MANAGING WATER UNDER UNCERTAINTY: REBALANCING PLANNING AND OPERATIONS

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ABSTRACT

Managing water resources must resolve among competing claims of different users, variable and uncertain supplies, limited understanding of ecological needs and the behaviour of the river system, and the unknowable shifts in all these aspects caused by climate change. Adaptive management of water resources presents new challenges for management researchers.

Keywords: water, adaptive management, decision structure, operations

INTRODUCTION

The challenges of managing the limited availability of water for competing uses are studied globally: for example, in Spain and Mexico (Easter, 2004); the Middle East and eastern Mediterranean (Chenoweth et al., 2011); California and Oregon (Burke, 2004); Utah (Khalil, McKee, Kemblowski, & Asefa, 2005); Brazil (Engle, Johns, Lemos, & Nelson, 2011); Taiwan (Suen & Eheart, 2006); China (Cai, 2004); Africa (Tilmant & Kinzelbach, Pre-publication); and Australia (Brennan, 2010). As water resources are increasingly contested, management regimes have to account more explicitly for variability, uncertainty, external influences and impacts, and emerging knowledge about system behavior. Debate in the literature suggests that extant approaches to water resource management fall short of this aim.

Part of the reason for the inadequacies observed when these management methods are used in practice is their emphasis on planning (Bhat & Blomquist, 2004). Water resources planning, and the methods in use to support it, seeks to fix particular aspects of the water system and then optimize the achievement of specific objectives; for example, reliability of supply (Ajami, Hornberger, & Sunding, 2008; Hashimoto, Stedinger, & Loucks, 1982). Pre-specifying the needs of one stakeholder, for example, the environment, may restrict the opportunities available to that stakeholder under varying conditions (Burke, 2004). By pre-determining key inputs and relationships, the system being modeled can be over-simplified (Maneta et al., 2009) and key interdependencies may be missed (Engle, et al., 2011). Further, attempts to make the problem more tractable by limiting the consideration of other policy sectors, for example, agricultural commodity prices, to alternative run settings or scenarios, underplay the need for coordination among policy options (Samuels, Woods, Hutchings, Felgate, & Mobs, 2006).

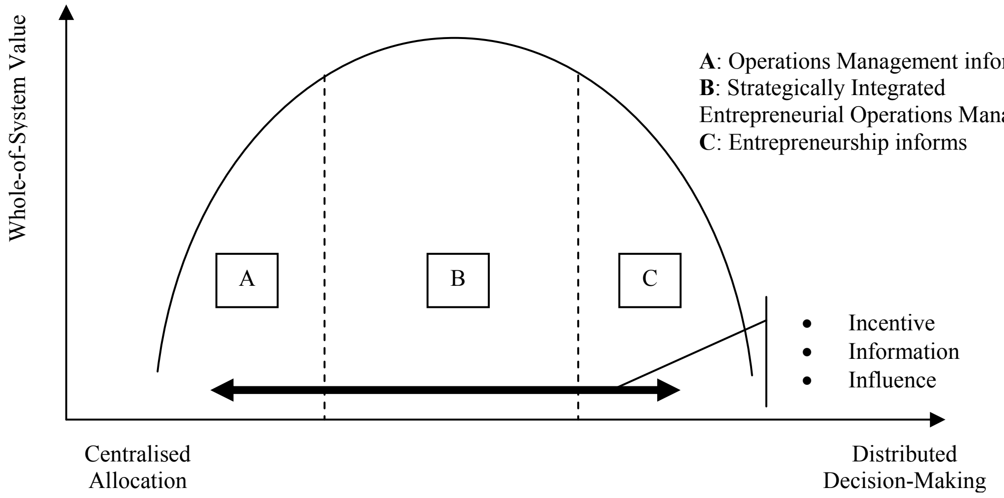
Relying solely on planning tools to deal with varying and uncertain water resource contexts and conditions, or conversely, divesting decisions to multiple parties without coordination, hampers whole system performance. Coordination efforts may merely reintroduce the constraints applying to the planning paradigm. However, the need to harmonise among centralized and decentralized decisions is raised by researchers in water resources (Bhat & Blomquist, 2004; Engle & Lemos, 2010; Perry & Easter, 2004) and climate change adaptation (Carter et al., 2007; Preston & Stafford-Smith, 2009). A corollary to this challenge is that of determining the objectives to be maximised by harmonization. The objectives – anticipatory or adaptive, targets – private or joint, styles – agronomic or Ricardian rent, and nature – habituation or hedonic, of adaptation are mutable (Hanemann, 2000). Further, many planning-based approaches frame objectives as attributes to suit the modeling techniques employed (Keeney & Gregory, 2005) rather than deriving them explicitly (Keeney, 2006). Conflicting objectives, for example, the need to manage water resources for both drought and flood conditions (Bhat & Blomquist, 2004), often remain unaddressed. The definitions and objectives in use for both integrated water resource management and adaptive management (Medema, McIntosh, & Jeffrey, 2008) reflect these difficulties. Broader goals, relating to whole system performance, good governance, inter-disciplinary expertise, and flexibility have been proposed; however, current approaches cannot fully satisfy them (Engle, et al., 2011).

