Strategic decision-making for water resource management in semi-arid metropolitan and rural areas

W. J. de Lange[1] & T. E. Kleynhans[2]
[1]*Western Cape Department of Agriculture, South Africa*
[2]*Department of Agricultural Economics, Stellenbosch University, South Africa*

Abstract

This paper explores natural resource management decision-making for sustainable long-term water resource management in semi-arid regions. The paper lobbies for reconsideration of current long-term natural resource management decision-making methodologies. It uses bulk-water resource management in semi-arid areas to illustrate shortcomings in current methodologies that could lead to unsustainable resource utilisation. Information asymmetry is put forward as the main reason for shortcomings in the current methodologies. The risk of ignorance concerning asymmetry is explained. The financial and political markets as management strategies for scarce resources are explained and revised, and shortcomings are identified.

The paper concludes by emphasizing the complexity of water management in semi-arid areas. A systems approach towards sustainable long-term water resource management in semi-arid areas is recommended and the process of multi-criteria decision-making is offered as a suitable decision-making aid, given that some refinements with regard to spatial, time and geographical dimensions of the methodology are developed.
Keywords: water policy development; strategic water management; bulk-water supply management; sustainable resource utilisation; multi-criteria decision analysis; seawater desalination.

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1 Introduction

Metropolitan areas like the City of Cape Town, situated in the semi-arid Western Cape Province of South Africa, are confronted with water scarcity problems. Domestic water use often exceeds own supply tempos and metropolitan areas like these therefore rely increasingly on adjacent rural areas for additional water supply. Various reasons could be put forward for this phenomenon, for which price-elasticity of demand and related arguments are often used. However, water resource decision-makers cannot be certain of the true total costs and benefits associated with these re-allocations of water. If addition supply expansion alternatives are extremely limited (such as in the case of most semi-arid metropolitan areas), a complex web of long-term impacts on both rural and urban areas comes to the fore. These long-term impacts (such as negative environmental impacts, structural changes in agriculture and population demographics) of re-allocations are neither yet fully understood nor quantifiable and cannot therefore be fully accounted for in long-term strategic water management considerations.

Furthermore, urban usage traditionally enjoys priority over rural usage and accordingly dominates the planning process in long-term water allocation management. As such, the strategic planning context is often narrowed in favour of urban areas. Such narrowing could be in terms of temporal and spatial dimensions, encouraging sub-optimal resource allocations within the broader regional context. This situation develops tension between urban and rural water user groups. In addition, efforts to reverse negative long-term externalities of sub-optimal allocations often prove more costly compared with avoiding such policies in the first place. These situations result from strategic water managers being unable to fully account for the long-term impacts of different water management strategies in their decision-making. This could be traced back to shortcomings in benefit-cost quantification methodologies where "softer" and less tangible impacts of water re-allocations cannot readily be defined in terms of monetary variables.

The above-mentioned situation illustrates both a failure in the market as resource allocation mechanism and a shortcoming in the political market, where water management authorities and government officials interpret their responsibilities in a narrow sense or measure optimality in terms of efficient water allocation exclusively to urban areas. Bulk water re-allocations from rural to urban areas have a negative socio-economic impact on rural societies, the natural environment and irrigated agriculture. These impacts are not readily accounted for in deciding whether or not to proceed with these re-allocation projects.

This dilemma has created an opportunity for research into the problem of sub-optimisation ("unsustainability") within natural resource allocation management. The problem at hand indicates complexity within a resource scarcity context, and by adding the challenge of truly sustainable but equitable and efficient resource utilisation, the problem becomes even more complex. Better management of uncertainties regarding long-term implications of bulk water supply options is needed to facilitate a better comparison of different management options. Decision support tools like multi-criteria decision-making (MCDM), which is generally used to support water resource management, needs to be adapted to capture considerations of relevance in the broader decision-making environment. This paper attempts to engage in refinements to MCDM in terms of the spatial and temporal dimensions of the decision-making context.

The research implies a refined regional MCDM in the City of Cape Town area and the adjacent rural areas sharing water resources with the city. Refinements to the contexts of MCDM methodology were made in terms of spatial and temporal dimensions. A spatial expansion was attempted by broadening the physical context (boundaries) of the decision-making area for water resource management in the above-mentioned area. This expansion implied expansions in decision-making representation, which were canvassed via a public survey, an expert panel survey and an expanded representation of key decision-makers. The public survey needed to yield a satisfactorily response rate, be politically transparent and objective, and imply changes in information loads. Expansion of the temporal dimension was attempted via the development of two "development paths" that had to be objective, transparent and concise. This expansion also required an expansion of decision-making criteria.

