Equity Considerations In Fiering's Prototype Water System

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Fiering (1974) presented a didactic model of a water system to illustrate upstream and downstream trade-offs in power generation versus flood control. Wood (1974) later extended the model to a two-season analysis, related the model to actual problems on the Tisza River basin in Hungary and raised such questions on bargaining as:

- where does bargaining start?
- how do sidepayments extend the range of choice?
- are utilities for certain sidepayments equal to utilities for expected benefits?

If Fiering's system is put in the context of an international river basin then the game-theoretic approach of Rogers (1969) provides a method of outlining strategies for each participant for both non-cooperative and cooperative development of the basin. This approach runs into difficulty, however, if:

1. One of the participants in 'The Game' is at a distinct disadvantage in relation to the other; in Fiering's example the downstream dyke construction is highly dependent upon both upstream reservoir construction and operation strategy.

2. One country is weaker than the other; in the India-Bangladesh model there was little prospect of a sidepayment from Bangladesh to India, thus restricting the range of choice.

3. The game is repeated i.e., where development is not a one-shot affair with a single decision, rather a recursive decision process with repeated dyke and reservoir constructions.

4. One desires a solution that is not just efficient, but also 'equitable' to both participants.

With growing concern for equitable development and the redistribution of wealth (particularly across international borders) the question is how can cooperative development occur with 'equity' joining the list of multiple objectives? Besides addressing the bargaining issues raised by Wood, this paper will briefly outline the problem of equity related to:

- criteria for wealth distribution
- cooperative and non-cooperative games
- value of information and risk sharing
- negotiation strategy and budgetary constraints
- opportunity costs and staged versus single development
- equalization schemes and the 'incremax technique'
- game theory with a 'weak' apponent

1. Equity and the Distribution of Wealth

A distinction must be made between an 'equitable solution' and a solution which 'redresses inequity'. An equitable solution may be one in which the decision outcome has some measure of equity or fairness to all participants (eg. an allocation of water shortages to regions along a river using goal programming).

A procedure which redresses inequity is one in which the status quo (ie. inequity) is altered via negotiation to some new position deemed 'less inequitable'. The 'incremax' procedure discussed below is an example of a technique to redress inequity.

The principle of 'equity' implies an even distribution of wealth. Problems of equitable development on a river basin must therefore be approached by the use of techniques for wealth distribution.

The question is does one divide up the resource itself, or simply share the benefits due to exploitation of the resource? In the context of the example presented in this discussion, several questions come to mind:

1. What is an 'equitable' division of reservoir storage between flood and power uses, particularly if the power generation and flood locations are separated by an international border?

2. If water allocation under shortage is based on today's production functions, how are future development options foreclosed?

3. If equity or efficiency implies a transfer of wealth (sidepayment) then how does utility for a certain sidepayment compare with utility for expected benefits?

4. Does 'equity' imply equal net benefits for both riparians, equal gross benefits, or is it related to some other characteristic of the riparions, GNP for example? Further, if two riparians are in inequitable positions before the development decision (say, one country is underdeveloped) how should benefits from common development be transferred to the underdeveloped country?

5. From the set of solutions identified by Wood in Figure 1, which solutions are 'more equitable' than others and what other solutions (if any) are also equitable?

2. Criteria for Wealth Distribution

There are no rational, objective criteria for determining patterns of distribution of wealth accruing from the exploitation of water resources. Some of the ones most frequently advanced are noted below:

Proximity or Riparian Position:

The proximity of water resources to a country's boundaries are generally the most important criterion for claiming a share of benefits. Furthermore, upstream countries traditionally claim little responsibility for downstream disbenefits due to upstream actions (pollution, floods, etc.)

Manageability:

It is sometimes stated that one riparian is in a better position to manage a water resource than another. In certain situations, one country may claim that control of an anadromous species of fish(i.e., those spawning in fresh waters) is best exercised by one state, yet this is hardly justification for allocation of the entire proceeds of exploitation.

Historic Rights:

Past use is often advanced as a basis for future distribution patterns. As an example, to counter this, power quotas, allocated from a joint venture on an international border, can obviously be reviewed as demand functions in the riparian countries change.

