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IRRIGATION DISTRICT MODERNIZATION IN THE U.S. AND WORLDWIDE

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SUMMARY - Irrigation district modernization is required to provide adequate water delivery service to farms if modern on-farm irrigation technologies are to be widely adopted worldwide. Within the last 10 years throughout the western U.S., there has been a rapid expansion of modernization efforts by irrigation districts, although it has certainly not been universal. Worldwide, however, only a few excellent examples of sustainable irrigation district modernization efforts exist. Social problems, inequity, and lack of reliability are key issues in international projects, while in the U.S., modernization efforts have focused on improved flexibility of water delivery service, and have often been driven by efforts to improve the environment or to transfer water. Because irrigation districts in the U.S. are so varied, the specific appropriate modernization activities vary by district.

Key words: Irrigation system performance, irrigation system operation, irrigation system design, irrigation management, irrigation development, irrigation efficiency, modernization, irrigation project, performance indicators, rapid appraisal process.

THE CONCEPT OF MODERNIZATION

Irrigation project modernization is a process of technical and managerial upgrading (as opposed to mere rehabilitation) of irrigation schemes with the objective to improve resource utilization (labor, water, economics, environmental) and water delivery service to farms (Wolter and Burt, 1996). Within this definition are several concepts.

First, modernization is a process that utilizes a wide variety of actions and tools to achieve specific objectives; modernization is not the actions themselves. Planners and engineers for international projects frequently equate specific practices such as canal lining and computerization with modernization. Such specific practices are often the lowest priority if one examines the process needed to meet the objectives. Unfortunately, proper objectives are often not defined.

Second, a key objective is to improve water delivery service to farms. This implicitly acknowledges on-farm irrigation as a major (if not the major) source of inefficiency in some projects, and also implicitly recognizes that the primary reason for an irrigation project to exist is to support farmers. We now understand that although there are major inefficiencies in water management at the on-farm level, it can be extremely difficult to improve those efficiencies until water is supplied to farmers with the proper service. The one exception appears to be land leveling; this water management practice almost always results in improved yields and efficiencies.

Third is the concept that an irrigation project exists to provide service, explicitly mentioned here as service by the irrigation project to the farm. Irrigation projects must serve the farmer sufficiently well that reasonably high on-farm production and on-farm irrigation efficiencies are attainable. To achieve good water delivery service at the farm level, engineers must first recognize that there are also qualities of service at other levels in the project. An irrigation project is typically composed of a series of layers through which water passes. Each layer has an obligation to provide a good level of service to the next lower layer (Burt and Styles, 1999). For example, the main canal system must provide water with good service to the secondary canals, the secondary canals only exist to provide good service to the tertiary pipelines or canals, and so on, down to the ultimate user, the farmer.

ON-FARM IRRIGATION SERVICE REQUIREMENTS

Service Components

The key service components of water delivery are (1) equity, (2) reliability, and (3) flexibility. The flexibility subcomponents are (a) frequency, (b) flow rate, and (c) duration. In general, equity and reliability are pre-requisites for improved flexibility. Farmers must be confident that water will be supplied when and how it is promised as a pre-condition for their investing in improved on-farm irrigation technologies. In order to meet this promise, a project must also have mechanisms to ensure equitable treatment among adjacent farmers – to not do so can breed anarchy and subsequent theft of water and destruction of structures.

Flexibility as a Pre-Requisite for On-Farm Investment

Although good equity and reliability of water delivery to the farms are pre-requisites for farmers to invest in improved on-farm irrigation management and hardware, these two service components are insufficient by themselves. Modern on-farm irrigation management (that is, the use of irrigation scheduling that matches soil and plant constraints) and modern irrigation systems also require that the water deliveries have sufficient flexibility.

Flexibility Requirements of Specific Irrigation Methods

The American Society of Civil Engineering (ASCE) publication “Selection of On-Farm Irrigation Methods” (Burt et al., 1999) provides a detailed description of how the degree of water delivery flexibility will influence the selection of an irrigation method. For example, if farmers have the ability to change flow rates at will, they can reduce tailwater runoff on furrows yet still obtain relatively similar infiltration opportunity times across a field. The mere mention of the word “automation” with respect to on-farm irrigation methods implies that the water delivery flexibility is such that water is available at any frequency (anytime) and for any duration, and that the proper flow rate will be delivered. Certainly, few irrigation districts within the U.S. and almost none overseas provide a sufficiently flexible service that on-farm systems can be automated without first constructing an on-farm reservoir.

