Journal of Hydrology 553 (2017) 438–446

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Research papers

Modeling resource basis for social and economic development strategies: Water resource case

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ARTICLE INFO

Article history:
Received 9 May 2017
Received in revised form 28 July 2017
Accepted 7 August 2017
Available online 18 August 2017

Keywords:
Water resources
Strategic approach
Water resources management
Game theory
Water resource allocation modeling
Cluster analysis

ABSTRACT

The article substantiates that the effectiveness of implementing socio-economic development strategies is to a large extent determined by the adequate provision of basic resources. The key role of water resources in economic strategic development is empirically illustrated. The article demonstrates the practicability of strategic management of water resources based on the principle of a combination of river basin management approaches and the consideration of regional development strategies. The Game Theory technique was used to develop economic and mathematical tools for supporting decision-making in meeting the needs of regional consumers under water balance deficit conditions. The choice of methods was determined from two positions: the methods should allow for the possibility of multi-variant solutions for the selection of optimal options for the distribution of limited water resources between different consumers; the methods should be orientated on the maximum possible harmonization of multidirectional and multi-scale interests of the subjects in the water management system of the different regions (including the state) in order to achieve a balance. The approbation of developing a toolkit for the example of the regions located in the Don and Kuban river basins resulted in the appropriate selection of priority regions for the allocation of water resources in terms of strategic management as well as the determination of measures of ensuring the sustainable use of the river basins under consideration. The proposed tools can be used for coordinating decisions on the water supply of regional economic systems with actual and projected indicators of socio-economic development of the respective regions for a strategic perspective.

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1. Introduction

1.1. Resource basis for strategic development

The strategic approach to managing economic development at various levels of structural hierarchy has become more prevalent and in demand in the past years as demonstrated in numerous studies dedicated to this subject (Dimitrou and Thomson, 2007; Friedmann, 2004; Vasilevska and Vasic, 2009; Tsybatov and Mikhaylovsky, 2015). Various countries participate in the development and implementation of supranational, national, regional, and local strategies encompassing socio economic development as a whole or focusing on the activation of evolutionary transformations in specific economic spheres and sectors. This trend has been observed in Europe, United States of America, Africa, China, and in Russia.

Nevertheless, formal strategy development does not always ensure the successful achievement of intended or relevant targets and development vectors. In practice, only the strategies that have appropriate resource provision can be efficiently implemented. The analysis of strategizing practices in Russian regions shows that, often, particular resources for strategic implementation are well determined, however, the sources and forms of attaining such resources as well as the possibility of their attainment in required quantities, is not always distinctly established. According to Fortune Magazine, nine out of ten organizations fail to implement their strategic aspirations in real economic conditions due, inter alia, to the fact that 60 percent of such organizations are unable to clearly link strategy to budgeting (Olsen).

It is important to note, that legitimization of the enhanced role played by the regions in strategic planning results in a situation where, on the one hand, competitive relationships are formed between regions in terms of availability of limited resources in

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http://dx.doi.org/10.1016/j.jhydrol.2017.08.007
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the country, and on the other hand, a range of various sector-based strategies emerge to trigger a degree of competition between strategies themselves in the context achieving their full resource provision. In this regard, it is essentially imperative to develop an analytical model for the distribution of limited resources (especially basic ones) across competing economic systems in order to achieve strategic development objectives.

1.2. The role of water resources in strategic economic development

Due to the different natures of the formation, attraction, distribution and consumption of the various types of resources, the creation of a single universal methodology of resource distribution to ensure the strategic development of economic systems cannot be achieved. For instance, there are essential resources that form the basis of the majority of the general and specialized socio-economic development strategies and play a systematic role in regional economics. Water is among such essential resources. A number of factors determine the special importance of water resources. According to the Water Problems Institution of the Russian Academy of Science, for 50 years, from the 1950s to the beginning of the 21st century, the demand for water has more than tripled. The concept of water stress was introduced to indicate a situation of critical water resource shortage, which will be experienced by over four billion people by mid 21st century. Furthermore, studies prove that the domestic and industrial use of water resources is 30 times higher than the consumption of all other resources (Danilov-Danilyan and Khranovich, 2010). Water resources play a fundamental role in the functioning of all sectors of the economy. Many countries including the Russian Federation have been historically characterized by extreme unevenness of water resources distribution, which determines the consequent problem of substantial inconsistencies in the availability and needs of subjects experiencing deficits. Decision-making in water resources distribution in terms of ensuring the implementation of development strategies (in territorial or sectorial representation) should conjugate, first, the selection and implementation of optimal options for the distribution of limited water resources between different consumers, which is directly related to the rational use of resources; secondly, with the maximum possible harmonization of the multidirectional and multi-scale interests of economic subjects (including the state) in order to strike a balance and, ultimately, improve the efficiency of the development and implementation of the sectorial and territorial development strategies.

