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MONITORING OPERATIONS PERFORMANCE IN LARGE-SCALE PUBLIC IRRIGATION SYSTEMS IN INDONESIA[1]

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ABSTRACT: Different allocation and delivery performance ratios are used to assess operations performance in a large scale public irrigation system in Indonesia. Results from this analysis indicate that field management practices deviate substantially from the official operating procedures. The lack of application of a single, standardized procedure for planning water allocations represents a serious constraint to effective monitoring and evaluating system performance. Underestimated and unrealistic planned allocations becomes the justification for overdiversion of water, and has the effect of undermining the resolve of managers to see to it that actual flows meet planned flows.

Miscalculating planned allocations, poor matches between planned flows and actual deliveries, overdiversion and misreporting have economic consequences as well. For example, strict adherence to the standard operating rule during the second dry season of 1987 would have resulted in 19,070,000 m^3 less water diverted into the irrigation system from the Brantas River or, at a conservative estimate of $1.78 per 100 m^3 water, a savings of $339,500. Scope exists for making improvements in management by closer adherence to the standard delivery rule, which will also facilitate proper monitoring and evaluation.

(KEY TERMS: water management; irrigation; simulation modeling; distribution rule; operating procedures; Indonesia.)

INTRODUCTION

Despite the high priority and the massive resources committed to irrigation development in the developing countries, the general consensus is that performance of large public irrigation systems has fallen far short of expectations (Repetto, 1986; Svendsen *et al.*, 1983). Important performance measures, such as acreage irrigated, yield increase, and overall efficiency, are typically lower than projected when investments were made. Other indications of inadequate performance include water availability, differences between head- and tail-end regions of a system, failure of benefits to reach targeted groups, low cost recovery percentages, and, in some areas, resulting waterlogging and soil salinity problems.

Inadequate operations and maintenance (O&M) has significantly reduced the benefits of large public irrigation systems (GAO, 1983; Svendsen *et al.*, 1983). It is projected that O&M problems are likely to become more severe in the future. They will also become more complex because of continued expansion of irrigated area and increasing inability of most developing countries to finance recurrent costs of rapid irrigation expansion programs (McLoughlin, 1988).

Many donors believe the greatest potential for increased agricultural production lies in reorganizing, rehabilitating, modernizing, and improving management for existing irrigation networks. This is based on sound economic reasoning; returns to good O&M can be expected, because once a project is operational, capital costs are regarded as sunk costs, and all net returns can, therefore, be attributed to O&M expenditures. Unfortunately, water allocation – one of the crucial aspects of O&M – is an astonishingly neglected area of research, despite its high potential payoff (Bottrall, 1981).

In the case of Indonesia, decreased dependency on food crop imports, especially rice, was a major objective in the Indonesian Government's emphasis on investment in agriculture during the 70s and early 80s. Large increases in crop production were achieved through adoption of modern high yielding rice varieties (HYVs), expanded use of fertilizers, weed and pest control, and investments in government irrigation systems, with top priority given to the country's irrigation infrastructure. It is estimated that over 14 billion dollars have been invested in construction and

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rehabilitation of irrigation systems in Indonesia during the past 25 years (Johnson and Vermillion, 1987).

However, returns to irrigation investments have not been as high as expected. Consequently, the Government of Indonesia has recognized that greater attention must be paid to improved management performance in order to realize the full potential of existing irrigation systems (Directorate of Irrigation I, 1986). Having achieved self-sufficiency in rice, the government must continue to sustain a steady growth in rice production in order to keep ahead of population growth (in excess of 2.1 percent per year). With limited scope left for new development of irrigation land (especially on Java, the most populous island), the government is striving to protect past investments through improved O&M of existing irrigation infrastructure. Large potential payoffs justify exploring new management strategies that will improve the operational efficiency of these systems.

The objective of this study is to evaluate the current status of irrigation system performance in Indonesia, identifying management constraints which limit the returns to earlier investments. Results obtained provide a basis for making recommendations to provincial irrigation services for improved management strategies as well as effective implementation of current operating procedures. This study presents a practical methodology for monitoring operations performance in public irrigation systems throughout Asia. Data are drawn from a large-scale public irrigation system in East Java.

ASSESSING IRRIGATION PERFORMANCE

In a recent article Svendsen and Small (1990) state that: (1) confusion about the actual extent of the irrigation system, (2) what aspects of performance should be assessed, (3) the standards with which to judge performance, and (4) confusion about the actual audience for the results makes it very difficult to quantitatively analyze irrigation system performance. To clarify the complex gradation between the direct application of water for agronomic purposes, compared to the indirect linkage between the use of water to improve human well-being, they have conceptualized the dichotomy of purposes within a nested means/ends framework. In their framework, a narrow purpose is seen as the means for achieving a specified end, which is the broader purpose within which the narrow purpose is nested. However, even within the narrow, most direct purpose, water distribution has two main dimensions – a technical and a socio dimension. The technical dimension relates to the distribution rule itself, and how effective the current water distribution rule is in securing an optimal match between irrigation water supply and demand (which directly determines the quality of the environment for agricultural production). The socio dimension relates to the capacity and will of system managers to ration water equitably, i.e., on the basis of an explicitly established distribution rule, and resist powerful pressures to misallocate irrigation water (Repetto, 1986).

In its simplest form, operations performance evaluation involves assessing performance and comparing that to deviation from prescribed procedures or from an accepted standard (Svendsen and Small, 1990). Where the established procedures (or more explicitly water distribution rules) are taken as given, improvements in operations performance must occur through increased adherence to the rules. In this case, operations performance depends on how reliably administrators can execute policies and programs determined by the implementation of the distribution rule.