In earlier days of U.S. irrigation projects – in the late 1800s through the late 1900s, rotation schedules (which are reliable and equitable, yet have almost no flexibility) allowed farmers to obtain moderately good crop yields (with some deep-rooted crops) with on-farm irrigation efficiencies in the 40-60% range. Earlier we would justify the low on-farm irrigation efficiencies by saying that if we examined water on a basin-wide basis, we didn’t really waste water, but merely recirculated it downstream. Therefore, such performance levels were acceptable for their time.

The days of accepting “moderately good” crop yields have disappeared in much of the U.S. Farmers need every economic advantage they can find, and water management is a key element in determining what yield they obtain per unit of input (power, fertilizer, labor, water). Furthermore, we now recognize the impacts of on-farm water management on environmental factors such as water flow to salt sinks, in-stream water quality and quantity and timing issues. In California, rotation schedules have almost completely disappeared in favor of more flexible arranged schedules. A recent study (Burt et al., 2000) by Cal Poly ITRC of 60 irrigation districts in the mid-Pacific Region of the US Bureau of Reclamation (USBR) (encompassing an area between Bakersfield, California and Klamath Falls, Oregon) showed that only one of those irrigation districts still has a rotation schedule. In the California districts that have other water supplies and still retain rotation schedules (only a handful of such districts still remain), farmers are rapidly switching to well water to obtain the flexibility they need to use drip and sprinkler systems.

In comparison to California, most international projects in Less Developed Countries have as a goal the development of a reliable and equitable rotation system. Unfortunately, many international irrigation engineers hold the opinion that the goal should stop there. The wide acceptance of this opinion is obvious if one visits India or if one looks at the huge amount of literature regarding "structured" designs that require little or no movement of cross regulators and flow control devices. These designs are built to support specific rotation-type irrigation schedules such as the Indian warabundi (Pradhan, 1996; Berkoff, 1990). In the Mediterranean area, the suspended canalettes that are frequently used can only deliver water to farmers on a rotation basis.

There are two primary problems with favoring "structured" designs with little flexibility. First, the irrigation project design for such schedules is fundamentally different, hardware-wise, from a design that will eventually enable the use of more flexibility. Such "structured" canal designs use proportional dividers and on/off schemes, meaning that inflexibility is physically built into the projects. Although some designers promote more flexible operation, they frequently recommend inflexible and outdated technology such as distributor flow modules – this is especially common with many European irrigation designs.

Second, it is documented (Sakthivadivel et al., 1999; Bandaragoda and Badruddin, 1992) that such simple and structured irrigation systems have inherent problems with inequity and unreliability – regardless of the theoretical arguments that deny such inequity but which are consistently advanced by their proponents. By designing such inflexible systems today, for installation tomorrow, designers are limiting the future for potential agricultural production, environmental protection, and good water use efficiency.

EVALUATING IRRIGATION PROJECTS FOR MODERNIZATION

If one accepts the definition of irrigation modernization that has been provided in this paper, then it follows that a proposal for modernization should be made only after conducting a proper evaluation of the project. Such an evaluation should focus on (1) the degree of service being offered at all layers within the project (main canal to secondary canal, secondary to tertiary, etc.), and (2) the factors that influence the level of service. Furthermore, it is helpful to have “internal indicators” that describe the degree of service available, and the factors associated with that service.

U.S. Project Evaluation

ITRC works on irrigation district modernization in almost all of the western states either directly for irrigation districts, or on behalf of agencies such as the US Bureau of Reclamation. Prior to making recommendations for modernization, each district receives a Rapid Appraisal Process (RAP) by ITRC. The RAP is conducted by senior ITRC engineers with a solid background in modernization. An RAP provides an understanding of the operation procedures, and includes a step-by-step tour of the district to learn how water is controlled and conveyed from the source to the individual fields. ITRC does not use a formal checklist for the U.S. RAPs.

