges	321,600	414,929	438,510	374,297
	46%	56%	60%	63%

Table 6. Analysis of average maintenance expenditure on important items.

Giritale	Rs	Percent
Weeding etc.	131,106	40
Desilting	39,235	12
Earth work	96,976	29
Repairs to structures	46,553	14
Graveling	-	-
Other items	14,966	5
	328,866	100
Ridi Bendi Ela		
Weeding	100,723	32
Desilting	50,451	18
Earthwork	34,598	12
Repairs to structures	62,894	20
Gravel	4,306	2
Other items	47,170	16
	306,142	100

The analysis is revealed that, to get the best out of the O&M allocation there is a need to look closely at the staff employed in O&M and the cost of traveling charged under general charges.

In Giritale 40 percent of the maintenance cost is for weeding and 29 percent for earthwork. Repairs to structures and desilting were only 14 percent and 12 percent. Weeding and earthwork would make the scheme look nice but the low expenditure on desilting and repairs to structures could give problems in water issues.

From the above it is seen that in Ridi Bendi Ela 32 percent of the expenditure is on weeding which should really take a lower priority than other items. Normally priority should be on 1) repairs to structures, 2) desilting, and 3) earthwork on critical sections of channel. These are the essential items to achieve the required water issues and controls of the distributary system.

The observations made from the analysis of expenditure for Ridi Bendi Ela are fairly similar to those of Giritale.

IDENTIFICATION OF "DESIRABLE LEVEL OF MAINTENANCE"

One of the main objectives of this study is to identify the "desirable level of maintenance" of major irrigation schemes. The work was commenced, first, by investigating the notion of desirable level of maintenance in a conceptual form and then by improving such understanding, making use of information gathered from field observations and data collection. For this work the list of questions presented in the original proposal by the consultants was used as a basis.

In order to understand the notion of desirable levels of maintenance the definitions of different levels of O&M were visualized as follows:

No maintenance. After some years of construction/ rehabilitation, canal discharge will be grossly inadequate to meet the cultivation requirements, resulting in continuous crop failures. Also the physical system will deteriorate rapidly to a total collapse. Maintenance cost is nil.

Poor maintenance. To carry out maintenance only at very critical sections. The canals will discharge significantly but still not adequately in the sense of sufficiency and timely distribution. Crop failures are likely as a result of this level of maintenance. Also the physical system will deteriorate badly and will be in need of rehabilitation at frequent intervals to avoid collapse of the system. Maintenance cost is low.

Adequate maintenance. To enable the canals to function at its existing capacity during the particular year under consideration and prevent deterioration at critical locations. At this level crops will not fail. However, significant deterioration of the physical system may take place every year and a full-scale rehabilitation will have to be undertaken after, say, about 10-15 years of construction/rehabilitation. Maintenance cost is medium.

Well-maintained. Well-maintained implies adequate level plus maintenance activities that will prevent significant deterioration. Rehabilitation may not be undertaken full scale for a long time except some selected improvement works. Maintenance cost is high.

Full maintenance. To keep the system at or near its original operating and physical conditions. This is almost a minor rehabilitation each year and no rehabilitation on a full scale will be required during the life span of the scheme. Maintenance cost is very high.

Technical levels are not the only criteria to decide on a "desirable" level. The O&M level should also be economically and institutionally "desirable." Thus, the concept of technically desirable level of O&M irrespective of resource constraints may not be appropriate for analysis under this study.

Immediate costs associated with well-maintained or full-maintenance levels may not be balanced by benefits from such maintenance levels, since there is a time lag between maintenance expenditure and related benefits. The canal system is usually designed and constructed/ rehabilitated to discharge 5 percent to 15 percent more than the requirements for the planned acreage. Hence, even with a low level of maintenance with the canal sedimented and overgrown with weeds, the canal could discharge the requirement and it takes some years for the canal not to discharge the required quantity. Even with slightly lesser discharge, the crop yields may not decrease significantly.

Even with the last two levels of maintenance some deterioration is inevitable. Further, the irrigation system is of a dynamic nature with new concepts of water management, agro-technical methods, changing ideas and policies, and sophistication of operation procedures, etc.