This paper proposes new conceptual frameworks and management approaches to address these challenges. Decisions about water are restructured to achieve a decision framework that distinguishes between available information and control points at different spatial scales and timeframes. This framework helps to revisit the appropriateness of assumptions and pre-determined policies as against more open and active decision opportunities in the water resources management system. Complementary management approaches are then developed that introduce new decision points and shared targets for cooperative decision-making. We show that by restructuring decisions in this way, the gap between information and control, as well as transaction costs, can be greatly reduced.

APPROACH

In a previous paper, we proposed that performance, on a whole system basis, could be maximized by achieving an appropriate balance between centralized and decentralized decision-making (see Figure 1). Referring to Figure 1 and the discussion earlier this paper, an emphasis on centralized decision-making requires too many variables to be fixed or assumed, leading to conservative rules and under-performance. Whereas, an emphasis on decentralized decision-making fails to adequately coordinate among competing and changing concerns. However, when decisions about both supply and demand of water are made at the right organizational level by the right stakeholder, whether in a coordinating (centralized) role or an individualistic (decentralized) one, whole system performance may be increased (Goldsmith & Samson, 2010).

Figure 1 Strategically Integrated Entrepreneurial Operations Management Applied to a Dynamic Whole-of-System Problem

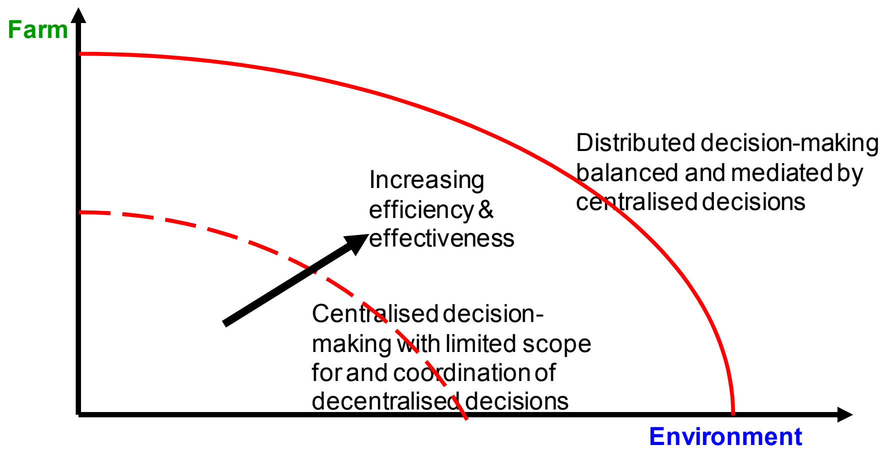


Extending beyond the single firm to the supply chain, the operations management literature seeks to exploit consumer heterogeneity and how service capabilities can be more flexible to these differences in the interests of supply chain performance, or a group of firms (Roth & Menor, 2003). However, in the entrepreneurial context, the role of government is to provide a stable platform for innovation by others (Lepak, Smith, & Taylor, 2007) rather than playing an active and collaborative role in the creation of new value. Advancing adaptive management of water resources to achieve both: coordination in the interests of maximising whole system performance under uncertainty; and, responsiveness to shifts in conditions, preferences and expectations for diverse, heterogeneous and interacting stakeholder groups, presents new challenges for management researchers.