ITRC has a formal process for evaluating the degree of service provided by the irrigation districts to the farms. This process was first used by Burt et al. (1981) in a survey of some 60 irrigation districts in California. It has subsequently been refined by ITRC and has been used twice to quantify the level of water delivery service provided by about 60 irrigation districts in the Mid-Pacific Region of the USBR (Burt et al., 1996, and Burt et al., 2000). Because equity and reliability are typically not serious concerns in California irrigation districts, the service ratings focus on flexibility. Table 1 shows the ranking procedure that is used. Each of the three aspects of flexibility receives a score of 1-5, with an overall score possible between 3-15. Table 2 provides information regarding the rankings of the most recent ITRC survey of Mid-Pacific Region (USBR) districts.

Table 1. ITRC Criteria For Ranking Flexibility Service To Farms In California.

Points	Condition
	FREQUENCY
1	Always a fixed rotation
2	Fixed rotation with trading, or limited frequency, or fixed rotation during peak season only
3	24 hours or more advance notice required before delivery is made
4	Less than 24 hours advance notice required before delivery
5	Farmer does not need to notify district before delivery
	FLOW RATE
1	Same flow rate must always be delivered
2	Several flow rates are allowed during the season
3	A different flow rate is available each irrigation, with up to two changes per irrigation allowed
4	Flow rate can be changed any time, provided advance notice is given to the district
5	Flow rates can be different and changed by the farmer without giving advance notice to the district
	DURATION
1	District assigns a fixed duration of irrigation
2	District assigns a fixed duration, but allows some flexibility
3	Farmers must select a duration with a 24 hour increment
4	Farmers can choose any duration, but must give notice before changing
5	Farmers can have any duration, with no advance notice required before changing

Table 2. Average Flexibility Of 58 Irrigation Districts In The Mid-Pacific Region Of USBR (Burt et al., 2000).

Flexibility Parameter	Ranking
Frequency	4.0
Flow Rate	4.7
<u>Duration</u>	<u>4.2</u>
Overall Flexibility Index	**12.9**
	(out of 15 max., 3 minimum)

Evaluation of Irrigation Projects in Less Developed Countries

A formalized RAP was developed by Burt and Styles (1999) in response to the need for a standardized procedure for evaluating international irrigation projects. In addition to improving a wide range of external indicators (e.g., Relative Irrigation Supply and Relative Water Supply), they also developed 31 internal indicators that quantify various aspects of water delivery service at all layers within an irrigation projects. Some of the internal indicators quantify the suitability or impact of various factors that influence the degree of service that is provided. Figure 1 provides an example of correlations found within the report.

In a March 2000 training program by ITRC and the Food and Agriculture Organization of the United Nations (FAO) in Thailand, Royal Irrigation Department (RID) engineers learned how to conduct an RAP and critique a portion of the Chainat irrigation project. The RID engineers were able to clearly define and prioritize modernization steps, which allowed them to competently critique consultant recommendations for a new World Bank modernization loan program. This training and critique program is expected to rapidly expand. Almost identical results were seen in Cd. Obregon (Rio Mayo Project) in Sonora, Mexico in 2003. ITRC has conducted RAP training in Nepal, the Philippines, and Vietnam.

