Chapter 6 - Internal Process Indicators

General

The previously described external indicators (Chapter 5) give an idea of the relative magnitudes of some major inputs and outputs of irrigation projects. An indicator such as "Irrigation Efficiency" assigns a specific value to the percentage of the irrigation water beneficially used within the project. None of the Chapter 5 external indicators provide specific information on instream or downstream impacts - they all deal with actions directly associated with the irrigation project itself.

It is clear that no single indicator is satisfactory for all descriptive purposes. It is also clear that there are uncertainties about the exact values of each indicator; hence, the recommended use of confidence intervals.

Within certain limits, external indicators can sometimes give an indication of inter-relationships between hydrologic levels (e.g., farm, irrigation project, hydrologic basin). This is accomplished by computing the values of the external indicators for each hydrologic level - something that is sometimes done with Irrigation Efficiency. Some external indicators, such as ITRC1 and ITRC2, focus on agricultural production and they can give good indications of how production has been impacted by the irrigation project, as well as what potential improvement remains to be achieved. However, none of the external indicators provide insight regarding the workings of the internal mechanisms (e.g., management, social, hardware) *within* an irrigation project.

Irrigation project investors have two basic questions which need answers:

Question #1. Is it possible to reap benefits by investing in an irrigation project rehabilitation or modernization?

Question #2. What specific actions must be taken so those benefits will actually be realized?

There are uncertainties as to how well the first question has been answered in the past. This is one reason why the external indicators ITRC 1 and ITRC 2 are proposed in Chapter 5. Certainly in many cases various government, technical, and investment groups have expected significant benefits achieved through irrigation investment. But the early part of this report indicates that theoretical benefits have not always been achieved (as now done in some projects financed by lending agencies).

This research project was funded, in part, to better answer the second question. This research assumes that it is insufficient to simply look at the inputs and outputs of an irrigation project. It is absolutely necessary to understand the internal mechanisms of irrigation projects, and to provide selective enhancement of those internal mechanisms, if irrigation project performance is to be improved. These "details" of internal mechanisms are so important that the investment must be based on specific actions to improve them, rather than deciding on the framework for detail improvement only after the investment is approved.

As stated earlier in this report, there has been significant work by various groups (Murray-Rust and Snellen, 1993; ICID, 1995) to develop internal indicators. Various researchers, including those at IWMI, have conducted detailed multi-year field studies to quantify the internal indicators in some projects. What has been missing, however, is a procedure which is both rapid and comprehensive enough to give good indications of the critical weak internal links in an irrigation system.

This research project has developed a new framework for assessing the internal processes of irrigation projects. It incorporates two major features:

1. A Rapid Appraisal Process (RAP)
2. A comprehensive set of internal indicators, which when examined as a whole, indicate how and where irrigation investments should be targeted.

The new internal indices provide ratings to hardware, management, and service throughout the whole system, an approach which has not been used in the past. The complete picture enables one to visualize where changes are needed, and what impact the changes would have at various levels. The new internal indicators, when combined with the RAP, provide an operational or modernization checklist.

The RAP of this research project was designed to obtain data for both the internal indicators and the external indicators. The researchers learned that external indicators require considerably more data and effort to compute than do the internal indicators.

Attachment D contains a listing of each internal indicator, the sub-indicators for that internal indicator, and the criteria for ranking each sub-indicator. Table 6-1 shows a small portion of Attachment D - the information for Indicator I-1. Indicator I-1 rates " Actual service to individual fields ", and has 4 sub-indicators:

- I-1A. Measurement of volumes to the field
- I-1B. Flexibility to the field
- I-1C. Reliability to the field
- I-1D. Apparent equity.

Each of the Sub-Indicators (e.g., No. I-1A) has a maximum potential value of 4.0 (best), and a minimum possible value of 0.0 (worst). The Ranking Criteria in Table 6-1 and Attachment D explain how the values of 0-4 are to be assigned.

The value for each Indicator (e.g., No. I-1) is determined by:

1. Applying a relative weighting factor (Wt.) to each sub-indicator value. The weighting factors are only relative to each other within the indicator group; one group may have a maximum value of 4, whereas another group may have a maximum value of 2. The only factor of importance is the relative values of the sub-indicators within a group.
2. Summing the weighted sub-indicator values.
3. Adjusting the final value based on a possible scale of 0-10 (10 indicating the most positive conditions).

Table 6-1. Indicator I-1 Information.

No.	Indicator	Sub-Indicator	Ranking Criteria	Wt
I-1	Actual service to individual fields			
I-1A		Measurement of volumes to field	4 - Excellent measurement and control devices, properly operated and recorded. 3 - Reasonable meas. & control devices, avg. operation. 2 - Meas. of volumes and flows - useful but poor. 1 - Meas. of flows, reasonably well. 0 - No measurement of volumes or flows.	1
I-1B		Flexibility to field	4 - Unlimited freq., rate, duration, but arranged by farmer within a few days. 3 - Fixed freq., rate, or duration, but arranged. 2 - Dictated rotation, but matches approx. crop need. 1 - Rotation, but uncertain. 0 - No rules.	2
I-1C		Reliability to field (incl. weeks avail. vs. week needed)	4 - Water always arrives with freq., rate, and duration promised. Volume is known. 3 - A few days delay occasionally, but v. reliable in rate and duration. Volume is known. 2 - Volume is unknown at field, but water arrives when about as needed and in the right amounts. 1 - Volume is unknown at field. Deliveries are fairly unreliable < 50% of the time. 0 - Unreliable freq., rate, duration, more than 50% of the time; volume is unknown.	4
I-1D		Apparent equity	4 - It appears that fields throughout the project and within tertiary units all receive the same type of water. 3 - Areas of the project receive the same amounts, but within an area it is somewhat inequitable. 2 - Areas of the project receive somewhat different amounts (unintentionally), but within an area it is equitable. 1 - It appears to be somewhat inequitable both between areas and within areas. 0 - Appears to be quite inequitable (differences more than 100%) throughout project.	4

Table 6-2 provides a listing of all of the internal process indicators which were developed for the Rapid Appraisal Process. As mentioned earlier, the ranking criteria for each sub-indicator can be found in Attachment D.

Table 6-2a. Internal Process Indicators, Sub-Indicators, and Relative Weighting Values.

No.	Indicator	Sub-Indicator	Wt.
	WATER DELIVERY SERVICE		
I -1	Actual service to individual fields based on traditional irrigation methods		
I -1A		Measurement of volumes to field	1
I -B		Flexibility to field	2
I -1C		Reliability to field (incl. weeks avail. vs. week needed)	4
I -1D		Apparent equity	4
I- 2	Actual Service to avg. point of EFFECTIVE Differentiation		
I -2A		# of fields downstream (less is better)	1
I -2B		Measurement of volumes to point	4
I -2C		Flexibility	4
I -2D		Reliability	4
I -2E		Apparent equity	4
I -3	Actual Service to avg. point of DELIBERATE Q Differentiation		
I -3A		# of fields downstream (less is better)	1
I -3B		Measurement of volumes to point	4
I -3C		Flexibility	4
I -3D		Reliability	4
I -3E		Apparent equity	4
I -4	Actual Service by Main Canals to Subcanals (Submains)		
I -4A		Flexibility	1
I -4B		Reliability	1
I -4C		Equity	1
I -4D		Control of flows to submains as stated	1.5
I- 5	Stated Service to Individual Fields		
I -5A		Measurement of volumes to field	1
I -5B		Flexibility to field	2
I -5C		Reliability to field (incl. weeks avail. vs. week needed)	4
I -5D		Apparent equity	4
I- 6	Stated Service to avg. point of EFFECTIVE Differentiation.		
I -6A		# of fields downstream (less is better)	1
I -6B		Measurement of volumes to point	4
I -6C		Flexibility	4
I -6D		Reliability	4
I -6E		Equity	4
I- 7	Stated service to avg. point of DELIBERATE Q differentiation.		
I -7A		# of fields downstream (less is better)	1
I -7B		Measurement of volumes to point	4
I -7C		Flexibility	4
I -7D		Reliability	4
I -7E		Equity	4
I- 8	Stated Service by Main Canals to Subcanals (Submains)		
I -8A		Flexibility	1
I -8B		Reliability	1
I -8C		Equity	1
I -8D		Control of flows to submains as stated	1.5
I- 9	Lack of Anarchy Index - (Evidence of No Anarchy in Canal System u/s of Ownership Change)		
I -9A		Degree to which deliveries are not taken out of turn above point of ownership change	2
I -9B		Noticeable non-existence of unauthorized turnouts from canals above point of ownership change	1
I -9C		Lack of vandalism of structures above the point of ownership change, to obtain flow	1

Table 6-2b. Internal Process Indicators, Sub-Indicators, and Relative Weighting Values.

No.	Indicator	Sub-Indicator	Wt.
	MAIN CANAL CHARACTERISTICS		
I- 10	Cross-Regulator Hardware (Main Canal)		
I -10A		Ease of cross-regulator operation under current target operation. (This doesn't mean that current targets are being met - just that it would be easy or difficult to meet them)	1
I -10B		Probable ease of cross-regulator operation if system was to be required to provide better service to turnouts (this is related to the suitability of the device, also)	2
I -10C		Level of maintenance	1
I -10D		Fluctuation (max daily ±%) of target value in the canal itself (NOT the DELIVERY target value) (e.g., water level in the canal rather than outlet Q)	3
I -10E		Travel time of flow rate change through length of this canal level	2
I -11	Capacities (Main Canal)		
I -11A		Headworks and first canal section capacity vs. peak actual (crop ET-rain) at time of maximum demand, under current operation (i.e., gross compared to net)	1.3
I -11B		Headworks and first canal section capacity vs. peak potential (crop ET - rain) with 100% cropping intensity at that time	2.7
I -11C		Capacity (limitations) of structures or canal cross section further down in the canal	2
I -11D		Availability of effective spill points	1
I- 12	Turnouts (from Main Canals)		
I -12A		Ease of turnout operation under current target operation mode/frequency.	1
I -12B		Ease of turnout operation if system provides better service to turnouts from this canal (this is related to the suitability of the device, also)	2
I -12C		Level of maintenance	1
I -12D		Capacity (limitations)	1
I- 13	Regulating Reservoirs		
I -13A		Suitability of number and location(s)	2
I -13B		Effectiveness of operation	2
I -13C		Suitability of capacities	1
I -13D		Maintenance	1
I- 14	Communications (Main Canal)		
I -14A		Actual frequency of communication of operators along this canal with upper level	1
I -14B		Actual frequency of communication of operators or supervisors along this canal (or indirectly by upper level that then transmits orders down to them) with personnel at lower level	1
I -14C		Dependability of voice communications (by phone or radio)	3
I -14D		Frequency of physical visits by supervisors to field operators	2
I -14E		Existence and frequency of remote monitoring (auto. or manual) at key spill points, including the end	3

Table 6-2c. Internal Process Indicators, Sub-Indicators, and Relative Weighting Values.

No.	Indicator	Sub-Indicator	Wt.
I -15	General Conditions (Main Canal)		
I -15A		Availability of roads along canal	2
I -15B		General level of maintenance	1
I -15C		General level of undesired seepage (if deliberate conjunctive use is practiced, some seepage may be desired)	1
I -15D		Availability of proper equipment and staff to adequately maintain this canal	2
I -15E		Time to travel from maintenance yard to most distant point (for major equipment maintenance crew)	1
I -16	Operation (Main Canal)		
I -16A		How frequently does the headworks respond to realistic real time feedback from the canal operators/observers?	2
I -16B		Existence and effectiveness of water ordering/delivery procedures to match actual demands. This is different than previous question, which dealt with mis-match of orders, wedge storage var. and wave travel time problems	1
I -16C		Clarity and correctness of instructions to operators	1
I -16D		Frequency of checking total length of canal	1
	SUBMAIN CANAL CHARACTERISTICS		
I- 17	Cross-Regulators (Submain Canals)		
I -17A		Ease of cross-regulator operation under current target operation. (This doesn't mean that current targets are being met - just that it would be easy or difficult to meet them)	1
I -17B		Probable ease of cross-regulator operation if system was to be required to provide better service to turnouts (this is related to the suitability of the device, also)	2
I -17C		Level of maintenance	1
I -17D		Fluctuation (max daily ±%) of target value in the canal itself (NOT the DELIVERY target value)	3
I -17E		Travel time of flow rate change through this canal level	2
I -18	Capacities (Submain Canals)		
I -18A		Headworks and first canal section capacity vs. peak actual (crop ET-rain) at time of maximum demand, under current operation (i.e., gross compared to net)	1.3
I -18B		Headworks and first canal section capacity vs. peak potential (crop ET - rain) with 100% cropping intensity at that time	2.7
I -18C		Capacity (limitations?) of structures or canal cross section further down in the canal	2
I -18D		Availability of effective spill points	1
I- 19	Turnouts (from Submain Canals)		
I -19A		Ease of turnout operation under current target operation mode/frequency	1
I -10B		Ease of turnout operation if system provides better service to turnouts from this canal (this is related to the suitability of the device, also)	2
I -19C		Level of maintenance	1
I -19D		Capacity (limitations)	1
I- 20	Communications (Submain Canals)		
I -20A		Actual frequency of communication of operators along this canal with upper level	1
I -20B		Actual frequency of communication of operators or supervisors along this canal (or indirectly by upper level that then transmits orders down to them) with personnel at lower level	1
I -20C		Dependability of voice comm. (by phone or radio)	3
I -20D		Frequency of physical visits by supervisors to field operators of this level	2
I -20E		Existence and frequency of remote monitoring (auto. or manual) at key spill points, including the end	3

Table 6-2d. Internal Process Indicators, Sub-Indicators, and Relative Weighting Values.

No.	Indicator	Sub-Indicator	Wt.
I -21	General Conditions (Submain Canals		
I -21A		Availability of roads along canal	2
I -21B		General level of maintenance	1
I -21C		General level of undesired seepage (if deliberate conjunctive use is practiced, some seepage may be desired)	1
I -21D		Availability of proper equipment and staff to adequately maintain this canal	2
I -21E		Time to travel from maintenance yard to most distant point (for major equipment maintenance crew)	1
I -22	Operation (Submain Canals)		
I -22A		How frequently do the headworks respond to realistic real time feedback from the canal operators/observers (spill, etc.)?	2
I -22B		Existence and effectiveness of water ordering/delivery procedures to match actual REQUESTS. This is different from previous question, which dealt with mis-match of orders and wedge storage variations and wave travel time problems	1
I -22C		Clarity and correctness of instructions to operators	1
I -22D		Frequency of checking total length of canals	1
I- 23	**BUDGETARY**		
I -23A		% of O&M collected as in-kind services or water fees from water users	2
I -23B		Estimated adequacy of actual dollars and in-kind services available (from whatever source) to sustain adequate O&M with present operation mode	2
I -23C		% of budget spent on operation modernization (as contrasted with rehabilitation)	1
I -24	**EMPLOYEES**		
I -24A		Frequency/adequacy of training of operators and managers (not secretaries and drivers)	1
I -24B		Availability of written performance rules	1
I -24C		Power of employees to make decisions	2.5
I -24D		Ability to fire employees	2
I -24E		Rewards for exemplary service	1
I -24F		Relative salary (relative to avg. farm laborer) of canal operators/supervisors (not gate tenders), incl. benefits such as housing	2
I -25	**WATER USER ASSOCIATIONS**		
I -25A		% of users in strong water user associations that have a functional, formal unit that participates in water distribution	2.5
I -25B		Actual ability of the strong WUA to influence real-time water deliveries to the WUA	1
I -25C		Ability of WUA to rely on effective outside enforcement of its rules	1
I -25D		Legal basis for WUA	1
I -25E		Financial strength of WUA	1

Table 6-2e. Internal Process Indicators, Sub-Indicators, and Relative Weighting Values.

	PRESSURIZED SYSTEMS TODAY		
I- 26	Ability of present service to individual fields, to accommodate pressurized irrig. systems		
I -26A		Measurement and control of volumes to field	1
I -26B		Flexibility to field	1
I -26C		Reliability to field	1
	PRESSURIZED SYSTEMS TOMORROW		
I-27	If they wanted to change to a more flexible system which would accommodate widespread conversion to pressurized methods with a reasonable project efficiency, what would be required?		
I -27A		Management	1
I -27B		Hardware	1
	OTHER		
I -28	Number of Turnouts per (operator, gate oper., supervisor)		1
I -29	What level of sophistication is there in receiving and using feedback information? It does not need to be automatic.		1
I -30	To what extent are computers being used for billing/record management?		1
I -31	To what extent are computers used for canal control?		1

No single internal process indicator is sufficient by itself to describe a project. But when the internal indicators are taken as a whole and combined with some of the external indicators, a clear image emerges about the design, operation, and management of an irrigation project. Furthermore, these indicators provide the basis for a rational program of rehabilitation and modernization which will enhance the operation, management, and outputs of an irrigation project. The internal process indicators of Table 6-2 must be assessed by qualified people who have a good understanding of irrigation project design, operation, and modernization.

Internal Indicators: Results

The following figures are based on Table 6-2. Typically, two figures are presented for each indicator. The first figure is the composite internal process indicator with a maximum value of 10.0 (Figure 6-1). The next figure describes the sub-indicators. The maximum value on this graph is 4.0 (Figure 6-2).

