CHAPTER 2

IRRIGATION SYSTEM PERFORMANCE - THEORY AND CONCEPTS

2.1 INTRODUCTION

This chapter narrates some of the essential concepts on performance of the irrigation system viz conceptualising the irrigation system in a nested hierarchy, review on the performance indicators of irrigation system and the recognition for making a systematic study of specific system for improving its performance.

During this century there has been a dramatic increase in the area irrigated. Most of this expansion has occurred through capital investments in infrastructure for the capture, storage and distribution of water and in the conversion of rain-fed areas into irrigable land. This type of development has created a number of groups who have a direct concern on performance of the irrigation system: investors, policy makers, planners, managers and users. Each of these groups is interested in assessing the effectiveness of the systems in which it has a stake. To do this, these groups require basic information on inputs and outputs of the system and also a systematic procedure to process these information and make use of it for improving the performance over years.
2.2 CONCEPTUALISATION OF IRRIGATION SYSTEM PERFORMANCE

Performance of irrigated agriculture is a very complex subject. The complexities are described by Smith (1990). Chambers (1988) describes the complexities of the canal irrigation system in terms of domains (physical, human, bioeconomic and water), dimensions (space and time) and the linkages between the domains and the elements within them. He has suggested the need for analysing system in its entirety to improve the performance. Hence, a parallel process of improving all the domains are necessary to achieve the full potential.

Irrigation systems often have a number of competing objectives and are assessed by different interest groups with different perspectives. A clear definition of the boundary of the system under study and its objectives would be highly useful in making the performance assessment of the system.

The framework of Small and Svendsen (1992) conceptualizing irrigation performance in terms of nested systems ranging from the water delivery system to the national social and political system is useful to delineate the boundary and goals of the system (Figure 2.1). They represent irrigation system as a set of physical and social elements used for acquisition, control, delivery and distribution of water to the crop root zones. Its output - water - is one of the number of inputs to the irrigated agriculture system. The outputs of this system - crops - in turn are an output to the agricultural economic system and so on.

Performance of a system is represented by its measured levels of achievement in terms of one or several parameters which are chosen as indicators of the systems' objectives (Abernethy 1989). Different sets of indicators are required to assess performance of the system at different
Figure 2.1 Irrigation in the context of nested system: Inputs and outputs

Key to Inputs/Outputs
1. Operation of irrigation facilities
2. Supply of water to crops
3. Agricultural production
4. Income in sector
5. Rural economic development
6. National development
levels depending on the objectives. For example, the Operational Performance of the system depends on the degree of fulfilment of either a specific quantified output target, indicated by indicators like yield, water use efficiency and cropping intensity, or a specific input target such as discharge, water level or timing of water deliveries.

The Strategic Performance looks at the process by which the available resources are utilised in order to fulfill the eventual outputs of the system, and involves assessment of the procedures by which targets are set in relation to both the available resources and objective setting process (Murray-Rust and Snellen 1992). Thus, performance of an organisation or a system is a measure of both the degree of fulfilment of the output objectives (customer satisfaction) and management of available resources (efficiency) in accomplishing the outputs. To facilitate this process, managers require a set of selected performance parameters or indicators. These indicators help in making informed judgement or guide in making decision about the future activities, by providing information on past activities and their results.

2.3 MANAGERIAL PERSPECTIVE ON PERFORMANCE INDICATORS

There is a great need for bringing the entrepreneurial perspective in managing the service sectors (Swamy 1996). Nevertheless the business management principles cannot be directly transferred to irrigation management in respect of profit-making. It is, however, possible to compare the business management and irrigation management in respect of providing services to the customers and draw parallel lessons. Here, the role of performance indicators in these two sectors are compared from the managerial perspectives.
i. Any business organisation requires to maintain a detailed and accurate record of day-to-day transactions both for reporting and evaluation purposes. Similarly, the irrigation agency requires daily or weekly discharge deliveries to different locations in the system to determine whether the water right has been satisfied seasonally or annually.

ii. Performance indicators provide the basis for planning, operating and controlling the business of the organisation. Hence, operational performance indicators can be viewed as critical variables that describe the contributions of individual activities to the overall result.

This type of performance-oriented management system is not unique to business. It emphasizes that the irrigation management is to be perceived as a management cycle with phases of Planning, Monitoring and Evaluation (Horton et al 1993). It brings the process of accountability built into the system to ensure that efficiency levels are acceptable.

2.4 REVIEW OF THE PERFORMANCE INDICATORS

The performance improvement process requires performance indicators which measured, can describe whether the system is achieving the managerial objectives. If the objectives are not achieved, the process should identify the factors that contribute to low performance. Measures are to be taken to improve the system performance (Oad et al 1989).