Sharing of benefits derived from water can be visualized as an efficient frontier among different stakeholders. Figure 2 illustrates the efficient frontier for the example of farm (irrigation agriculture) and environment (water-dependent ecosystems). The frontier depicts the maximum whole system performance that can be achieved for a particular pairing of priorities among farm and environment objectives. The efficient frontier illustrates the utility of moving away from sharing water itself to sharing the benefits, or value, derived from it. Rather than being restricted to a zero-sum game approach, for example, where less water for farm means more water for environment, the efficient frontier seeks to maximize the combined performance of both stakeholders and reflects win-win opportunities to the extent that they are available.

Figure 2 also illustrates our proposition, developed in this paper, that restructuring decisions about water resources management makes it possible to expand the efficient frontier, or whole system performance, by accessing previously untapped value from stakeholder flexibility, cooperation and choice.

Figure 2 Expanding the Efficient Frontier



In a number of related papers with various co-authors, Keeney lays out the some of the common problems in decision structures and the opportunities presented by a more rigorous process. The benefits of Keeney's suggestions, such as carefully separating, connecting and articulating both fundamental and means objectives, and incorporating questions of uncertainty and attribute design, appear substantial (Keeney, 1994; Keeney & Gregory, 2005). For example, Keeney points out that while fundamental objectives can be used to derive means-ends relationships these will tend to be restricted to a hierarchy of known alternatives, whereas new means-end relationships can be surfaced from a facts-led approach so that means objectives can stimulate a broader search for alternatives (Keeney, 1994). New means-end relationships are also the focus of entrepreneurial efforts (Schumpeter, 1934; Shane & Venkataraman, 2000).

A decision framework for water resources management clarifies and restructures decisions according to the levels of decision context, fundamental objectives and means objectives. As well as clarifying decisions across these levels, the decision framework has reorganized decisions according to spatial scales and timeframes. The decision framework makes a number of useful contributions. First, it sorts decisions across spatial scales and timeframes so that their interaction across multiple scales and jurisdictions can be examined. Second, it restructures decisions according to Keeney's typology (Keeney, 1994) to better distinguish among decision context, and fundamental and means objectives. Third, in a corollary to the decision typology, operations decisions are re-emphasised and the distinction between policy, planning and operations is clarified. Fourth, by being more explicit about operational decisions, the role of a range of decentralized decision-makers is reintroduced in an active form. Finally, by connecting operations and planning decisions in a single framework, the 'facts-led' surfacing of new alternatives and new combinations of fundamental objectives recommended by Keeney (Keeney, 1994) can be accessed, and operations possibilities can inform thresholds, tipping points and synergies at the strategic level.

At the operational level, the decision framework we propose is more detailed and explicit about operational choices which extant planning approaches have assumed away. A key integrating concept that is introduced in this framework is that of water products and services, which describe both the commodity itself and the services attached to it. An analogy can be drawn with airline seats, where the airline differentiates seat availability and price according to cost (e.g. landing slots), competing passenger demand, and the level of service (e.g. exchange flexibility), and passengers in turn express their preferences by making their selection among the available seats and attendant conditions. For each decision-maker, airline and passenger, their preferences incorporate their privately-held knowledge and risk appetite (Knight, 1921).

