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Research on method of water resources management based on WSR

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ABSTRACT

Based on the application of an oriental "Wu-li Shi-li Ren-li" system methodology, it presents the method of water resources management; it also discusses the management program and model of water resources based on the WSR, which would be integrated the water management in irrigation area and society, economy, eco-environment and water-saving agriculture as a systematic project to comprehensively research as well as combine engineering, agriculture and biotechnology. It has formed an integrated system from water development, storage, diversion, maintenance to efficient utilization to make Wu-li in right, Shi-li in reason, Ren-li in harmony, so as to promote water management research in the arid and semi-arid irrigation district to develop in deeper and higher way.

KEYWORDS

Water resources; Making-decision; WSR.

INTRODUCE

Water shortage has become a global problem. Annual water resource in China is about 2.8 trillion m^3, ranking the sixth in the world. But per capita and per acre water resource is 2,730 m^3 / and 1,870m^3 / mu, respectively, accounting for 25% and 76% of the world's average level. Our country is scarcity of water resource, and its distribution is very uneven: 81% of water resource concentrates in the south of the Yangtze River basin. 45.3% of the population living in the north of the Yangtze River cultivate 64.1% of total land, but only use 19% of the country's water resource. In this region, per capita water is 517 m^3, which is equivalent to 1/5 of national per capita and 1/20 of the world per capita. Therefore, water resource shortage mainly occurs in northern China. Its water crisis has become more serious than ever before. Especially in the arid and semi-arid area of inland river basin, the contradiction between the societal, economic and agricultural development and water shortage in irrigated area has become a burning issue. Therefore, in order to reconcile the contradiction between the societal, economic and agricultural development and water shortage in irrigated area, we avoid using quantitative analysis to get optimal scheme and reconcile contradiction with "Ren-li". Based on the "Wu-li Shi-li Ren-li" (hereinafter referred to as the WSR) to establish the water resource methodology, research of water resources management in the arid and semi-arid region will have great benefits in society, economy and agriculture.

Speaking of "Wu-li Shi-li Ren-li", Qian Xuesen and Xu Guozhi who were the doyens of system engineering discussed WSR in the 1970s.[1] As for "Ren-li", Lao Tz (Li Dan) who was a superior philosopher of the early mankind's history began to realize "Heavenly Principles" and "Ren-li" in more than two thousand years ago: it was from the Nameless than Heaven and Earth sprang, the name is but the mother that rears the ten thousand creatures, each after its kind. In the 1990s, Gu Jifa etc, from system science Institute of Chinese academy of sciences, found that their views on leadership science were consistent with "Ren-li" through researching leadership science. Leaders have advantages in the aspect of "Ren-li", but they sometimes lack natural science and management knowledge. Therefore, on the basis of integration of "Wu-li Shi-li Ren-li", we put forward that a good manager should understand the "Wu-li Shi-li Ren-li" to further form the system methodology of "Wu-li Shi-li Ren-li".

Water resources management in the arid and semi-arid irrigated region is a burning issue for water-saving agricultural research. According to the above analysis, this research not only takes engineering measures, but also adopts administrative means. From the perspective of management, the management on water resources distribution should be the premier problem to solve. Therefore, the basin system has become the preferred object of the water resources distribution.[2] After the establishment of water resources management model, the water resources allocation and management in irrigated area have become the key link to improve the resources utilization. Water management in irrigated area has been realized in terms of water diversion, water delivery and irrigation.

THE WSR ANALYSIS OF WATER RESOURCES MANAGEMENT IN THE IRRIGATED AREA

The "Wu-li" of water resources management in the irrigated area

Wu-li mainly refers to the mechanism of material movement, often applies natural science knowledge to answer what is the "thing", and it needs authenticity. Shi-li refers to the truth that mainly solves how to plan these things, and often applies management science knowledge to answer how to do. Ren-li is the principle to conduct oneself. It is men that deal with any matters and things, and it is men that judge whether these things are proper. Ren-li usually takes the humanities and social science knowledge to answer what should be done.