Abernathy (1986) has presented a strong argument for assessing performance in terms of a limited objective, water delivery, rather than the larger objective, agricultural output. He has also argued it is important to examine equity as well as the efficiency of water delivery. Abernathy (1986) has proposed a means of measuring performance. His system, the inter-quartile ratio (IQR), is defined as:

$$IQR = \frac{h75}{h25} \tag{1}$$

where:

h75 = average depth of water received by all land in the best quarter (mm/ha), and

h25 = average depth of water received by all land in the poorest quarter (mm/ha).

An IQR ratio of 1:1 implies complete equity, while an IQR ratio of 4:1 indicates that farmers in the best quarter of the irrigation scheme are receiving four times as much water as farmers in the poorest quarter.

Seckler *et al.* (1988), have proposed a simpler methodology for measuring performance by results. To measure the operation performance level they use the formula presented in Equation (2). Since actual output is divided by planned output, the index is a dimensionless parameter.

$$R = \frac{AO}{PO} + e \tag{2}$$

where:

R = the performance index,
AO = actual output,
PO = planned output, and
e = an acceptable range of error.

Using the relationship between the planned output of the system (as specified by the policy or design objectives) and the actual output obtained from operation of the system, an index of performance is calculated. When $1 - e < R < 1 + e$, the system is operating within acceptable performance limits. This index is one measure of management's performance level in implementing the current water distribution policy. It says nothing about the appropriateness of the given rule in meeting the established policy objectives. The advantage of this method is its generality. Output can be measured in any acceptable unit, such as an index of water flow or area irrigated. Another advantage of this methodology is that intra-system performance comparisons can be made, as can cross-regional or cross-country comparisons.

A similar concept to the above methodology is the Management Performance Ratio (MPR), developed in 1986 and applied by staff members from the International Irrigation Management Institute (IIMI) in Indonesia (Johnson and Vermillion, 1987). The MPR compares actual to planned discharge in the form of a ratio, and thus also represents a dimensionless parameter.

$$MPR = \frac{AD}{PD} + AVR \qquad (3)$$

where:

MPR = management performance ratio,

AD = actual discharge (l/sec),

PD = planned discharge (l/sec, and

AVR = acceptable range of variation around the line where the MPR ratio equals 1.0.

The reader will note that the MPR is actually a special case of the more general management by results methodology. Here, the concept of range of acceptable variation around the MPR in Equation (3), corresponds to "e" in Equation (2). After calculating this relationship using available data, comparisons can be made at main, secondary, and tertiary levels throughout an irrigation system, thus allowing the managing agency to evaluate performance in spatial terms within the system rather than only at system level. This paper uses the MPR concept, but goes deeper and disaggregates the ratio in order to carefully examine the critical components of management performance.

IRRIGATION SYSTEM MANAGEMENT IN INDONESIA

Most Indonesian irrigation systems begin with an off-the-river diversion weir. Daily flow through this structure represents the actual supply available to the system. This supply may be limited by low river flow or because of government restrictions on maximum diversion. Normally, at a diversion weir on the river, water is diverted to a primary canal, and further subdivided into secondary canals, tertiary canals, and quaternary and field channels. Operation of the canal system is governed by a set of rules for allocating and distributing water with the provincial irrigation service (PRIS) responsible for operating and properly maintaining the canal system. Responsibility for water distribution and conveyance maintenance is turned over to farmer water user associations, usually at the tertiary gate.

Warujayeng Irrigation Project (WIP) Site Description

WIP is a run-of-the-river system whose main intake is at Mrican on the Brantas River near Kediri in East Java. It covers an area of approximately 13,500 ha of irrigated rice land. There are two dry seasons. In the first dry season (April-July), the major crop grown is padi rice. Secondary crops, mostly soybeans, represent approximately 25 percent of the cropped area. During the second dry season (July-November), secondary crops predominate, with only a small amount of authorized padi permitted in poorly drained areas. Some unauthorized padi is grown as well, but legally, these rice fields are to receive the same amount of water as secondary crops. Maize and soybeans represent more than 90 percent of the secondary crop area during this season. In addition, sugarcane is an important component of the cropping system, currently occupying 10-15 percent of the project area.

General Allocation Procedures

Indonesian irrigation allocation decisions revolve around the *pasten* concept which describes the relationship between water supply available at the intake gate and turnouts, and water needed by crops at different growth stages (IIMI, 1986). In order to accommodate the dynamics of irrigation management, both supply and demand in Indonesia are usually expressed in units of liter per second (l/sec) or (l/sec/ha); this paper follows that same convention. Demand for water is estimated by using indices of Relative Water Requirements (RWR) for various crops at different growth stages (Table 1). The RWR formula assumes that fields receive their full water requirement. Water demand for each tertiary block is calculated using information on specific crop areas and growth stages (the RWR index) and an assumed canal loss coefficient. Irrigation water demand is summed across all tertiary blocks, taking into account losses from secondary and primary canals. This water quantity represents the total irrigation demand for the system. Total demand is compared with total system supply, and the resulting ratio is used to make decisions about allocation. With plentiful water, i.e., demand does not exceed supply, the system is run with continuous flows. As system supply drops below demand, allocation to each tertiary block is reduced in proportion to the system deficit. As water supplies become critically short, a seven- or ten-day rotation program is introduced. In the WIP area, the program rotates water in order to the areas under jurisdiction of each of the three sub-section managers.

TABLE 1. Per Hectare Water Requirements Relative to a Secondary Water Requirement of 1.0.