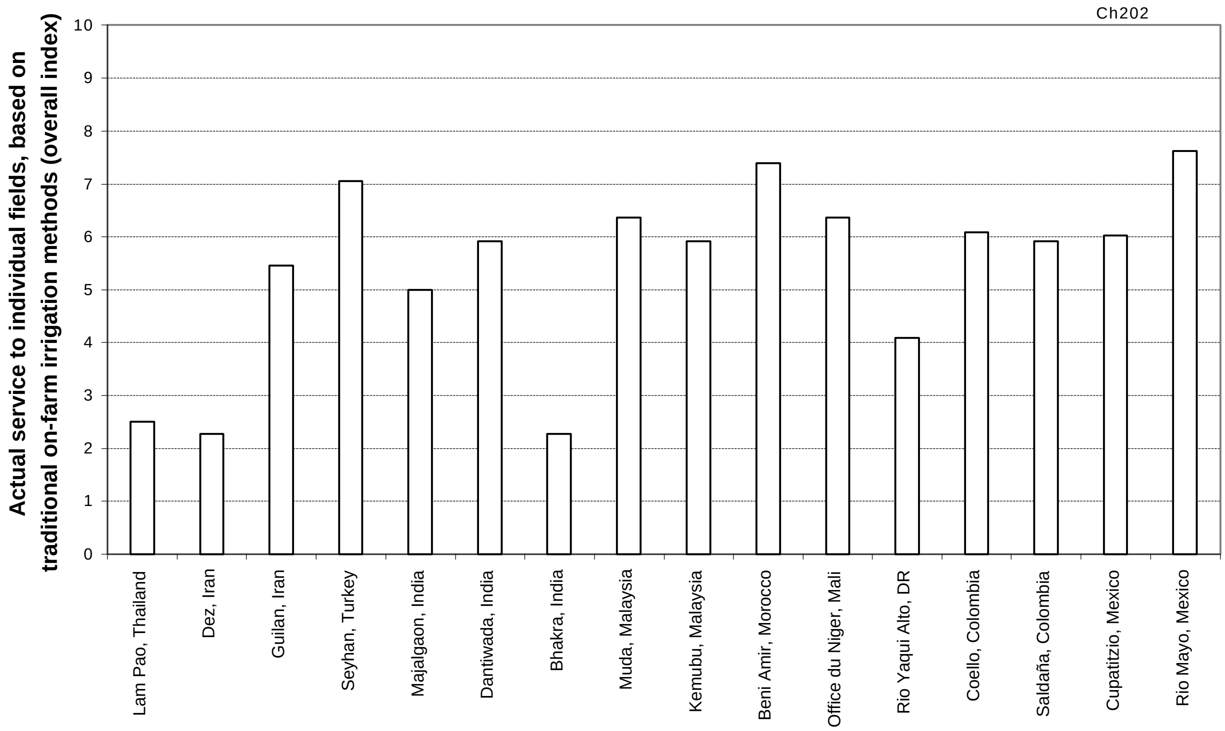

Figure 6-1. Indicator I-1. Actual water delivery service to individual fields, based on traditional field irrigation methods.

The legends for many of the figures in this chapter will follow the convention seen in Figure 6-2 below, defined as:

- "A" Lightly shaded columns
- "B" Dark columns, completely filled in
- "C" Columns with occasional horizontal hash marks
- "D" Columns with no fill-in
- "E" Columns with cross-hatching and dots

Column "A" will always be on the far left hand side of a group. The lack of a column with a particular shading indicates a value of zero for that sub-indicator. For example, Figure 6-2 has no column "A" for Lam Pao, Dez, Guilan, Majalgaon, Dantiwada, Bhakra, Kemubu, Office du Niger, or Rio Yaqui Alto. In all those projects the measurement of volumes of water delivered to individual fields is so poor or lacking that they merited a "0.0" score for that sub-indicator.

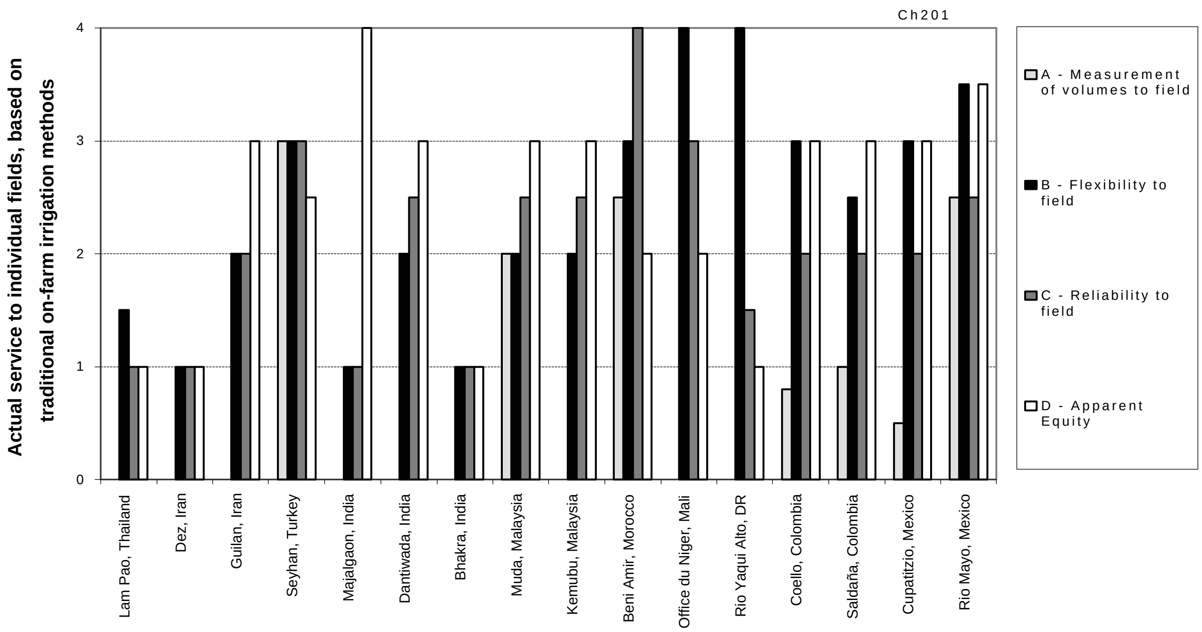

Figure 6-2. Actual water delivery service to individual fields. Based on traditional field irrigation methods. Sub-indicator values for Indicator I-1.

Most field (on-farm) irrigation methods in these irrigation projects are relatively simple, and the farmers and irrigation project staff have low expectations of the level of water delivery service needed. This will be contrasted later with the level of water delivery service needed for pressurized field irrigation systems. As explained earlier, Tables 6-1 and 6-2 indicate the relative weighting given to each sub-indicator of Indicator I-1. Reliability and equity are both given 4 times the relative importance given to measurement of volumes to the fields when computing the final value for Indicator I-1. This indicates the very high importance of those factors in avoiding anarchy by users. Therefore, Guilan and Office du Niger (as examples) received relatively high overall ratings even though water deliveries to individual fields are not measured volumetrically. The ranking and weighting criteria found in Table 6-2 are quite important for developing standardized internal indicators. The authors offer these ranking criteria as a first version of such a procedure, recognizing that this is a new concept and it will be improved with time.

Figure 6-1 shows that the majority of the projects visited have relatively similar overall service ratings, although there are major differences in the components of service. The level of service to individual fields definitely has room for immediate improvement, but by the same token, it is not devastatingly poor in most cases. For the most part, irrigation projects which have been recipients of "modernization" aspects perform better in this important aspect than those which have not received modernization. Bhakra (India) is an example of a project in Asia without modernization and its rating for Indicator I-1 is very low. Lam Pao, Dez, and Bhakra are outstanding in their relatively low levels of water delivery service. Lam Pao, Dez, and Bhakra also had noticeable farmer dissatisfaction with the water service. The "level of service" does not include a measure of the adequacy of water in volume. For example, Lam Pao and Bhakra have very different Relative Water Supplies (Annual RWS_{ITRC} =2.2 for Lam Pao vs. 1.2 for Bhakra).

Rather, Indicator I-1 is a measure of the reliability, flexibility, equity, and measurement of the existing supply (whatever it is) to individual fields.

Figure 6-2 shows that 2 projects (Office du Niger and Rio Yaqui Alto) have outstanding flexibility in water delivery service to individual fields. Both projects have two important design/operation characteristics (seen later in this report) - they have a very high density of turnouts, and they allow spill of canal water. The high amounts of tailender canal spill from the lateral canals was not a deliberate design feature, but it could have been. In both projects, the spill reduces the overall project irrigation efficiency because both projects, (especially Office du Niger,) lack a systematic design for recapturing the spill within the project. In both projects such a design feature (spill recovery) could have been incorporated, which would have provided both a high irrigation efficiency and flexible delivery to the fields.

Rio Mayo has little spill in its distribution system, and does not have the topography, physical layout, and soils which would allow any spill to be easily recaptured and reused. Therefore, it requires a completely different engineering and operations strategy to provide the high degree of flexibility - the operators know the flow rates throughout the project reasonably well, have excellent communications and mobility, and work quickly and quite efficiently to provide flexibility.

The RAP examined the level of service provided at each level in the hydraulic system. These levels are:

1. To the field (as seen in Figures 6-1 and 6-2).

2. To the point of effective differentiation. This is the furthest downstream point in the irrigation distribution network with a realistic flow control and measurement structure. "Realistic" means that if the flow is supposed to be split into 2 equal components, it is indeed possible to do so relatively well. Likewise, if there is a specified flow rate downstream of that point, the point is one of "effective differentiation" and it is realistically possible to control and measure that flow.
3. To the point of deliberate differentiation. This is the furthest downstream point in the irrigation distribution network at which the flow is deliberately split or controlled. The fact that the flow is divided at a point does not mean that the split is effective or equitable. The point of "effective" differentiation may be the same as the point of "deliberate" differentiation, or it may be further upstream. For example, a small channel may supply several fields simultaneously, but there is no effective means of equitably dividing the flow between the various fields.

4. To the submains (laterals), from the mainlines.

Furthermore, there may be a difference between the "actual" service to a level and the "stated" service. In the project office, a person may hear one story (the "stated" service story), but then see a completely different level of "actual" service in the field.

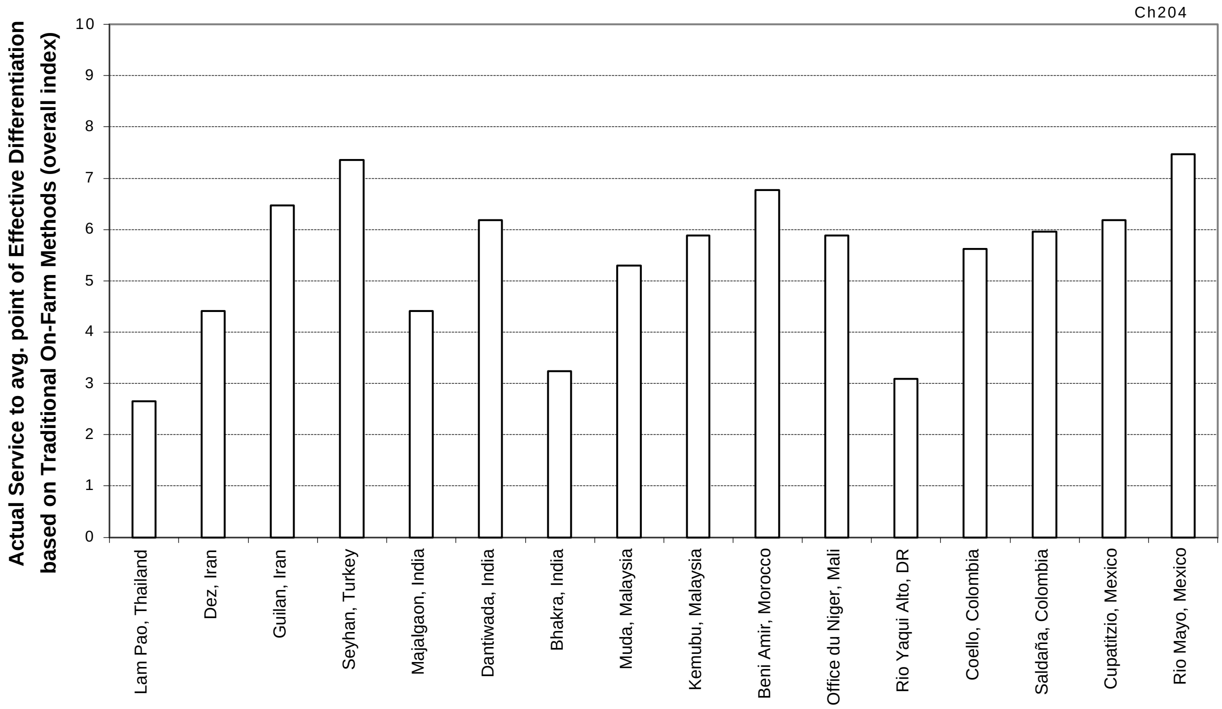

Figure 6-3. Indicator I-2. Actual service to the average point of effective differentiation.

Figure 6-3 displays Indicator I-2, which rates the water delivery service to a point which is typically upstream of the field level in the irrigation projects visited. Several fields were typically downstream of the final control point. In the western United States, the average point of effective differentiation is typically a single field.

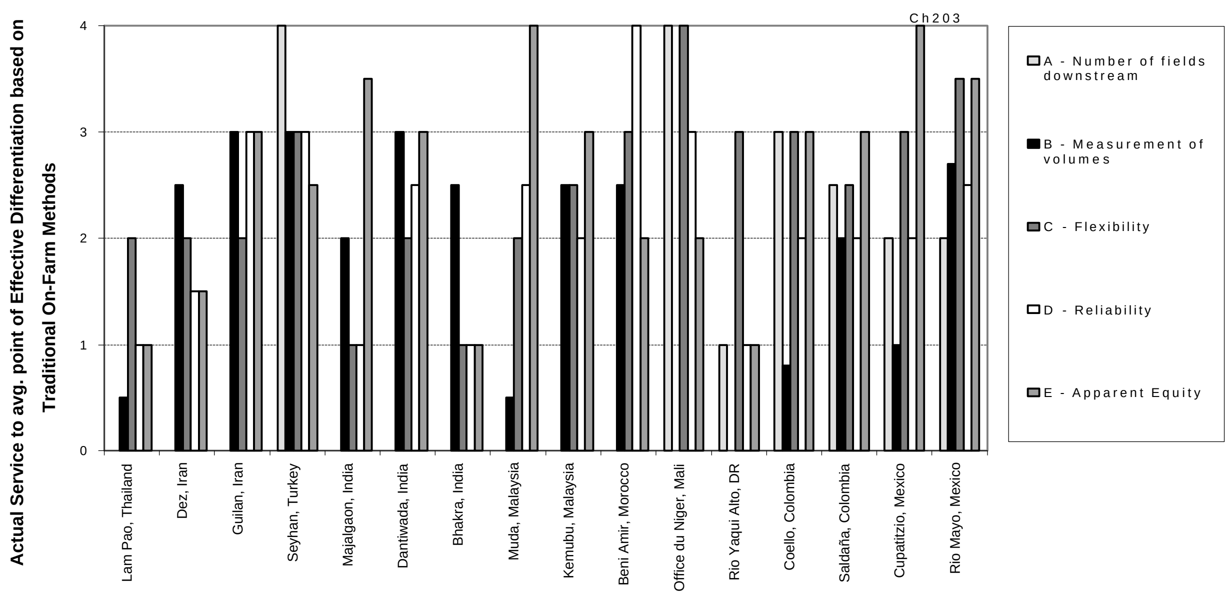

Figure 6-4. Sub-indicator values of Internal process indicator I-2. Actual service to the point of effective differentiation.

The sub-indicators or components of Indicator of I-2 are found in Figure 6-4. It can be seen from Figure 6-4 that all of the Asian Projects visited (Lam Pao, Majalgaon, Dantiwada, Bhakra, Muda, and Kemubu) received a "zero" score for the number of fields downstream of this point - indicating that there is a low density of turnouts.

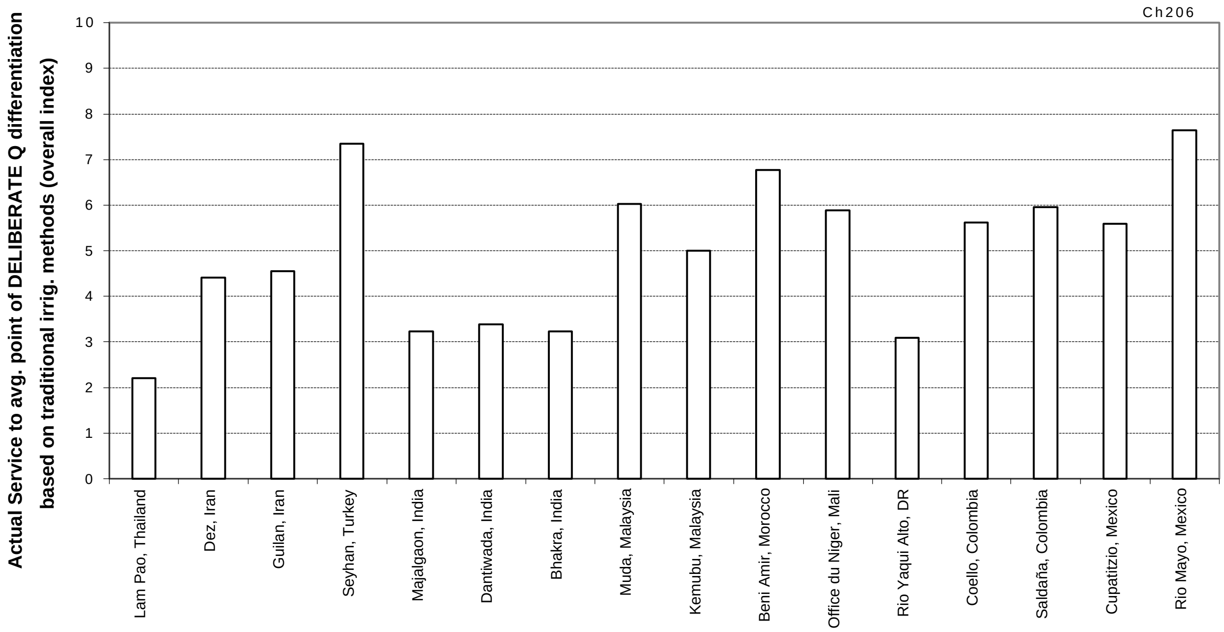

Figure 6-5. Internal process indicator I-3. Actual service to the point of deliberate differentiation.