The "Wu-li" of water resources management in the irrigated area is to study the rules of headwater, storage, delivery, utilization and discharge, which requires hydrology, hydraulics, hydraulic engineering, farmland water conservancy and other aspects knowledge.

The "Shi-li" of water resources management in the irrigated area

The "Shi-li" of water resources management in the irrigated area studies water resources allocation, distribution and regulation in the irrigated area, which requires operational research, organizational management, modeling and simulation, computer science, software engineering, and applied mathematics knowledge. The "Shi-li" of water resources management in the irrigated area is described through the model, and it ultimately uses multi-objective decision-making system model to describe. Its system structure is shown in Figure 1.

The "Ren-li" of water resources management in the irrigated area

Water resources management in irrigated area is the compound system with hierarchical structure and macro-function, which consists of socioeconomic system, eco-environment system and water system. Water yield, quality and investment have formed the interdependent and constraint relationship. The system reflects the comprehensive features and independent units of functions. Therefore, system coordination has become the "Ren-li" of water resources allocation management.

The "Ren-li" of water resources management mainly refers to the coordination, including constraints between the models made by "Shi-li", the relationship among the parameters in the model, the principles followed by the models, such as combination of qualitative and quantitative, man-machine combination, the combination of various departments and technical coordination.

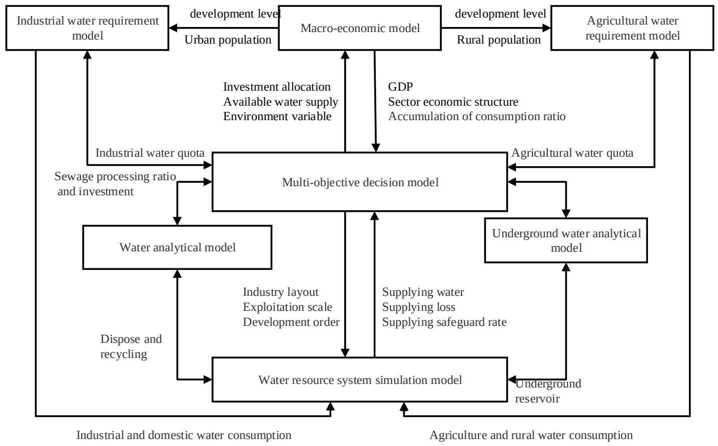

Figure 1: Structure of "Shi-li" of water resources management in the irrigated area

The integrated water resources management in the irrigated area

"Wu-li Shi-li Ren-li" (the WSR) system analysis method is the overall plan combined various analysis methods. According to the different natures of practice, methods are made to be hierarchical, methodical, systematic and standardized. It is a concept system that disperses non-spontaneously in the overall plan and contains two organic connection elements: one is the strategic level; the other is a tactical level. The division of the strategic and tactical levels is not based on the difference of the macroscopic and microscopic, but on cognitive activities instead of practice. Cognitive activities are the strategic activities that determine the system purpose, goal, direction, principles and policies. They have something to do with the future survival and development from the perspective of long-term and global thinking. The WSR system generally solves the practical problems and is a kind of method combined of qualitative and quantitative.

Water management in the irrigated area involves many departments and personal interests, embodying the "Wu-li Shi-li Ren-li" management system. With mutual penetration and fusion of multiple subsystems, the formation and development of water resources management in irrigated area contribute to the conflict and the development of water resources management. Affected by unstable, dynamic and changeful water management in irrigated area as well as rainfall, drought and other uncertain factors, there are many possible evolutions. The research on water resources management in irrigated area will help the sustainable development of agricultural irrigation area.

In water resources management of the irrigated area, "Wu-li Shi-li Ren-li" method reflects the oriental thinking. Wu-li is natural rules of water management in irrigated area. Shi-li is water management, distribution and behavior theory. Ren-li is rational thought, belief and behavior norms involved in water resources management in the irrigated area as w ell as the feedback and interest coordination of different subsystems. The WSR methodology embodies not only relations between the objective world and science and relations between organizational management and system science, but also relations among the different cultural backgrounds as well as behavior science. The whole water management system is composed of various subsystems rather than derived systems. Every subsystem plays a positive role in the overall interests. Decision maker of the organization is a social person. Therefore, water management theory and method should revolve around the following innovative thinking and management means: integrated management by objectives; collaborative shared information management; nested multidimensional organization management.