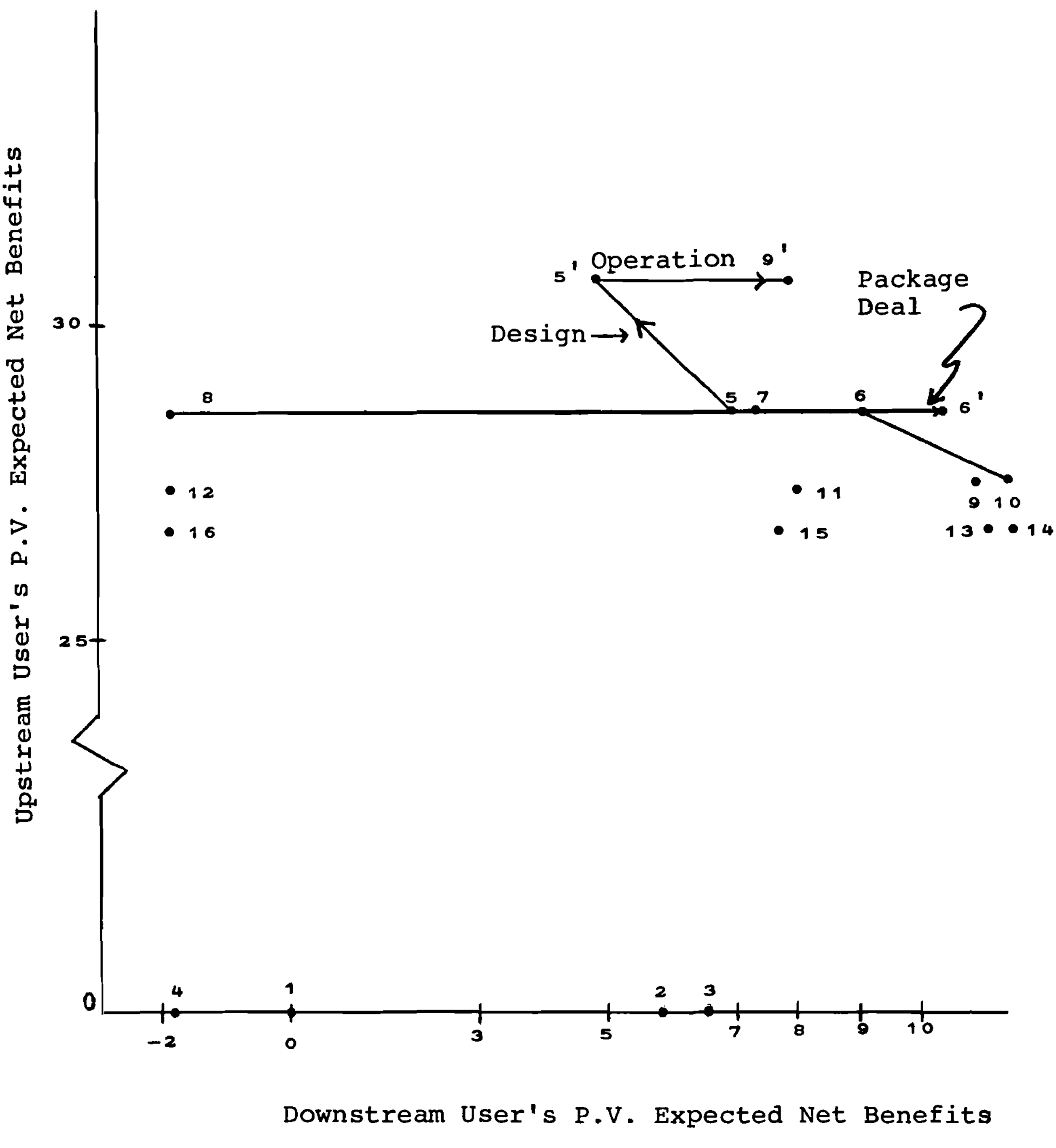
Need:

Many states advocate that they require a higher share of wealth because they have a greater dependence on the benefits (e.g.,power, fish catch) for food, employment, income, etc. The real question is how to define need. What percentage of income, protein or employment should a state derive from a resource in order to qualify as being dependent on it?

Capacity to Exploit:

The criterion of exploitability tends always to favour the larger nation with the better technology, demand and infrastructure. This criterion alone has led to the severe depletion of many of the world's anadromous fish species.

Figure 1*: Extending The Pareto Surface with Sidepayments and two Bargaining Schemes.



* This Figure adapted from Wood, 1974

Common Heritage:

A final criterion, although little applied, is the one that provides that water resources are for the benefit of all mankind and benefits should in some way be shared by all states of the world. An example is the right to navigation by all nations on the Danube.

An Example of Resource Distribution:

In the case of international fisheries in the Northwest Atlantic, the fifteen member states of the International Commission agreed to distribute the wealth of fish stocks on the basis of an arbitrary formula. Fourty percent of the total allowable yield was distributed in the basis of catches over the past 10 years (Historic), 40 percent on the basis of catches over the past 3 years (Historic), 10 percent was reserved for the coastal state (Proximity) and 10 percent on the basis of special considerations (Need) or for the interest of new members (Common Heritage). There is nothing to say that this is the best allocation, nor that it can be monitored and enforced, yet it is an example of wealth distribution.

One would suspect that the analogy to the above example in the case of international river basins would be limited to transient fish stocks. There is a strong case, however, for water quantity distribution using the criterion of need by underdeveloped countries on river basins (eg. Mexico on the Colorado and Rio Grand Rivers).