Rao (1993) has reviewed and provided a detailed discussion on the performance indicators of water delivery system, irrigated agriculture system and agricultural economic system, developed and used by the various authors. The present literature review addresses the performance indicators relevant to the operational objectives of the study area of this,
namely, the equity, reliability and predictability of water delivery system and a few other indicators required to assess the overall system performance.

2.4.1 Water Based Indicators

Delivery of water in a controlled manner through main system operation plays a dominant role in improving the system performance.

2.4.1.1 Equity

Equity is a generic term used to represent the fairness in distribution of water within different reaches of the system. Equity is defined by different groups with different perspectives. In areas having water scarcity, perfect equity means, the shortage of water is distributed fairly over the entire command resulting in the reduction of productivity. However, to get a higher productivity in the same command with the available water, certain area is notified that they will get enough water to the required demand. So a policy decision is necessary whether the main objective is to achieve perfect equity or higher productivity or upto which level one is ready to forego one or the other to obtain the optimum result. Most of the equity indicators are mainly based on the depth of water applied over the different regions based on their command area.

i) Coefficient of Variation (CV): It is used to find the variation between the depth of water applied to different units of the system.

\[
CV = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{\bar{x}} = \frac{100 * S.D.}{\text{Mean}}
\]
where,

\[ \bar{x} = \text{Weighted mean depth of water received by } n \text{ units} \]
\[ x_i = \text{depth of water received by farms } i \]

ii) Inter Quartile Ratios: Abernethy (1986) has developed two indicators, namely, Inter Quartile Ratio (IQR) and Modified Inter Quartile Ratio based on statistical concept.

IQR is defined as \( h_{75}/h_{25} \), \( h_{25} \) being the depth of water such that one quarter of all the field blocks receives less than this (that is, top 25 per cent of the command area), and \( h_{75} \) is the lower limit of the most favoured quarter (that is, bottom 25 per cent of the command area). To estimate this, the depth of water received by each block or reach are arranged in ascending order and a plot is prepared as shown in Figure 2.2.

Modified Inter Quartile Ratio (MIQR) is an improved measure of the Inter Quartile Ratio. MIQR is a ratio of the average depth of water received by all the field blocks in the best quarter to the average depth of water received by all the field blocks in the worst quarter.

These ratios indicate that the depth of water received by the best quarter is as many times higher than that of the depth of water received by the worst quarter.

iii) Theil used the root mean square deviation as a measure to find equity.

\[ \text{Theil's Index} = \sqrt{\frac{\sum (P_i - A_i)^2}{(\sum A_i)^2}} \]
IQR = $h_{75} / h_{25}$

MIQR = upper/lower shaded areas

Figure 2.2 Definition sketch of Inter Quartile Ratio
where,

\[ P_i \quad - \quad \text{Predicted water supply in sample unit } i \]
\[ A_i \quad - \quad \text{Actual water supply in sample unit } i \]

iv) Christiansen's uniformity coefficient (UCC): By this coefficient, the depth of water received by the individual blocks are verified for their uniformity in application. The value from 0 to 100 denotes the condition of inequity to perfect equity.

\[
\text{UCC} = 100 \times \left( 1 - \frac{\sum (|x_i - \bar{x}| / a_i)}{(\sum a_i / \bar{x})} \right)
\]

\[ \bar{x} \quad - \quad \text{weighted mean depth of water received by } n \text{ units} \]
\[ x_i \quad - \quad \text{depth of water received by block } i \]
\[ a_i \quad - \quad \text{area of the block } i \]

v) Molden and Gates' Equity Indicator (\( P_E \)):

\[
P_E = \frac{1}{T} \sum_{T} CV_R(Q_d/Q_R)
\]

where,

\[ Q_d \quad - \quad \text{Actual amount of water delivered by the system} \]
\[ Q_R \quad - \quad \text{Amount of water required for consumptive and other uses downstream of the delivery point} \]
\[ CV_R \quad - \quad \text{Spatial coefficient of variation over the region } R \]
\[ T \quad - \quad \text{Time period} \]

Based on extensive field study in Minneriya and Kaudulla systems in Sri Lanka, they have classified the system performance as Good (when
PE is between 0.00 and 0.10), Fair (when PE is between 0.11 and 0.25) and Poor (when PE is above 0.25).

vi) Delivery Performance Ratio

Murray-Rust (1989) introduced the Delivery Performance Ratio (DPR), the ratio between actual discharge to target discharge. It is an operational performance descriptor and it is relatively simple and easy to conceptualize. Here the crucial factor is the target discharge at the denominator and this value has to be arrived based on the objectives of the water delivery system. Accordingly, this ratio gives the assessment of spatial variation of equity, adequacy and reliability that are used to derive the target discharge.

