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Ecology-safe Management of Drinking Water Supply Systems

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Executive Summary

Principle purpose. The principle purpose of the project is to develop a specific modeling technique and procedure for decision making in combined civil engineering, environmental and social systems when data are extremely fuzzy and uncertain. The implementation basis is the drinking water supply system for the population in the middle and lower streams of the Amu-Darja river.

The main aims of the project are following:

1. Development of a modeling and decision making technique for the drinking water supply system in the extremely hard ecological conditions.
2. Implementation of a multi-variant decision analyzing and making system based on experts procedure in the Uzbek practice.
3. Including the ecological factors as main ones in the civil engineering projection.
4. Processing and system analysis of the data on the different alternatives for the drinking water supply of the problematic areas in the streams of the Amu-Darja river.
5. Adaptation of the computerized Decision Support System DEMSU/DMAKER developed in NODES R&D Ltd. to the Amu-Darja problem.
6. Performing an expert choice procedure with involvement of the independent experts from several countries (Uzbekistan, Israel, Russia).
7. Transferring DEMSU/DMAKER system and the technique of its smart implementation to the Uzbek specialists to use it in other projects.

Collaboration. The roles in the collaborators were the following:

Uzbek partners: 1) data gathering and processing;
2) participating in the expert procedure;
3) mastering DEMSU/DMAKER and supplementary programs;
4) participating in the results analysis.

Israeli partners: 1) development of a decision making procedure for complex engineering systems with essential ecological and social factors;
2) adaptation of the decision support system DEMSU/DMAKER to be implemented in the drinking water supply problem;
3) performing the expert choice procedure;
4) participating in the results analysis;
5) transferring DEMSU/DMAKER system to Uzbek partners, including special learning interactions.

What have Uzbek partners got. The Uzbek partners have got the following as the result of the collaboration:

1. Modern technique of decision making implemented in the Amu-Darja problem. This approach will be used to solve other complex problems like Aral Sea one etc.
2. Computer program adapted to the problems like drinking water supply. The market price of the program is 30 to 35 thousand US dollars.
3. Two computers (Pentium) equipped with the world wide standard software like MS DOS 6.22, Windows for Workgroups 3.11, Excel 4.0, Access 2.0, World 6.0 etc.
4. Experience of the international cooperation which they hadn't have.

Research Objectives

Project importance and actuality. This project intended to make a contribution to solution of the serious social and ecological problem of the drinking water supply of the population in the middle and lower streams of the Amu-Darja river. In present more then 6 million people suffer from the shortage of the drinking water of appropriate quality. The main reason is that practically the Amu-Darja river is only source of the drinking water in the region. However it's extremely polluted. This pollution is caused mainly by the penetrating of the water streams from the agricultural fields in the streams of the Amu-Darja river. These flows content a lots of mineral salts and pesticides which are used almost without any control. For instance the average usage of pesticides in the world is 7 kg/ha in Uzbekistan it is 58 kg/ha. As a result the concentration of the pesticides in the soil is up to 20% of their utilization volume.

The drinking water supply problem is only one of the components of the ecological problem in Uzbekistan in other Middle Asia countries like Tyrkmenistan, Kazahstan, Afganistan etc. However the drinking water problem is the most urgent one.

The project is intended to systematically analyze different variants of water quality improvement in the middle and lower streams on the Amu-Darja river. There is a great lot of researches devoted to this problem (see the annotation). First of all of Uzbek and Russian scientists. The main of the current project was to analyze a basic set of alternatives. This allows to achieve the following:

1. Make the analysis more objective.
2. Investigate the problem from the different points of view.
3. Involve independent experts.
4. To get the estimates for alternatives without highly cost technical researches of each of them.

Innovation. On the initial stages of the project an attempt was made to maximally formalize the problem. However with getting more and more data it became evident the main direction must be an expert approach. The quantitative data got were not full and unreadable.

A special expert procedure has been developed. It was based on the following principles:

1. Combination of the expert and available quantitative data.
2. Principally iterative character of expert procedure.
3. Multi-stage procedure with different expert groups.
4. Combination of the different expert estimations (weighted estimations, pair comparison, number estimations) in one procedure.
5. Choice of the best criteria tree out of several trees.
6. Procedure of the most important criteria choice out of the full list.