Thus, maintenance levels to keep a system at or near its original operating and physical conditions are not feasible. A lower level of maintenance (causing a certain degree of deterioration) and periodic rehabilitation will be "desirable" economically. In addition to the technical aspects and consideration of the dynamic nature of the system, the economics of different levels of maintenance, that is low-cost of low-maintenance level together with high-cost of full-scale rehabilitation, versus high-cost of higher-maintenance level coupled with low-rehabilitation cost, should be analyzed to determine the best level of maintenance to be adopted.

As mentioned earlier, the study commenced with a theoretical notion of "desirable level" of maintenance. This understanding was eventually updated based on the observations gained from the investigations carried out in Giritale and Ridi Bendi Ela. The views of the consultants are given here.

The "desirable level" of O&M can be defined as the level of O&M which satisfies the following criteria:

* The technical needs of the schemes;
* Economical viability; and
* The needs of the farmers and the level of O&M which are therefore socially acceptable.

We have given definitions of five levels of O&M beginning with the case of "no maintenance" and increasing upto a level of "full maintenance." Since these two can be considered as the two extremes the "desirable level" of maintenance should be between these two levels.

In selecting a "desirable level" we have to be realistic as far as possible to the existing circumstances and therefore the selection criteria should not be purely theoretical. However, as we have used the word "desirable" to define this level we need not be concerned too much with the existing constraints, in particular the finances. Therefore, the selection should be guided by experience and sound judgment.

To understand what the technical needs are that should be satisfied, it is necessary to look at what is the main function of the system. In short, it can be said that the basic function of an irrigation scheme is to store and divert the natural flow of a river/stream to farmers' land as required. If the various components of the scheme, namely headworks, main canals, branch canals, distributary channels and field channels can be made to function as expected above, then the scheme satisfies the basic technical needs.

In going through the various levels of O&M defined earlier we see that the definition of "adequate maintenance" just reaches this level. We see that "well-maintained" will give a

greater degree of confidence. But considering the realities of financing we should not desire too much. The "desirable level" is person-specific. We try to convince the persons concerned to accept this as an acceptable definition.

Under "adequate maintenance" it is stated: "To enable the canals to function at its existing capacity during the particular year under consideration and prevent deterioration at critical locations." Thus, under this level of maintenance the canal should continue to discharge the required volume of water as a continuation of the previous years' level of functioning. However, certain components of the scheme will deteriorate but such level of deterioration would be confined to safety margins already built into the system. The level in canal bunds would reduce during the year; minor defects in structures, such as cracks and scours may occur. Roads would start settling and potholes would begin to appear. However, critical items would be repaired and kept functional. Over a number of years the defects above would accumulate and gradually the scheme will degrade, maybe in 10-15 years, to a state when rehabilitation would become necessary.

The amount of funds required to maintain the scheme at "adequate level" would be different from location to location and according to how well the scheme was originally designed and constructed. Hence, it is not possible to give a definite period for the rehabilitation cycle. Even to arrive at the period of rehabilitation cycle for a particular scheme it would be necessary to monitor the expenditure, physical work done, discharges in canals, and other relevant data for about 10 years. It is improbable that reliable data for such an analysis are available for any irrigation scheme in Sri Lanka.

To satisfy the second criterion for the "desirable level" of maintenance, it is necessary to establish the economic viability of adopting the "adequate level" of maintenance. In economic terms, desirable level of maintenance is the level which maximizes the net present value of the future benefit/cost streams at the current "social rate of discount."

The technically desirable level has been defined as a level of maintenance which will permit adequate performance of the system for a reasonable period before rehabilitation. Economically desirable level on the other hand, is based on the technical relationship between the economic costs and benefits attached to alternative technically acceptable maintenance regimes.

This requires the identification of the intertemporal (over time) relationship between costs and benefits for technically acceptable alternative maintenance regimes.

The information required is:

a. the effect of each alternative regime on project life from construction to rehabilitation.
b. the annual project benefits over the time span (which varies according to the maintenance regime from construction to rehabilitation). This recognizes the fact that project performance deteriorates for any conceivable maintenance regime. In other words, the life span of a man-made artifact or for that matter any material thing is finite.
c. shadow prices for all quantified costs and benefits as at the date of analysis expressed preferably at the midpoint of project life.