Crop	RWR*
Secondary Crops	1.0
Paddy Rice	
Land Preparation	6.0
Transplanting and Vegetative	4.0
Flowering	4.0
Ripening	2.5
Paddy Rice (unauthorized)	1.0
Sugarcane	
Young Cane (< four months)	1.5
Old Cane	0.0
Fallow 0.0	

*A dimensionless value.

Although the *pasten* system originated during the Dutch colonial period, its application has evolved over time. Two major variants of it are currently in use in Indonesia: the Factor-K system used in West and Central Java, and the Relative Non-Rice Crop Factor (FPR) system used in East Java. Compared to the *pasten* method, FPR simplifies the water allocation procedure since it gives the required flow at the turnout gate (versus at the field) where the flow is actually controlled and, therefore, is simpler to administer (IIMI, 1986).

In East Java, estimation of irrigation water requirements at each turnout structure in the WIP follows these procedures. For each 10-day period, an irrigation inspector collects data on specific crop acreage for each tertiary block within his command. This information is provided to him by the respective village water master of each tertiary block. In turn, irrigation inspectors submit this information to the sub-section manager who aggregates the data for all tertiary units served by each diversion point within his sub-section. From this information, he computes the *luas palawija relative* (LPR) value – the total cropped area expressed in hectares of secondary-crop area equivalents where it is assumed that per hectare irrigation water requirements for secondary crops have an index value of 1.0 as 1.0. LPR is calculated using the RWR values listed in Table 1 and is expressed in ha.

LPR for a given teritary block j is equal to the RWR_i per hectare multiplied by the corresponding number of hectares of crop i (A_i), summed across all crop-fields. Formally, for all crops i, this can be written as:

$$LPR_j = \sum_i^n A_i \cdot RWR_i \quad i = 1, \ldots, n, \quad j = 1, \ldots, m \tag{4}$$

where:

n = number of crops,
m = number of blocks, and
LPR_j = relative non-rice crop area (ha).

To illustrate actual application of the technique, data in Table 2 assumes two tertiary blocks, A and B. Block A has 100 ha, 40 ha in rice: 20 ha in land preparation and 20 ha in the vegetative stage, and 60 ha in maize (any stage). Block B also has 100 ha, but has only 10 ha of rice (all vegetative stage), 40 ha of soybean and 50 ha of sugarcane (young). As can be seen, the LPR for Block A is 260 ha and the LPR for Block B is 155 ha. The respective shares for each block are calculated by dividing each block's LPR by the total LPR value for all the blocks. In this way, tertiary block irrigated water shares are calculated for each block in the system for each time period.

Irrigation water demand for tertiary block j then is calculated by multiplying the FPR by the LPR_j, divided by the jth tertiary block conveyance loss factor.

TABLE 2. Relative Crop Factor Method of Calculating Block-Level Irrigation Water Shares.

Crop	Relative Water Requirement	Area (ha)	LPR (ha)	Share of Water (percent)
		FARM A		
Rice				
Land Preparation	6	20	120	
Vegetative Stage	4	20	80	
Maize	1	60	60	
TOTAL		**100**	**260**	**63**
		FARM B		
Rice				
Vegetative Stage	4	10	40	
Soybean	1	40	40	
Sugarcane	1.5	50	75	
TOTAL		**100**	**155**	**37**

Since all of the irrigation systems in Indonesia are operated in l/sec, the units here for Q are in l/sec. This is calculated as:

$$Q_j = \frac{(FPR \cdot LPR_j)}{\left(1 - \frac{TL_j}{100}\right)} \quad j = 1,\ldots, m \qquad (5)$$

where:

m = number of blocks,

Q_j = irrigation demand for block j (l/sec),

FPR = normal secondary-crop irrigation requirement at the turnout (l/sec/ha),

LRP_j = relative secondary crop area in block j (ha), and

TL_j = distribution loss in the jth tertiary block measured in percent.

This same procedure is used on a system level to calculate the total water demand requirement. The total crop water requirement for the entire irrigation system, QD_{sys}, is adjusted for conveyance losses in the secondary (S_L) and primary (P_L) canals.

$$Qd_{sys} = \frac{(FPR \cdot LPR_{sys})}{\left[\left(1 - \frac{T_L}{100}\right) \cdot \left(1 - \frac{S_L}{100}\right) \cdot \left(1 - \frac{P_L}{100}\right)\right]} \qquad (6)$$

where:

T_L = tertiary loss measured in percent.

S_L = secondary canal losses in percent,

P_L = primary canal losses in percent, and

Qd_{sys} = total water demanded for the entire irrigation system (l/sec).

$$LPR_{sys} = \sum_{j=1}^{m} LPR_j \qquad (6a)$$

where:

m = total number of tertiary blocks in the irrigation system.

If system water supply (Q_{sys}) is equal to or greater than system demand, no adjustment factor to the normal FPR values is necessary. Normal FPR values are rated according to the dominant soil texture in the system as follows: FPR for heavy soil = 0.12 l/sec/ha; FPR for medium soil = 0.24 l/sec/ha; and FPR for light soil = 0.36 l/sec/ha).