Internal process indicator I-3 (Figure 6-5) shows the actual service to the point of deliberate differentiation. These scores are lower than those for Indicator I-2 (effective differentiation) for Lam Pao, Guilan, Majalgaon, Dantiwada, Muda, Kemubu, and Cupatitzio. The lower scores indicate that the irrigation project loses control of the water at the lower ends (toward the field) of the hydraulic system, and that flows are poorly split and re-regulated downstream of more effective upstream control points.

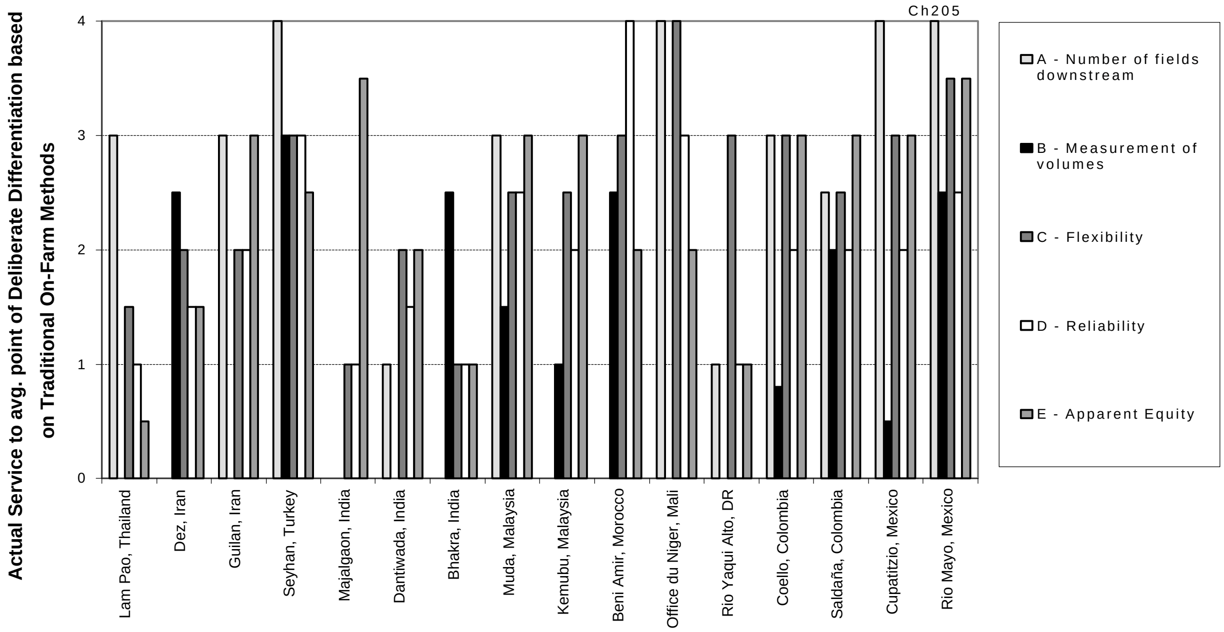

Figure 6-6. Sub-indicator values of Internal process indicator I-3. Actual service to the point of deliberate differentiation.

A hypothesis of this research was that the quality of water delivery service to the fields would depend upon the quality of water delivery service of the main canals to the submains, and the quality of service provided by the submains to the points of differentiation. Figure 6-7, when compared to Figure 6-1, shows that Lam Pao, Seyhan, Muda, Beni Amir, Office du Niger, Coello, Saldaña, and Rio Mayo have equally high or low service to the field as what is provided by the main canal to the submain. In other words, the overall quality of service did not appreciably change. On the other hand, the quality of service for Dez and Bhakra deteriorated with distance down the water network. Nevertheless, the Dez and Bhakra conditions are still consistent with the hypothesis - which suggests that good conditions cannot exist downstream unless good conditions exist upstream.

However, Guilan, Majalgaon, Dantiwada, Kemubu, Rio Yaqui Alto, and Cupatitzio all went the opposite direction. The water delivery service was considerably better at the field level than what was provided by the main canal. The estimated irrigation efficiencies for these projects were 46, 32, 29, 20, 31, and 25 percent, respectively (average = 30%). Also, the level of water delivery service delivered by the main canal was typically quite low (average = 4.0) and the actual service to individual fields (average score = 5.3) also has considerable room for improvement. These three factors indicate that *if there is plenty of water available*, the upper levels of a canal system may be operated less-than-satisfactorily without further degrading the service downstream. However, the data show that the final product (downstream service = 5.3 out of 10.0) is still not superb and the irrigation efficiencies are quite low. A conclusion is that just because the service further downstream did not degrade, the quality of service was still poor, and therefore, this is not a desirable model to follow.

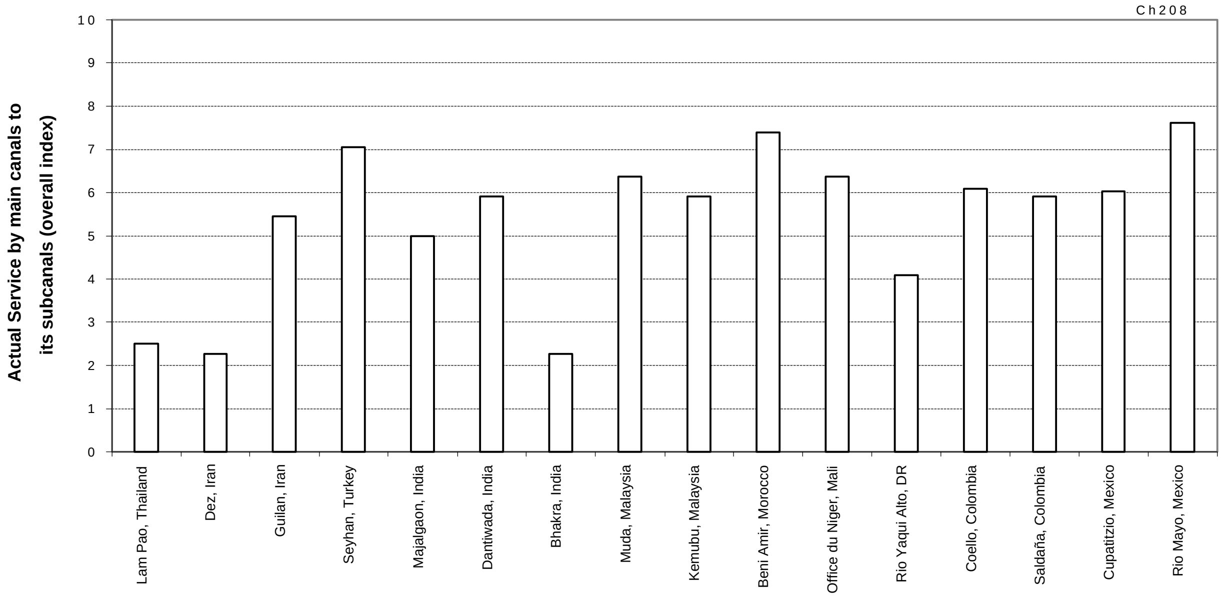

Figure 6-7. Internal process indicator I-4. Actual service by the main canals to the submain canals.

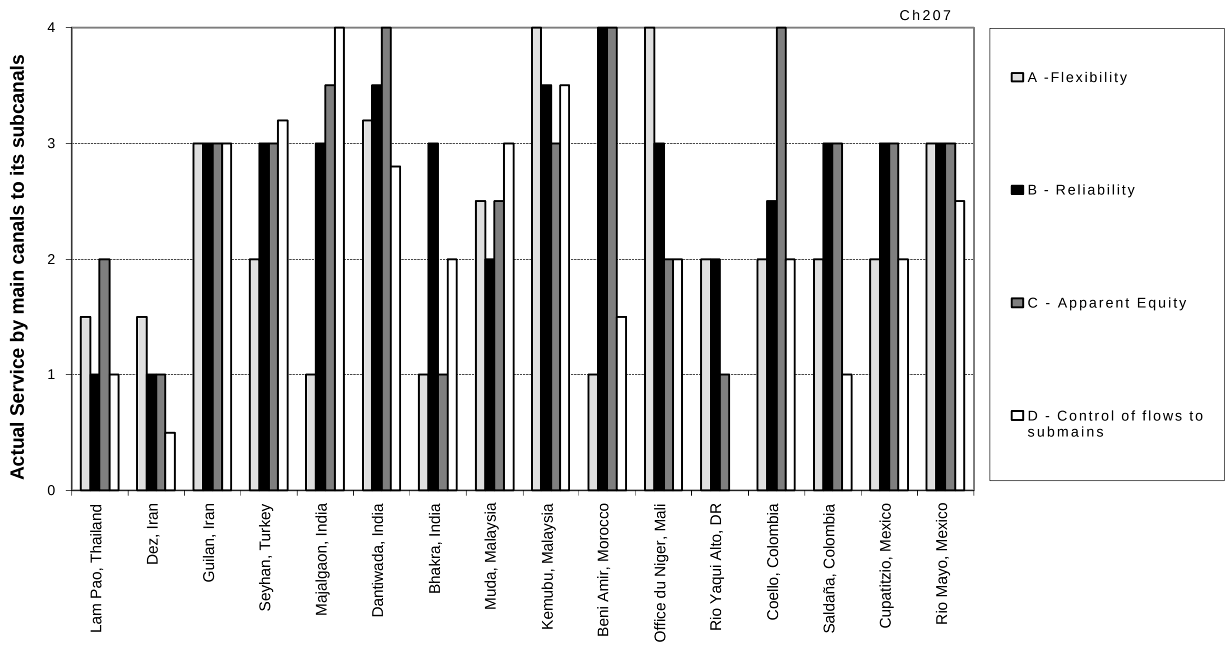

Figure 6-8. Sub-indicator values of Internal process indicator I-4. Actual service by the main canals to the submain canals.

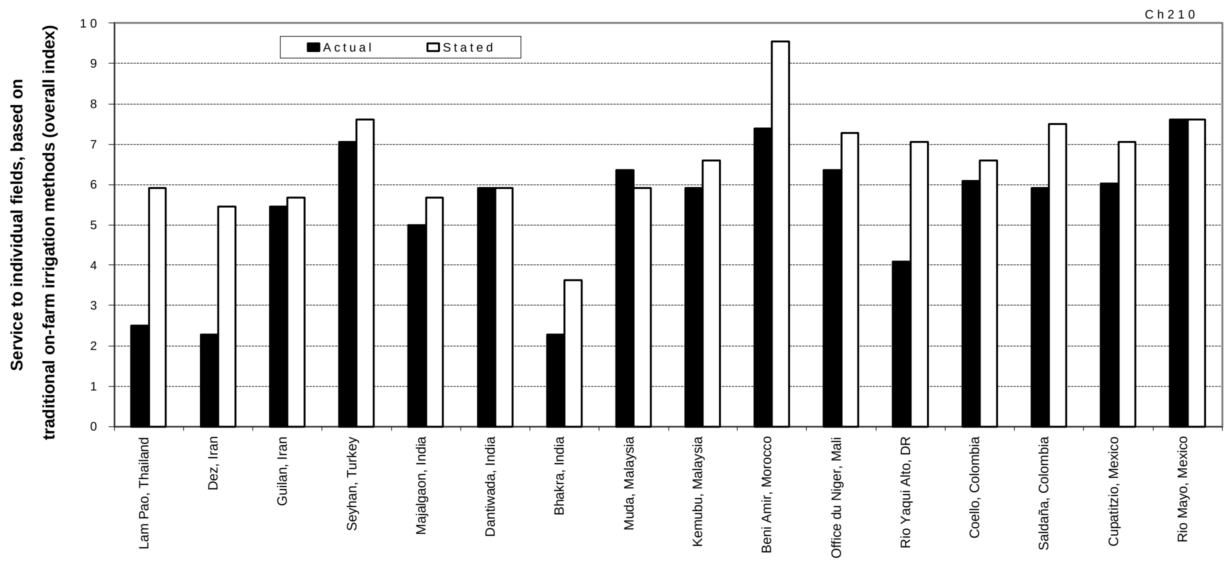

Figure 6-9. Internal process indicator I-5 and Indicator I-1. Stated and actual service to individual fields.

Figure 6-9 shows Indicator I-5, as well as the values for the earlier Indicator I-1 - both of which are for the service to individual fields. Three (Lam Pao, Dez, Rio Yaqui Alto) of the four projects with the lowest water delivery service ratings have highly over-inflated stated opinions of the service they offer. The fourth project with a very low field service rating (Bhakra) has a moderately over-inflated opinion of its service.

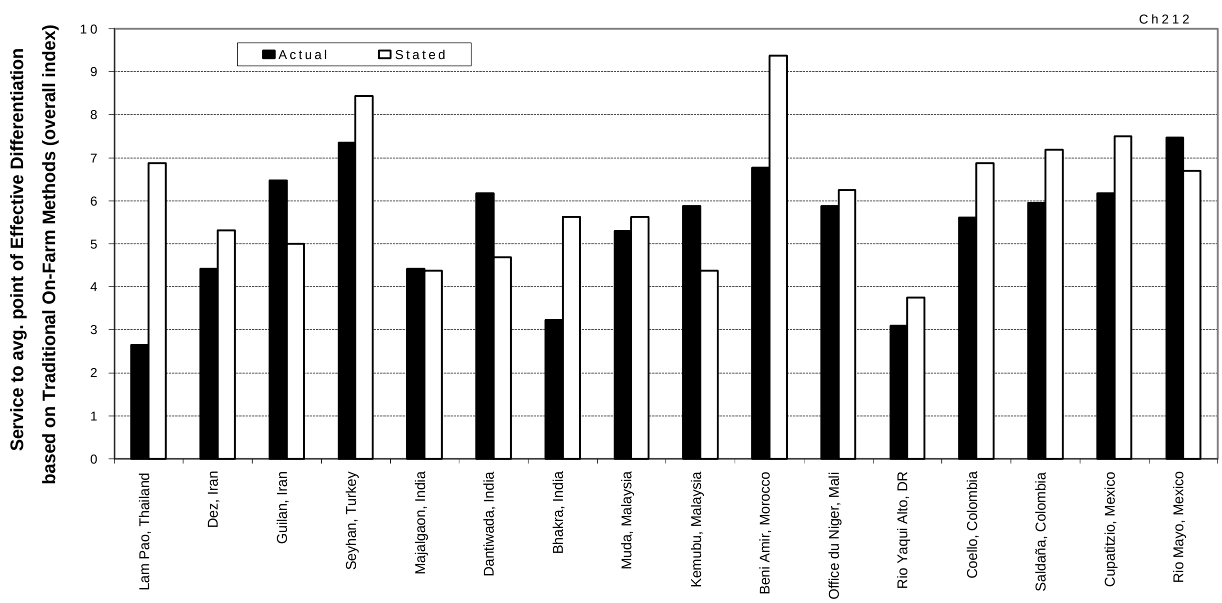

Figure 6-10. Internal process indicator I-6 together with Indicator I-2. Stated and actual service to the average point of effective differentiation.

Figure 6-10 is similar to Figure 6-9, but refers to the average point of effective differentiation. Again, it can be seen that Lam Pao and Bhakra projects have greatly inflated views of the level of service which they provide (as contrasted to actual service). Dez and Rio Yaqui Alto, the two other projects with the lowest service to the field, also have somewhat inflated viewpoints. Interestingly, Rio Mayo, Cupatitzio, Kemubu, Muda, Dantiwada, Majalgaon, and Guilan have better-than-stated service - indicating that field operators may be taking matters into their own hands and providing better service than official policy dictates.

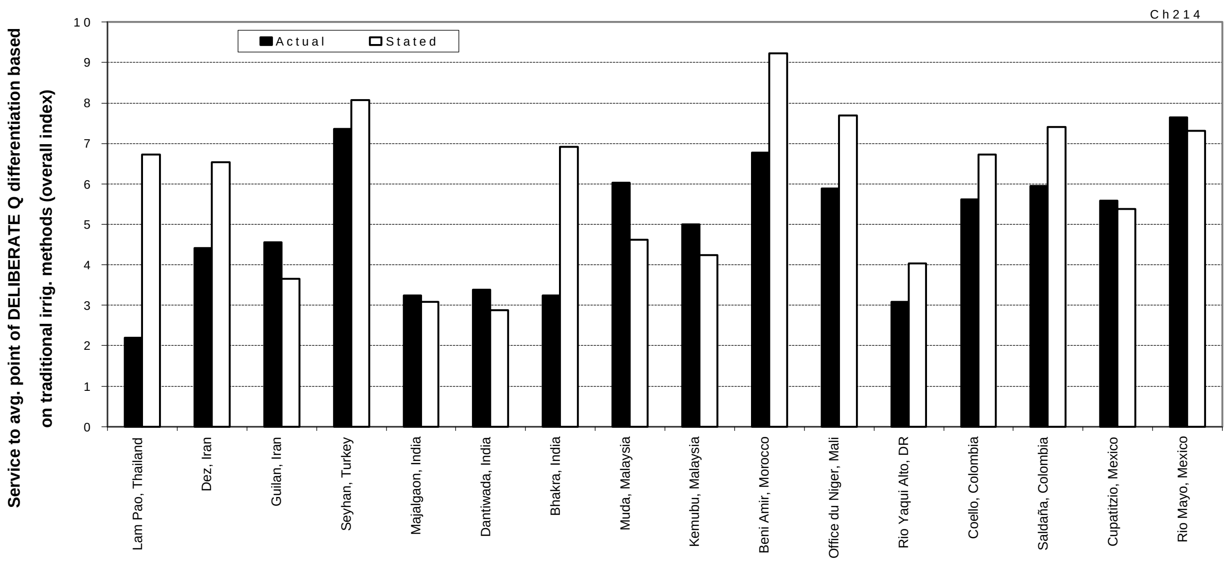

Figure 6-11. Internal process indicator I-7 and Indicator I-3. Stated and actual service to the average point of deliberate differentiation.