PROGRAM BASED ON THE WSR WATER RESOURCES MANAGEMENT IN IRRIGATED AREA

Functions definition of water management in irrigated area

Wu-li understands the physical elements and background, irrigation engineering theory, irrigation area water resources change law. Shi-li analyzes a whole function target and information structure in irrigated district and provides the model. Ren-li optimizes various sectors involved in water resources management and individual interests and management organization and deals with relationship between the whole interests and function.

Inspecting water resources situation and condition in irrigated area

Wu-li mainly inspects water management system structure, information and management, river volume and irrigation water, canal water system, crops planting area, rainfall in crop growth period and other basic conditions affecting water resources management. Shi-li inspects whether water allocation model reflects the interests of each subsystem, the whole function, knowledge and software required by system management. Ren-li mainly use the CATWOE analysis method.

The establishment and formation of system target

Wu-li determines function objectives, principles, and index set of water management in irrigated area. Shi-li selects weights for function objectives of water management in irrigation area. Ren-li balances the relations between department interests and overall interests, the relationship between ecological benefits and economic benefits and the relationship between crops requirement and water yield as well as determines water sector structure and environmental impact.

The formation of water management decision model in the irrigation area

Wu-li coordinates hardware, software and technologies of water resources management. Shi-li coordinates the relations between water resources knowledge base and model management. Ren-li coordinates the relation among theoretical model and reality and subsystem targets.

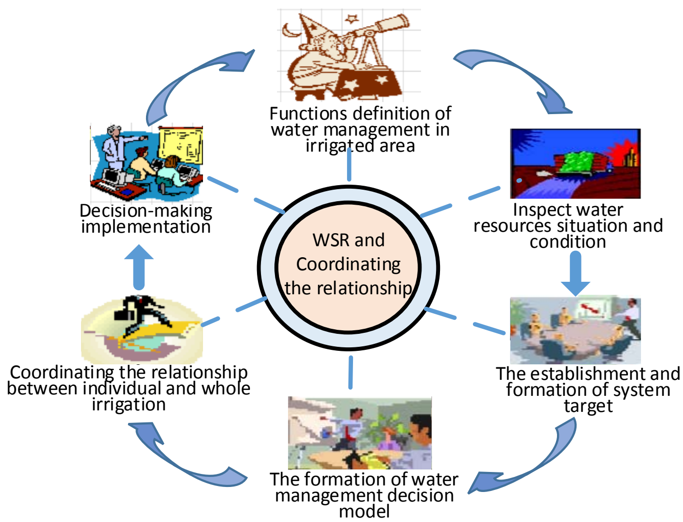

Figure 2: The process based on the WSR water management

Coordinating the relationship between individual and whole irrigation

Wu-li turns the physical conditions of water resources management into reality conditions in the irrigation area. Shi-li selects optimization model combined synergy and process. Water management in irrigation area should consider relation between water required by various departments and the different crops planting area in whole irrigated area, relation between industrial structure and eco-environment, as well as subsystem participation, organizational management and the model weight understanding and modification---Ren-li.

Decision-making implementation

Wu-li should consider the matching between the physical structure of irrigation system and the overall feature. At the same time, according to water resources allocation rules in basin irrigation area, Wu-li implements the decision scheme and modifies model in line with the implementation result to promote a higher level of development. Shi-li is to train operators and managers of each system. Ren-li inspects interests coordination and feedback of the different subsystems.

The process based on the WSR water management is shown in figure 2.

WATER MANAGEMENT COUNTERMEASURES IN IRRIGATED AREA BASED ON THE WSR METHODOLOGY

Application of integrated technology is the key to manage water resources

From the point of technology of water management in irrigated area, engineering measures are the first choice for years. However, with the passage of time, if only from the point of engineering, channel achieving high standard lining is to improve the utilization of water, but to damage the local ecological environment (for example, the trees near high-standard lining channels in the Hexi corridor of Gansu province were dry to death because of inadequate water). Given this point, the ecological environment is one of the important factors to take engineering measures.