Support from different organizations. This project was strongly supported by may organizations in Israel, Uzbekistan and Russia. This support can be divided into two directions:

1. Organizations that assist in getting and processing the real information on the present state of the drinking water supply system in Uzbekistan and on forecasts of the

population growth, water demands dynamics, water quality figures in the Amu-Darja river etc. These are first of all two organization which participated in the project and the following institutions which support the research:

- Uzbek Research Institute for Sanitation, Hygiene and Professional Diseases;
- Uzbek Project and Research Institute "Uzniigradostroitelstvo";
- Scientific and Industrial Association "Uzbekgidrogeologia".

2. Those organizations which participated in the expert procedure of the project. In addition to the mentioned above these are the following:

- Technion (Israel);
- Mecorot (Israel);
- Tahal, Water Planning (Israel);
- Ben-Gurion University of Beer-Sheva (Israel);
- Oil and Gas Academy (Russia);
- Moscow University (Russia).

Methods and Results

The main result of the project is the development of a special multi-stages expert procedure and it's implementation in the ecology-safe management of the drinking water supply system to the population in the lower and middle streams of the Amu-Darja river.

The procedure involves the following steps:

1. Forming the variants (alternatives) for the drinking water supply of the population in the problematic regions in the Amu-Darja river streams.
2. Estimation of the technological, economical and ecological factors per variants.
3. Building a full list of possible criteria to be involved in the expert procedure.
4. Analysis of the full list of criteria and building a set of principle criteria.
5. Building several criteria trees on the basis of the principle criteria set.
6. Choice of the best criteria tree including importance factors for each criterion and sub-criterion.
7. Holding a common expertise.
8. Analysis of an expert interaction.

This procedure is an iterative one since results of later steps lead to performing some previous ones again on the basis of reviewed data.

Four groups of specialist were involved in this procedure:

1. Core Group - direct participants of the project. this group was involved in all the steps.
2. Consultant Group - several Uzbek institutions mentioned above which assist in steps 2 and 3.
3. Basic Expert Group is formed from Core group and some independent experts which are expertised in the problem. This group is involved in steps 4 and 6.
4. Common Expert Group is formed of inderpendent experts from 3 countries: Uzbekistan, Israel, Russia. They are involved in the basic step of the procedure - step 7.

Organizations/Independent Experts per Groups

No	Organization/Independent Expert	Core Group	Consul-tant Group	Basic Expert Group	Commo n Expert Group
1	Nodes Design and Implementation Ltd., Israel	*****	*****	*****	*****
2	UZGIPROKOMMUNZPROJECT, Uzbekistan	*****	*****	*****	*****
3	Mecorot Ltd. Computer Department, Israel			*****	*****
4	Mecorot Ltd. Technological Department , Israel				*****
5	Technion, Civil Engineering, Israel		.	*****	*****

6	Technion, Operations Research, Israel				*****
7	Vodproekt, Russia			*****	*****
8	Tahal Ltd., Computer Department, Israel				*****
9	Tahal Ltd., Economic Department, Israel				*****
10	Independent expert 1, Uzbekistan				*****
11	Independent expert 2, Uzbekistan				*****
12	Independent expert 3, Uzbekistan				*****
13	Independent expert 4, Uzbekistan				*****
14	Independent expert 5, Uzbekistan				*****
15	Independent expert 6, Uzbekistan				*****
16	Ben-Gurion University, Physics Department, Israel			*****	*****
17	Moscow University, Russia				*****
18	Oil and Gas Academy, Applied Mathematics, Russia			*****	*****
19	Oil and Gas Academy, Systems Analysis, Russia			*****	*****
20	Oil and Gas Academy, Pipelines Construction, Russia				*****
21	Laboratory for Drilling, Russia			*****	*****
22	Uzbek Research Institute for Sanitation, Hygiene and Professional Diseases, Uzbekistan		*****		
23	Uzbek Project and Research Institute "Uzniigradostroitelstvo", Uzbekistan		*****		
24	Scientific and Industrial Association "Uzbekgidrogeologia", Uzbekistan		*****		
25	DCL Systems Engineering Ltd., Israel				*****
26	Moscow Municipality, Engineering Department, Russia				*****
27	Green Cross, Moscow Department, Russia				*****
28	Ben-Gurion University, Mechanical Department, Israel			*****	*****
29	Israel Center for Social and Economic Progress, Israel				*****
30	Moscow Mining Academy, Russia				*****
31	ALS Ltd., Israel			*****	*****

Six independent experts are anonymous and were provided by the Uzbek collaborators of the project.

Principle data involved in the project can be divided into the following groups which come from the algorithm of the expert procedure:

1. Objective economical, technological and ecological data (population, drinking water demands, water quality, estimations of the costs etc.);
2. Expert data of the basic expert group;
3. Expert data of the common expert group;
4. Results and analysis of the expert procedure.