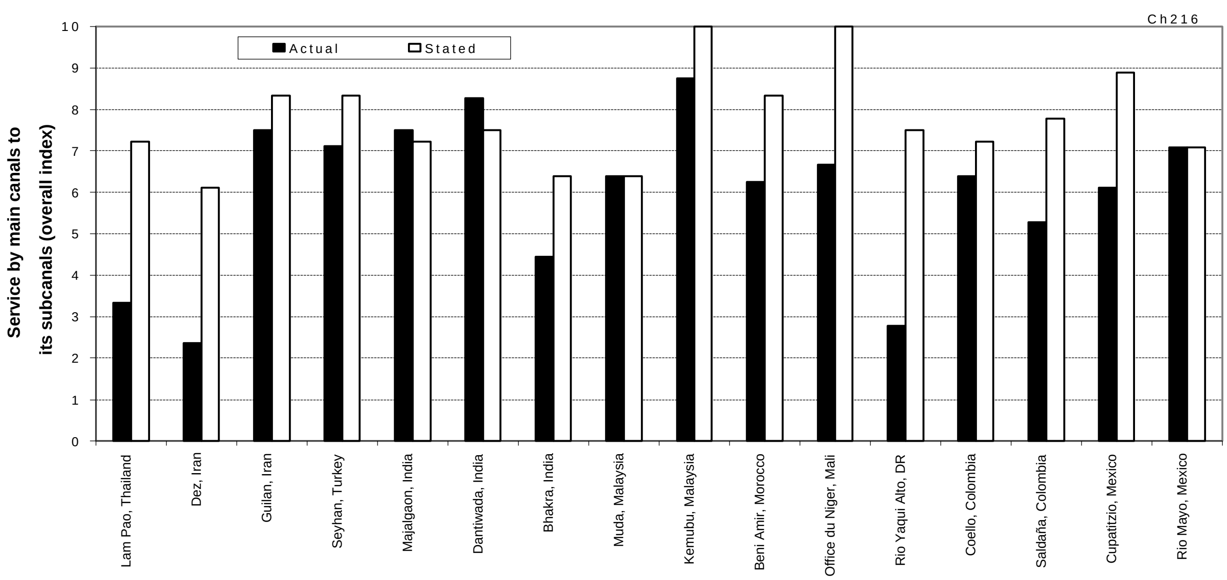

Figure 6-12. Internal process indicator I-8 and Indicator I-4. Stated and actual service by main canals to subcanals.

Figure 6-12 again shows a large inconsistency between stated and actual service by the main canals on Bhakra, Rio Yaqui Alto, and Lam Pao projects. These projects provide low levels of service to the individual fields, but the inconsistency is also shared by many of the other projects, including Office du Niger, Saldaña, and Coello. The projects which stand out positively in the previous figures (stated vs. actual service) are Guilan, Dantiwada, Muda, and Rio Mayo. It appears that the supervisors and senior engineers have realistic understandings of (and recognition of) the benefits and shortcomings of their project operations.

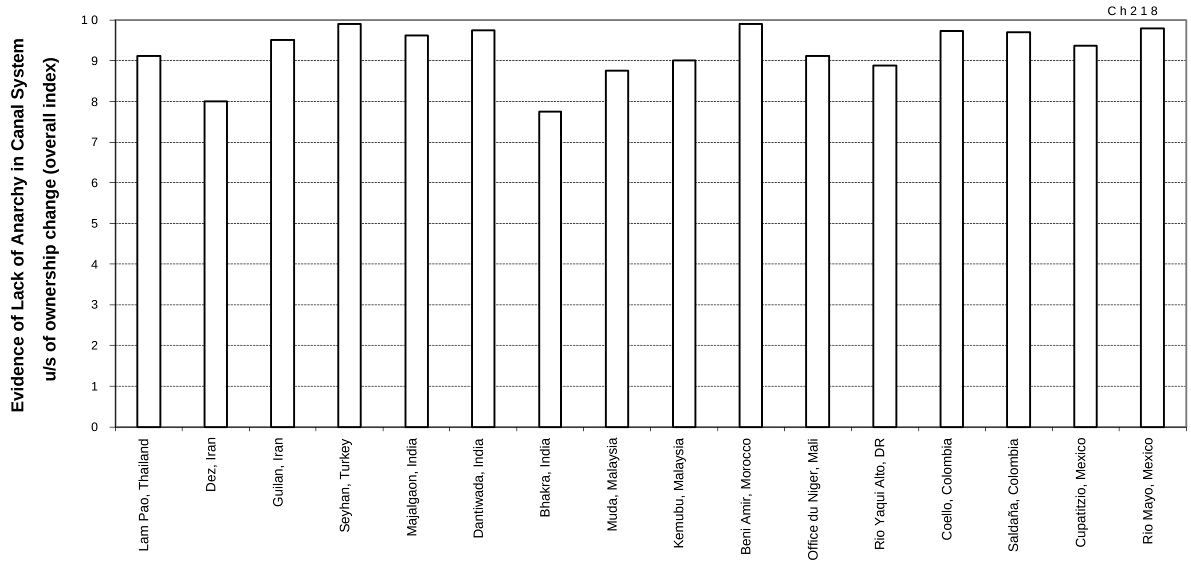

Figure 6-13. Internal process indicator I-9. Lack of anarchy index.

Indicator I-9 rates the lack of noticeable anarchy observed in the projects. A score of 10 indicates that all water is taken when authorized and at authorized turnouts. The predominate factor for "anarchy" generally results from taking water out of turn rather than vandalism of structures or the existence of unauthorized turnouts. Dez had noticeable unauthorized turnouts and vandalism which also contributed to its lower-than-average score. The topic of anarchy will be discussed in more detail in later chapters.

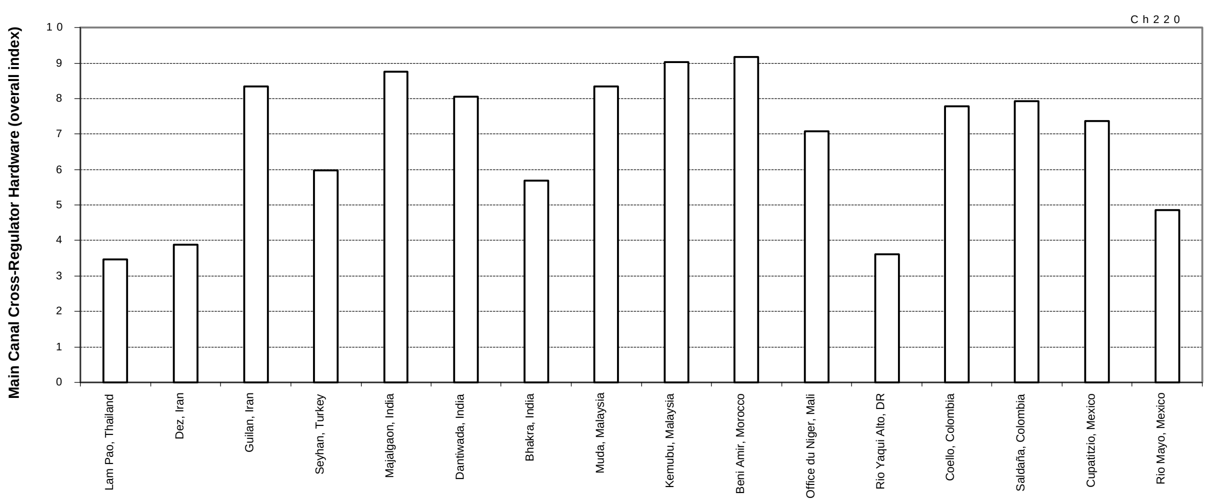

Figure 6-14. Internal process indicator I-10. Cross Regulator Hardware (Main Canal). Overall value.

Figure 6-14 is the first graph which clearly demonstrates a need for improved engineering designs and operation - in this case, within the main canal system itself. Figure 6-15 separates out the rating between ease of operation, level of maintenance, fluctuations of target levels, and wave travel time. A few of the projects have high ratings, but there are also a significant number of very poor ratings. Rio Mayo is an example of a main canal system with poor hardware but well trained, mobile, and motivated staff who are getting the most they can out of their hardware. However, for Rio Mayo to improve its performance beyond the current level of service, the canal hardware must first be improved.

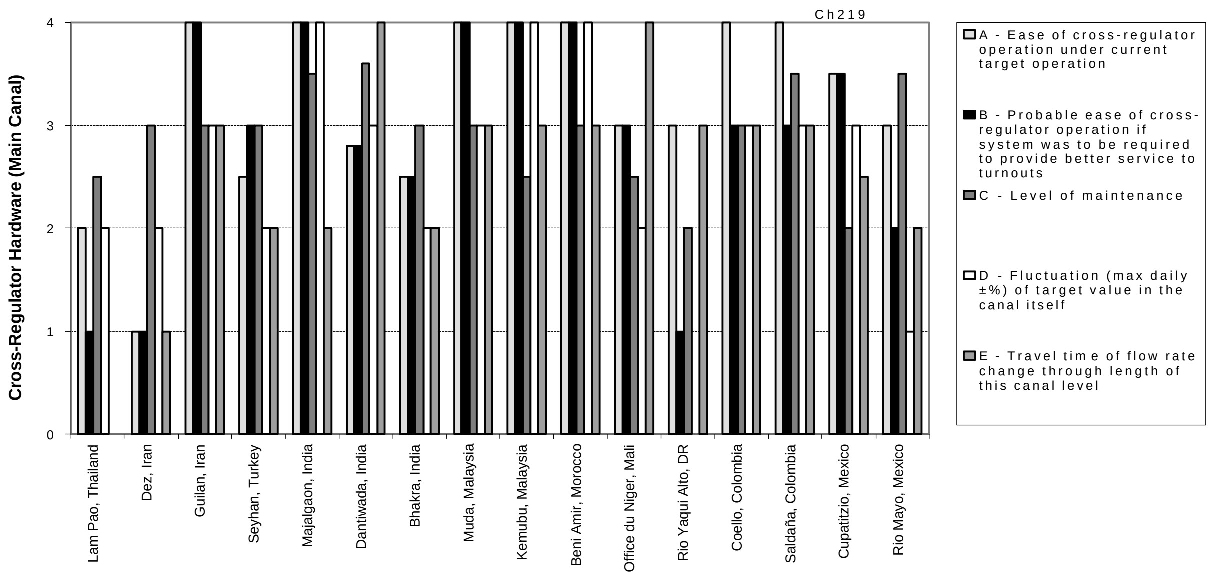

Figure 6-15. Internal process indicator I-10 sub-indicator values. Main canal cross regulator hardware.

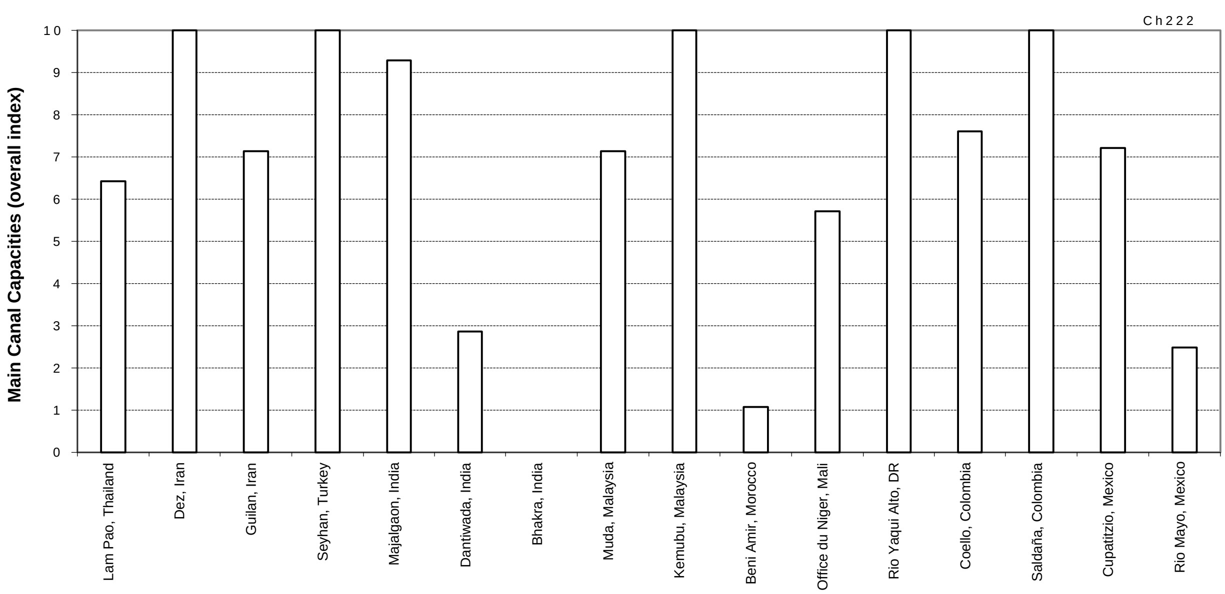

Figure 6-16. Internal process indicator I-11. Main canal capacities.

Internal process indicator I-11 combines some of the elements of the IWMI7 and ITRC3 external indicators (Water Delivery Capacity, %). It shows that 5 of the 16 projects have no restrictions, even at 100% cropping intensity. Other projects have moderate to severe canal capacity problems. It is interesting to note that there is little correlation between the canal capacities and the level of service provided by the irrigation projects. In other words, the fact that a project has small canal capacities is not related to how well the limited supply is delivered.

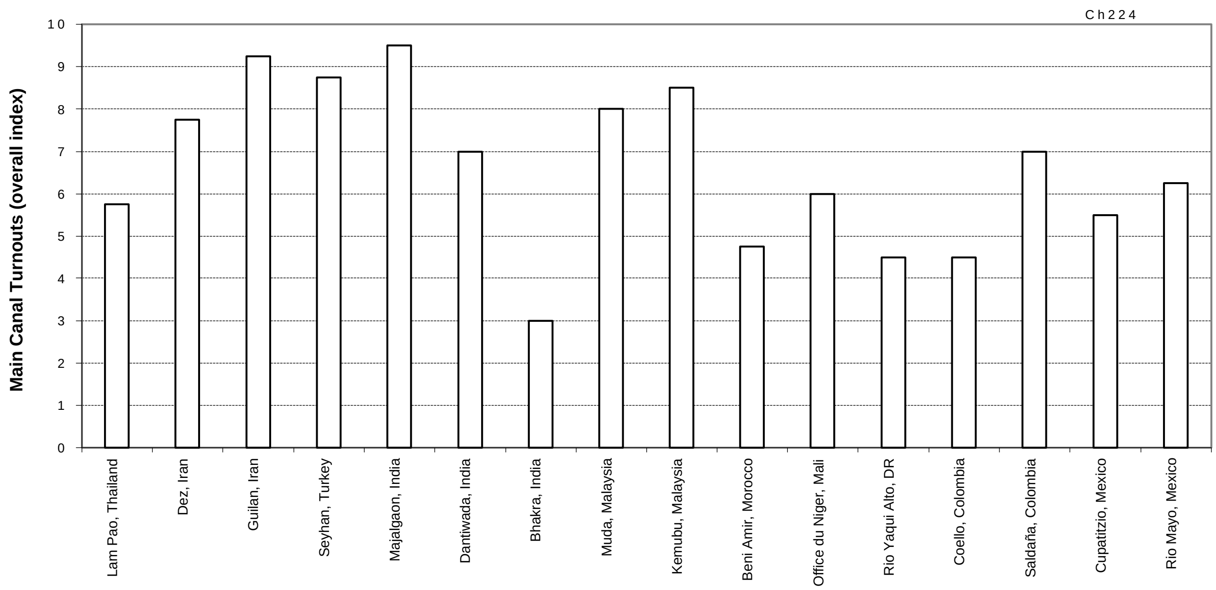

Figure 6-17. Internal process indicator I-12. Main canal turnouts.

Another important design and operation point is the turnouts from the main canal. Turnout designs vary widely in their ease of operation, and in how well operators can control and measure flow rates. Bhakra (the sole project without any modernization aspects) has a noticeably poor design and operation.

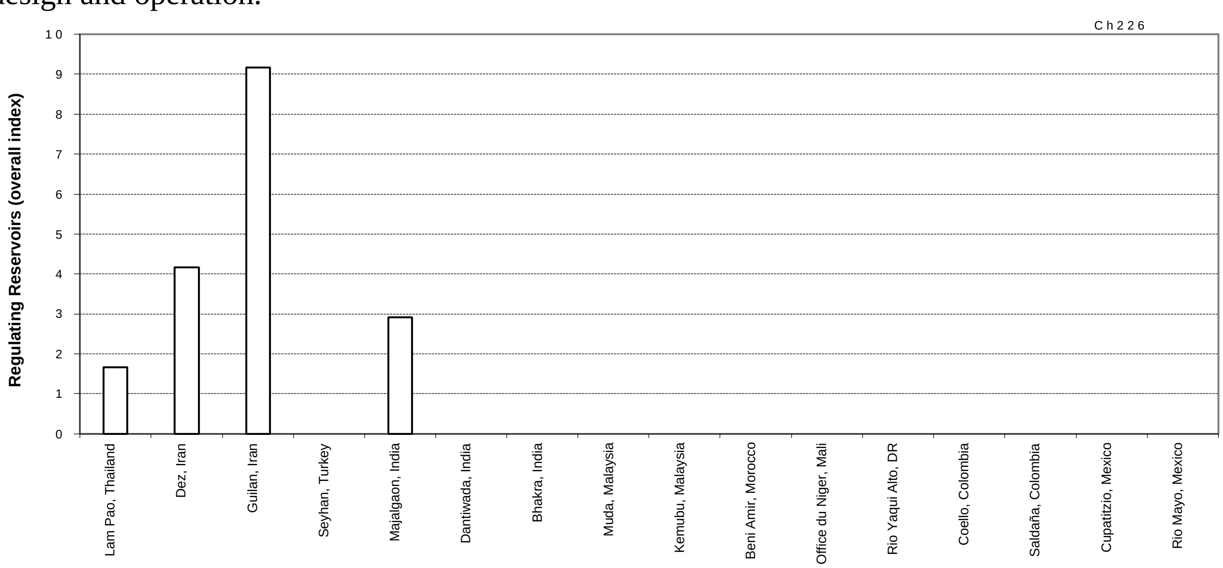

Figure 6-18. Internal process indicator I-13. Regulating reservoirs.