To enable coordination of the requirements of multiple stakeholders, water products and services have to serve as shared targets for decision. Essentially, this means varying the availability of different types of water products and services to articulate supply-side advantages, such as reduced delivery losses and improved satisfaction of environmental constraints, and to elicit user advantages, such as survival of key assets and increased productivity. Types of water products and services might include:

- Advance order – orders or order patterns placed ahead to enable user to lock-in priority and supplier to undertake background planning
- Supply on order – supply released on order, similar to present situation
- Supply on demand – system preconfigured, or interim storage arrangements used to reduce lead time to delivery (e.g. through real-time control systems being investigated in the Rivers theme)
- Supply to window – user indicates period during which order is required, providing flexibility for supplier to co-schedule deliveries
- Supply on condition – user indicates condition under which order is required (e.g. provided rain is not expected during the lead time to delivery)
- Stay of supply – user agrees to use alternative source of supply at discretion of supplier regarding timing
- Supply with secondary – supply to user generates opportunity for secondary use (e.g. via interim storage, or downstream of user, or co-scheduled delivery)
- Secondary supply – user is positioned and volunteers to take advantage of secondary supply should it become available.

Based on the example of the River Murray in south-eastern Australia, some of these opportunities for cooperation are already accessed through arrangements ranging from negotiated deals to behind-the-scenes allocation of priorities; however, water products and services differ from these arrangements. First, they confer a more active decision-making role on participants by introducing additional decision points. Second, they provide to all participants the same information and opportunity that may be used in forward planning, and to stimulate innovation. Third, they can be adapted or adjusted as knowledge about system and participant behaviour develops and changes. This flexibility in water product and service design promotes adaptation, learning, innovation and releases the full performance benefits available from infrastructure enhancements such as real-time control for water on-demand.

ANALYSIS

Clearly, it is not simply a matter of more decision points equating to an expansion of the capacity of the whole system to perform. The question goes to the appropriateness of these decision points, that is, their propensity to expose value-creating possibilities. A redesigned water ordering and delivery system greatly expands the availability of information to support each decision when compared with the current 'pull-order' system. The nature of the additional information includes: access to privately held information, such as farm resources; users' revealed preferences; and two-way information exchange, for example, between the quantities of different water products and services offered and the choices made by users.

CONTRIBUTION AND FURTHER RESEARCH

The case of adaptive water management provides a practical opportunity to explore problems involving multiple stakeholders working across multiple scales and in a context of uncertainty and change. As such, the case presents new challenges for management researchers. This paper demonstrates that the shortcomings identified in the water resources literature are mirrored in decision approaches, although they are expressed differently. Practicalities constrain managers to planning-based approaches in support of centrally-determined decisions. However, this restriction is not insurmountable, and we have shown how decisions can be restructured in favour of whole system performance and adaptation.

References

Ajami, N. K., Hornberger, G. M., & Sunding, D. L. (2008). Sustainable water resource management under hydrological uncertainty. *Water Resources Research, 44*(W11406).

Bhat, A., & Blomquist, W. (2004). Policy, politics, and water management in the Guadalquivir River Basin, Spain. *Water Resources Research, 40*(W08S07).

Brennan, D. (2010). Economic potential of market-oriented water storage decisions: Evidence from Australia. *Water Resources Research, 46*(W08537).

Burke, S. M. (2004). Water banks and environmental water demands: Case of the Klamath Project. *Water Resources Research, 40*(W09S02).

Cai, X. (2004). Optional water development strategies for the Yellow River Basin: Balancing agricultural and ecological water demands. *Water Resources Research, 40*(W08S04).

Carter, T. R., Jones, R. N., Lu, X., Bhadwal, S., Conde, C., Mearns, L. O., et al. (2007). New Assessment Methods and the Characterisation of Future Conditions. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden & C. E. Hanson (Eds.), *Climate Change 2007: Impacts, adaptation and vulnerability* (pp. 133-171). Cambridge, UK: Cambridge University Press.

Chenoweth, J., Hadjinicolaou, P., Bruggeman, A., Lelieveld, J., Levin, Z., Lange, M. A., et al. (2011). Impact of climate change on the water resources of the eartern Mediterranean and Middle East region: Modeled 21st century changes and implications. *Water Resources Research, 47*(W06506).

Easter, K. W. (2004). Introduction to the special section on Institutional Arrangements and the Effects on Water Resources. *Water Resources Research, 40*(W12S01).