Description of all the steps, data involved and results are below.

Step 1. Forming the variants.

The basis for the forming of the variants are forecasts of the population dynamics and the drinking water demands in the problematic regions. There are four administrative regions in Uzbekistan. Ecological situation in them differ from extremely hard in Karakalpakstan to a little bit less problematic in others.

Population of Problematic Regions (in millions)

	1990	1995	2000	2005	2010
Karakalpakstan	1.35	1.48	1.63	1.79	1.96
Bukchara & Navoi	1.78	1.98	2.20	2.44	2.71
Kashkadarin	1.74	1.93	2.13	2.36	2.61
Khorezm	1.06	1.18	1.31	1.46	1.62
TOTAL	5.93	6.57	7.27	8.05	8.90

According to the existing forecasts the grouth of demands for the drinking water is higher than the grouth rate of the population. This is due to the deterioration of the existing sources of the drinking water. The below table shows the shortage rates of the drinking water and not the whole demands.

Drinking Water Demands (1,000 cubic meters/day)

	2000	2005	2010
Karakalpakstan	0.84	1.04	1.31
Bukchara & Navoi	0.45	0.76	1.35
Kashkadarin	0.42	0.58	0.79
Khorezm	0.57	0.75	0.99
TOTAL	2.28	3.13	4.44

There are many variants of the drinking water system improvement being investigated in Uzbekistan. Only those which are technologically and politically realistic are included in current project. The Core group specialists made such an analysis.
These scenarios are presented in the below table.

Scenarios of the drinking water supply

No	Scenario	Positive Factors	Negative Factors
1	Water from local sources (Amu-Darja) with deep clearing and desalination.	There is no need in construction of water delivering facilities.	1. Large capital investments. 2. Pollution of the soil and underground waters. 3. Up to 30% wastes of the water.
2	Drainage water with deep clearing and desalination by the desalination.	See 1.	See 1.
3	Water from the Zerafshan river and some other sources by means of pipelines (after deep clearing).	Highly protected water and hence its quality.	1. Large capital investments. 2. Large amount of steel pipes (must be exported). 3. Compensation of the agricultural water demands in Samarkand and Kashkadarin regions.
4	Duplex system. Drinking water from the Zerafshan river and/or local sources and utilitarian water from the local sources with soft clearing.	Reducing the drinking water demands.	1. Large investments in the residential areas to install duplex pipes system. 2. Each department must be equipped with water counters.
5	Water channel from the upper reaches of the Amu-Darja river with water intake from the Amu-Darja or Vaksh river.	1. Water quality is high. 2. Can be built rather quickly.	Since the channel is mostly open one water protection must organized.
6	"Clean river". Full stopping of the collector and drainage water escape into the Amu-Darja river.	Solves the problem of the ecological situation in common.	1. Extremely large investments. 2. It is not clear when a proper quality can be reached (it may take up to 25 years).

Step 2. Economical and technological estimations.

An economical analysis has been performed for the different scenarios. It should be mentioned that this analysis was based on the prices of 1990. So real proportions can be distorted. However this is the only available basis. These estimations were performed mostly by the Uzbek collaborators from the Core Group.

Economic figures per scenario

No		Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	Scen. 6
1	**Capital Costs (mln. rubles).**	11.009	11.898	13.969	10.266	7.709	73.268
2	**Current Costs (mln. rubles).**	2.477	3.820	2.017	1.530	8.505	561
3	**Prime Cost of 1 cub.m (copeeks).**	120	185	97	74	412	27
4	**Derived Costs (mln. rubles).**	3.798	5.428	3.693	2.762	17.297	1.486
5	**Energy Wastes (mln. kwatt/hour)**	16.256	7.850	21.226	8.928	40.353	3.890

Step 3. Full criteria set.

This step was performed by the Core Group with some assistance of the Consultant Group. The full criteria list is a the basis for the further criteria tree developing. the aim of this step is to present to experts all reasonable factors to compare different scenarios. The full set covers more than 150 criteria.

Step 4. Building principle criteria set.

This step was performed by the Basic Expert Group. It involves a classical expert choice procedure. The aim of the procedure is to choose the most important criteria out off the full set. About 60 criteria have been chosen as principle ones. They are presented below in step 6.

Step 5. Building criteria trees.

Criteria tree is a basis for an expert analysis of alternatives. Each branch on any level should be clearly observed by experts. According to methodology of expert choice it should content 6-7 points (criteria). This is also restriction of the DEMSU/DMAKER system.