Regulating reservoirs can provide tremendous benefits in terms of easy and efficient operation. All canal systems have difficulties with wave travel time and unsteady flows and spills. Regulating reservoirs can provide operators with a re-starting point in addition to consolidating surface spill and buffering main canal flows. They are a major component of many modernization schemes. Figure 6-18 shows that very few regulating reservoirs are used to date, and those which exist tend to have low ratings in terms of design and management. The exception is Guilan, which utilizes a network of regulation reservoirs at the lower end of its distribution system.

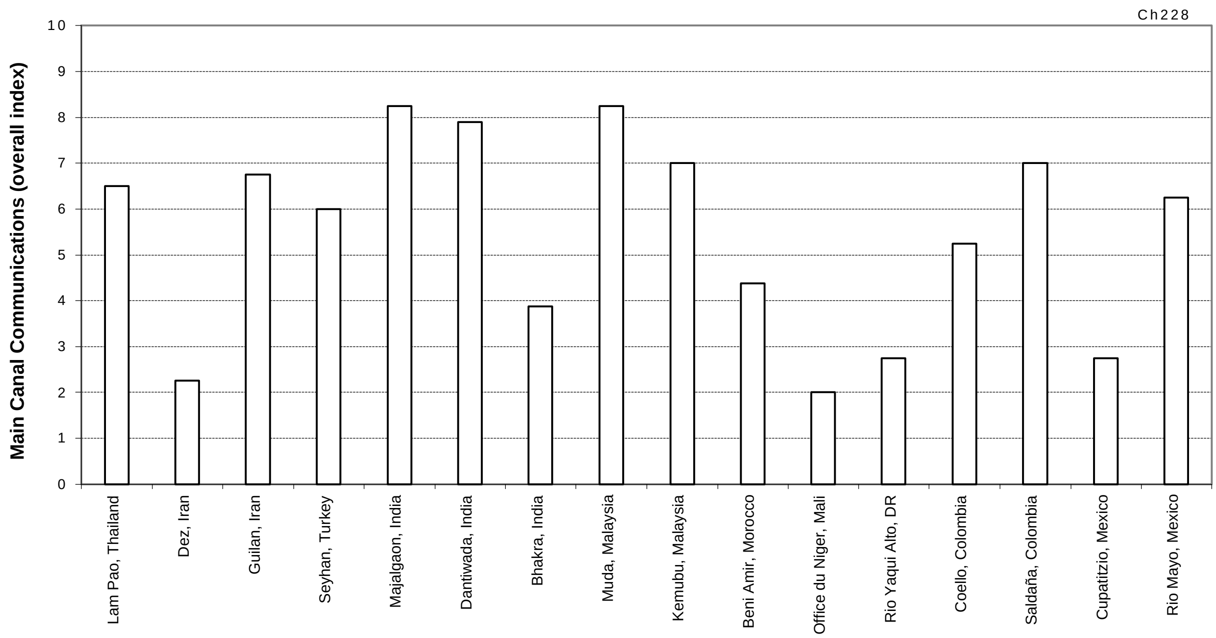

Figure 6-19. Internal process indicator I-14. Main canal communications.

A major consideration in canal management is communications between operators and monitoring of water levels and flows at key control or spill points. One of the first steps in good modernization programs is the purchase of two-way radios for operators. Modern irrigation projects make extensive use of remote "monitoring" at key points, even if there is no remote "control" at those locations. Figure 6-19 shows that all of the projects have room for improvement, and that the majority of projects have considerable modernization potential in this regard. Figure 6-20 shows that remote real-time monitoring (either manual or automatic) only exists in Lam Pao, Guilan, Seyhan, Majalgaon, Dantiwada, Muda, Kemubu, and Beni Amir, and the real-time monitoring is only extensive in Muda, Kemubu and Majalgaon. As a side note, the most active component of irrigation district modernization in California at the moment is in the field of Supervisory Control and Data Acquisition (SCADA). Dozens of California irrigation districts are voluntarily installing remote monitoring and control points (at their own cost) as they attempt to improve their water delivery service while facing a decreasing water supply.

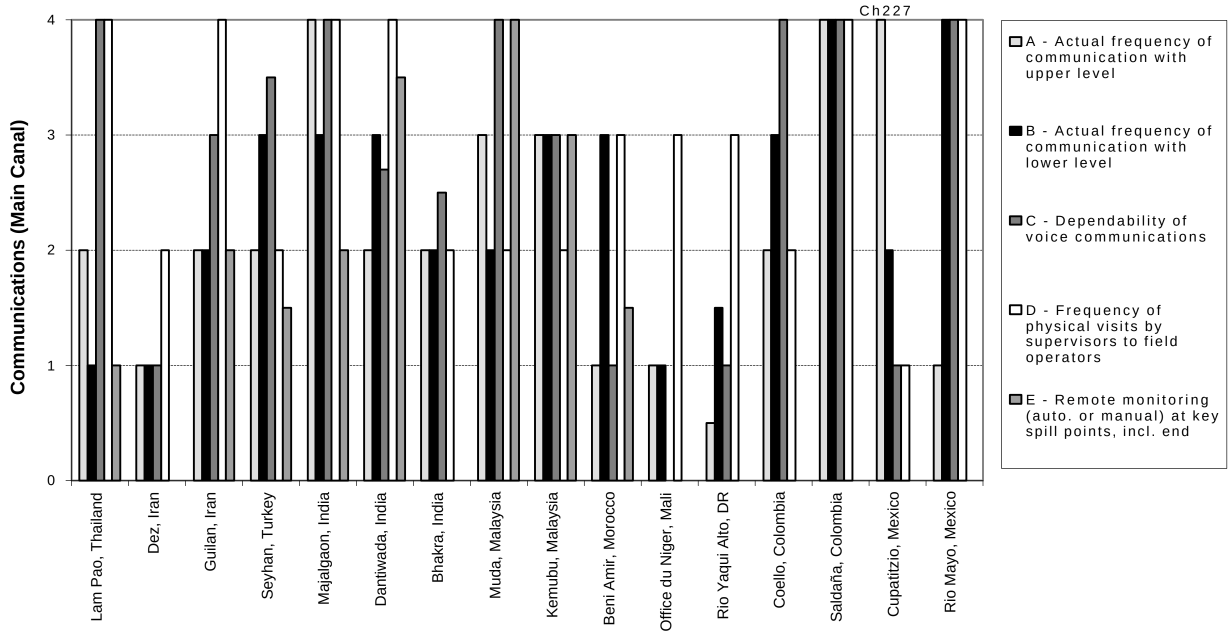

Figure 6-20. Internal process indicator I-14 sub-indicators. Main canal communications.

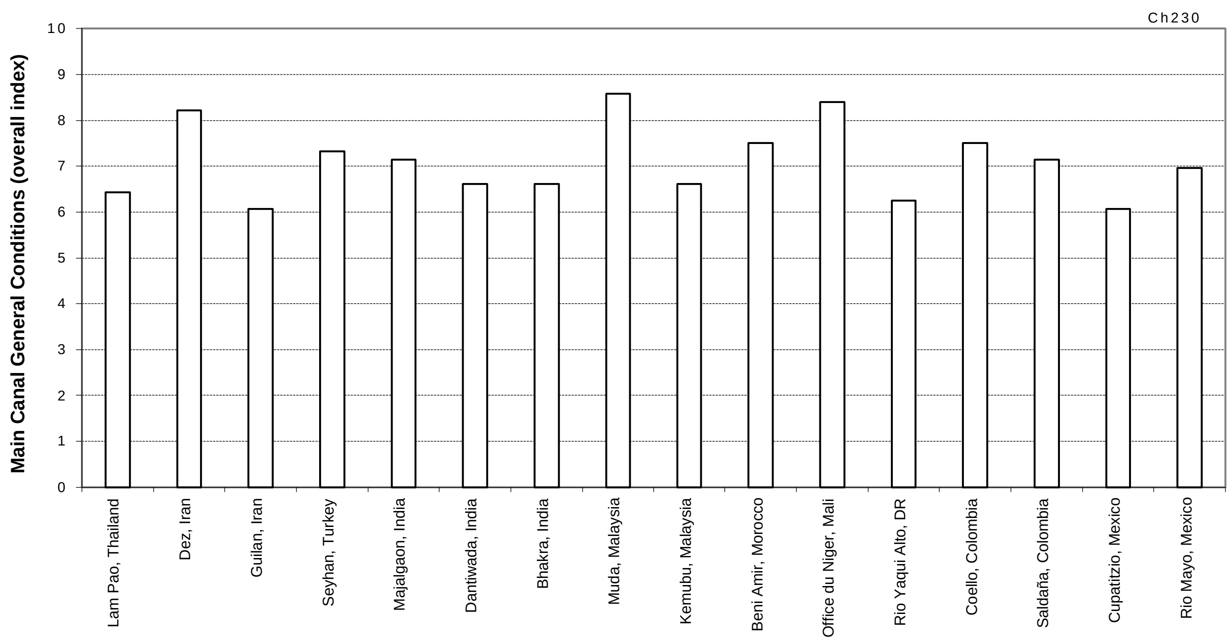

Figure 6-21. Internal process indicator I-15. Main canal general conditions.

Figures 6-21 and 6-22 show the state of general conditions along the main canals. Although there are major differences in the sub-indicators, the overall Indicator I-15 values are quite similar. Furthermore, the conditions appeared to be reasonably good - although not perfect. This indicates that although individual projects may need better main canal maintenance or canal access, this is generally not the key aspect of the main canals which affects the level of water delivery service.

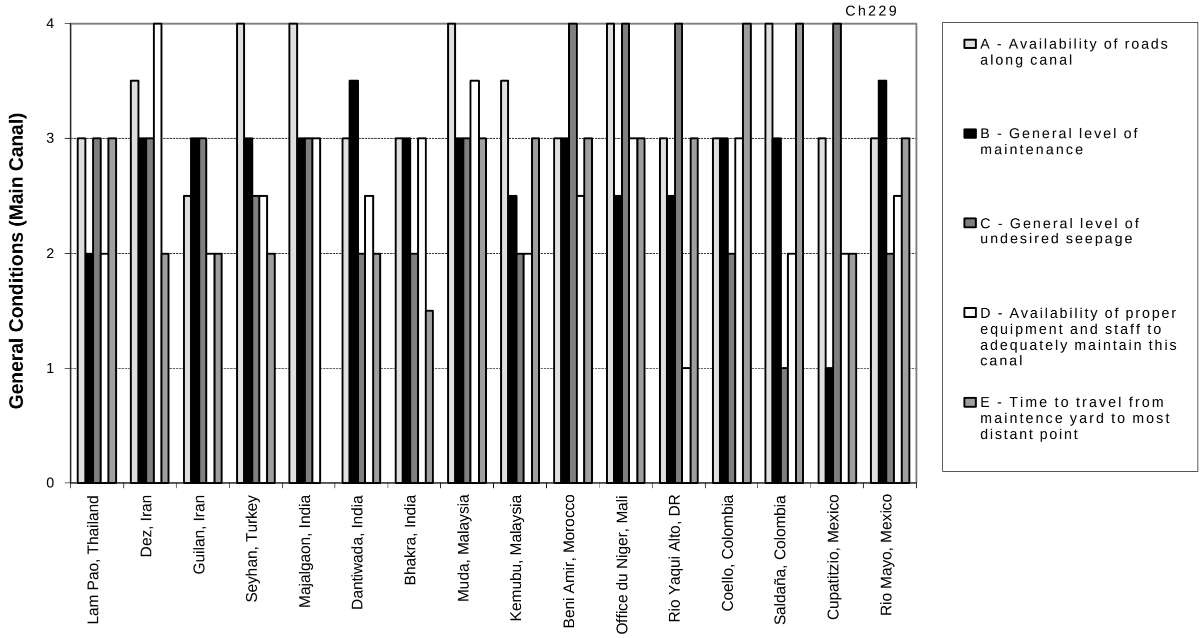

Figure 6-22. Internal process indicator I-15 sub-indicators. Main canal general conditions.

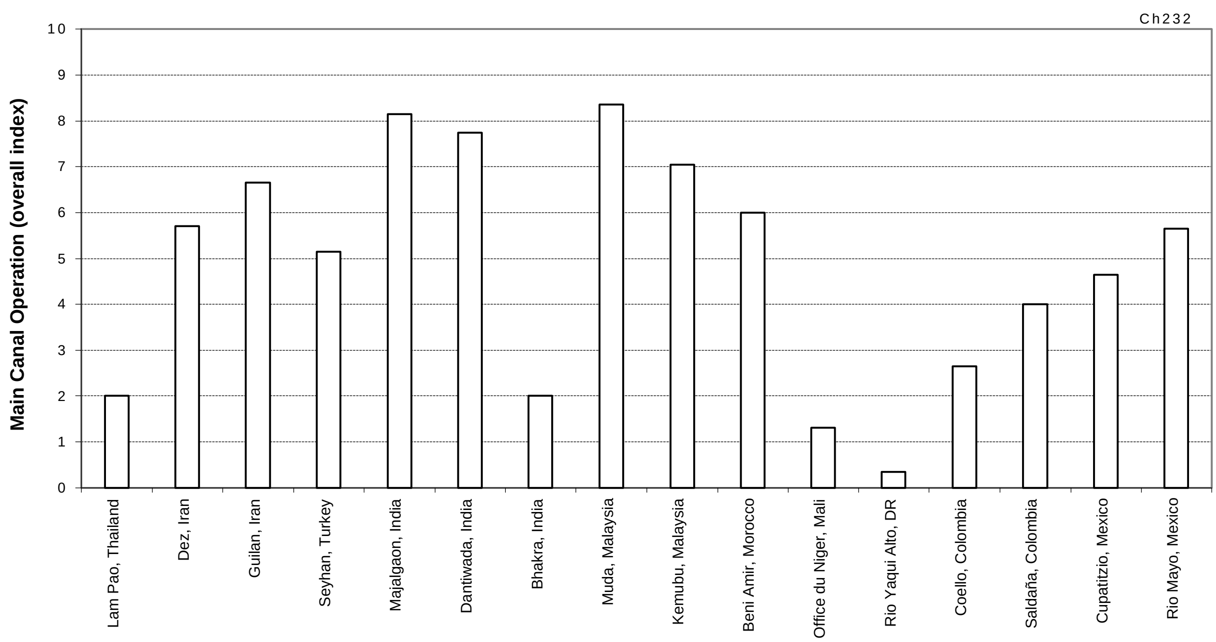

Figure 6-23. Internal process indicator I-16. Main canal operation.

Figures 6-23 and 6-24 primarily indicate how well the people in charge of the main canal, the reservoirs, or the diversion dams understand basic concepts of irrigation. While there are numerous challenges in irrigation projects which are difficult to understand and solve, there is really no justification for not receiving excellent scores on Indicator I-16. Indicator I-16 deals with basic responsibilities - checking the canal, giving clear and correct instructions to operators, and matching main canal water flows to actual (not hypothetically calculated) water needs. In some projects, the people who are in charge of the main reservoir discharges are almost completely disconnected from the people who have responsibility for everything else within the irrigation project, thus yielding low scores for this indicator. In some projects the flows remain constant throughout the whole year regardless of the cropped acreage, rainfall, and ET rates. In other projects the flows match complicated hypothetical computations with little or no meaningful feedback from the field. Poor main system management puts a tremendous strain on managers and operators lower in the system who are attempting to do a reasonable job of water management.

The preceding figures show that there are major improvements needed in *both* main system management and hardware.