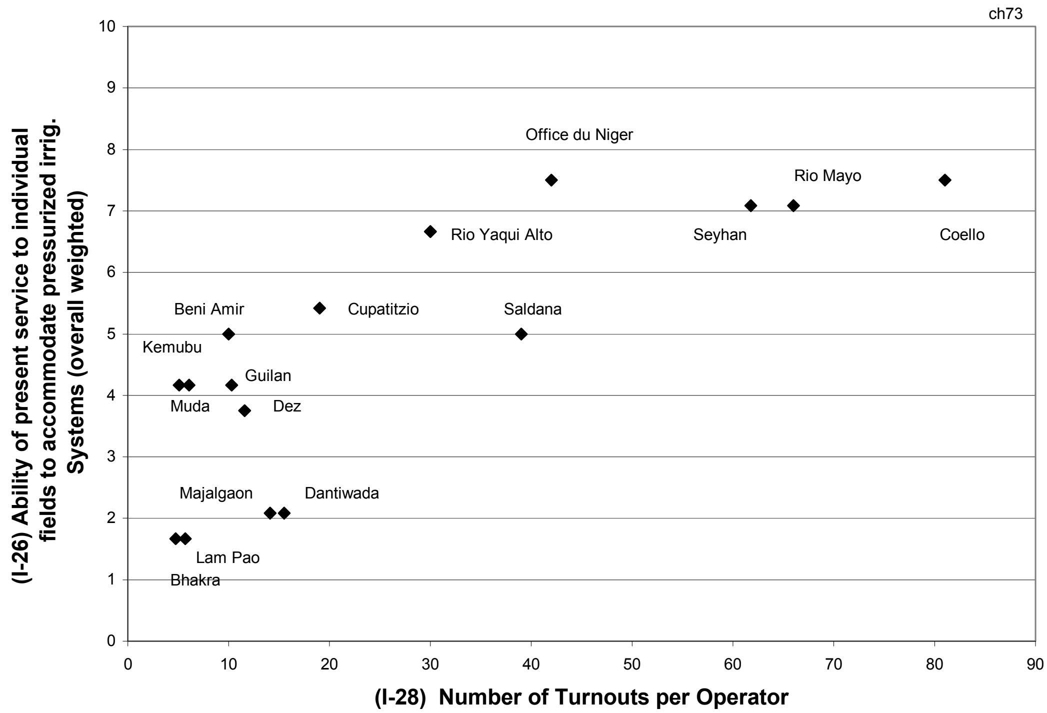

Fig. 1. Example Relationship Between Two Internal Service Indicators Used On International Irrigation Projects By Burt and Styles (1999). Score Range = 0-10 for Indicator I-26.

TYPICAL IRRIGATION DISTRICT MODERNIZATION EFFORTS

Within the U.S., modernization efforts have focused on improving the flexibility of water delivery while simultaneously improving the irrigation efficiency of the district (including conveyance efficiency and on-farm irrigation efficiency). Typical actions include modification of check structures to improve water level control, extensive usage of recirculation systems, improved water ordering procedures and software, incorporation of hand-held dataloggers, improved flow measurement and control at all levels, and wide acceptance of SCADA (Supervisory Control and Data Acquisition) systems. Most SCADA systems first emphasize remote monitoring, followed later by remote manual control. Some districts move directly to automation with associated SCADA systems – but the automation is never centralized.

We prefer distributed control, in which local controllers perform the minute-to-minute closed loop control of a structure and the SCADA system allows for the monitoring of the process and also allows a central dispatcher/operator to change the target points for the local control. Modernization efforts through ITRC also heavily depend on training of all levels of personnel, from the ditchriders (operators), to the engineers and managers, to the board members.

In the U.S., most large-scale irrigation automation projects failed until the late 1990's. There are many reasons for these failures, including the lack of understanding of control algorithms, improper SCADA design, poor sensors, inappropriate control applied to canals, poor PLC hardware, etc. But more than anything else, perhaps the failures were caused by the lack of attention to detail. In irrigation automation, the devil is in the details. ITRC has now developed detailed flow charts for the complete automation process, and we have learned that automation is much more expensive and time consuming than we had thought – if it is to work successfully for a long time. We now have excellent unsteady simulation models, superb control algorithms, an understanding of all the PLC programming steps in addition to programming the algorithms, and knowledge of required PLC, sensor, and SCADA specifications, and good hardware (PLC, sensors, radios, VFD controllers, etc.).

ITRC also has an excellent track record of successful canal automation projects – ones that work very well in a variety of conditions including both upstream control and downstream control. The final hurdle for us is the relationship with the integrator – the company that does the final installation and programming of the PLC and the Human-Machine-Interface (HMI). We are working on that aspect, and hope to streamline the programming aspect within a year.

We know that in the U.S. every irrigation district must be evaluated separately because there is such a wide variation of existing structures, size of districts, topography, age of structures, management styles, water supply constraints, and existence of outlets for drains. Many districts have a physical infrastructure that was initially installed over 100 years ago.