From water resources allocation in the river origin to irrigation system, water resources management fully embodies “Shi-li” and “Ren-li” of the comprehensive system analysis. First is the issue of water resources allocation in inland river basin, especially some regions short of water, and rational water distribution in upstream, middle stream and downstream. Second is to research on water allocation and coordination in terms of time and space in irrigated area to get quota irrigation of all sorts of crops. Third is to research water distribution in the canalization to realize the optimization of water distribution plan. Finally, water resources assigned to the field are dynamically allocated in the period of crop growth to achieve the maximum irrigation output under the condition of insufficient irrigation.[3]

On the other hand, water management in the irrigated area takes water-saving agriculture technology and engineering measures. Engineering water-saving technology not only plays a significant role in macro water storage and diversion, but also improves the production and saves water directly. Agricultural water-saving technology is related with agricultural production and has affected in a wide range. Biological water-saving technology is formulated in accordance with crop requirement, and its main function is to improve transpiration water efficiency and the basis of corresponding engineering and agricultural water-saving measures. According to WSR analysis of water resources management in arid and semi-arid irrigated area, water management measures have been made: first, the construction of the water diversion project; second, irrigation equipment modernization, pipelining in some conditional places and the adoption of trickle irrigation and sprinkling irrigation and development of automatic irrigation system and advanced green farming system. Automatic irrigation system is operated by computer to irrigate according to different conditions for saving water. Third, agricultural internal cultivation is undergoing the change, turning considerable area of crops into horticultural crops with a higher economic value. After optimization of “Wu-li”, the improvement of utilization coefficient of irrigation water and the potential transpiration evaporation rate are very limited. Focus on “Shi-li” and “Ren-li” is through water resources management to achieve the purpose of improving the utilization ratio of water resources and water output in irrigated area.

Coordinating the relationship between the parties to set up the water resources management system in irrigated area

Research on water management of arid and semi-arid irrigated region is the basis of its implementation. However, "implementation" is much more complex than the "research". The implementation of the plan is a process of "Ren-li" coordination. Research on water resources management is a complicated system project with a strong comprehensiveness. The implementation is not just a problem of science and technology, but also related to a series of social, eco-environment problems and so on. “Wu-li Shi-li Ren-li” should be taken into overall consideration.

In arid and semi-arid irrigated area, water resources management is not a simple problem solved by system optimization and mathematical model, but an issue combined qualitative with quantitative applying a multi-objective model to solve. On the basis of mathematical model, combined with the expert qualitative and quantitative experience and computer technology, implementation plan is made in line with the “Shi-li” and “Ren-li”. Water management decision support system requires the man-machine combination, according to the results of computer quantitative analysis and combining the experts’ experience, to adjust parameters and form a new model. Through multiple simulation iteration and learning, the final decision-making model is Wu-li in right, Shi-li in reason, Ren-li in harmony.

Improvement of the utilization efficiency of water resources depends on some advanced water-saving technologies, such as sprinkling irrigation and drip irrigation. The application of advanced technology should consider the economic costs, and how to coordinate with the current production mode and productive relations, such as adjusting agricultural water investment return rate, management level, the scale of operation, and agricultural structure. These technologies promotion is in line with the "WSR" and supported by grassroots organizations and the masses, so as to become water management mechanism to improve efficiency of agricultural water in irrigation area.

According to "the WSR” methodology, on the one hand, improvement of the utilization efficiency of water resources should be carried out according to the water resources situation in irrigation area to adjust agricultural structure and crop distribution and to establish reasonable cropping system. All kinds of water-saving technologies should be vigorously promoted and assembled. Water-saving management policies should be established and relevant laws and regulations should be amplified. On the other hand, according to the existing spatiotemporal distribution of water resources in irrigation area, we systemize water resources allocation, diversion and distribution during crop growth to make the most of the limited water resources in irrigation area.