Normal FPR used by PRIS at Warujayeng is based on a light textured soil (SEC, 1985), and thus, under a balanced water supply-demand situation, the appropriate FPR would be 0.36. In other words, each ha of secondary crop in the system is designated to receive 0.36 l/sec/ha of irrigation water with the water received as continuous flow. As supplies diminish in relation to demand, a system-deficit adjustment factor is added to the equation. This adjustment factor, usually known as the "K value," is simply the ratio of expected system supply to system demand. The normal requirement for each secondary reach is multiplied by the K value, and this guarantees, at least in principle, proportionate reductions to all secondary and tertiary units in line with the overall system deficit. Sub-section managers determine the planned flow to each secondary reach in their jurisdiction according to Equation (7).

$$Q_{sec}(planned) = \frac{K \cdot (FPR \cdot LRP_{sec})}{\left[\left(1 - \frac{T_L}{100}\right) \cdot \left(1 - \frac{S_L}{100}\right)\right]} \quad (7)$$

where:

$$K = \frac{E(Q_{sys})}{Qd_{sys}} \quad (7a)$$

where:

$E(Q_{sys})$ = the expected quantity of water available for the system (l/sec).

Although WIP is a run-of-the-river irrigation system, taking water from the Brantas River, since there are two hydroelectric dams and reservoirs upstream, expected supply is relatively dependable. Thus, the forecasted supply for the next ten-day period is normally accurate, particularly since Warujayeng is one of the first systems diverting water after it is released from the dams. The situation is more erratic for irrigation systems downstream, especially those close to Surabaya.

EVALUATING IMPLEMENTATION OF FIELD PROCEDURES

Two aspects are important in the process of evaluating implementation procedures for irrigation system operation. The first aspect relates to the actual methods used by irrigation sub-section managers in calculating *planned allocations* for turn-outs at secondary canals and tertiary blocks. In order to study this within the WIP, a comparison between the standard operating procedures defined according to the FPR allocation rule and the actual field practices observed in planning allocations within the different sub-sections was made. Since data exist on reported crop areas for all secondary reaches and various sampled tertiary blocks, calculations were made by staff from IIMI using the official FPR methodology to determine the correct planned water delivery for many secondary off-takes. These values can then be compared to the actual planned discharge values developed by provincial irrigation staff, in the form of a Planned Performance Ratio (PPR) where a ratio of 1.0 implies that irrigation staff are following the correct procedures. This ratio can be used to quantify the extent to which field management practices deviate from accepted operating rules. Furthermore, because information related to the exact methods used by sub-section managers in calculating these planned flows was elicited through personal interviews, causes of any deviations from the correct procedures can be assessed.

$$PPR = \frac{Q_{PP}}{Q_{FP}} \quad (8)$$

where:

Q_{PP} = allocation quantity actually planned by PRIS staff (l/sec), and

Q_{FP} = allocation calculated using the FPR equation as recommended (l/sec).

The second aspect relates to how effectively actual quantity of water delivered corresponds to the irrigation services' planned allocations. The ratio of realized discharge flow to planned allocation is measured as an Implementation Performance Ratio (IPR). Once again, deviation from the ideal ratio of 1.0 implies some form of irrigation system management problem.

$$IPR = \frac{Q_R}{Q_{PP}} \quad (9)$$

where:

Q_R = actual quantity of water delivered to irrigation (l/sec), and

Q_{PP} = quantity of water planned by PRIS staff to deliver (l/sec).

Overdiversion in the head of the system and a general bias against tail-end users were investigated by comparing MPRs (calculated as a composite of the PPR and IPR), for selected secondary reaches and tertiary blocks in the system. This analysis was restricted to 1987, a relatively dry year where overall system water deficiencies provided greater incentives for mismanagement. Lastly, a comparison between data collected by IIMI field staff and data from the irrigation inspectors' reports can reveal inaccuracies in reporting that could lead to inefficiencies of water use and mismanagement. The ratio of reported flow to actual flow measured in the field indicates the extent of misreporting at the WIP.

The next section assesses the extent to which existing field practices at WIP deviate from the established FPR procedures. PRIS data for this part of the study, including reported crop acreage and discharge flow rates for ten secondary reaches, were collected from the irrigation head office at Nganjuk in 1987. Information related to the specific methods for calculating planned water allocation for each ten-day period was elicited through interviews with the three sub-section managers at WIP. Data presented by IIMI were actually measured in the field. Figure 1 provides a schematic of the WIP and also demarcates the boundaries of the three sub-sections.