Motivation to modernize comes from environmental restrictions on in-stream flow rates or qualities, efforts to conserve water in order to sell it through transfers (to pay for improvements), removal of water from agriculture to other uses, reduction of electric power bills, the demands of farmers to improve water delivery service, and others.

In international projects, modernization efforts have been much less extensive. In the study by Burt and Styles (1999), it was difficult to find 16 projects that had received even some aspect of modernization. Most "modernization" efforts appear to focus on canal lining and rehabilitation of existing structures, rather than on improvements. Furthermore, there is almost always confusion between employing a single hardware device, versus a comprehensive analysis of modernization to improve service. This inappropriate approach, combined with a frequent but unrealistic hope that some type of centralized computerized management or control equals modernization, almost always yields less-than-spectacular results. The poor results then perpetuate the belief by many international observers that irrigation modernization is unworthy of funding. The basic problem is that such approaches do not meet the criteria for modernization as defined at the beginning of this paper.

There is also an incorrect perception by persons in major donor agencies such as the World Bank that the ills of international irrigation projects can be solved almost exclusively through "software", sometimes referred to as Irrigation Management Transfer (IMT) or as Participatory Irrigation Management (PIM). One should not forget that IMT – the transfer of responsibilities from the central government to local water user organizations – requires that the newly formed water user associations receive water in a usable, equitable, and reliable manner. Without such security, the water user associations have historically failed. Burt and Styles (1999) clearly documented that all irrigation projects need a mix of both hardware and "software" (management, legal, etc.) changes, rather than only one or the other. As in the U.S., the specific recipe for optimum improvements will vary depending upon the individual project. However, the proper approach to modernization is to focus on achieving reliability and equity with a reasonable degree of flexibility. This approach requires similar control strategies for main and secondary canals as those found in the western U.S. irrigation district modernization plans.

Over the years, I have developed a list of factors, any one of which will almost guarantee failure of modernization programs. Some of these factors include:

a) A desire to model the hydraulics of a complete system. I have never needed to do this. Granted, we do model a canal if gates are to be automated – but we do not model beyond that.
b) The existence of a large gap between what project managers <u>state</u> is occurring in the project, versus what actually <u>exists</u> in the project.
c) Money spent on developing models to route flows through an irrigation system – especially when based upon numerous assumptions that will never occur in the field.
d) An inadequate budget for maintenance, spare parts, and long-term support.
e) Dirty offices and bathrooms without good plumbing. This indicates a lack of concern for details, and the lack of motivated staff and management.
f) A staff that has no motivation for working well and hard, and which cannot be fired for poor performance.
g) A modernization plan that does not require many years for implementation, with very deliberate implementation in the field and adequate training and budget.
h) No local "hero" who lives at the project and who will make certain that things work out.
i) A plan that focuses only on computers and PLC-based automation, and does not put a substantial percentage of the budget into simple structures and recirculation systems.

j) An operation plan that dictates gate movements from the central office.
k) The lack of a “service mentality” at all levels within the irrigation project.

CONCLUDING REMARKS

Irrigation districts throughout the western U.S. are very actively involved in modernization efforts that will continue for several decades. ITRC has developed a benchmarking procedure to quantify the quality of service that an irrigation district provides, and data are available for districts to compare their service against other districts. International projects have much fewer examples of successful modernization efforts, and the concept of modernization is less understood than in the U.S.

U.S. irrigation district managers are typically hired and fired by farmer board members, and must therefore be responsive to farmer input. In international projects, the top decision makers are often far removed from the farm and may have little understanding of (or accounting to the users of) the internal operation of water control and of the nature of unsteady flows in irrigation projects. Because many of the projects operate in a top-down mode where it is taboo to question decisions from superiors, proper modernization is difficult to conceptualize or initiate until decision makers are more aware of the proper concept of modernization.

A formalized Rapid Appraisal Process (RAP) has been developed for international irrigation projects. Furthermore, a set of internal performance indicators has been developed to quantify the degree of service provided by international irrigation projects, as well as various factors that influence that service.

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