2 Contextual and theoretical background

Water service authorities (such as governments) usually promote an efficient but equitable and sustainable allocation of water (Eberhard, [11]; Shand *et al.*, [31]; Thomas and Durham, [37]). Such an allocation is, for practical reasons, impossible to achieve, but it does serve as a management guideline. Given a budget constraint, decision-makers are challenged to opt for the management option that will find a balance between sustainable development, environmental conservation and social welfare maximisation. (Note that social welfare creation includes sustainable development and environmental conservation.) Figure 1 illustrates this phenomenon. Water managers need to decide whether to follow a market- or a command-and-control-dominated approach. Either a command-and-control- or a market-driven strategy will dominate the resource management strategy (usually a combination is used), and rarely will it be the case that a particular strategy could exclusively be defined as a command-and-control- or a market-driven strategy.

If water resource managers apply the principle of marginal benefit by turning to the market for bulk water resource management, the competitive market is utilised as a mechanism for allocating water use rights to more efficient uses in their management area (Eberhard, [10]; Pearce, [27]; Thrall, [38]). Market allocation theory states that an efficient and equitable allocation of water resources (water use rights) will be achieved if the suitable market structures are in place - i.e. the assumption of perfect competition (Mueller, [24]). This means that the market (assuming water managers facilitate the functioning of such a market) will allocate water use rights to users who will make the greatest contribution to social welfare. However, frequent market failures occur in cases with public goods, such as water, because of high transaction costs, externalities (unaccounted for impacts) and the faulty telescopic tendency of market participants (Blignaut and De Wit, [5]; Goodstein, [16]; Pearce, [27]; Pearce and Turner, [28]). The market also needs large numbers of independent sellers and buyers, which is not always the case with tradable water use rights in semi-arid areas (e.g. the greater City of Cape Town). In addition, to have an efficient and free market, the social cost of a transaction must correspond with its private cost. If not, society as a whole could be harmed because the drive to private gain may not simultaneously lead to an increase in social welfare (Arrow, [1]).

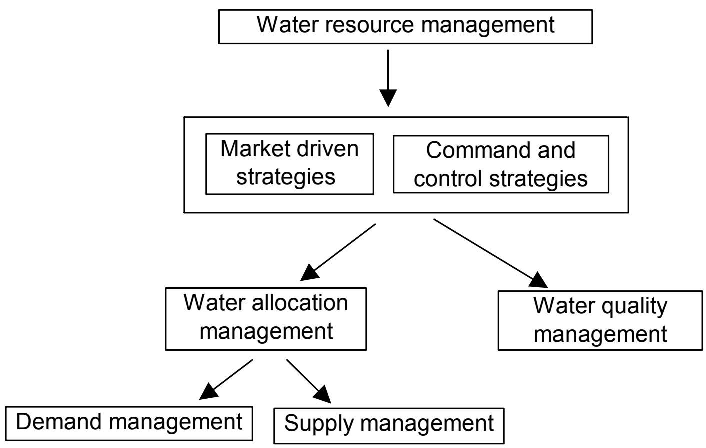

Figure 1: A contextual framework for bulk-water resource management.

The market is also criticised for of its inability to maximize social welfare in an objective way, because the market only accounts for a weighted sum of individual prices (Arrow, [2,3]). The social outcome of such an allocation has not been evaluated and may therefore be politically unpopular. Proof can be found where the re-allocation of water use rights from rural to urban use is approved because of higher effective urban demand. Water prices cannot therefore fully account for all trade-offs of rural to urban re-allocations (e.g. the contribution of agriculture to the economy, the relative value of rural areas in sustaining the rural population and the relative value of rural amenities for tourism). The market merely provides one of many allocations because of the inherent inability of welfare economics to present an objective method to achieve maximum social welfare via any given voting procedure (like the market) from an aggregation of individual welfare functions. The market for tradable water use rights could therefore not be seen as the ultimate allocation mechanism for society as a whole.