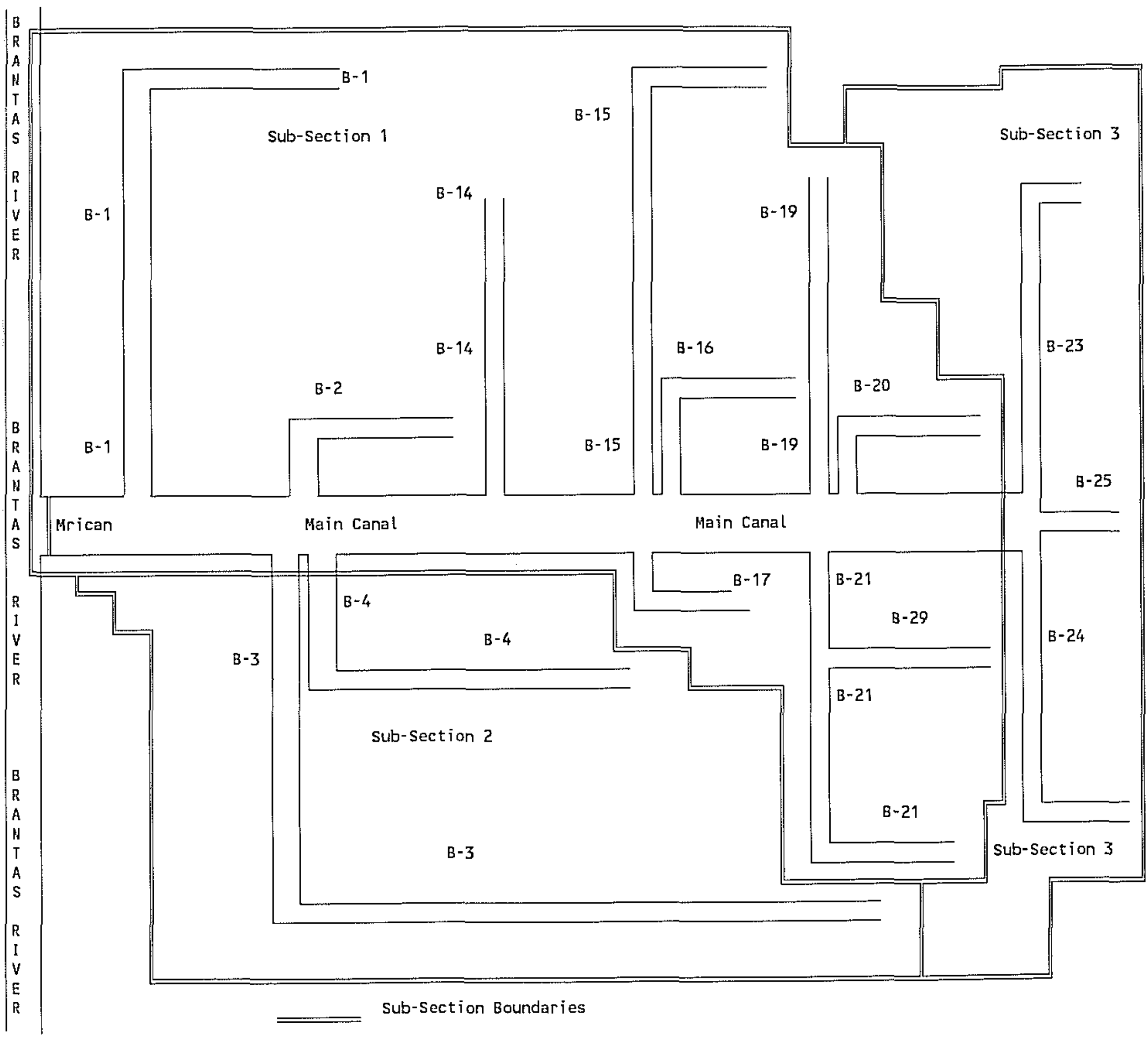

Figure 1. Canal Schematics for Warujayeng Irrigation System.

OPERATIONS PERFORMANCE ANALYSIS

When properly following their procedures, irrigation allocation to a secondary reach is calculated by provincial irrigation staff by summing the irrigation requirement for all tertiary blocks within that area and multiplying this value by a secondary and tertiary canal conveyance loss coefficient (Equation 5). To determine how closely the procedures used for calculating planned water allocation correspond to the official standard procedures, ten secondary reaches in the WIP were selected for analysis. Data on planned allocation flows calculated and reported by local irrigation service officials were compared to planned allocation flows calculated, following standard FPR procedures. In Table 3, the PPR values have been computed for each secondary reach for three 10-day periods during the 1987 season.

TABLE 3. Planning Performance Ratios (PPR) for Ten Secondary Reaches at Warujayeng During Ten-Day Period of 1987.

Secondary Reach	PPR (PRIS Plan/IIMI Plan)			
	August	September	October	Average
		SECTION 1		
B-2	0.96	0.70	0.50	
B-14	0.82	0.68	0.50	
B-15	0.82	0.65	0.47	
B-19	1.07	0.79	0.51	
B-20	0.94	0.72	0.50	
Average	**0.92**	**0.71**	**0.50**	**0.71**
		SECTION 2		
B-3	1.16	1.15	1.13	
B-4	1.21	1.46	n.a.	
Average	**1.19**	**1.31**	**1.13**	**1.21**
		SECTION 3		
B-24	0.33	0.27	0.24	
B-25	0.25	0.33	0.31	
B-28	0.37	0.51	0.41	
Average	**0.32**	**0.37**	**0.32**	**0.34**

n.a. = Data not available.

Evaluating the Procedures Used to Plan Allocations

The PPR for Sub-Section 1 averaged across all secondaries during the middle of August was 0.92, indicating little deviation from the standard procedure. However, during the middle of September and October, when water shortages were more critical, this ratio dropped considerably. With an average ratio value of 0.71 for all three periods, there is significant deviation from the prescribed procedures for determining the planned discharges to each reach. Similarly, Sub-Sections 2 and 3 exhibit wide deviations from the ideal PPR value, averaging 1.21 and 0.34, respectively. What explains the difference in magnitude and direction of these PPRs from the standard? As can be seen in the following paragraphs, to a large extent, this variation reflects the divergence in methods used to calculate planned allocation in each of the three sub-sections; all of which differ to some degree from the prescribed rule.

Sub-Section 1. FPR for each ten-day period is calculated at the provincial irrigation service district office and relayed to the sub-section manager, along with the total LPR for the system (LPR_{sys}), and the expected flow through the diversion weir during the coming ten-day period $E(Q_{sys})$. Sub-section managers use this information to calculate the expected water loss in the system ($Q_{sys,loss}$). The $Q_{sys,loss}$ is used in determining planned allocations to each secondary in his area (Q_{sec}). That is,

$$LPR_{sec} \cdot FPR = \sum_{sec=1}^{s} Q_{sec} \tag{10}$$

where:

s = number of total secondary canals in the entire system.

$$E(Q_{sys}) - \sum_{sec=1}^{s} Q_{sec} = Q_{sys,\ loss} \tag{11}$$

where:

s = number of total secondary canals in the entire system.