All components of a tree are divided into two groups:

- elementary criteria (those got on step 4);
- compound criteria - weighed combination of elementary and compound criteria.

In common, all levels by exception of the last one are consisted of compound criteria. However in practice elementary criterion can be included in any level.

Different criteria trees are different combinations of elementary criteria which are thus differently represented in a general weighed function.

Below are presented three variants of criteria tree (only first level compound criteria are shown for better understanding. Elementary criteria are the same.

Variants of Criteria Tree

Variant No 1	Variant No 2	Variant No 3
1. Costs 2. Ecology 3. Reliability 4. Temporal Factors 5. Implementation and Risks 6. Political and Social Factors	1. Design 2. Construction 3. Exploitation 4. Cooperation with Different Industries 5. Financial Sources 6. Political and Social Factors	1. Readiness 2. Immediate influence 3. Influence in 5-10 years 4. Long-term influence 5. Influence to the Regional Problems in Common

Criteria trees building includes estimation of the weights of all elementary and compound criteria. This is done on the basis of the Basic Group expert estimations. The results are presented in step 6.

Step 6. Choice of the best criteria tree.

The principle of the choice of the best criteria tree is max stability when different experts' estimations differ from each other. The best tree should reduce this difference by giving higher weights to criteria which have less deviation. There is no need to present all intermediate results. The last choice is presented bellow.

Criteria Tree

1.Costs.
- 1.1. Capital Costs.
  - 1.1.1. Materials.
    - 1.1.1.1. Steel Tubes.
    - 1.1.1.2. Concrete.
    - 1.1.1.3. Cement.
    - 1.1.1.4. Wood.
    - 1.1.1.5. Others.
  - 1.1.2. Equipment.
  - 1.1.3. Manpower Resources.
  - 1.1.4. Land Costs.
  - 1.1.5. Temporary Constructions.
  - 1.1.6. Transportation.
  - 1.1.7. Other Wastes.
- 1.2. Operational and Maintenance Costs.
  - 1.2.1. Materials.
  - 1.2.2. Manpower Resources.
  - 1.2.3. Electric Power.
  - 1.2.4. Fuel.
  - 1.2.5. Amortization.
  - 1.2.6. Maintenance.
  - 1.2.7. Others.
- 1.3. Reduced Costs.
- 1.4. Prime Cost of 1 Cubic M. of Water.
- 1.5. Renew Costs.
- 1.6. Modify Costs.
- 1.7. Development Costs.

2. Ecology.
- 2.1. Drinking Water Quality.
  - 2.1.1. Provided Water Quality.
  - 2.1.2. Water Quality Improvement in Time.
  - 2.1.3. Water Quality Degradation in Time.
  - 2.1.4. Water Quality Degradation Along Amu-Darja.
  - 2.1.5. Period with Guaranteed Quality.
  - 2.1.6. Improvement of the Quality in Other Regions.
  - 2.1.7. Degradation of the Quality in Other Regions.
- 2.2. Direct Compensation Costs.
- 2.3. Positive Influence on the Environment.
- 2.4. Environment Damages.
- 2.5. Improvement of the Other Water Resources.
- 2.6. Ecological Reliability.

3. Reliability.
- 3.1. Technological Reliability.
- 3.2. Possible Failure Damage.
- 3.3. Additional Water Supply in Emergency Periods.
- 3.4. Ecological Reliability.
- 3.5. Water Quality Reliability.

4. Temporal Factor.
- 4.1. Construction Period.
- 4.2. Project Development Period.
- 4.3. Investments Dynamics.
- 4.4. Possibility of Water Supply During Construction.

5. Reliability and Risks.
- 5.1. Technological Possibilities of Uzbekistan.
  - 5.1.1. Project Development.

5.1.1.1. Specialists.
5.1.1.2. Technological Basis.
5.1.2. Construction
5.1.2.1. Manpower.
5.1.2.2. Specialists.
5.1.2.3. Technological Basis.
5.2. Financial Possibilities of Uzbekistan.
5.3. Period of Guaranteed Water Supply.
5.4. External Support.
5.4.1. Technological Support.
5.4.2. Financial Support.
5.5. Cost Risks.
5.6. Technological Risks.
5.7. Political Risks.
6.Political and Social Factors.
6.1. Water Resources Dependence on Other Countries.
6.2. Social Influence of the Root problem.
6.3. Implementation Dependence on Other Countries.
6.4. Influence on the Other Regions Water Supply.
6.5. Indirect Influence on the Social Situation in Uzbekistan.
6.6. Inner Support in Uzbekistan.