Indeed, some margin is created for government interference when the market for water use rights fails. This implies that public trust is placed in bureaucrats and politicians to compensate for market failures by making use of rules and regulations to allocate water use rights in such a way that they will contribute to social welfare maximisation. A functional bureaucratic system is used to motivate politicians to act in the best interests of the public (Buchanan and Tullock, [6]; Mueller, [24]). A principal-agent relationship can be found between water managers (agents) and the receivers of such services (public or principal). The problematic choice before the agent is whether, and to what extent, to involve the preferences of the principal in strategic water resource allocation decisions. By ignoring the principal's (public's) preferences, a somewhat paternalistic stand is adopted because the agent assumes, without consulting the principal, superior information and a recommended allocation of water use rights will be in the best interest of the principal. However, government intervention leads to the need for detailed monitoring and measurement because of problems regarding hidden incentives and different time-frames between principals and agents (Goodstein, [16]; Kleynhans, [20]). Also, strategic decision-making in bulk water supply management has a typical twenty-year planning horizon while a bureaucracy functions in four- to five-year terms. Long-term bulk water supply planning could therefore be hampered if politicians continually opt for short-term water supply solutions just to enhance their own political positions. Incentive-related problems, such as the aforementioned, occur because of the separation of power and responsibility (i.e. those having decision-making power in government agencies do not bear responsibility for their decisions, at least not to the same extent as profit-seeking entrepreneurs in a market setting do). There are also no signals in the collective decision-making process that are comparable to profits and losses in the market for water use rights. Therefore, no reliable way exists of judging efficiency where outputs are not produced and sold under competitive conditions.

Both market- and command-and-control-oriented approaches therefore show uncertainties and inefficiencies regarding water resource allocation, and some alternatives that make uncertainties more tangible are called for. MCDA presents a way of managing these uncertainties and subjectivities in order to make unknown factors more tangible (Stewart, [33]). One of the principles of the MCDA approach is to help decision-makers organise and synthesise relevant information to enhance decision-making (Heynes, [17]).

3 Decision-making in water resource management

Water in its natural form has no costs attached to it - as long as it is used in its natural form with no additional effort to enhance the usefulness (utility) derived from using the resource (Terreblanche, [36]; Turpie *et al.*, [39]). However, the moment the resource is manipulated and/or transformed to enhance the utility derived from using the resource, additional costs will emerge. Cost considerations are important determinants in bulk-water management, with the quantification of costs not necessarily being in monetary terms. Standard monetary terms ease the comparison of different bulk water projects because such terms are defined per se; however, they ignore the local context in which the costs occur, and the challenge is therefore to capture all costs in the decision-making process.

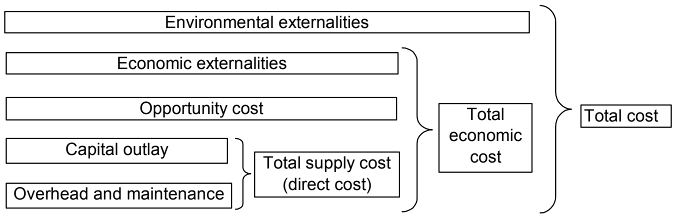

Figure 2: Cost components of management alternatives. Source: (Rogers *et al.*, [29]).

A wide range of estimating techniques is available to aid in such quantification. These efforts have achieved success in estimating total supply cost (direct cost) but have been less successful in estimating the total economic cost and total cost of alternatives. Direct costs are reasonably well covered and normally consist of an engineering approach, summating the capital outlay, operating and maintenance costs over the project lifetime. Some controversy may be found in the determination of a suitable discount rate for future direct cost, but in most cases an assumption can be made to overcome this problem (Gollier, [15]; Goodstein, [16]; Pearce, [27]). The estimation of total economic cost and total cost remains problematic. This implies that water management decision-makers are confronted with incomplete decision-making information. Also, different options often have different proportions of direct and indirect costs. Take, for example, two bulk water supply alternatives: a new dam site or a water production facility like a seawater desalination plant. Direct costs with both options could be accounted for with relative ease against an acceptable level of certainty, and it would probably be the case that the dam would have a lower direct cost per kilolitre of water compared to the desalination plant. However, it could be that the dam contains more unknown and unaccounted-for long-term externalities compared with the desalination plant. Such externalities are not taken into account to the same extent as the measurable (direct) costs of the two options. Decision-makers are therefore left with little choice but to focus more on the direct cost in making a choice between the two options. Such a dilemma implies that decision-makers assume the risk of making unsustainable long-term management decisions based on incomplete information. The irony of the situation is that, lamentably, future negative impacts become apparent only when it is too late to reverse the situation because of sunken costs. The danger for sustainable water management therefore lies in basing strategic decisions on incomplete information or even worse: being ignorant of a potentially large cost component Figure 2. It should be clear that strategic decision-making in bulk water management faces a classic case of decision-making in situations of incomplete cost information, with numerous uncertainties (Joubert *et al.*, [19]; Mander *et al.*, [22]; McDaniels *et al.*, [23]; Pavlikakis and Tsihrintzis, [26]; Shand *et al.*, [31]). One step forward in accommodating externalities is the development of decision support techniques that will at least manage uncertainties and intangible factors to structure the decision-making process.