The LPR for each secondary canal (LPR_{sec}) is multiplied by the FPR. This value is added to the expected water loss within that secondary reach to arrive at the planned allocation to that secondary during the next ten-day period. Expected water losses within secondaries are derived by multiplying the $Q_{sys,loss}$ by the fraction of the total WIP system canal length in that secondary. The one serious drawback with the use of this method is that $Q_{sys,loss}$ is treated as an indirect function of LPR_{sec} and FPR. The determination of FPR is itself a rather ad hoc affair. Rather than maintaining a fixed FPR value (0.24 or 0.36), FPR is adjusted each period in response to "complaints from farmers" and to account for changing values of LPR_{sec} and $E(Q_{sys})$. This method compounds errors associated with it.

Sub-Section 2. The planned allocations for B3 and B4, the major secondary reaches in Sub-Section 2, are calculated not by the Sub-Section 2 manager, but by the Sub-Section 1 manager. This is because those two secondaries branch off the primary canal within Sub-Section 1, and thus the Sub-Section 1 manager has responsibility for water flows along the primary canal at the point of diversion into B3 and B4. Water allocations for the other nine smaller secondary reaches in the sub-section are under the responsibility of the sub-section manager. Determination of planned allocation for these other nine smaller secondaries appears to be a post-facto operation. Essentially, planned allocations are not "determined" until after water has been delivered to the secondary gates. Inspectors for each reach of the canal open gates in a more-or-less subjective fashion as they try to gage what the water requirement to each secondary and what the system deficits currently are. "Planned allocations" appear to be recorded after the fact in order to be consistent with reported flows. This approach is seriously flawed and bears no resemblance to the standard procedure recommended for planning irrigation allocations.

Sub-Section 3. The manager of Sub-Section 3, which is in the tail of WIP, uses a method more consistent with prescribed procedures. Conveyance losses for each secondary reach are estimated based on last period's losses. Realized flows to all tertiary blocks of the secondary are summed, multiplied by a tertiary loss factor (0.83), and subtracted from the realized flow to the secondary reach. This technique is presented in Equation (12).

$$Q_{sec,\,loss} = Q_{sec} - \sum_{tert=1}^{t} Q_{tert} \cdot 0.83 \qquad (12)$$

where:

t = number of tertiary blocks served by the secondary canal.

From this a relative loss from the previous period (in percent) is derived ($Q_{sec,loss}/Q_{sec}$). This value is used in calculating planned allocations for the coming ten-day period, as follows:

$$Q_{sec}(planned) = LPR_{sec} \cdot FPR \cdot \left(1 + \frac{Q_{sec,\,loss}}{Q_{sec}}\right). \qquad (13)$$

The main problem here is the estimation of secondary reach canal losses. Little reliance can be put on the realized flow values. In fact, 30 percent to 40 percent under-reporting is fairly common in reporting secondary reach discharge flows. Obviously, using such figures could significantly affect the accuracy and reliability of the above procedure. Despite these two problems, this procedure does follow the prescribed approach for calculating planned allocations more closely than the others, at least in theory. Yet, in practice, the planned allocations as reported by sub-section staff had the widest deviations from the correctly calculated planned allocations, as observed by the very low ratios in Table 3.

In summary, as indicated earlier each sub-section manager uses a different method to calculate his planned allocations. This creates obvious problems, especially if head-end reaches are allocated a disproportionately high amount of water. With a fixed supply of water, tail-end users are forced to reduce their irrigation applications, since planned allocations are directly affected by, and at the mercy of, upstream users. Undoubtedly this explains, in part, why secondary canals B-24, B-25, and B-28 of Sub-Section 3 have such low planned performance ratios (PPRs).

Actual vs. Planned Allocations

The effectiveness with which planned allocations are implemented was assessed and presented in Table 4 as the ratio of the realized discharge flow to the PRIS planned allocation. This ratio has been defined as the Implementation Performance Ratio (IPR). Once again, deviations from the ideal 1.0 ratio are significant, especially for Sub-Sections 1 and 3. In Sub-Section 3, secondary reaches received on average water flow almost four times higher than determined in the planned allocation. This can be compared with Sub-Section 1 which received, on average, 1-1/2 times its planned allocation and Sub-Section 2 which received only slightly more than its planned discharge flow.

Some interesting observations can be seen by comparing Tables 3 and 4. As stated earlier, the procedures used by Sub-Section 1 manager underestimated the correct planned allocation by an average of about

TABLE 4. Implementation Performance Ratio (IPR) and Management Performance Ratio (MPR) for Ten Secondary Reaches During Ten-Day Periods of 1987.

Secondary Reach	IPR (Realized/Planned (PRIS))				MPR (Realized/Planned (IIMI))			
	August	September	October	Average	August	September	October	Average
				SECTION 1				
B-2	1.16	1.02	1.21		1.12	0.81	0.60	
B-14	2.04	1.41	1.76		1.67	0.95	0.88	
B-15	1.70	1.41	1.84		1.39	0.92	0.86	
B-19	1.35	1.14	1.39		1.44	0.90	0.71	
B-20	2.16	1.09	1.85		2.03	0.79	0.93	
Average	**1.68**	**1.24**	**1.61**	**1.51**	**1.53**	**0.87**	**0.80**	**1.07**
				SECTION 2				
B-3	1.17	1.18	0.90		1.36	1.35	1.02	
B-4	1.07	0.50	1.51		1.29	1.06	0.83	
Average	**1.12**	**0.84**	**1.21**	**1.06**	**1.33**	**1.21**	**0.93**	**1.16**
				SECTION 3				
B-24	2.99	4.96	4.57		0.99	1.32	1.09	
B-25	1.72	3.40	6.94		0.43	1.12	2.16	
B-28	3.05	3.65	2.98		1.13	1.86	1.22	
Average	**2.58**	**4.00**	**4.83**	**3.81**	**0.85**	**1.43**	**1.49**	**1.26**

Note: August, September, and October cover the 11th-20th days for each month.