Below are results of the expert estimation of the weights for the chosen criteria tree. Basic expert group member took part in this procedure. Only first level criteria are presented in this table. Results in the table are presented in processed form - all the weights are from 0 to 1 and the sum of all the weights for all criteria is equal 1, that is in normalized form. In practice different experts can give their estimates in different form (pairwise comparison, not normalized etc.).

Criteria Tree Weights

Expert	Costs	Ecology	Reliabi-lity	Temporal Factors	Imple-mentatio n and Risks	Political, Social Factors
1	0.25	0.25	0.15	0.09	0.21	0.05
2	0.18	0.17	0.16	0.16	0.13	0.20
3	0.30	0.25	0.05	0.25	0.05	0.10
5	0.10	0.35	0.05	0.10	0.35	0.05
7	0.18	0.40	0.04	0.10	0.25	0.03
16	0.20	0.45	0.03	0.05	0.15	0.12
18	0.35	0.20	0.10	0.10	0.20	0.05
19	0.50	0.20	0.05	0.05	0.10	0.10
21	0.20	0.35	0.05	0.15	0.20	0.05
28	0.25	0.50	0.05	0.05	0.05	0.10
31	0.30	0.15	0.15	0.15	0.15	0.10
Average	**0.26**	**0.30**	**0.08**	**0.12**	**0.15**	**0.09**

Step 7. Common expertise.

Common expertise is aimed to receive estimation of all scenarios involved in the project. Experts should give their estimates to all criteria and sub-criteria through the tree for all scenarios. Thus a common estimation can be done. It is based on criteria weights (step 6).

Following step 6 all the data are presented in normalized form which very suitable to analyze. However it's almost impossible to get information from different experts in such form. Bellow are 6 tables showing 6 first level criteria and their estimates given by the experts.

Costs Criterion

Expert	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	0.20	0.10	0.25	0.10	0.25	0.10
2	0.14	0.09	0.15	0.20	0.39	0.03
3	0.15	0.15	0.20	0.25	0.20	0.05
4	0.10	0.10	0.15	0.10	0.40	0.15
5	0.30	0.15	0.15	0.15	0.20	0.05
6	0.20	0.15	0.20	0.10	0.25	0.10
7	0.10	0.10	0.20	0.25	0.25	0.10
8	0.15	0.10	0.15	0.20	0.35	0.05
9	0.25	0.20	0.20	0.10	0.20	0.05
10	0.25	0.25	0.10	0.05	0.25	0.05
11	0.20	0.10	0.10	0.10	0.40	0.10
12	0.20	0.10	0.15	0.10	0.35	0.10
13	0.25	0.10	0.10	0.30	0.20	0.05
14	0.20	0.15	0.10	0.25	0.25	0.05
15	0.20	0.25	0.15	0.05	0.25	0.10
16	0.15	0.20	0.15	0.10	0.30	0.10
17	0.25	0.20	0.10	0.15	0.20	0.10
18	0.30	0.10	0.10	0.05	0.35	0.10
19	0.30	0.10	0.15	0.10	0.30	0.05
20	0.20	0.25	0.15	0.10	0.25	0.05
21	0.25	0.10	0.05	0.15	0.40	0.05
25	0.20	0.15	0.15	0.15	0.25	0.10
26	0.15	0.15	0.15	0.25	0.25	0.05
27	0.20	0.20	0.10	0.15	0.20	0.05
28	0.15	0.10	0.25	0.15	0.30	0.05
29	0.30	0.20	0.20	0.05	0.20	0.05
30	0.15	0.15	0.20	0.25	0.20	0.05
31	0.20	0.20	0.10	0.10	0.35	0.05
Aver.	**0.21**	**0.15**	**0.15**	**0.14**	**0.28**	**0.07**