4 Decision support for strategic water resource management

The existence of externalities in water management decision-making are due to numerous interrelationships between different factors, each playing a role in the benefits and costs associated with alternatives. To manage such a "messy" situation calls for an integrated approach to water resource management. Systems thinking is at the core of integrated resource management, and MCDA forms part of an integrated and trans-disciplinary approach to water resource planning (Figure 3) (City of Cape Town: Water Services, [8]; Thomas and Durham, [37]).

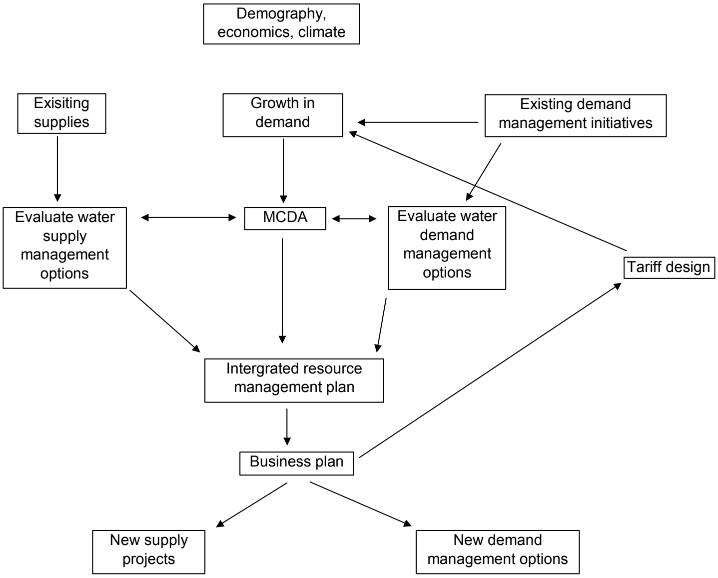

Figure 3: Integrated water resource planning. Source: (Eberhard and Joubert, [13]).

Integrated water resource management may be considered in at least three ways (Du Plessis *et al.*, [9]).

First, it can imply the systematic consideration of the various dimensions regarding the quality and quantity of water. Important here is the acceptance that water comprises an ecological system formed by a number of independent components. Each component (quantity and quality, surface and groundwater) may influence other components, and therefore, needs to be managed with regard to its interrelationships. At this level of integration, management's attention is directed to joint consideration of aspects such as water supply, waste treatment and water quality.

Second, integrated water management can imply that, while water is a system, it is also a component that interacts with other systems. This points to interactions between water, land, and the environment, recognising that changes in any one may have consequences for the other. At this level, management's interest becomes focused on issues like floodplain management, erosion control, non-point pollution, agricultural drainage and recreational use of water.

A third, and broader interpretation is to approach integrated water management via the interrelationships between water and the social and economic environments. Here the concern is to determine the extent to which water is both an opportunity for and an obstacle to sustainable economic development. At this level, interest turns to the role of urban water use.

Integrated water resource management implies anticipation of the short- and long-term impacts of water management decisions (Belton and Stewart, [4]). Short-term impacts can be anticipated with an acceptable level of certainty; however, long-term impacts present a major challenge. Such issues are far too complex to be analysed by an individual decision- maker for their potential long-term consequences. The decision-maker is therefore dependent on decision support for making the best decision given the context (Carmichael *et al.*, 2001; Hobbs *et al.*, [18]; Laukkanen *et al.*, [21]; Oosthuizen *et al.*, [25]; Slinger, [32]; Stewart *et al.*, [34]; Van Zyl and Leiman, [40]; Wierzbicki, [41]).