Based on the WSR methodology to establish water management mechanism in irrigation area, we give full consideration to social, economic, ecological and other factors in the process of water management in irrigation area. In the framework of the WSR system methodology, we establish multi-objective water management model in irrigation area to fundamentally solve the problem that the scheme can not get the public support.

Multi-level and multi-objective group decision-making method of the reasonable allocation of water resources

The process of water management in irrigation area is a process of negotiations that are based on a set of representative plans. Depended on the model system, each time 5 ~ 7 alternatives are generated for decision makers to choose. After making the choice, the best solution will be the basis of the next round of negotiation. Repeat the process until the final planning scheme is made.

Because the irrigation water management involves many decision makers of the basin, local and the irrigation area, which is the group decision-making problem. It involves many decision times and is multi-time decision-making. With multiple decision goals of social economy and ecological environment, it is a typical multi-objective decision-making problem. It also involves water intrinsic properties such as nature, society, economy, ecology, and hydrology as well as constraint conditions such as engineering, water quantity, water quality and investment. It is a highly complex multi-phase, multi-level and multi-objective, multi-subject risk decision making problem. In order to make the decision process quantitative and increase transparency, every alternative has a good information structure meeting the requirements of management decisions (TABLE 1).

Alternatives are non-inferior solutions of multi-objective significance. Its formation is to seek ideal point in many non-inferior solutions. In the process of practical operation, introduction of the measurement index system of development model can decrease inconsistency degree of different development indicators. By introducing the measurement index system of a planning scheme’s influence on different regional development can coordinate the interests of different decision makers from different areas. Overall planning model optimization and simulation can reduce the hydrological risk in solution selection. The combination of expert qualitative judgment and quantitative calculation deals with uncertain problem in scheme selection. This way can ensure the planning scheme with the good internal coordination and external adaptability.

TABLE 1: the requirements of management decisions

The target or decision space	Scheme	Decision makers
Per Capita GDP Gross output value of industry and agriculture Per capita grain output Per capita ecological area Minimum water loss Maximum output Water use efficiency Water saving method Water supply Project scale The total investment Water consumption	Plan 1 Plan 2 Plan 3 Plan 4 Plan 4 ……	Watershed decision makers The local decision makers Decision makers in Irrigation area Canal system decision makers Irrigation decision makers

The multi-objective decision analysis technology based on QFD

Water resources management decision based on the WSR system is the decision problem of complicated system, requires policymakers to participate in the decision making, and plays an important role in the problem definition. With a view to understanding the policymakers' preference easier, we combine QFD and multi-objective decision analysis to set up decision analysis framework based on QFD. By using the QFD method to obtain the requirements and desires of decision makers effectively, we convert them into specific decision goals and integrate decision-makers' real demands into decision analysis to improve the actual effect of decision analysis.[4]

Quality function deployment (QFD) is a kind of systematic approach used to listen to voice of customer. It converts appropriately the customer's desire into production plan, product design, manufacturing and other specific technical requirements in different stages to shorten the development cycle, improve quality and reduce cost. QFD is widely used in Japan, the United States and some European countries, and has achieved the success.[5]

To sum up, as for multi-objective decision-making, its analysis process can be divided into three stages: (1) on the basis of the task analysis, we turn general but vague statement about the overall goal into a set of more specific and easily analytical targets, define the problem environment and main factors influencing problem; (2) we construct a suitable model that is used to describe the key factors and the their relationship, as well as the policymaker's preference;(3) we rely on model to analyze and evaluate, compare and rank feasible plans, and identify the best solution in the certain significance. If policymakers aren't satisfied with the analysis result, we can reconstruct by new information gotten in the analysis.