Engle, N. L., Johns, O. R., Lemos, M. C., & Nelson, D. R. (2011). Integrated and Adaptive Management of Water Resources: Tension, Legacies, and the Next Best Thing. *Ecology and Society, 16*(1), 19.

Engle, N. L., & Lemos, M. C. (2010). Unpacking governance: Building adaptive capacity to climate change of river basins in Brazil. *Global Environmental Change, 20*, 4-13.

Goldsmith, S., & Samson, D. (2010). *Combining Theories of Operations Management and Entrepreneurship: Creating New Value in Water Resources.* Paper presented at the Decision Sciences Institute, 41st Annual Meeting, San Diego, US.

Hanemann, W. (2000). Adaptation and its Measurement. *Climate Change*(45), 571-581.

Hashimoto, T., Stedinger, J. R., & Loucks, D. P. (1982). Reliability, Resiliency, and Vulnerability Criteria for Water Resource System Performance Evaluation. *Water Resources Research, 18*(1), 14-20.

Keeney, R. L. (1994). Using Values in Operational Research. *Operations Research, 42*(5), 793-813.

Keeney, R. L. (2006). Eliciting Knowledge about Values for Public Policy Decisions. *International Journal of Information Technology & Decision Making, 5*(4), 739-749.

Keeney, R. L., & Gregory, R. S. (2005). Selecting Attributes to Measure the Achievement of Objectives. *Operations Research, 53*(1), 1-11.

Khalil, A., McKee, M., Kemblowski, M., & Asefa, T. (2005). Sparse Bayesian learning machine for real-time management of reservoir releases. *Water Resources Research, 41*(W11401).

Knight, F. H. (1921). *Risk, uncertainty and profit* (1939 ed. Vol. 16). Boston and New York: Houghton Mifflin Company, The Riverside Press, Cambridge.

Lepak, D. P., Smith, K. G., & Taylor, M. S. (2007). Value Creation and Value Capture: A Multilevel Perspective. *Academy of Management Review, 32*(1), 180-194.

Maneta, M., Torres, M., Wallender, W., Vosti, S., Howitt, R., Rodrigues, L., et al. (2009). A spatially distributed hydroeconomic model to assess the effects of drought on land use, farm profits, and agricultural employment. *Water Resources Research, 45*(W11412).

Medema, W., McIntosh, B. S., & Jeffrey, P. J. (2008). From Premise to Practice: a Critical Assessment of Integrated Water Resources Management and Adaptive Management Approaches in the Water Sector. *Ecology and Society, 13*(2), 29.

Perry, J., & Easter, K. W. (2004). Resolving the scale incompatibility dilemma in river basin management Retrieved W08S06, 40

Preston, B., & Stafford-Smith, M. (2009). Framing Vulnerability and Adaptive Capacity Assessment: Discussion paper. In CSIRO (Ed.), *Climate Adaptation Flagship Working Paper*. Canberra, Australia: CSIRO.

Roth, A. V., & Menor, L. J. (2003). Insights into Service Operations Management: A research agenda. *Production and Operations Management, 12*(2), 145-164.

Samuels, P., Woods, B., Hutchings, C., Felgate, J., & Mobs, P. (2006). *Sustainable water management in land-use planning*. London, UK: Construction Industry Research and Informations Association.

Schumpeter, J. A. (1934). *The Theory of Economic Development: An inquiry into profits, capital, credit, interest, and the business cycle*. Cambridge, MA: Harvard University Press.

Shane, S., & Venkataraman, S. (2000). The Promise of Entrepreneurship as a Field of Research. *Academy of Management Review, 25*(1), 217-226.

Suen, J.-P., & Eheart, J. W. (2006). Reservoir management to balance ecosystem and human needs: Incorporating the paradigm of the ecological flow regime. *Water Resources Research, 42*(W03417).

Tilmant, A., & Kinzelbach, W. (Pre-publication). The cost of non-cooperation in international river basins. *Water Resources Research, TBA*(TBA).