1.3. Review of existing water resources distribution models (Literature review)

Given the importance of water resources in socio-economic development and the distribution complexity in limited availability conditions, many scholars have devoted research towards the development of analytical modeling tools to support decision making in this area.

Water resources distribution optimization issues are addressed in modern scientific research from different methodological positions using various methods, models and instruments: the optimization of water resources distribution to improve employment growth in industry and agriculture as a key driver for economic development using a meta heuristic algorithm (Davijani et al., 2016); an integrated model for the optimization of water resources distribution in terms of adaption, dynamics and multi-objectives as key characteristics of the complex water resources system. This model is based on the use of system dynamic and non-dominated sorting genetic algorithm II methods, multi-objective genetic algorithm, and project pursuit method (Zhou et al., 2015a,b); optimal spatial allocation of water resources based on Pareto ant colony algorithm (Hou et al., 2014); modeling a supply and demand balance for water resources from a sustainable development prospective, taking into account technological and social factors as well as environmental aspects (Ali et al., 2017); the use of an integrated modeling framework for managing water resources and developing alternative distribution policies (George et al., 2011; Letcher et al., 2007).

When addressing water resources distribution issues, a series of researchers pay great attention to risk and uncertainty factors, and construct appropriate optimization models, for example, through integration of chance-constrained programming, semi-infinite programming and integer programming into an interval linear programming, of stochastic simulation models (Li and Guo, 2014; Lia et al., 2016); creation of a multi-objective model involving water distribution equality and economic efficiency risk control. The Gini coefficient is introduced to optimize water distribution equality in water consuming sectors (agricultural, domestic, and industrial sectors), and CVaR (the conditional value-at-risk method) is integrated into the model constraints to control the economic efficiency loss risk corresponding to variations in water availability (Hu et al., 2016a,b). The issues of equity and efficiency in the allocation of limited water resources could also be addressed through the use of a multi-objective programming model, built first with the objective of maximizing the economic benefit efficiency to allow for the development of improved water distribution strategies and with the second objective being to maximize water distribution equality (measured using the Gini coefficient). A Compromise Programming (CP) method is employed to trade off economic benefit efficiency and equity in the water allocation, which can provide relatively flexible choices and trade-offs according to the decision makers' preferences (Hu et al., 2016a,b).

Attempts to take into account the multidirectional interests of the subjects and the search for methods to achieve a balance in the allocation of water resources are undertaken both at the organizational level using the bi-responsive modeling approach (Karsu and Morton, 2014), as well as at river basin areas utilizing bankruptcy rules in water resources allocation (Mianabadi et al., 2014), and with regard to water resources at a more general level using agent-based modeling to simulate the behavior and interactions of the parties participating in a conflict scenario, which is modeled as a game (Akhbari and Grigg, 2013) or, alternatively, applying multi-objective genetic algorithm to analyze the conflict between different water consuming sectors (Chang et al., 2009).

As such, the water resources allocation system is regarded as an administered or market-based system, or a combination of the two. Each of the two types of systems is characterized by specific advantages and disadvantages, which determine behaviors of its agents, the choice of regulation tools and selection of analysis and modeling variables accordingly (Zhao et al., 2013), as well as the actual formation of a mechanism for water resources allocation for planning usage at regional level using the Fuzzy logic (Tu et al., 2015).

A number of researchers provide models that do not only solve current problems but also prospective water distribution issues taking into account the peculiarities of specific territorial systems and river basins (Milano et al., 2013).

Thus, from the prospective of balancing the interests of economic agents at different levels, there are several approaches to water resources management. In this paper, the authors define equilibrium as: «In the state of equilibrium of economic systems, there could be a separation of limited resources which ensures the balance of their use by managing the volumes of distribution, ensuring the continuity of production and economic growth of individual economic units and the economic system as a whole».

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