2.4.1.2 Reliability

Reliability is the degree to which the irrigation system and its water deliveries conform to the prior expectations of its users. Reliability is an important operational objective because, only when there is assured supply of water, the farmers begin and practice cultivation operations in a confident manner. It is generally more difficult to assess because it is subjective, dealing with the quality of irrigation service as well as quantity. It covers both the reliability of discharges or water levels and the reliability of timing of deliveries (Murray-Rust and Snellen 1994).

i) Reliability of Discharges (R_q)

\[ R_q = \frac{\text{Actual discharge}}{\text{Target discharge}} \]

Reliability of Time (R_t)

\[ R_t = \frac{\text{Actual duration of water delivery}}{\text{Target duration of water delivery}} \]
ii) Reliability Index: Makin (1991) has developed an index for reliability. It is the difference between the percentage of observed flow not exceeding the target flow + 10 per cent and target flow - 10 per cent.

iii) Molden and Gates Dependability Indicator ($P_D$):
Reliability is sometime denoted as dependability by a few authors.

$$P_D = \frac{1}{R} \sum_{R} CV_T(Q_D/Q_R)$$

where,

- $Q_D$ - Actual amount of water delivered by the system
- $Q_R$ - Amount of water required for consumptive and other uses downstream of the delivery point
- $CV_T$ - Temporal coefficient of variation over the time period $T$
- $R$ - Region

They have also classified the system performance as Good (when $P_D$ is between 0.00 and 0.10), Fair (when $P_D$ is between 0.11 and 0.20) and Poor (when $P_D$ is above 0.20).

2.4.1.3 Predictability

The predictability of flow is indicated by the water delivery schedule or operational plan. If there is no such a schedule or plan, then, there is no predictability. Without predictability the concept of reliability does not make sense.
2.4.2 Irrigated Agriculture System Indicators

i) Availability of Inputs: The availability of agricultural inputs other than water also play a role in the performance of the system. Availability of inputs include fertilisers, pesticides, labour and capital.

ii) Productivity: Productivity is defined as the ratio of input to output. It is generally denoted as yield per unit of water used and yield per unit of land.

Productivity of land = Yield/unit area of land
Productivity of water = Yield/unit quantum of water

2.4.3 Agricultural Economic System Indicators

i. Profitability to the farmers = net benefit per unit land

ii. O & M expenses incurred by the Irrigation Agency

iii. Income from water charges collected by the Revenue Department

The existing dual control and responsibility between Irrigation Agency (O & M expenses incurred) and the Revenue Department (water tax collection) do not permit comparison of the expenses to the collection of tax and this lacks accountability. Maintenance of the records of O & M expenses and irrigation fees collection by the irrigation agency would be useful to assess the percentage of self-sufficiency of the system.

2.4.4 Social System Indicators

The irrigation systems in Tamil Nadu are jointly managed by the agency and the farmers. System managers do the business of water delivery
services and farmers are the clients. Hence, it is important to get farmers' views on water delivery through field survey. The following information can be obtained from farmers.

1. Farmers' knowledge and satisfaction
2. Farmer - Agency interaction
3. Information flow - bottom-up & top down

Out of these indicators, a limited set of indicators has to be selected in relevance to the system objectives, so that they could be used in the routine planning, operation, monitoring and evaluation procedures. Two considerations are necessary in the selection of the performance indicators for a particular system.

1) Indicators must be simple to communicate and easier to compute by the field personnel, and
2) Indicators must be capable of providing adequate information on system performance without demanding excessive data collection and cost.

2.5 PERFORMANCE STANDARDS

Performance of an irrigation system is governed by many factors ranging from policy and planning decisions at the national level to the operation and maintenance at the farm gate level (IIMI 1990). Pure measures of performance have little meaning until they are compared with some type of performance standard. The types of performance standards identified are external standard, relative standard and internal standard (Small and Svendsen 1990). External or relative standards are useful to make comparisons among systems or organisations. Each system requires a set of internal standards to compare its actual performance and to
improve its performance over years. Internal standards are to be established for any system by observing its performance over years.

It is observed that each irrigation system has its own characteristics in terms of the physical design, climatic conditions, water rights and the operation and management conditions and performance is system specific. Therefore, a systematic way of studying the performance of the system, identifying the critical activities that affect the performance of the system and providing guidelines or methodology to improve the system performance would be more useful and practical (Vaidyanathan and Janakarajan 1989). Hence, this research study is a modest attempt in this direction. This study attempts to improve the performance through information management perspective. Sathanur Irrigation System in Tamil Nadu has been selected for this study.