The social-institutional point of view is determined by what the society and the institutions can sustain over time. This can differ from the technically and economically desirable level.

Costs which appear to be economically justified may not be feasible from socio-political and institutional points of view. The growing literature on O&M fee collection bears ample witness to this point.

The economic methodology to determine the desirable level of maintenance of any major irrigation scheme needs a careful analysis of a number of factors affecting an irrigation scheme.

The approach with the highest level of theoretical soundness and analytical rigor has been described earlier.

In spite of the great deal of effort applied on information-gathering in our study, it became apparent that a "first best" approach of the type discussed is not feasible with given information, time, and other resource constraints. Hence, a "second or third best" approach has to be used.

If time and other resources were available, and O&M problems could await findings of a "first best" approach solution, then the answer is to carefully monitor several selected schemes for a long period. This, clearly is not an available option.

The other acceptable means of constructing the benefit/cost relationship over time is to select a number of irrigation schemes which represent different stages of a typical scheme over the economic life from construction to rehabilitation. The greatest challenge here is to abstract from problems of location specificity. Thus, the accumulated experience of irrigation engineers will have to be relied upon to select schemes which have more or less similar design, command area, natural environment, and socioeconomic environment.

Then information-gathering can commence in a scheme just constructed, another midway in the cycle, another "just-before" rehabilitation, and finally a scheme which has just been rehabilitated.

Thus, it will be possible to determine whether the present O&M regime (average) is economical. However, the selection of an optimum regime would require educated guesses. The difficulty here is in judging what changes are brought about by incremental changes in the O&M regime.

Yet another possibility is to develop a theoretical model which relates O&M costs into known, measurable variables and then statistically estimate the coefficient of the independent variables of that functional relationship. Apart from the derivation of the functional relationship by theoretical means, this involves the generation of data on the relevant variables from a sufficiently large sample of irrigation schemes.

This is an option discussed at length by the consultants, but discarded due to measurement problems and the prohibitively high resource requirements of such an exercise to cover the necessary observations' number which will give the required degrees of freedom for statistical estimation. Another major problem is location specificity and the large number of environmental variables which affect the performance of irrigation projects.

Considering the facts discussed above it may not be possible to determine accurately the economically desirable level of maintenance.

The third criterion to be discussed is the acceptance of this level of maintenance by the farmers. It can be stated that the farmer is mostly concerned with the availability of water in his allotment to carry out his agricultural activities to his satisfaction. For this purpose the distribution system must deliver water to his farm in adequate quantity at the proper time. If this function could continue year after year he would have confidence in the irrigation system.

This is a basic need for him to give his best efforts and investments to the cultivation and the result would be an optimal level of production. If the level of maintenance defined as "adequate" could satisfy this need during a rehabilitation cycle then we can assume the farmer would be satisfied with the system and therefore it would be socially acceptable.

The above analysis for the purpose of establishing that the "adequate level" of maintenance can be considered as the "desirable level" of maintenance, has given positive responses in two of the three criteria stated earlier. The second criterion is accurately indeterminate under the present study. Since, according to this analysis, two of the criteria are satisfied, it is recommended that the "adequate level" of maintenance be accepted as the "desirable level" of maintenance.

INSTITUTIONAL STRENGTHS AND WEAKNESSES

The present study clearly indicates that the actual level of maintenance is far below the adequate level and the main difficulty in achieving the desirable maintenance is due to restrictions in obtaining necessary financial resources. It was also found that the only possible improvement in this direction is to increase institutional strengths while minimizing the present weaknesses so that the limited funds can be utilized in a more productive form.

In trying to comprehend the institutional strengths and weaknesses relevant to operation and maintenance (O&M) of major irrigation systems two major dimensions, namely: (i) state dominated irrigation management system and (ii) the role of farmers as "users" of irrigation systems need to be embraced.

The study revealed that the existing state-dominated irrigation management system works greatly with central control while aiming to insure uniformity at national level. As a result, the importance given to implementing maintenance programs of a project in the light of its specific needs is inadequate. The existing management system is too much concerned about maintaining its accountability to the Treasury and to the Auditor General rather than about the effectiveness of the programs to be implemented.