30 percent (Table 3). Obviously, such an allocation would be unacceptable to the vast majority of water users in a system. It is not surprising then that actual deliveries (realized flows) exceeded the provincial irrigation service plan by more than 50 percent on average. This is illustrated in Table 4. In the first period, an 8 percent deficit allocation plan (see Table 3) was met with a 68 percent increase over that planning schedule. During the second ten-day period of September, a 29 percent deficit allocation plan was compensated with a 24 percent excess diversion rate. Similarly, during the second ten-day period of October, a grossly underestimated planned allocation – averaging only 50 percent – was compensated by an average 61 percent excess diversion flow over the planned rate. In the situation where provincial irrigation service planned allocation overestimated the correct planned allocation, as in Sub-Section 2, over-diversion was never a serious problem. Here, IPRs averaged only 1.06. Secondary reaches for Sub-Section 3 all had consistently low PPRs, and accordingly, had the highest over-diversion rates. Almost four times the water planned (380 percent more) was actually delivered to the secondaries. Given such consistent results both across secondaries and time periods, it is questionable whether planned allocations are ever taken very seriously.

In general, realized flows exceed planned allocation relative to the degree by which planned allocation was underestimated. The more closely the PPR was to 1.0, the less the IPR exceeded 1.0. To the extent that these planned allocations apportion water in the most efficient and equitable manner, closer adherence to the standard procedure represents a gain in economic terms and achieves a greater measure of equity in water distribution. Such a statement cannot be made here since planned allocations (calculated by the provincial irrigation service staff) are themselves the result of deviations from the standard method of calculation.

A better representation of the current procedure's effectiveness at implementing the FPR rule is obtained by multiplying the PPR by the IPR.

$$PPR \cdot IPR = \frac{Q_{PP}}{Q_{FP}} \cdot \frac{Q_R}{Q_{PP}} \tag{14}$$

As can be seen, this results in the formulation for the overall Management Performance Ratio (MPR):

$$\frac{Q_R}{Q_{FP}} = MPR. \tag{15}$$

When calculated for the different Sub-Sections 1, 2, and 3 (see Table 4), MPR values of 1.07, 1.16, and 1.26, respectively, are obtained. These values are closer to the ideal ratio, but it is still apparent that stricter observance of the FPR procedure would result in economic and equity gains – both across and within the different sub-sections. Especially troubling are the deviations from 1.0 across sub-sections within a given period. In this regard, over- and under-diversions within the WIP were a serious problem. For example, Sub-Section 1 used over 1-1/2 times its correctly calculated planned allocation during August (MPR = 1.53), and yet realized only 87 percent and 80 percent of its correct planned allocation during September and October, respectively. This is in contrast to Sub-Section 3 which had average MPR values of 0.85, 1.43, and 1.49 for August, September, and October, respectively.

Another problem associated with over-diverting to compensate for unrealistic planned allocation is the resulting falsification of flow reports. Inspectors feel forced to under-report the realized flow figures in order to stay in line with PRIS' planned allocations. All data related to realized flows in the above analysis were taken by IIMI staff through field observation. Across all three time periods, official irrigation service reports for every secondary reach under-reported actual flows. On average, only 69 percent of the total flow were reported. Table 5 details the discrepancies between reported data and data actually measured in the field.

TABLE 5. Realized Flow Ratios (PRIS/IIMI)

Secondary Reach	Realized Flow Reported (PRIS/IIMI)			
	August	September	October	Average
		SECTION 1		
B-2	0.92	0.88	0.77	
B-14	0.49	0.65	0.5	
B-15	0.59	0.50	0.54	
B-19	0.56	0.77	0.72	
B-20	0.42	0.85	0.59	
Average	**0.60**	**0.73**	**0.64**	**0.66**
		SECTION 2		
B-3	0.73	0.67	0.63	
B-4	0.77	0.81	0.78	
Average	**0.75**	**0.74**	**0.71**	**0.73**
		SECTION 3		
B-24	0.64	0.70	0.88	
B-25	0.57	0.66	0.85	
B-28	0.43	0.58	0.74	
Average	**0.55**	**0.65**	**0.82**	**0.67**

Economic Values

At present, farmers in WIP do not have to pay for public irrigation water. However, clearly this water has a significant value both in WIP and in other irrigation systems downstream, as well as for municipal and industrial (M&I) use in cities along the Brantas River, including Surabaya, the second largest city in Indonesia. Based on economic analysis by Kelley (1989) in WIP, for the second dry season in 1987, the net return per 100 m^3 of water was $1.78. Using this value for irrigation water, strict adherence to the standard FPR rule during the second dry season of 1987 would have resulted in 190,700 100 m^3 less water diverted into the WIP system from the Brantas River, or a potential savings of $339,500 based on $1.78 per 100 m^3 of water.

Water Delivery and Planned Allocations: Implications for Equity

Large-scale public irrigation systems are notorious for their reported systematic bias in water delivery. In many cases, there is extensive evidence to document the case of over-diversion of water near the head of the system with concomitant deficits at the tail (Bromley *et al.*, 1980; Wickam and Valera, 1979; Bottrall, 1981; Kelley and Johnson, 1989). To quantify the extent of head to tail bias, MPRs were computed and compared for various tertiary blocks across the system. These ratios have been calculated for the periods August 11-20, September 11-20, and October 11-20 and appear in Table 6. The sampled tertiary blocks have been grouped into clusters according to distances from the main diversion at Mrican. These data do not indicate spatial bias in distribution; in fact, data in Table 6 support tail-end bias as strongly as it supports head-end bias. As can be seen in the table, as contrasted to the middle of the system, there is tendency for increasing ratios at the head- and tail-ends of the system.