Ecology Criterion

Expert	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	0.15	0.15	0.10	0.05	0.10	0.45
2	0.11	0.11	0.17	0.17	0.22	0.22
3	0.05	0.10	0.20	0.20	0.05	0.40
4	0.10	0.10	0.10	0.10	0.20	0.40
5	0.10	0.15	0.15	0.10	0.15	0.35
6	0.15	0.15	0.15	0.10	0.15	0.30
7	0.05	0.10	0.05	0.10	0.20	0.50
8	0.10	0.10	0.25	0.20	0.15	0.20
9	0.10	0.15	0.05	0.10	0.20	0.40
10	0.15	0.10	0.10	0.15	0.20	0.30
11	0.05	0.05	0.15	0.15	0.25	0.35
12	0.05	0.05	0.25	0.30	0.15	0.20
13	0.10	0.05	0.20	0.20	0.20	0.25
14	0.10	0.10	0.15	0.15	0.25	0.25
15	0.05	0.05	0.20	0.20	0.15	0.35
16	0.05	0.05	0.25	0.20	0.15	0.30
17	0.15	0.15	0.10	0.15	0.10	0.35
18	0.05	0.10	0.15	0.15	0.20	0.35
19	0.05	0.05	0.25	0.20	0.15	0.30
20	0.10	0.10	0.15	0.15	0.25	0.25
21	0.10	0.10	0.10	0.10	0.20	0.40
25	0.05	0.05	0.25	0.25	0.05	0.35
26	0.05	0.05	0.20	0.25	0.10	0.25
27	0.10	0.10	0.15	0.15	0.10	0.40
28	0.05	0.05	0.20	0.15	0.20	0.35
29	0.05	0.10	0.20	0.15	0.15	0.35
30	0.10	0.10	0.15	0.05	0.20	0.40
31	0.10	0.10	0.15	0.15	0.15	0.35
Aver.	**0.08**	**0.09**	**0.16**	**0.16**	**0.17**	**0.34**

Reliability Criterion

Expert	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	0.15	0.15	0.25	0.10	0.10	0.25
2	0.14	0.14	0.18	0.18	0.18	0.18
3	0.10	0.10	0.25	0.10	0.20	0.25
4	0.10	0.10	0.35	0.05	0.10	0.30
5	0.10	0.10	0.30	0.05	0.20	0.25
6	0.05	0.05	0.20	0.10	0.40	0.20
7	0.15	0.20	0.25	0.05	0.15	0.20
8	0.10	0.15	0.25	0.05	0.20	0.25
9	0.10	0.10	0.20	0.10	0.35	0.15
10	0.05	0.05	0.20	0.10	0.30	0.30
11	0.15	0.10	0.30	0.05	0.20	0.20
12	0.10	0.10	0.40	0.10	0.15	0.15
13	0.10	0.15	0.20	0.10	0.20	0.35
14	0.10	0.10	0.25	0.15	0.10	0.30
15	0.10	0.10	0.20	0.10	0.20	0.30
16	0.10	0.10	0.25	0.10	0.20	0.25
17	0.20	0.15	0.15	0.05	0.25	0.20
18	0.05	0.10	0.20	0.15	0.30	0.20
19	0.10	0.10	0.20	0.20	0.15	0.25
20	0.20	0.15	0.20	0.15	0.10	0.20
21	0.15	0.15	0.25	0.10	0.10	0.25
25	0.20	0.15	0.25	0.05	0.20	0.15
26	0.15	0.20	0.20	0.10	0.15	0.20
27	0.15	0.15	0.25	0.10	0.15	0.20
28	0.05	0.10	0.20	0.15	0.30	0.20
29	0.15	0.15	0.15	0.05	0.20	0.30
30	0.10	0.10	0.30	0.05	0.25	0.20
31	0.10	0.10	0.20	0.10	0.30	0.20
Aver.	**0.11**	**0.12**	**0.24**	**0.10**	**0.20**	**0.23**

Time Factor Criterion

Expert	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	0.20	0.20	0.22	0.10	0.23	0.05
2	0.15	0.15	0.25	0.15	0.25	0.05
3	0.20	0.20	0.20	0.10	0.25	0.05
4	0.25	0.25	0.21	0.05	0.20	0.04
5	0.25	0.20	0.20	0.10	0.20	0.05
6	0.30	0.30	0.15	0.10	0.12	0.03
7	0.25	0.25	0.15	0.10	0.20	0.05
8	0.20	0.20	0.25	0.05	0.25	0.05
9	0.30	0.30	0.11	0.10	0.15	0.04
10	0.30	0.30	0.10	0.12	0.15	0.03
11	0.20	0.20	0.20	0.15	0.20	0.05
12	0.15	0.20	0.30	0.05	0.28	0.02
13	0.25	0.25	0.15	0.10	0.20	0.05
14	0.25	0.25	0.15	0.12	0.18	0.05
15	0.15	0.15	0.30	0.05	0.30	0.05
16	0.30	0.25	0.12	0.15	0.15	0.03
17	0.20	0.20	0.20	0.10	0.25	0.05
18	0.20	0.20	0.25	0.10	0.20	0.05
19	0.25	0.20	0.20	0.06	0.25	0.04
20	0.20	0.20	0.20	0.10	0.25	0.05
21	0.25	0.25	0.15	0.10	0.20	0.05
25	0.25	0.25	0.20	0.05	0.20	0.05
26	0.25	0.25	0.20	0.05	0.22	0.03
27	0.15	0.15	0.32	0.05	0.30	0.03
28	0.20	0.20	0.20	0.10	0.25	0.05
29	0.20	0.20	0.20	0.10	0.25	0.05
30	0.25	0.25	0.17	0.08	0.20	0.05
31	0.25	0.20	0.20	0.10	0.20	0.05
Aver.	**0.23**	**0.21**	**0.20**	**0.10**	**0.22**	**0.04**