It is evident that in actual practice the estimates of O&M are made only for the purpose of "requesting and granting" an allocation without reflecting a plan of action based on real needs. In actual fact in the two schemes which were studied in detail, there is no connection between estimates and expenditure.

Furthermore, the management system at present has failed to concentrate on maintenance programs in terms of priorities of the specific schemes. The major portion of the budget is being spent on weeding and earthwork even though the priority area is the maintenance of the structures.

The existing monitoring mechanisms for allocation of funds, their readjustment, and appropriate use of such limited funds are inadequate. Such poor monitoring coupled with cutbacks of allocations not only reduces the efficiency and effectiveness of maintenance programs but deteriorates the motivation and confidence among farmers and officials. Also the present management system seems to measure its performance mostly in terms of allocation received rather than the achievements made in terms of spending money productively while creating benefits for the farmers. Perhaps, the time has arrived in these terms for the officials to recognize

that the efficiency of the organization and management is as important as receiving funds for O&M works.

The study concludes that the present management control system heavily depends on its bureaucratic institutional framework which is being operated at the consumption of a fairly high percentage of limited funds available for maintenance of irrigation systems. It was found that the bureaucratic system is ineffective due to staff inefficiency and lack of vigor in action-oriented management.

The active participation of the farmers is essential for the efficient management of any irrigation scheme. During the past few years an explicit attempt has been made to mobilize farmers' participation as well as the integration of the services rendered by various government and semigovernment organizations involved in irrigated agriculture. The Programme for the Integrated Management of Major Irrigation System (INMAS) started by the Irrigation Management Division (IMD) of the Ministry of Lands, Irrigation and Mahaweli Development has this objective in its primary function. This program was started in 1984 and a high degree of success has been achieved in this direction.

The irrigation systems used for the present case study (i.e., Giritale and Ridi Bendi Ela) are both covered by the Irrigation Systems Management Project (ISMP) which can be considered as a further development in the direction of institution-building initiated by the INMAS Programme. Specially, in another study carried out by TEAMS (Pvt) Ltd. and financed by the USAID/IIMI, it was found that the institution-building at subproject level and field-channel level is taking place quite positively. Certainly these developments will have a tremendous effect in the direction of efficient management of O&M while ascertaining farmer participation which can reduce cost.

With the commencement of the INMAS Programme the government decided in 1984 that the cost of O&M of irrigation schemes larger than 200 acres should be paid for by the farmers who are the beneficiaries. This cost is estimated at Rs 200 per acre per annum (1982). The balance Rs 100 should be paid by the farmers at the initial stage. According to this formula, gradually the contributions by the government will decrease in steps of Rs 20 per year and correspondingly the farmers' contribution will increase.

The collection of this fund has been implemented from 1984 in 17 of the 24 districts in Sri Lanka. These 17 districts are in the dry zone of the country which constitutes the area where most of the major irrigation schemes exist. The level of collection of funds from the farmers has gradually faded out and hence the overall outcome is a failure.

Recently, the government decided not to collect this fund from farmers in schemes less than 200 ha as they are considered too small to warrant the effort of collection. In these schemes farmers are encouraged to maintain the distribution system by their own efforts with assistance from the Irrigation Department.

Another decision taken recently is to limit the farmers' contribution to Rs 100 per 0.4 ha per annum for those cultivating two seasons a year and Rs 60 per 0.4 ha per annum for those cultivating one season per year. The decision to increase 20 percent per year as decided earlier is suspended for the present. This was done to give some relief to the farmers and also to allow them sometime to get used to the idea of contributing to the O&M fund.

The experience gained from a number of studies undertaken by TEAMS clearly indicates that what is more important in this direction is to determine ways and means of insuring user support in the management of O&M activities rather than searching tactics to ascertain farmer contribution to the O&M fund. The achievement initiated by the INMAS Programme and exemplified by

the ISM Project are rewarding steps in this direction, even though these innovations are yet to be improved.

The execution of O&M activities as a joint-management venture between farmers' organizations and state institutions can reduce cost and hence will facilitate O&M work. Also the 'user support' for such joint management of O&M activities will create a feeling among farmers that the irrigation system is 'theirs' and hence it should be looked after. This is an important preventive maintenance measure quintessential in an effective O&M strategy.