In the case of water allocation, Gouevsky apparently is examining equitable distribution of water between industry, agriculture and municipal uses during periods of shortage. A related problem is how to distribute shortage across borders and between different uses.

3. Cooperation and Non-Cooperation

Looking back at Fierings' Model, for the upstream (US) riparian, the decision K=4, F=0 in Table 1 clearly dominates all others. Knowing this decision, the downstream (DS) riparian would likely decide D=5 to maximize net benefits.

As a two person non-zero sum game without cooperation this pure strategy leads to an equilibrium at solution number 6 since departure from this solution would not increase net benefits to one participant without reducing those of the other. Several questions arise:

1. What is the effect of budgetary constraints on the equilibrium points?

2. Can the positions of both participants be improved by cooperation?

3. Do questions of 'equity' affect the final decision? We know that the payoffs may change, but will the decision itself vary?

4. What happens to the game if the two participants have different perceptions of payoff values as a consequence of employing different data bases, interest rates or optimization techniques?

4. Value of Information

Given the information that upstream has decided not to build the reservoir (K=0), downstream can then take the decision D=6 and gain .63 marginal net benefits over a D=5 decision. One might at first suggest that knowledge of the K=0 decision is worth no more than .63 to downstream. This might be so if the D=6 decision were truly independent of the D=5 decision.

Upstream Decision		Downstream Decision DYKE SIZE			
Reservoir Size	Operating Rule	D=4	D=5	D=6	D=7
K=0		0,0 1	0,5.93 2	0,6.56 3	0,-1.88 4
K=4	F=.0	28.57,7.03 5	28.57,9.37 6	28.57,7.49 7	28.57,-1.88 8
K=4,	F=.25	27.48,11.09 9	27.48,11.40 10	27.48,7.96 11	27.48,-1.88 12
K=4,	F=.50	26.85,11.25 13	26.85,11.24 14	26.85,7.81 15	26.85,-1.88 16

TABLE 1: Payoffs for Upstream and Downstream[1].

1. From Wood, 1974. The entries indicate upstream, then downstream net benefits. Solution numbers in lower right hand corners.

Clearly they are dependent; suppose a D=5 decision were taken and construction started. Upstream then announces a K=0 decision and DS switches to D=6. The revised cost of D=6 due to design changes etc., is likely greater than the 10 it would have cost to start with D=6 at the beginning. So the cost of the information is the .63 marginal net benefit less the added costs from design changes.

Suppose DS was relatively underdeveloped, a criterion for wealth transfer might be that US must announce its strategy first (i.e. information transfer) so that DS can act so as to seek its best outcome in Table 1. Upstream can only deviate from its initial committment if Pareto-optimality is guaranteed.

5. Opportunity Costs

For each upstream decision DS can choose an optimum strategy from Table 1. If DS makes his decision first, however, without knowing the US decision, then DS may end up with a sub-optimal decision. Table 2 illustrates the net benefit foregone by DS for each value of D, K and F if the wrong decision is chosen. Some of the foregone benefits, however, are recoverable, simply by adding on a unit of dyke; others are not, particularly if dykes are built too large. Some questions arise:

1. How risk adverse is the downstream decision maker? Whereas net benefits are lower, in general, for a D=4 decision, the benefits foregone due to an error are entirely recoverable. Perhaps for the sake of equity one of the participants can simply absorb the risk as a proxy for wealth transfer.

2. How much are the recoverable benefits decreased by higher staging costs (i.e. it would likely cost more to build 2 units of dyke, than add 1 unit later, than build 3 units from the start)?

3. Can the dyke-dam construction strategies be viewed as an n-stage recursive decision process as shown in Figure 2, and how long should the planning horizon be? The issue here is that a dyke-dam decision cannot be an isolated event due to the repeated nature of development (as in the KÖRÖS basin, for example, where new dykes repeatedly made the previous constructions redundant).

DOWNSTREAM Decides First:	UPSTREAM Decides Second:			
	K=0	K=4	K=4	K=4
	-	F=0	F=.25	F=.5
D = 4	6.56 (6.56)	2.34 (2.34)	.31 (.31)	0 0
D = 5	.63 (.63)	0 (0)	0 (0)	.01 (0)
D = 6	O (O)	1.88 (0)	3.44 (0)	3.44 (0)
D = 7	8.44 (O)	11.25 (0)	13.28 (0)	13.13 (0)

TABLE 2: Downstream Opportunity Costs

NOTE : The table entries indicate net benefits foregone due to a poor decision. Numbers in brackets are recoverable benefits if dyke unit(s) are later added.