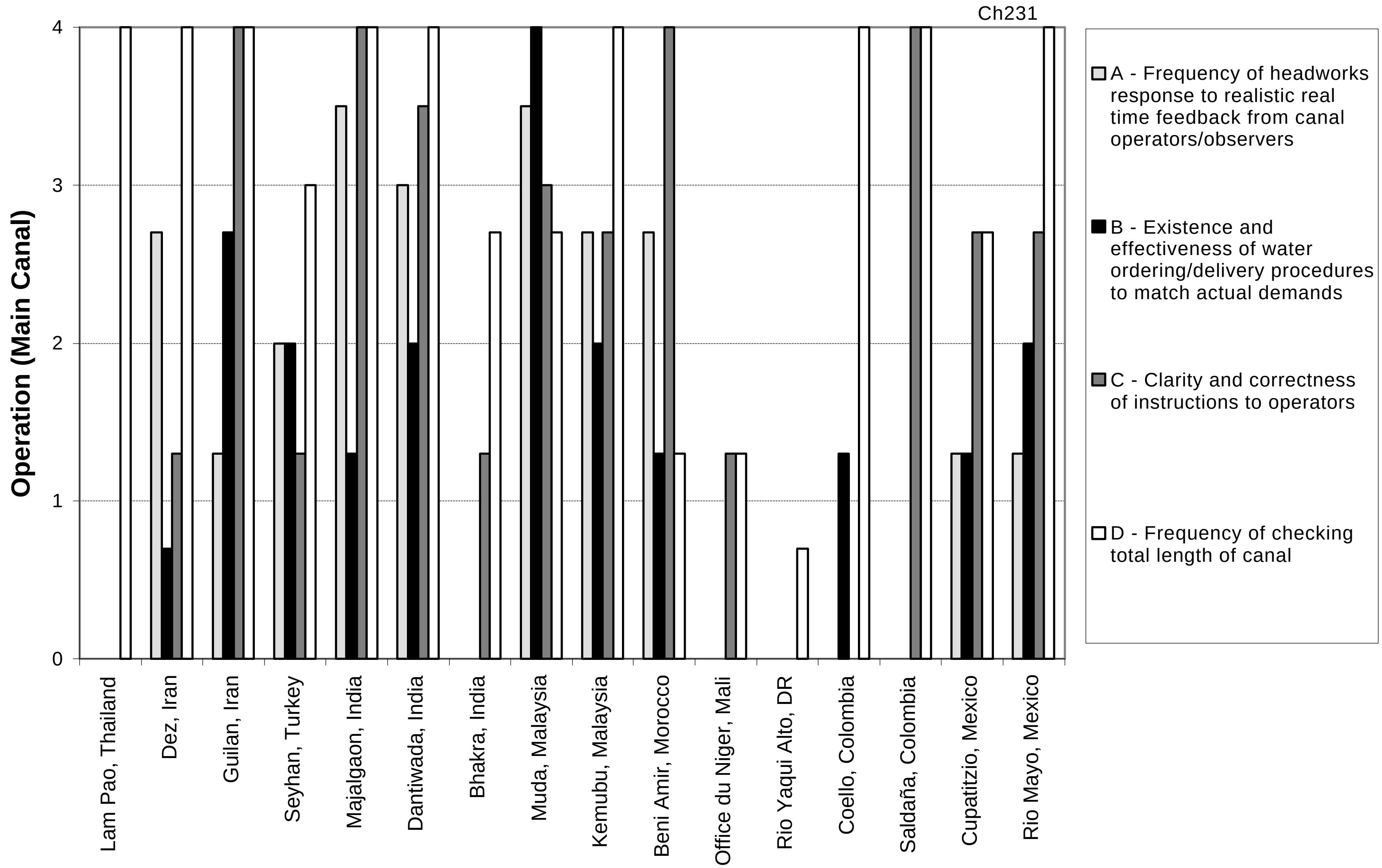

Figure 6-24. Internal process indicator I-16 sub-indicators. Main canal operation.

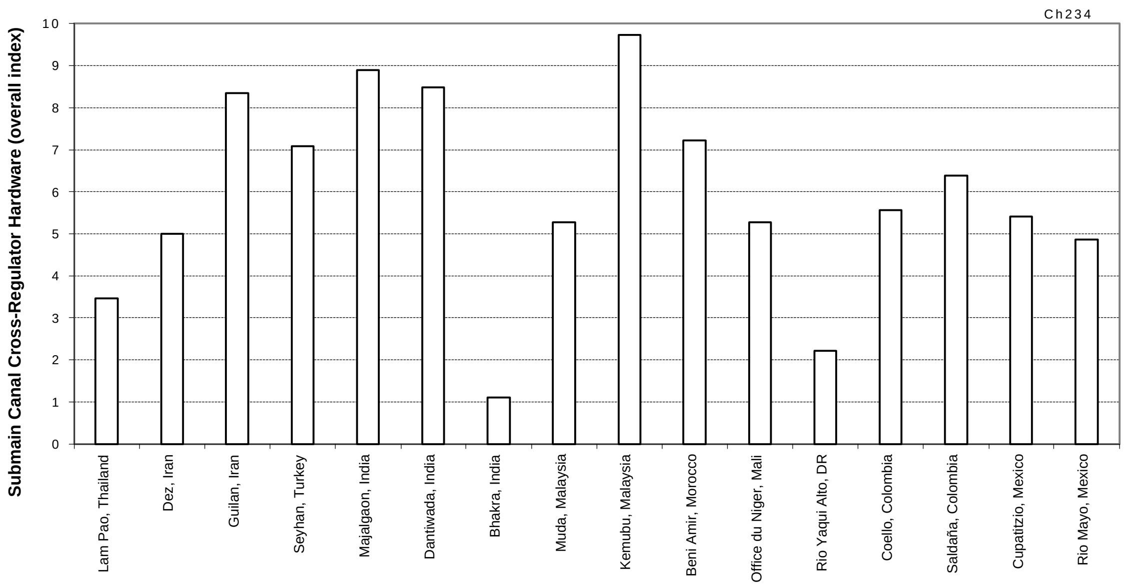

Figure 6-25. Internal process indicator I-17. Submain canal cross-regulators.

Figure 6-25 displays the first in a series of internal process indicators which are identical to the earlier main canal indicators. There are some notable differences between the two levels. A few projects have somewhat better submain cross-regulator ratings than for the main canal (Dez and Seyhan). On the other hand, Bhakra, Muda, Office du Niger, Coello, Saldaña, Cupatitzio, and Rio Yaqui Alto have considerable lower ratings at the submain levels. Rio Yaqui Alto has Begemann gates (a type of flat plate hydraulic automatic gate for upstream control) throughout its submain network, and almost none of them work correctly or at all. Those that function only do so in a manual mode.

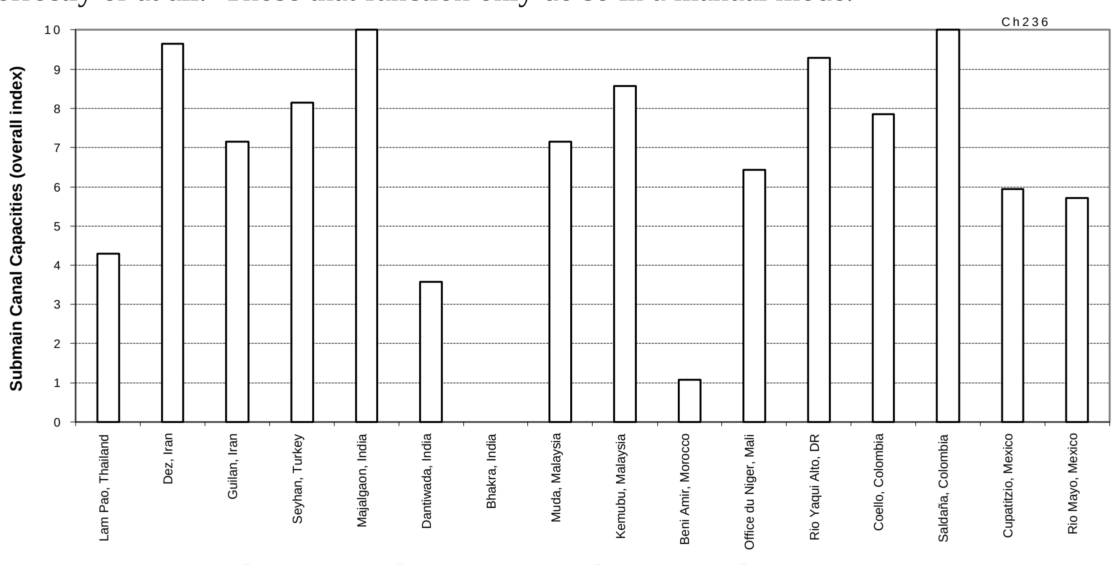

Figure 6-26. Internal process indicator I-18. Submain canal capacities.

Submain canal capacities (Figure 6-26) approximately correspond to the main canal capacities seen in Figure 6-16. Notable exceptions are Rio Mayo (larger submain capacities) and Lam Pao (smaller submain capacities). Indicator I-18 shows that overall, submains are undersized - a major design flaw if one desires to provide water with high flexibility.

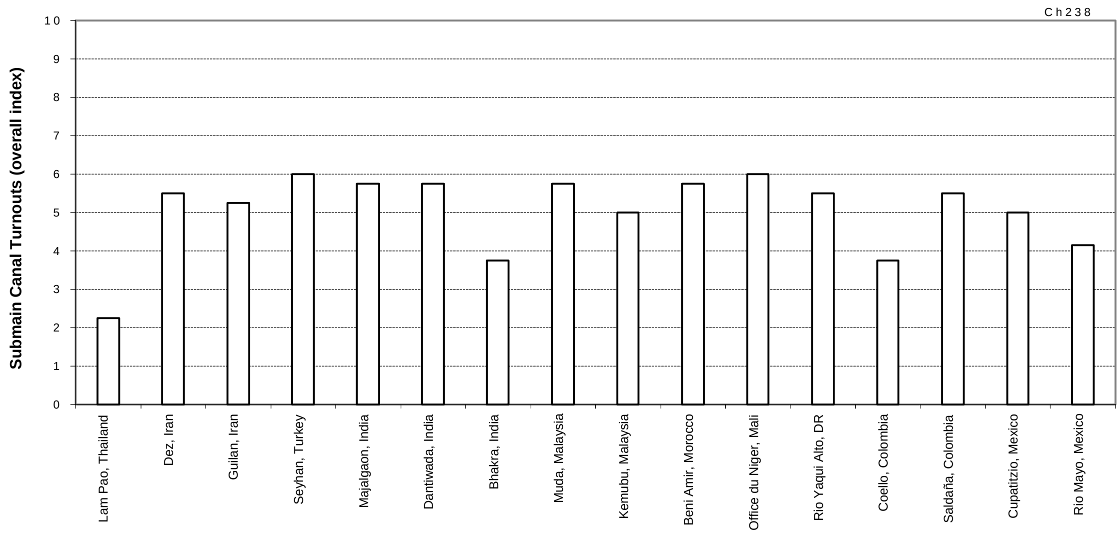

Figure 6-27. Internal process indicator I-19. Submain canal turnouts.

Indicator I-19 (Figure 6-27) shows that while a few projects rated fairly high (Dez, Guilan, Majalgaon), in general there is insufficient design and maintenance attention given to submain canal turnouts - making canal operation inefficient and inflexible canal operation. In many cases the turnouts were supposed to work quite well, but did not in the field because of design or installation problems. Figure 6-28 provides further insight. Cupatitzio's modular distributors, although theoretically excellent, were installed incorrectly and had poor maintenance. In only 3 of the 16 projects were the turnouts sized large enough.

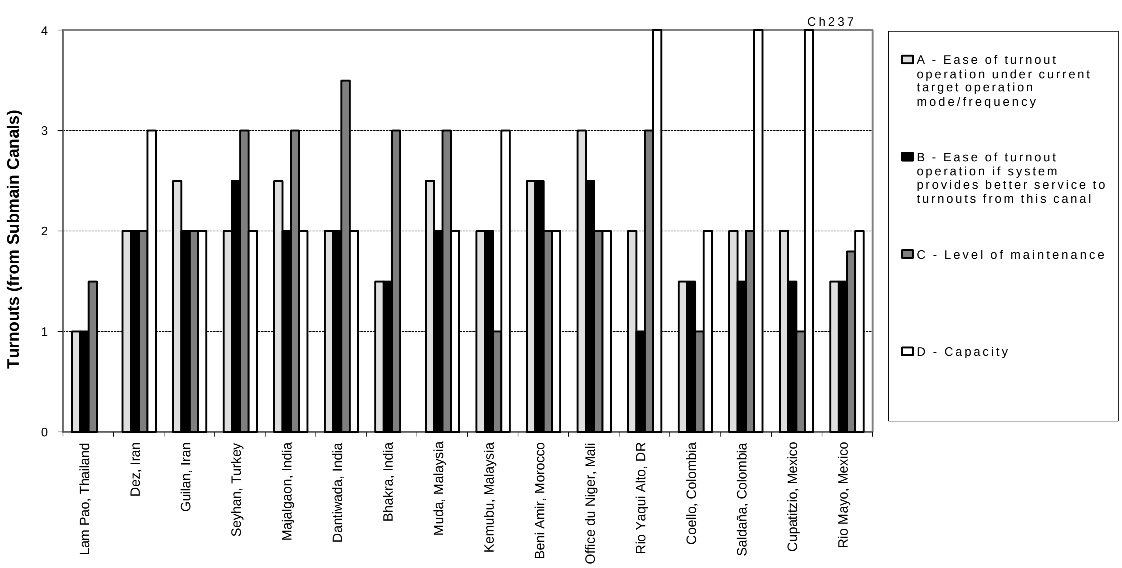

Figure 6-28. Internal process indicator I-19 sub-indicator values. Submain canal turnouts.

Figure 6-28 shows that the level of maintenance of the turnouts from the submain canals was sub-optimum on all of the projects.

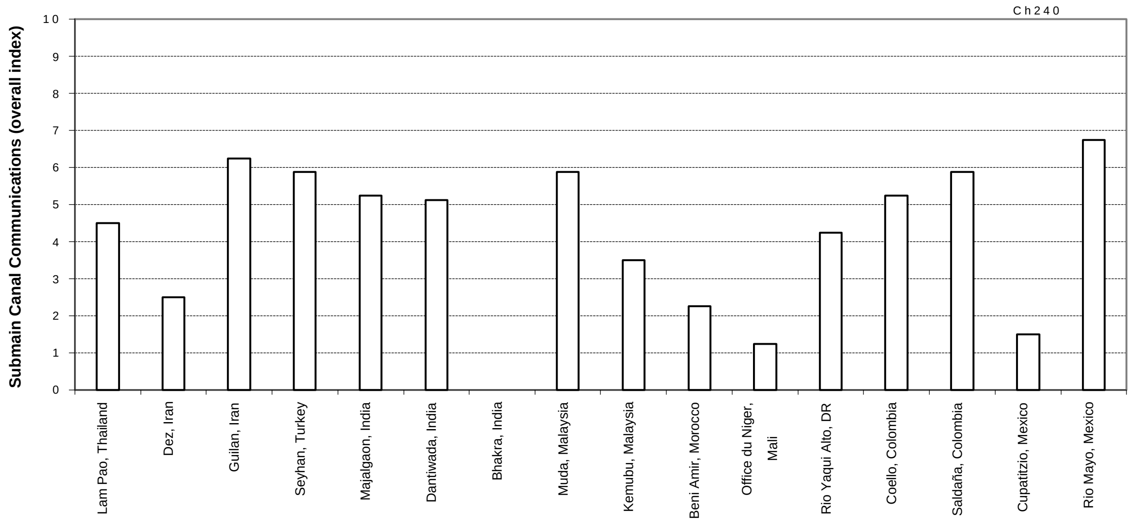

Figure 6-29. Internal process indicator I-20. Submain canal communications.

Figure 6-29 shows Indicator I-20, which rates submain canal communications. The scores are considerably lower than for the main canal system (Indicator I-14, Figure 6-19). Figure 6-30 shows that on many of the projects, there is very little communication with either the upper level or the lower level of the canal (i.e., with the people receiving the submain canals deliveries).

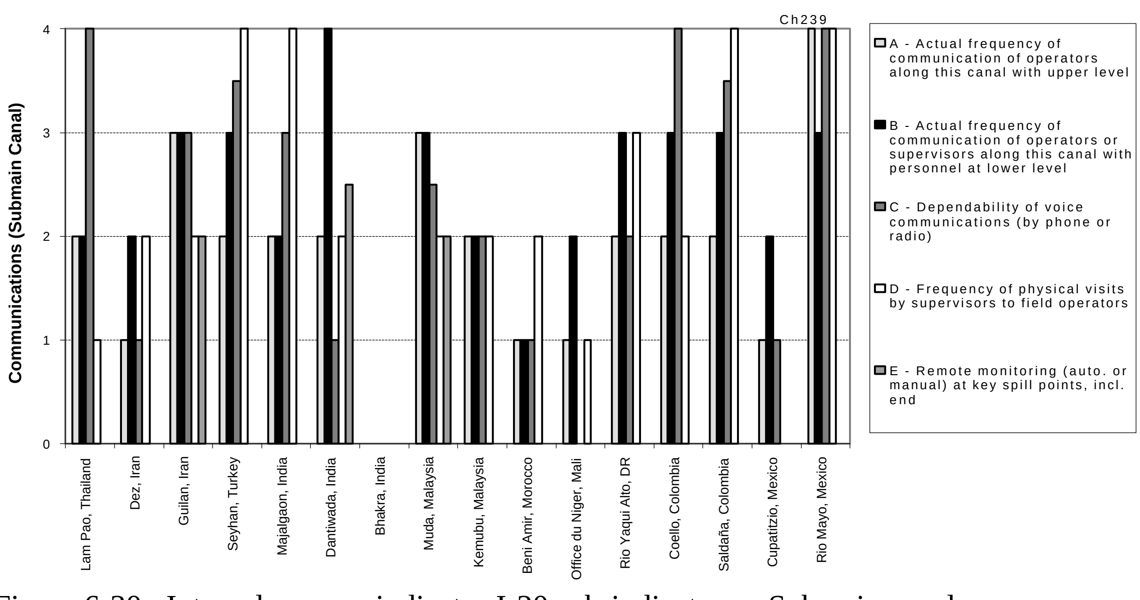

Figure 6-30. Internal process indicator I-20 sub-indicators. Submain canal communications.