Decision support and decision analysis will not solve a decision-making problem, nor are they intended to do so. Their purpose is to produce insight and to promote creativity to help decision-makers make better decisions (Stewart, [33]). Decision support is directly related to explaining decision-making behaviour and voting theory, which is related to utility theory because an expected utility maximising strategy exists in voting situations as well as in decision-making situations (Laukkanen *et al.*, [21]). In order to justify and explain behaviour, rational choice theory appeals to three distinct elements in the choice situation (Belton and Stewart, [4]; Eberhard and Joubert, [12,13]). First, there is the feasible set, which can be defined as a set of all actions (water management alternatives) that satisfy various logical, physical and socio-economic constraints (decision-making criteria). The second is the causal structure or the situation that determines which action will lead to which outcome (interrelatedness between actions and outcomes). The third is a subjective (normative) ranking of the feasible alternatives, usually derived from a ranking of expected outcomes. To act rationally then simply means to choose the highest ranked element in the feasible set (Belton and Stewart, [4]; Elster, [14]); however, it is important to stress the subjective nature of these decision-making environments as well as the limitations of an analytic-reductionistic mindset (Arrow, [1]; Sen, [30]).

MCDA appeals in strategic water management because it manages uncertainties and makes subjectivity more tangible. This does not imply that MCDA will eliminate subjectivity in decision-making - it only manages subjectivity since it and subjectivity will remain part of decision-making, particularly in choosing criteria on which to base the decision and in choosing what weight to allocate to each decision-making criterion. MCDA manages subjectivity by making the need for subjective choice explicit and the process of taking account of this subjectivity more transparent (Stewart, [33]). Such transparency is important since it promotes stakeholder participation, especially in cases where multiple stakeholders are involved, as is the case in water resource management.

MCDA is both a process and a methodology that provides a consistent approach to compare alternatives that have impacts on, or are relevant to, a number of different criteria. Essentially, the process comparing management alternatives from different points of view (criteria) and combines these comparisons (scores) to obtain an overall ranking of alternatives. Each criterion is evaluated from different disciplines.

The following statements describe the character of MCDA (Belton and Stewart, [4]):

- MCDA tries to take explicit account of the multiple conflicting criteria for decision-making.
- MCDA assists in structuring the problem of choice.
- All models used in MCDA provide a focus and a common language for discussion.
- MCDA facilitates decision-making by assisting the decision-maker to place the problem in context, to determine the stakeholder preferences and to present the information.
- MCDA acts as a sounding board against which ideas can be tested.
- MCDA improves the justification of decisions

It must be noted that MCDA does not claim to provide a "correct" or "true" system of weights or scores, as these are determined by the inputs of the stakeholders of the decision-making process (Hobbs *et al.*, [18]; Stewart *et al.*, [34,35]). The "correct" system reflects the trade-offs society is willing to make in any specific situation. The relative importance attached to each criterion and the correct treatment of their comparative importance is critical to implementation. However, the assessment and interpretation of importance weights is often a topic of controversy between decision-makers. In addition, the weights of criteria are based on normative grounds - economic theory is therefore less suitable to resolve controversy between decision-makers.

5 Conclusion

Despite the general acceptance of the concept of integrated water resource management, progress in its implementation has been slow and unsystematic. This is partly because of obstacles to integration. The slow pace of adoption also indicates that decision makers are learning as they proceed, with no obviously correct model to follow. As a result, individuals are usually cautious and follow an incremental strategy in which they move forward slowly. Key obstacles to integrated water management include decisions regarding what information is needed to assist in planning and management decisions as well as deciding how to incorporate the public into the management process.

Employing MCDA in the water management decision-making process is certainly a step in the right direction. However, the process should be further refined and expanded by comparing sequences of management alternatives over time instead of comparing alternatives at the same time. By doing this, new dimensions, such as spatial, temporal and geographical dimensions come to the fore. Defining MCDA as a process on a bigger spatial scale, will force decision-makers to think more broadly regarding the consequences of water management decisions. The time dimension will pre-empt consideration of the long-term implications of different sequences of management alternatives. The geographical broadening of MCDA would include aspects such as impacts on rural areas from where water is re-allocated to urban areas. If rural areas were to be included, rural communities would have to be included. The public needs to be consulted regarding preferences in terms of sequences of alternatives over time, and the challenge lies in communicating complex issues in a simple way to the public in order to obtain a meaningful answer. Within such refinement lies the difficult question regarding whether, and to what extent, public opinion should be questioned in long-term strategic decision-making. Questions regarding the rationale of simplifying complex problems, such as strategic water management, and presenting these questions to the public in order to identify public preferences remain.

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