Implementation and Risks Criterion

Expert	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	0.15	0.15	0.25	0.05	0.30	0.10
2	0.15	0.15	0.25	0.10	0.25	0.10
3	0.15	0.15	0.20	0.05	0.30	0.15
4	0.05	0.05	0.30	0.10	0.40	0.10
5	0.10	0.10	0.25	0.05	0.35	0.15
6	0.15	0.10	0.30	0.05	0.30	0.10
7	0.15	0.15	0.25	0.10	0.25	0.10
8	0.25	0.20	0.25	0.05	0.20	0.05
9	0.20	0.15	0.25	0.05	0.25	0.10
10	0.20	0.15	0.25	0.05	0.30	0.05
11	0.10	0.05	0.30	0.10	0.35	0.10
12	0.20	0.20	0.25	0.05	0.25	0.05
13	0.20	0.20	0.20	0.05	0.25	0.10
14	0.20	0.25	0.20	0.05	0.20	0.10
15	0.10	0.10	0.30	0.05	0.35	0.10
16	0.15	0.15	0.25	0.05	0.35	0.05
17	0.15	0.15	0.20	0.10	0.30	0.10
18	0.20	0.15	0.25	0.05	0.30	0.05
19	0.20	0.15	0.25	0.05	0.25	0.10
20	0.10	0.10	0.20	0.10	0.40	0.10
21	0.10	0.15	0.30	0.05	0.30	0.10
25	0.15	0.15	0.25	0.05	0.35	0.05
26	0.15	0.15	0.25	0.05	0.30	0.10
27	0.10	0.10	0.30	0.05	0.35	0.10
28	0.25	0.20	0.20	0.10	0.20	0.05
29	0.10	0.10	0.35	0.05	0.35	0.05
30	0.15	0.15	0.20	0.05	0.35	0.10
31	0.20	0.15	0.20	0.10	0.30	0.05
Aver.	**0.16**	**0.14**	**0.25**	**0.06**	**0.30**	**0.09**

Political and Social Factor Criterion

Expert	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	0.05	0.05	0.30	0.05	0.35	0.20
2	0.18	0.18	0.18	0.18	0.18	0.10
3	0.25	0.20	0.20	0.05	0.20	0.10
4	0.15	0.15	0.25	0.10	0.30	0.05
5	0.10	0.15	0.25	0.05	0.30	0.15
6	0.20	0.20	0.20	0.05	0.20	0.15
7	0.15	0.15	0.20	0.10	0.25	0.15
8	0.25	0.25	0.15	0.05	0.20	0.10
9	0.15	0.15	0.15	0.10	0.30	0.15
10	0.20	0.20	0.25	0.05	0.20	0.10
11	0.10	0.10	0.25	0.05	0.35	0.15
12	0.15	0.15	0.20	0.05	0.25	0.20
13	0.20	0.15	0.20	0.05	0.25	0.15
14	0.20	0.20	0.15	0.10	0.20	0.15
15	0.15	0.15	0.20	0.10	0.30	0.10
16	0.25	0.20	0.20	0.05	0.15	0.15
17	0.20	0.20	0.20	0.05	0.20	0.15
18	0.20	0.20	0.20	0.05	0.20	0.15
19	0.05	0.05	0.20	0.10	0.25	0.20
20	0.10	0.15	0.25	0.05	0.20	0.15
21	0.20	0.20	0.20	0.10	0.15	0.15
25	0.15	0.15	0.20	0.05	0.20	0.25
26	0.15	0.15	0.25	0.05	0.25	0.15
27	0.20	0.15	0.20	0.05	0.25	0.15
28	0.25	0.25	0.10	0.05	0.20	0.15
29	0.15	0.15	0.15	0.15	0.30	0.10
30	0.15	0.15	0.20	0.05	0.30	0.15
31	0.10	0.10	0.20	0.10	0.35	0.15
Aver.	**0.17**	**0.17**	**0.20**	**0.07**	**0.25**	**0.14**

Expertise procedures were performed by means of decision making system DEMSU/DMAKER developed in "NODES D&I Ltd."