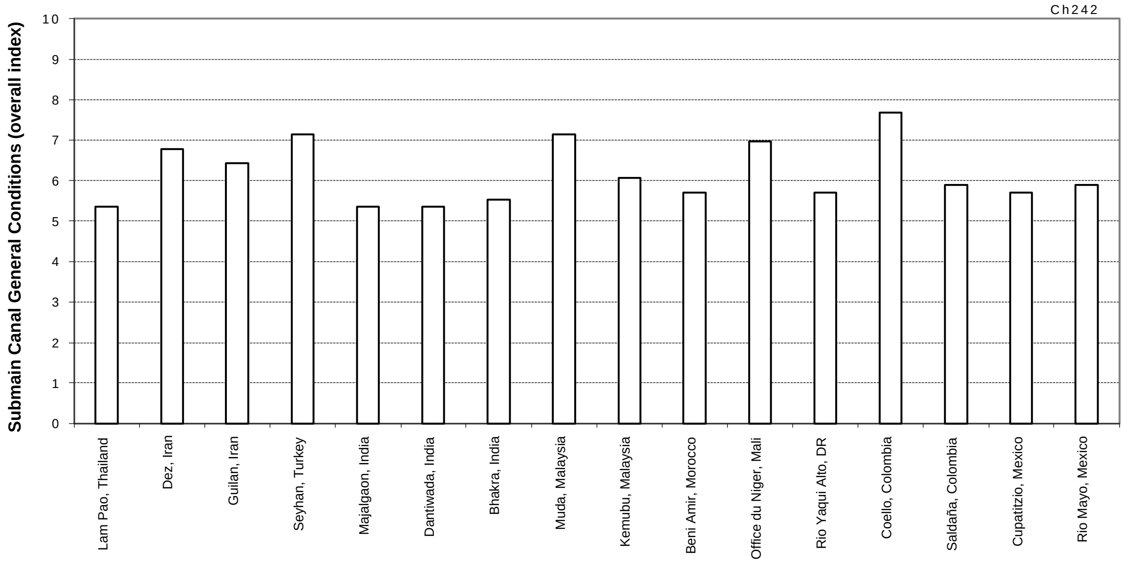

Figure 6-31. Internal process indicator I-21. Submain canal general conditions.

Indicator I-21, when contrasted to its corresponding Indicator I-15 (Figure 6-21) shows somewhat degraded conditions as one moves downstream from the main canal. The average indicator value for the main canals was 7.1, as compared to 6.2 for the submains.

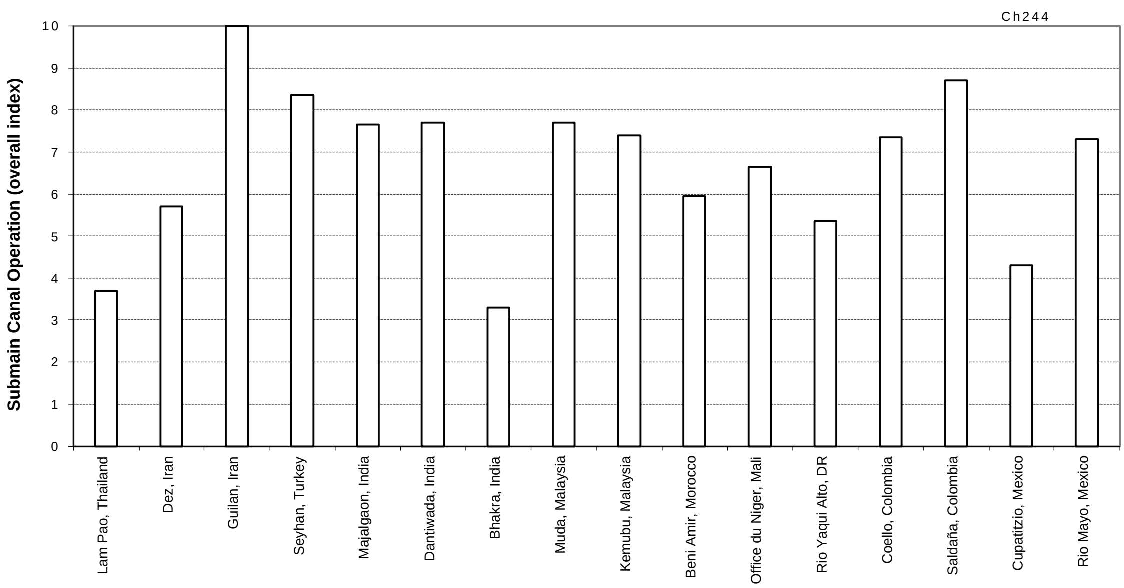

Figure 6-32. Internal process indicator I-22. Submain canal operation.

Indicator I-22 is rather surprising when contrasted to Indicator I-16 (Figure 6-23) for main canal operation. It shows that in almost all cases, the operators of the submain canals do a better job of operating than those who control the releases into the main canals.

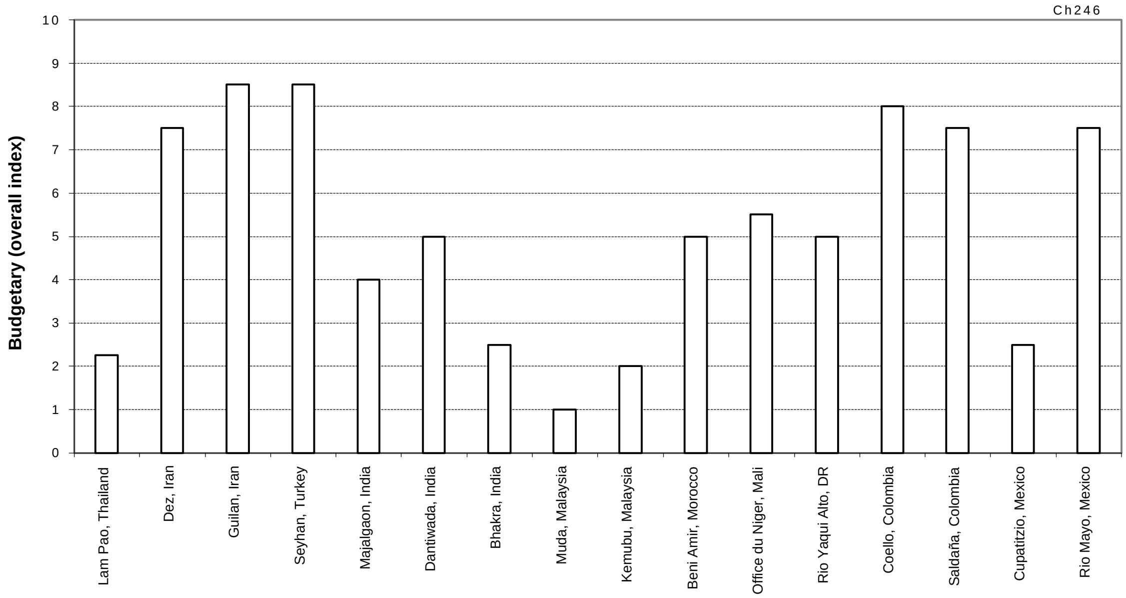

Figure 6-33. Internal process indicator I-23. Overall project budget index.

Internal process indicator I-23 was developed to look beyond the simple collection of fees for O&M. As seen in Figure 6-34, it includes an estimate of the adequacy of O&M to *sustain* the present mode of operation (which may be insufficient), and also takes a glimpse at the investment in modernization. Some projects are in the middle of modernization efforts such as Office du Niger, Dantiwada, and Majalgaon, while others such as Coello and Saldaña were constructed with "modern" aspects years ago and have little or no modernization budget.

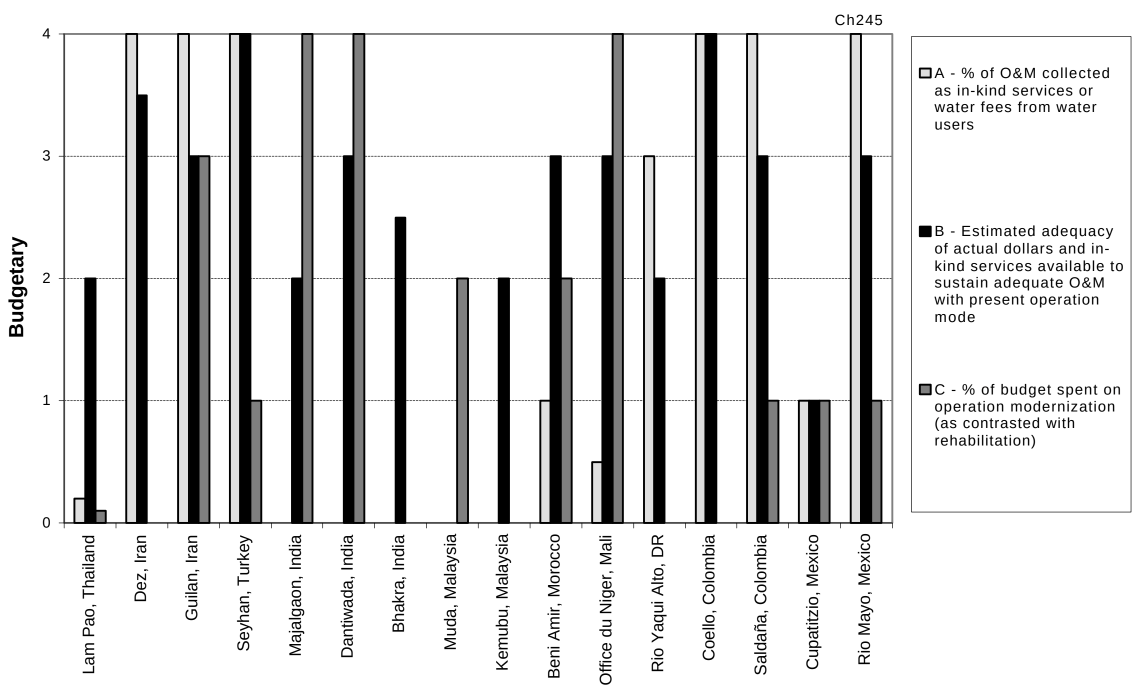

Figure 6-34. Internal process indicator I-23 sub-indicators. Overall project budget index.

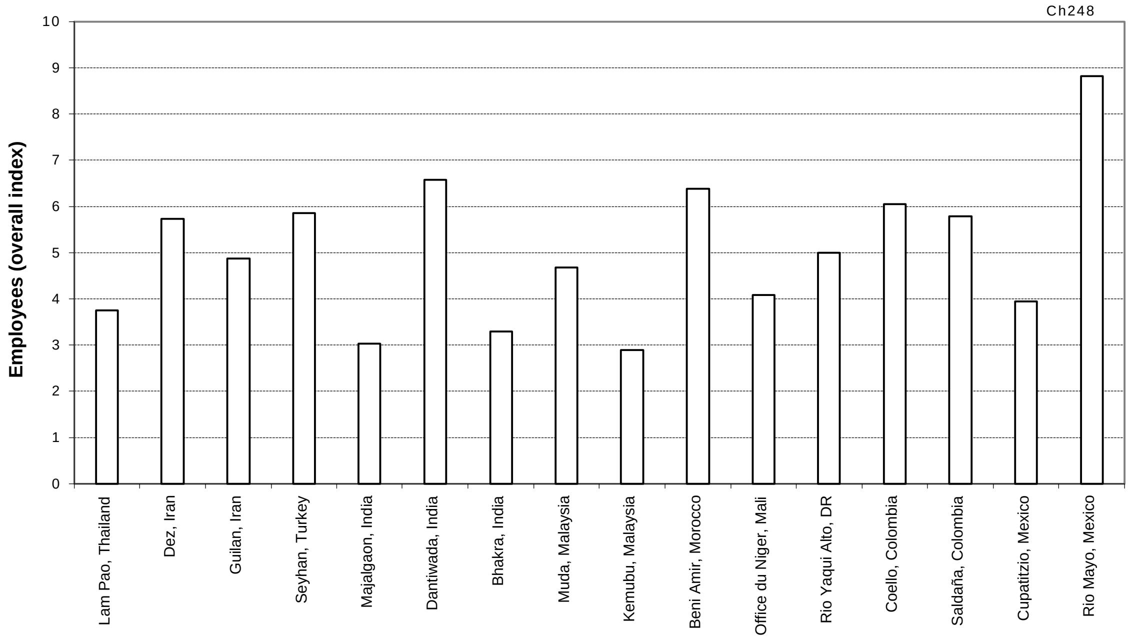

Figure 6-35. Internal process indicator I-24. Employee index.

The quality of the workforce is important in any project, and Internal process indicator incorporates factors which may influence the motivation levels of employees - such as the ability of management to fire employees, relative salaries, and incentive programs. Figure 6-35 provides the overall employee index, while Figure 6-36 and Table 6-3 provide specific details.

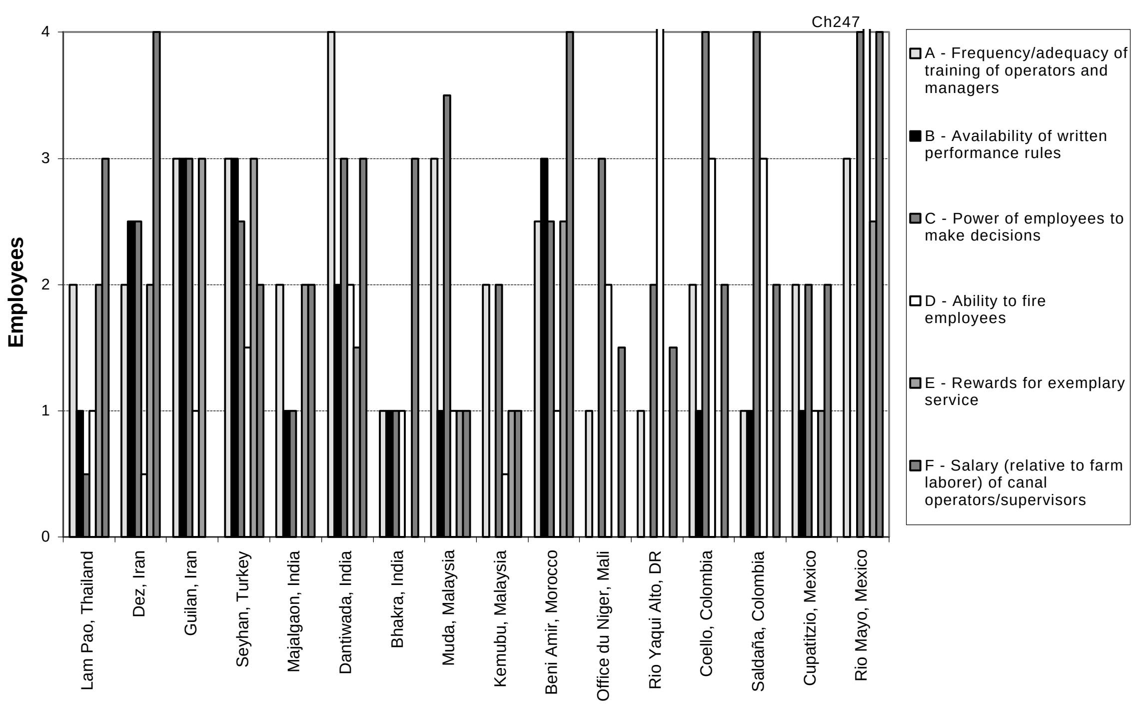

Figure 6-36. Internal process indicator I-24 sub-indicators. Employee index.

Table 6-3. Data on Internal process indicator I-24 sub-indicator values

Item	Avg. Value (0 = minimum; 4 = maximum)	Coefficient of Variation
Frequency/adequacy of training of operators and managers	.57	.41
Availability of written performance rules	.34	.85
Power of employees to make decisions	1.67	.43
Ability to fire employees	.94	.85
Rewards for exemplary service	.35	.83
Salary (relative to farm laborers) of canal operators/supervisors	1.18	.52

Table 6-3 and Figure 6-36 show that there are major differences between projects, but overall, the projects received low ratings in regard to their employee management. The Latin American projects appeared to give their employees the greatest latitude in making decisions, perhaps because they were operated by functional water user associations that operated much like businesses. Salaries for operators were only slightly higher than those for typical agricultural day laborers, indicating that in many projects there is a low value and possibly low expectations, placed on the work of operators -. It is very evident that the average level of training, rewards, and clear employee evaluation procedures is extremely low for the operators.

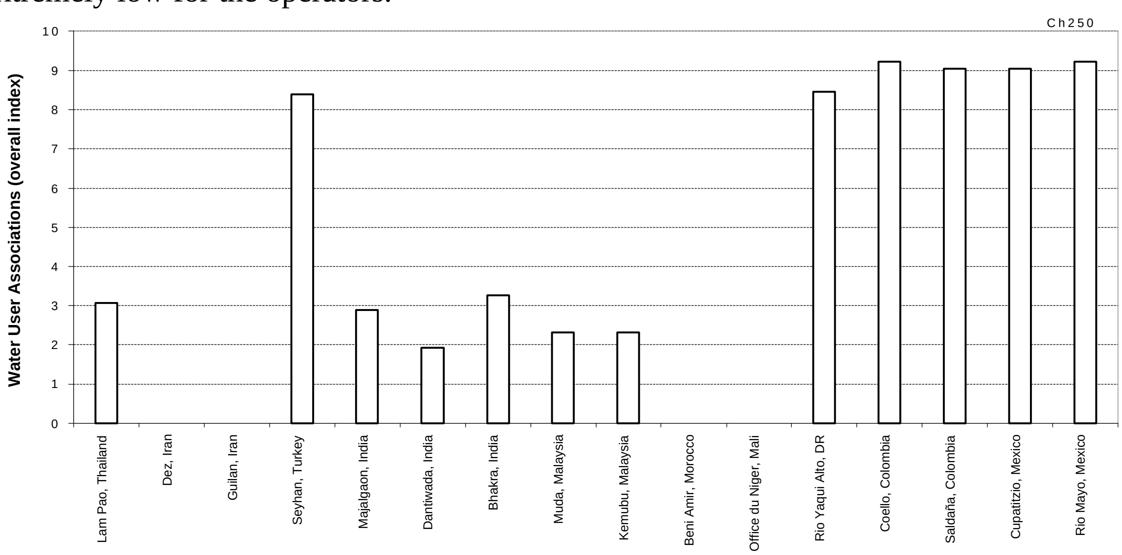

Figure 6-37. Internal process indicator I-25. Water User Associations.