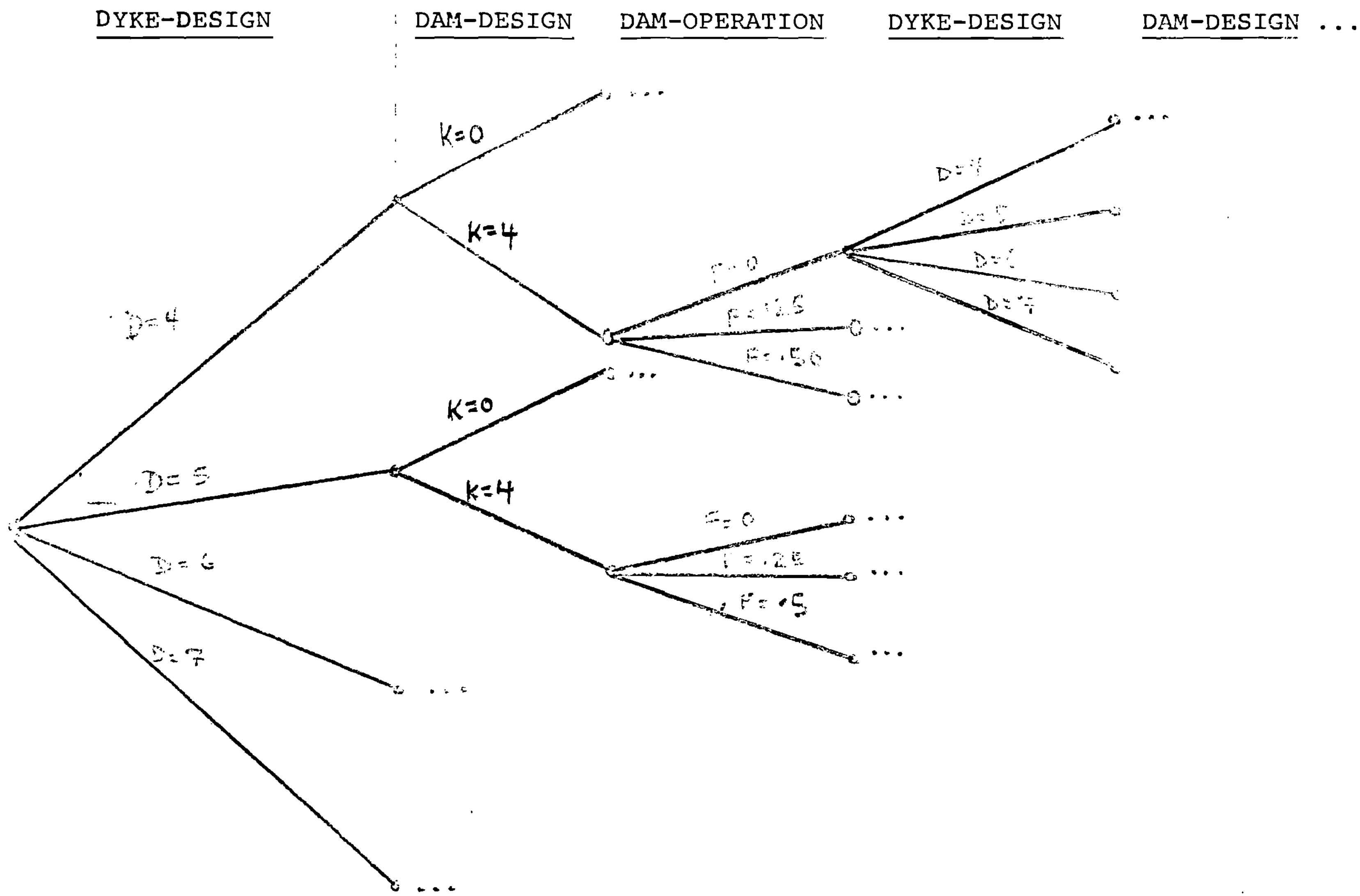


Figure 2: Dam and Dyke Decisions as a Recursive Decision Process.

6. Bargaining:Package Deal or Two Stage Decision?

Given a US decision K=4, F=0, from Table 1 DS would likely decide on D=5 leading to solution 6. Clearly DS would prefer an F=.25 decision by US and might press for solution 10. It thus appears that both DS and US agree that K=4 is the best 'design' solution, but are at odds over the 'operating' policy. In a bargaining session it might well turn out that both parties agree on the K=4 decision now,yet decide to reserve judgement on the operating policy unit at a later date. Let us examine the effect a 'two-stage' decision process on the benefits obtainable to each participant, as compared to a 'package deal' of design and operation parameters.

6.1 Package Deal Negotiation

Let us suppose that downstream is unwilling to pay any sidepayments except for those which might induce US to operate at F=.25 or F=.50. Negotiation starts at the equilibrium point 6 and US points out that for D=5, the extra benefits from a K=4, F=.25 over a K=0 decision is 5.47. Suspecting that US will build the reservoir anyway, DS calculates the marginal benefit of a F=.25 policy over an F=0 policy (2.03 for D=5) and offers US a sidepayment equal to the loss US might sustain in operating at F=.25, namely 1.09. This brings us to solution 6' in Figure 1 DS gains 3.38 and US loses as much gross power benefit as it gains in hard cash.