Perhaps the major reason for this unexpected result relates to the way in which irrigation management is structured. There are three sub-section managers. Each has responsibility (and authority) for overseeing a fair and equitable distribution of water in his respective sub-section. Under each manager are inspectors charged with the same responsibility for their own particular areas. Neither the managers, inspectors, nor large influential farmers necessarily live at the head of their sub-section or area for which they are responsible. This immediately removes one of the chief incentives of head-end bias. It is also of interest to observe that within Sub-Section 1, higher

TABLE 6. Equity in Field Implementation in Terms of Management Performance Ratios (MPRs).

Tertiary Block	Distance from Mrican Headgate (kms)	Management Performance Ratio August 11-20	September 11-20	October 11-20	Average
		SUB-SECTION 1			
a3	7.1	n.a.	0.68	n.a.	
a4	7.1	n.a.	1.22	0.88	
a5	7.1	n.a.	1.06	0.42	
Average	**7.1**	**n.a.**	**0.99**	**0.65**	**0.82**
a91	16.2	n.a.	1.33	0.60	
a92	16.2	n.a.	1.27	0.61	
a94	16.2	n.a.	1.20	0.63	
Average	**16.2**	**n.a.**	**1.27**	**0.61**	**0.94**
a206	18.4	1.56	2.25	1.38	
a207	18.4	0.46	0.49	0.35	
a208	18.4	1.67	0.82	1.18	
Average	**18.4**	**1.23**	**1.19**	**0.97**	**1.13**
Sub-Section Average	**13.9**	**1.23**	**1.15**	**0.74**	**0.96**
		SUB-SECTION 2			
a58	11.7	1.63	1.57	1.43	
ai58	13.6	n.a.	1.75	2.43	
a73	12.7	1.33	1.19	1.00	
a74	12.7	0.88	0.64	0.50	
Sub-Section Average	**12.7**	**1.28**	**1.29**	**1.34**	**1.30**
		SUB-SECTION 3			
a98	21.2	n.a.	3.48	4.10	
a99	21.2	1.23	1.94	2.60	
Average	**21.2**	**1.23**	**2.71**	**3.35**	**2.43**
a196	23.5	1.60	3.21	1.71	
a197	23.5	1.41	1.68	1.75	
a198	23.5	0.51	0.54	0.66	
a199	23.5	0.60	1.00	2.04	
Average	**23.5**	**1.03**	**1.61**	**1.54**	**1.39**
Sub-Section Average	**22.3**	**1.13**	**2.16**	**2.45**	**1.91**

n.a. = Data not available.

ratios are found at the lower end of the system, near the area where the sub-section manager resides. One would expect his location in the system to play some role in explaining the data.

CONCLUSION

Different allocation and delivery performance ratios (PPR, IPR, and MPR) are used to assess operations performance in the Warujayeng Irrigation Project in East Java, Indonesia. Results from this analysis indicate that field management practices at WIP deviate substantially from the official FPR operating procedures. The lack of application of a single, standardized procedure for planning water allocations represents a serious constraint to effective monitoring and evaluating system performance. Furthermore, non-standardized methods of calculating planned allocations introduces arbitrariness and potential for abuse, inefficiency, and inequity within the system. Underestimated and unrealistic planned allocations becomes the justification for over-diversion of water, and has the effect of undermining the resolve of managers to see to it that actual flows meet planned flows.

Miscalculating planned allocations, poor matches between planned flows and actual deliveries, over-diversion and misreporting – all in ample evidence at the WIP site – have economic consequences as well. Taken together, they can have a significant impact on the efficient distribution of water. If we extrapolate the results of this study to all technical irrigated area in Java, strict adherence to the standard FPR rule during the second dry season of 1987 would have resulted in a savings in water in excess of $30 million. This is based on a conservative estimate for agricultural use of $1.78 per 100 m^3 of water; its value for use as municipal and industrial water in Surabaya would be much greater.

Considerable scope exists for making improvements in management by closer adherence to the standard water allocation and delivery rule procedure. For proper monitoring and evaluation purposes, the methods employed by each of the sub-section heads in allocating water across their reaches should be standardized. Specific ways to encourage closer adherence to the standard system procedures at the WIP site are listed below.

Monitoring

Closer monitoring of section manager activities by respective project heads. It is suggested that random, periodic checks be made by the higher-level irrigation authorities (e.g., PRIS section staff at Nganjuk for the WIP), at which time all activities related to the planning and delivering of water throughout the system would be monitored. Generally, no program exists for monitoring performance.

Education

Interviews with section and sub-section managers revealed that some confusion and misunderstanding about the standard procedures has resulted from changes in those procedures made in 1981. To the extent that procedures are not followed due to a lack of understanding, conducting training programs for sub-section managers, irrigation inspectors, gatekeepers, and their assistants should alleviate that problem.

Incentives

It is suggested that an incentive structure be employed whereby the management staff is rewarded for better performance, i.e., closer adherence to the current rule, through salary increments, promotions, or extra holidays. Relative performance can be measured by deviation from the ideal PPR and IPR values of 1.0. Comparisons can be made across reaches in a system or across systems, reflecting management capability of sub-section and section managers, respectively.

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