How to effectively obtain the policymakers' preference is one of the key problems of multi-objective decision analysis. Therefore, the current study focuses on how to promote interaction among decision makers and decision analysts and decision support system to take full use of knowledge, experience and judgment of the decision makers. However, in the interaction, existing method usually requires decision makers to express their desires about the specific target in the constructed model made by the decision analysts. In many cases, policy makers may not be the experts in practical problems, nor do not they study the specific target. What they really care about are those comprehensive properties that affect decision making and goals that they should achieve.[6,7]

Based on the above analysis, it is necessary to distinguish between the attribute of decision makers and target attribute of decision analyst. The former reflects the problem description made by decision makers, which is usually comprehensive but vague requirement about problems. The latter is the target attribute of multi-objective decision. Thereby, policymakers should be placed in an appropriate position that let them to offer demands in their familiar thinking way and gives full play to the policymakers and decision analysts in their respective roles for the purpose of making decision analysis procedure more natural and harmonious.

Based on QFD analysis, we can create the following multi-objective decision analysis model:

$$\mathrm{z} = (\mathrm{z}_1, \mathrm{z}_2, \cdots, \mathrm{z}_\mathrm{m})$$

$$z_i = f_i(y_1, y_2, \cdots, y_m) \quad i = 1,2,\cdots,n$$

$$h_j(y_1, y_2, \cdots, y_m) = 0 \quad j = 1,2,\cdots,m$$

Restrains:

$$y_k = g_k(x_1, x_2, \cdots, x_l) \quad k = 1,2,\cdots,m$$

$x = (x_1, x_2, \cdots, x_l) \in X$

Wherein: z represents for policymakers properties; Y = (y_1, y_2,..., y_m) is decision analysis target; X is the decision variables; f (·) is the relationship between decision analysis targets based on incidence matrix structure and policy makers attributes; h (·) represents relationship between the decision analysis targets; g (·) is the relationship between the decision variables and decision analysis target; X is the feasible region of x. In many cases, relations between policymakers' attributes and decision analysis target as well as relation between decision analysis target attributes are often qualitative. To this end, we introduce the qualitative reasoning method. In the quantity space, bound script is introduced to discretize the space and to form qualitative submodel which consists of a set of qualitative equations describing relations between qualitative variables. For example, z_i = M+ (y_i), z_i = M- (y_k). M+ and M- represent monotone increasing and monotone decreasing, respectively. The qualitative equation describes that the environmental indicators (z_i) is positively related to green area (y_i) and negatively related to the industrial output (v_k).

On the basis of the model, ideal point $\tilde{z} = (\tilde{z}_1, \tilde{z}_2, \cdots, \tilde{z}_n)$ constructs a standard function $s(\tilde{z}, z)$, uses $s(\tilde{z}, z)$ to measure the gap between z and $\tilde{z}$, through the minimization in the non-inferior solutions to find the closest point that is a valid point. If policymakers are not satisfied with the results, we can modify the ideal point or make appropriate adjustments to the model to get the new $\hat{z}$. After continuous interaction, available point ($\hat{z}^i$) is generated by ideal point sequence $(\tilde{z}^l, \hat{z}^l)$. If the process is constraint, ($\hat{z}^i$) extremity is the solution of the problem. QFD is embedded in the process of multi-objective planning analysis. We set up multi-objective decision analysis framework based on QFD and distinguish decision makers attribute from the specific decision-making target attribute. Thereby, decision makers propose real demands according to their own familiar thinking to overcome the interaction difficulties of traditional multi-objective decision and to improve the effect of decision analysis.

CONCLUSION

Water resources management and decision in irrigation area have the following features: the system components diversity and relative independence; complicated structure and weak structural characteristics; procedural structure characteristics; nested nature of system structure. Due to the system characteristics, we adopt complicated system theory, comprehensive integration and the oriental "WRS" methodology to research and analyze water system management in irrigation district.

Water resources management in irrigation area should revolve around the thinking integrated overall management by objectives, collaborative shared information management, nested model and multidimensional organization management. Based on the WSR water resources integrated methodology in the irrigation area, we will integrate the water management in irrigation area and society, economy, eco-environment and water-saving agriculture as a systematic project to comprehensively research as well as combine engineering, agriculture and biotechnology. It has formed an integrated system from water development, storage, diversion, maintenance to efficient utilization to make Wu-li in right, Shi-li in reason, Ren-li in harmony, so as to promote water management research in the arid and semi-arid irrigation district to develop in deeper and higher way.

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