6.2 A Two Stage Negotiation Scenario: The Design Negotiation

Both bargainers agree that negotiation starts at solution 6, yet disagree on cooperative measures to improve the solution.

The upstream bargainer glances at Table 1 and notices that solution 5 (K=4, F=0) gives, in net benefits, 7.03 to downstream for doing nothing. US therefore demands at least 3.5 units (50%)[1] as a sidepayment for constructing the dam. DS rebuffs this notion claiming that alone, by constructing D=6, he can obtain at least 6.56 units of net benefits (solution 3).

US points out that a D=6 decision by DS implies costs of 10 units, whereas for a sidepayment to US of much less than 10 DS can do better than solution 3.

DS reconsiders in the light of his recent budget problems and offers 3 units of sidepayment to US with the condition that US will operate at F=.25. US refuses, proposing, that the reservoir design should be settled now and the operational problems at a later date. DS agrees, but reduces his offer to 2.0 units sidepayment and they move to point 5' in Figure 1. DS appears to be worse off than if he had built the dykes alone but his budget problems constrain his choices and he believes that significant benefits can be obtained at little cost to him in the second round of negotiations on operating policy.

1. This type of arbitrary demand is not unlikely. For example, the U.S.A. paid Canada one half the present value of expected annual flood benefits in the U.S.A. due to a dam built in Canada. See Krutilla, J. "The Columbia River Treaty", John Hopkins, Baltimore, 1967.

Negotiations on the Operating Policy

Some time later DS and US negotiate the operating policy. They first establish a table of marginal benefits and losses for each participant as a result of a change in operating policy (F) for various values of D, as in Table 3, below.

Change In F		D (Dyke Decision)			
From	To	4	5	6	7
0	.25	-1.09, 4.06	-1.09, 2.03	-1.09, .47	-1.09, 0.0
.25	.50	- .63, .16	- .63, .04	- .63,-.15	- .63, 0.0

Table 3 Marginal Net Benefits to Upstream and Downstream For Changes in Operating Policies

For example, from solution 5, the gain to DS in a change from F=0 to F=.25 is 4.06 and the corresponding loss to US is 1.09.

From Table 3, DS sees that F=.25 is worth more to DS than the loss to US (if D=4 or 5). Furthermore, an F=.5 policy is completely dominated by the F=.25 policy in terms of marginal benefits to DS compared to marginal loss to US.

To obtain the F=.25 solution, DS offers US exactly the value of DS's loss, assuming D=4, i.e., 1.09 in sidepayment. US accepts willingly and they move to point 9' in Figure 1. Seeing that D=5 involves a cost of 5 more units for increased benefits of .31 DS decides to stop here.

6.3 Discussion:

i) in the two stage decision result, at point 9' US is clearly better off than at 9 but DS asks himself:

i) Does solution 9' dominate 3? In other words is he really better off with 8.09 net benefits (sidepayment 3.09) over 6.56 net benefits (costs 5.0). In particular, if his nation's utility for <u>certain</u> sidepayments is greater than his utility for <u>expected</u> benefits he may be better off to spend his budget at home (solution 3) than send hard cash abroad (solution 9').

Clearly some further understanding of the utility relationship between sidepayments, benefits and costs is required.

ii) How are DS's options and benefits affected by waiting to see what US does before building any dykes? DS could accept strategies such as 'wait one year and then decide' or 'build one unit of dyke, see what US does and decide if a second unit is required' and so on. This recursive aspect, including the interdependency of strategies might be approachable by variations of recursive game theory or METAGAME theory.

iii) Has either party benefited from a particular type of negotiation? Table 4 illustrates that, in spite of higher downstream net benefits in the package deal case, DS may prefer the two-stage negotiation, depending upon his utility for sidepayments and costs. For the same reasons it is not clear from Table 4 which type of negotiation US prefers.

iv) Which solutions are more 'equitable'? It is clear that DS is at a disadvantage in bargaining due to the 'upstream - downstream' nature of the problem. If US$\rightarrow$DS (where $\rightarrow$ denotes the direction of wealth transfer) then any solution in which net benefits for US are greater than 28.57 is inequitable since US is profiting at DS's expense. Hence solutions 5' and 9' are inequitable under this definition. On the other hand, if

TABLE 4: The Net Positions For Two Negotiating Strategies

	Package Deal		Two Stage Negotiation	
Decision	US K=4, F=.25	DS D=5	US K=4, F=.25	DS D=4
Costs	-40.00	-5.0	-40.00	0
Gross Benefits	67.48	16.40	67.48	11.09
Sidepayments	1.09	-1.09	2.0+1.09	-2.0-1.09
Net Benefits	28.57	10.31	30.57	8.09
B/C Ratio	1.73	2.7	1.82	3.58

DS ⟶ US, any solution with US net benefits less than 28.57 is inequitable. Budget constraints, and cost sharing schemes, of course would refine this rather general definition. Another way to combine equity and efficiency would be to minimize the distances of equitable solutions from the efficient one (No. 10 in Figure 1).