Figures 6-37 and 6-38 provide some insight regarding the extent and strength of water user associations in the irrigation projects. The first obvious point is that 4 of the projects had no functional water user associations. The next point is that all of the Latin American irrigation projects not only had water user associations - those associations also received relatively high ratings. The third point is that all of the Asian projects had some type of water user association, but basically they were ineffective (with the exception of Seyhan). Office du Niger is a special case, and will be discussed later. The water users have a unique institutional arrangement in which they participate in decisions related to the expenditure of maintenance funds.

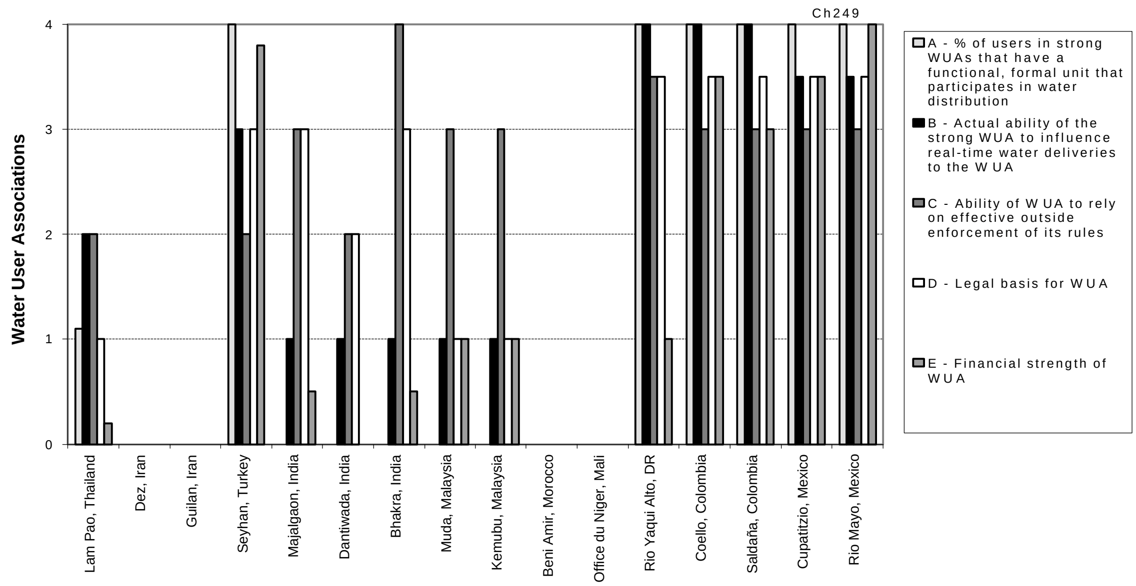

Figure 6-38. Internal process indicator I-25 sub-indicators. Water User Associations.

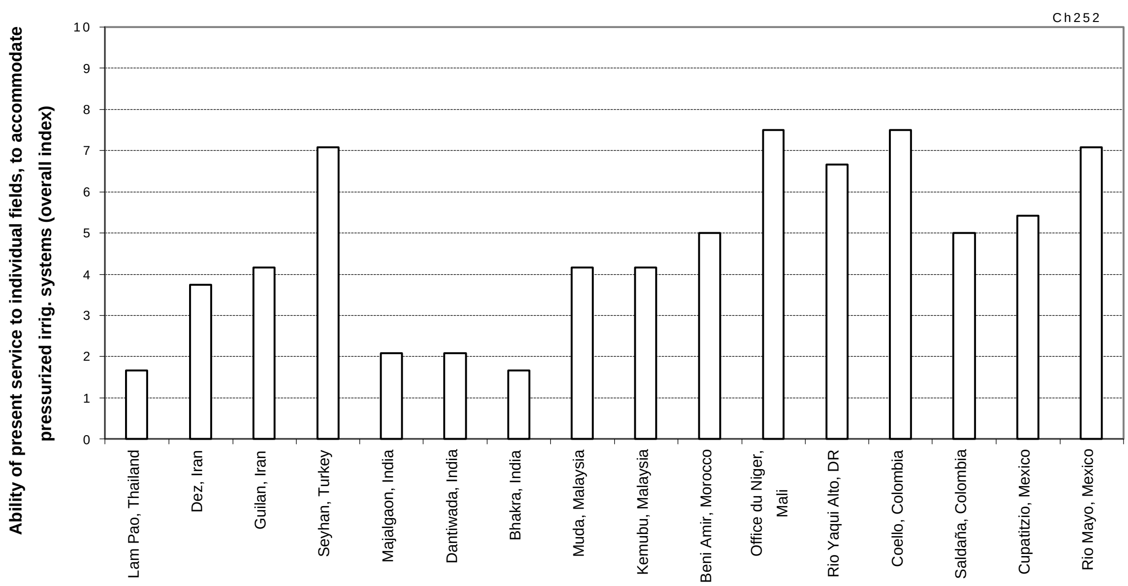

Figure 6-39. Internal process indicator I-26. Ability to accommodate pressurized field irrigation systems today.

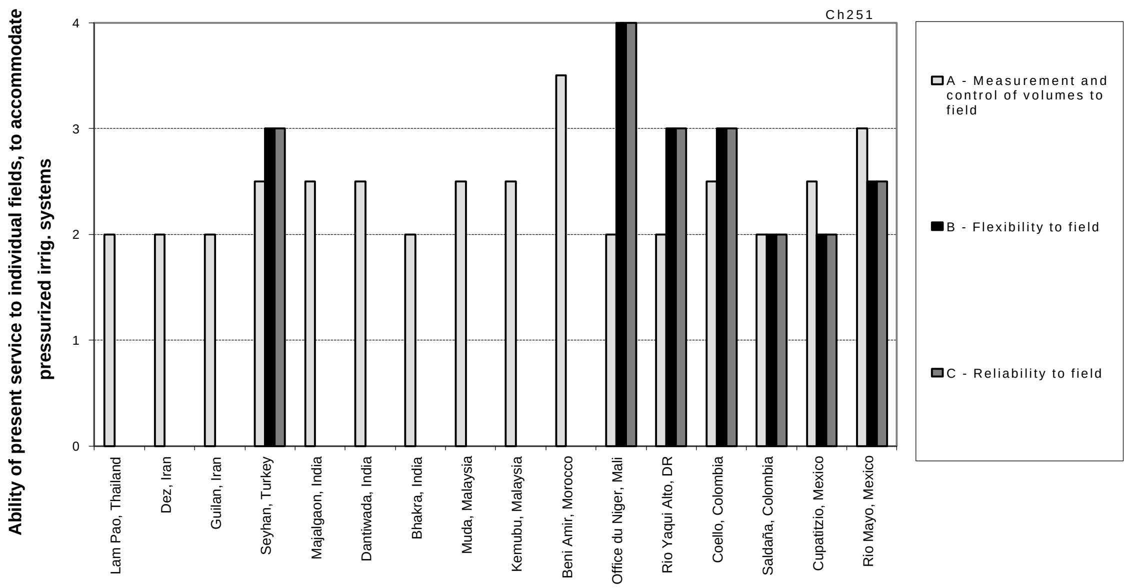

Figure 6-40. Internal process indicator I-26 sub-indicators. Ability to accommodate pressurized field irrigation systems today.

Indicator I-26 (Figures 6-39 and 6-40) highlights a major reason for examining internal processes. It provides for the evaluation of the need to upgrade field irrigation systems. With rice irrigation there will not be a sudden (if ever) shift toward pressurized (sprinkler and drip) irrigation systems. However, most rice irrigation projects have significant potential for crop diversification during the dry season and sometimes even during the wet season. Surface irrigation of upland crops, under the correct conditions, can be efficient and inexpensive. Surface irrigation performance can be quite low if soils are non-uniform; the field slopes are undulating or greater than .05m/m; and if the fields are small, thereby limiting the implementation of modern land grading techniques (Burt, 1995).

Pressurized irrigation systems have problems related to power costs, but those concerns are often negated if one considers the total energy inputs (land grading, fertilizer, etc.) into farming against the potential higher yields that are obtainable in some cases with pressurized irrigation methods. There are certainly theoretical arguments against the adoption of pressurized methods (including the true problems of maintenance with drip/micro systems). Nevertheless, the area of land irrigated with those methods is growing rapidly because of the over-riding advantages of pressurized irrigation in many conditions.

The lesson to be learned from Figures 6-39 and 6-40 is that the water delivery system engineering and management of most of the irrigation projects are not close to being able to support modern field irrigation techniques. This is a major factor to consider, given the potential future discrepancy between population and agricultural production, as well as the need to make better first-time use of irrigation water. Figure 6-40 shows that the Latin American irrigation projects are generally the most advanced in their ability to provide the necessary water delivery service to the field and to accommodate pressurized irrigation methods. In addition, Seyhan and Office du Niger are outstanding projects in other areas of the world in this regard.

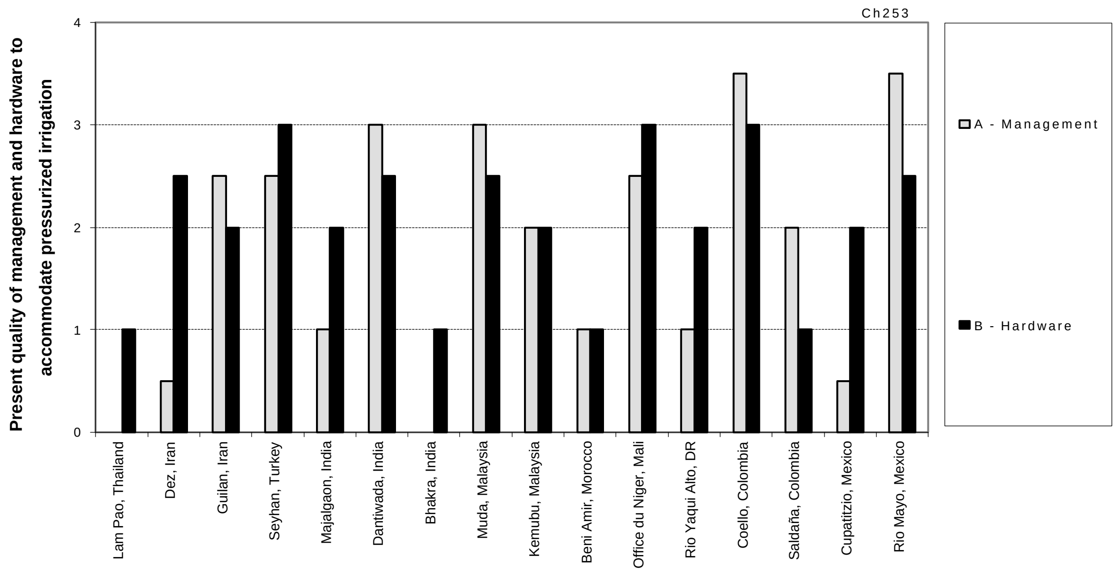

Figure 6-41. Internal process indicator I-27 sub-indicators. Present quality of management and hardware in terms of accommodating pressurized field irrigation systems tomorrow.

Figure 6-41 shows the present quality of management and hardware in terms of accommodating pressurized field irrigation systems tomorrow. A high rating such as the 3.5 Management/Operation rating for Rio Mayo indicates that the present management procedures are quite good for this objective. The Hardware rating of 2.5 for Rio Mayo indicates that there is still considerable room for improvement on the Hardware aspect. However, the Hardware rating of 2.5 for Rio Mayo is high enough to indicate that the Hardware changes would be relatively easy to accomplish (compared to lower scores). The emphasis on modernization for this project would be Hardware, with some attention given to the Management.
Lam Pao and Bhakra have very low scores, indicating that both Hardware and Management need tremendous improvement if those projects are to move into the field irrigation methods of the 21st century. In both cases, investment in only one aspect would not achieve the desired effect.

An interesting case is Beni Amir (Morocco). It receives very low ratings, although it often scored quite high on previous indicators such as Irrigation Efficiency. The hardware and management/operation of Beni Amir was designed for outdated field irrigation methods. Beni Amir has very low capacities in its distribution system and the hardware and management are designed to only supply one field at a time in the lower level of the canal distribution system on a rotation basis. This is clearly not conducive to modern field irrigation methods, which need flexible deliveries and long, frequent irrigations at variable flow rates. The current improvements in management/operation are intended to provide better service to those outdated field irrigation methods, but are only geared to modifying (not replacing) a rigid operation that it is incompatible with pressurized field irrigation methods. It will require major restructuring of the thinking and key hardware components if Beni Amir is to be upgraded for the 21st century.

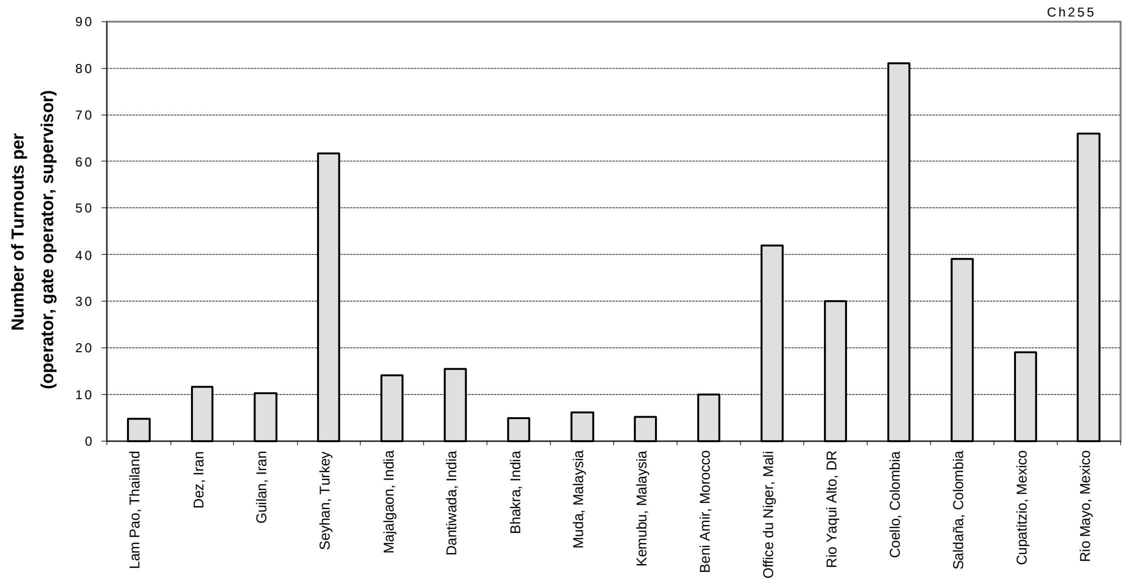

Figure 6-42. Internal process indicator I-28. Number of turnouts per operator.

Indicator I-28 rates the various irrigation projects according to the number of turnouts per operator. This Internal process indicator is unique in that the scale is not on a 0-4 scale, but rather reflects the actual number of turnouts per operator. It is also unique in that a small number is better than a large number. It is obvious that there are major differences between irrigation projects, indicating major differences in communication, management skills, and efficiency of employees.

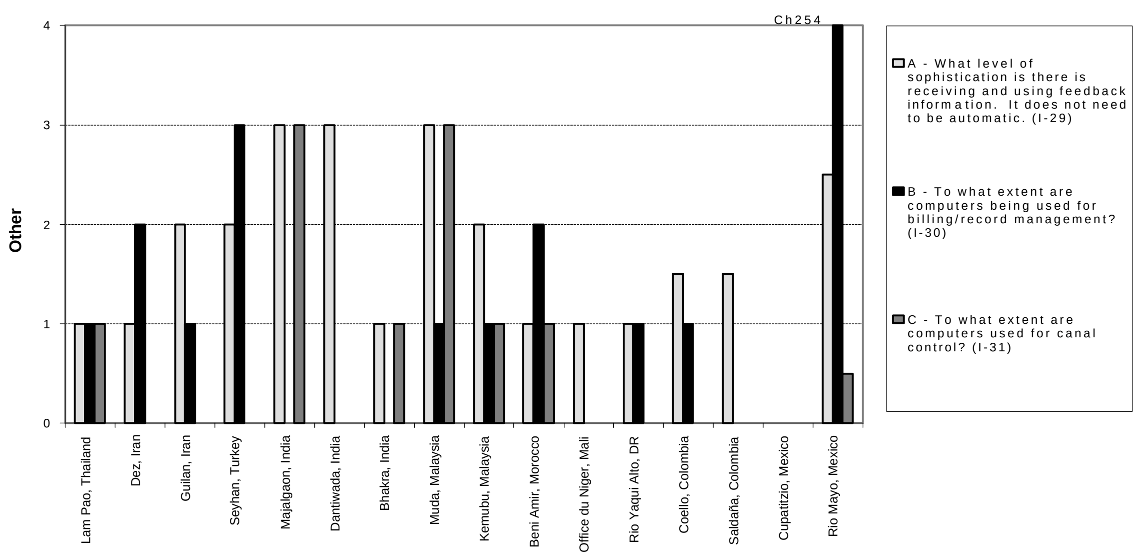

Figure 6-43. Internal process indicators I-29, I-30, and I-31.

The three Internal process indicators shown in Figure 6-43 show interesting aspects of management in the irrigation projects. The conclusions are:

1. Overall, there is very little good utilization of information feedback for the management of irrigation projects. That is, there is little real-time information on *actual* (as opposed to supposed) flow rates, water levels, spills, etc. Where there is information available, it is often utilized properly.

2. A few projects use computers for billing and record management. Only Rio Mayo received a "perfect" score of 4.0. Dez, Seyhan, and Beni Amir are the only other projects which have made significant efforts in this regard.

3. Computers are rarely used for actual canal control. Majalgaon is an exception, and in that case computers are only used in a portion of the project.