7. Equalization Schemes and Incremax

Allocative decision making regarding the provision of public goods and services, including locational decisions, have usually been made on the basis of Pareto-efficiency. It is now generally accepted, however, that considerations of equity and distributive justice should be considered in allocative problems involving conflicts of interest.

As an example, let us suppose that the relative allocation of storage to power generation and flood control favours upstream power generation. As a result of increased development of agriculture downstream, the allocation becomes inefficient and hence some kind of adjustment is desired so that while efficiency is assured, both upstream and downstream riparians benefit 'equitably'. Salih (1969) and Wolpert have used an equalization scheme called 'incremax' to allocate services to two communities so as to reverse an inequity; the analogy here might be as follows: negotiate the allocation of storage to flood control from a position of inequity (point I in Figure 3) to some equitable position along line AB-(of course, 'equitable'does not necessarily imply a 50 - 50 split of storage). There is no doubt that this procedure can tell us how to bargain to find a point of so-called equity, but how do we <u>get</u> there in the context of our case example?

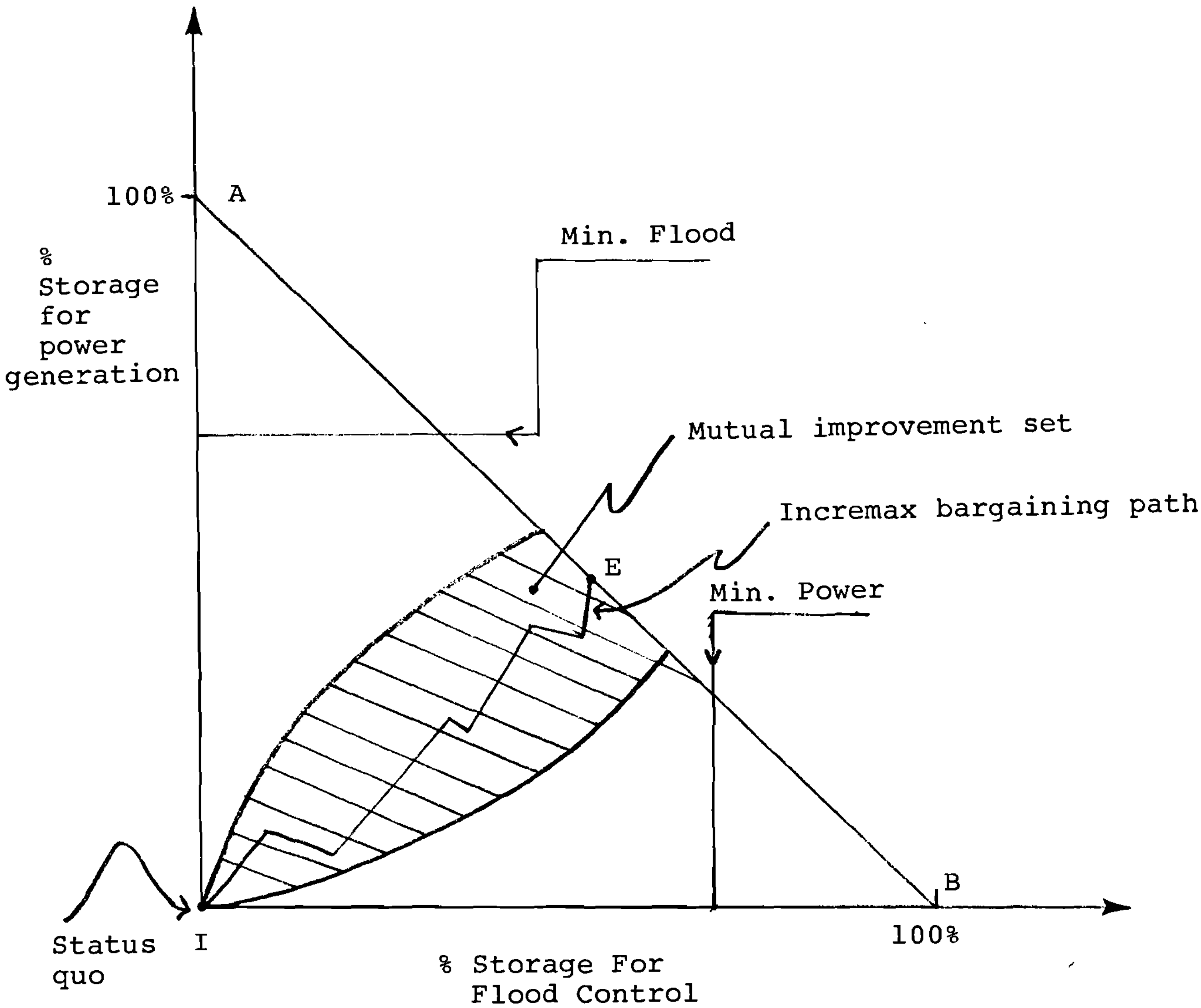


Figure 3 : Incremax Bargaining to Redress an Inequity in Allocation of Storage to Floods and Power Generation.

It should be noted that the time element is ignored in Salih's example, yet is a fundamental element in considering wealth transfer.[2]

8. Multiple Pareto Frontiers

Let us now suppose that the two participants disagree on the calculations in Table 1; this may come about from:

i) different interest rates used in each of the two countries

ii) different assessments of expected flood damages

iii) different production functions for agriculture, power generation etc.,

iv) deliberate misinformation from one or both participants

The question is how to proceed in negotiation along different Pareto frontiers as perceived by each of the participants?

9. Staging Dyke Development and Metagame Theory

Suppose that DS sees his choice to be dependent on the US choice. For example, suppose that DS seems to be following a policy whereby its choice is made to depend on the US choice. Four such policies are as follows:

i) build 1 unit of dyke (D=5) regardless of what US decides

ii) build no units of dyke (D=4) regardless of what US decides

iii) build no units of dyke (D=4); if US decides K=0, build D=5

iv) build no units (D=4); if US decides K=4, build no extra units of dyke, etc.

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2. One of the conclusions of the Fundacion Bariloche World Model was that if 2% of the developed world's GNP were transferred to less developed nations it would take 50 years for wealth to be distributed evenly.

To the above four policies many can be added to include sidepayment conditions, varying operating policies and so on.

The problem can be further complicated if US now views its choice as dependent on the DS decision, although in this particular example this is not the case.

The theory of Metagames(Howard, 1968) deals with finding equilibria in a 'metagame', i.e., a game in which one participant makes a basic choice and the other makes a policy choice. A 'upstream downstream' metagame is formed from counterpolicies taken by upstream in view of downstream policies towards upstreams' basic choice in the original game.

10. Budget Constraints

Two of the six "strategies" presented by Rogers (1969) involved different budgeting schemes:

Case 5: A joint optimal development plan is made by both India and Pakistan, subject to the proviso that their budgets are allocated each to its own region.

Case 6: A joint optimal plan is made in which the separate budgets are summed together as a regional budget.

Although sidepayments were not considered explicitly, it is clear in Case 6 that the budget from one country may be spent inside another.

In our dyke-reservoir example, budget constraints on both participants may tend to increase the possibility of sidepayments to upstream for the following reason: if the sidepayment demanded by US is less than downstream's budget constraint, then DS may be better off paying a sidepayment than either waiting for more funds or doing nothing.

As for upstream under his own budget constraint, he may be able to convince DS that US funds are insufficient to undertake the project without a contribution from DS, thus pressuring DS for support.

11. Weak or Underdeveloped Opponent

Suppose that one participant were 'weak' (no threats to offer) or underdeveloped (little technology) or poor (no cash available for sidepayments), or simply in a poor bargaining position (i.e. the downstream riparian). For a 'fair and equitable' outcome to both participants, some approach based on other than efficiency criterion may be required. Game theory with a 'weak opponent' may provide a basis upon which to formulate strategies to deal with bargaining problems along a river basin. An interesting note about Rapoport and Kahan's (1974) work on strong versus weak coalitions is that in their studies the 'strong' participants form coalitions against the 'weak'. Does this then imply that the upstream riparians would combine against the downstream ones?

12. Facility,Location and Concessions Equilibrium

Another approach using equity considerations is the 'concessions equilibrium' technique of Mumphrey (1974). Citizen opponents of planned facilities (e.g.,reservoirs, airports, nuclear power plants) may use tactics such as law suits, proposition of alternate plans, and engagement of outside experts to attack the engineer's plans. Even if they do not accomplish their goal of stopping implementation, the delays in construction, facility redesign, law suits, and other events which surround such opposition add to the total facility cost. In some cases it is less expensive to offer sidepayments or concessions (e.g.,recreation facility, landscaping, new schools etc.) rather than acting defensively to the opponents' tactics. (Refer to Figures 4 and 5).

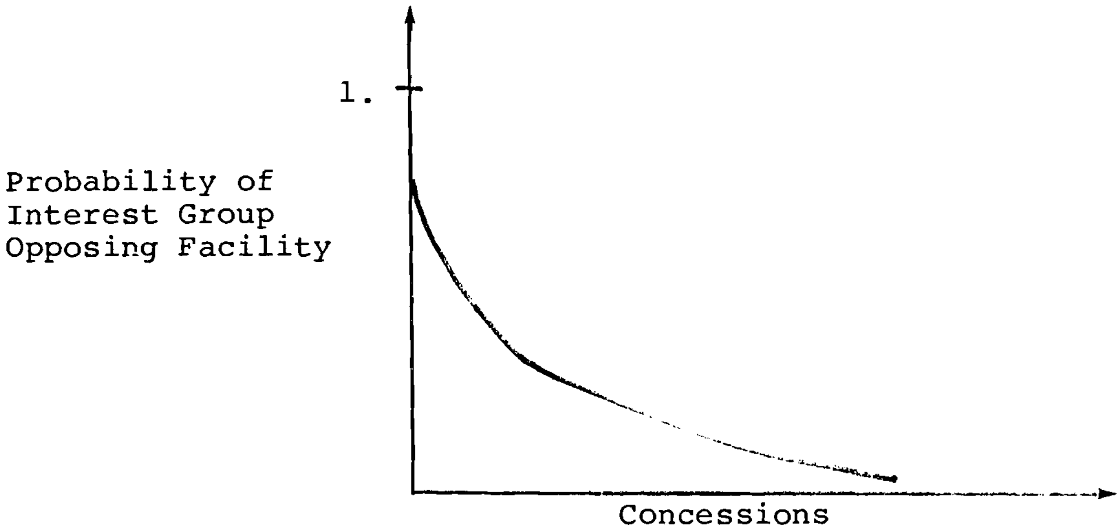

Figure 4 : Probability of Opposition versus Concessions

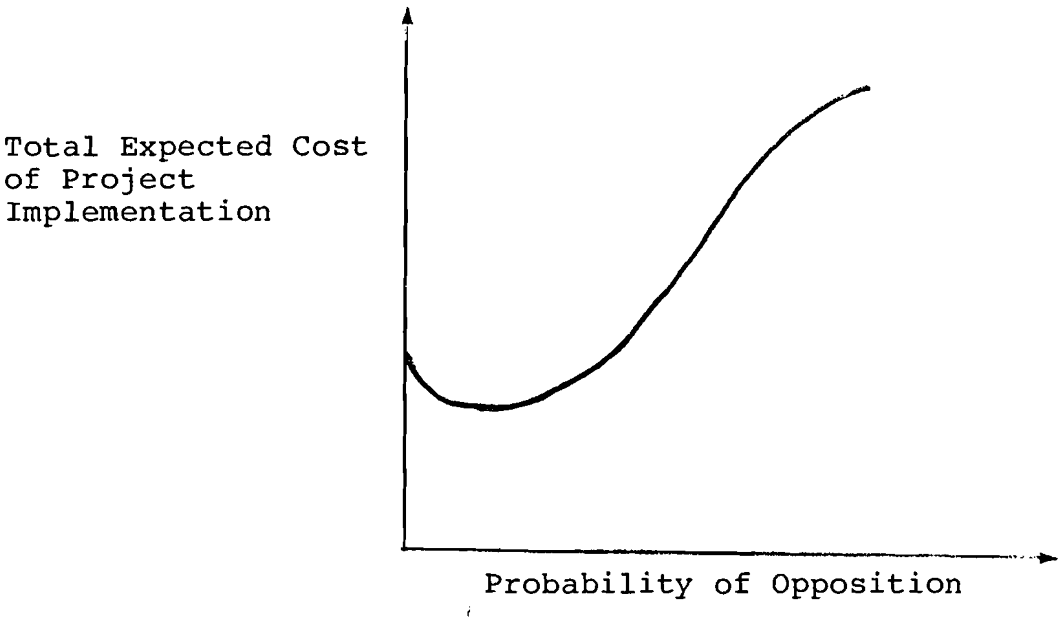

Figure 5 : Project cost including concessions versus probability of Opposition

The analogy in our dyke - reservoir example, relates to opposition to the reservoir by interest groups that may exist upstream or downstream of the proposed location. The concessions required to reduce the probability of opposition can be applied not just to regional interest groups but may also transcend international borders.

So the issue on sidepayments developed previously can not be viewed solely as it relates to bargaining on reservoir design and operation; rather it resolved as part of a larger context including the placation of interest groups, the relative utility of the nation and region for sidepayments, and the costs of concession facilities.

13. Conclusions

The prototype model of Fiering has provided a basis upon which to outline the upstream - downstream bargaining problem.

Although game theory may provide some insight into strategies for upstream - downstream cooperation, there is additional work needed on the relation of water resources development to multiple interest groups.

To make the model applicable in the context of an international river basin we should include such aspects as the recursive nature of the decision problem, interdependency (staging effects) of strategies, different perceptions of payoffs, equilization schemes and concessions to interest groups, and finally, the addition of 'equity' into our list of multiple objectives.

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