DEMSU/DMAKER is an integrated multi-processors systems. The core of it is a system of spreadsheets (called worksheets), which can be connected in hierarchical way. Each element of a worksheet can be number, function, algorithm or worksheet. This allows to keep large nonhomogenious databases.

There are several processors or applications: Cost Analysis, Reliability Analysis, Product Tree, Logistic, Life Cycle Cost and Decision Making. Last one was used in the project.

Decision Making processor includes the following decision making methods:

- Pareto Group Allocation;
- Pairwise Comparison;
- Global Scaling and Normalization;
- DELPHI;
- Rational Manager Saaty.

One of this methods is chosen depending on interface to experts and aims of decision making procedure.

Step 8. Analysis of results.

Analysis of results of the expert choice procedure has 3 principle steps:

1. Validation of the consistency of results. This is performed by estimating concordation factors for all criteria and scenario. This factors should show that there is no contradictory experts' data. This analysis shows positive results. The figures themselves are not appropriate in this report.
2. Static results. They are shown below.
3. Dynamic results, that is sensitivity analysis. This was not performed within the current project, since it needs additional data analysis. This is to be performed by the Uzbek collaborators by means of the DEMSU/DMAKER system which is transferred to the Uzbek laboratories together with computers.

Static Results of the Expert Choice

Scenario	Costs (0.26)	Ecology (0.30)	Reliability (0.08)	Time (0.12)	Implemen-tation (0.15)	Politica l (0.09)	Total
Local Sources	0.21	0.08	0.11	0.23	0.16	0.17	**0.15**
Drainage Water	0.15	0.09	0.12	0.21	0.14	0.17	**0.14**
Zerafshan River	0.15	0.16	0.24	0.20	0.25	0.20	**0.19**
Duplex System	0.14	0.16	0.10	0.10	0.06	0.07	**0.12**
Amu-Darja Channel	0.28	0.17	0.20	0.22	0.30	0.25	**0.23**
"Clean	0.07	0.34	0.23	0.04	0.09	0.14	**0.17**

River"							

It's seen that according to the performed expert choice the most preferable alternative is fifth one - construction of drinking water channel from the upper streams of the Amu-Darja river to the lower streams. But we should be very careful with interpretation of results since the number of experts on the next iterations should be grater. This is to be done by the Uzbek laboratories on the basis of the described procedure and by means of the DEMSU/DMAKER system they've got.

Impact, Relevance and Technological Transfer

There are two main results the Uzbek specialists have got from the project. First of all the special expert procedure which has been developed under specific conditions of the drinking water supply problem. Secondly the results of it's implementation. The second result is less important and less interesting because of the reasons mentioned above. However the procedure supported by the specific software (DEMSU/DMAKER) may be very useful for the further development of the current and other problems.

The is no basis for the scientifically grounded decision making for large projects in Uzbekistan institutions. Previously a political rationale was a dominated one. Especially in such fields as water supply and irrigation. So the Uzbek participants of the project as well as their colloquies who were concerned by it got a good training in decision making approaches and expertise.

This experience is a good basis for the further activity.

Project Activities/Outputs

1. During the project development a series of interactions between participants took place.

There were 3 meetings in Tashkent:

- March-April 1994. (Dr.Levner, Dr. Chernov, all Uzbek participants);
- February 1994 (Dr.Levner, all Uzbek participants);
- September-October 1995 (Dr.Chernov, all Uzbek participants).

There were four meetings in Israel:

- June-July 1994 (Mr. Machlin, Mr. Nijazhodjaev, Prof. Zukerman, Dr.Levner, Dr.Chernov);
- November 1994 (Dr.Poberejsky, Prof. Zukerman, Dr.Levner, Dr.Chernov);
- March 1995 (Dr.Poberejsky, Prof. Zukerman, Dr.Levner, Dr.Chernov);
- May 1995 (Mr.Mahlin, Prof.Zukerman, Dr.Levner, Dr.Chernov).

2. The following training took place:

- Decision making principles and decision making by means of the DEMSU/DMAKER system (April 1994, Tashkent).

3. The following seminars took place:

- Ecologically-Safe approaches to the drinking water supply (April 1994, Tashkent).

4. The following publications took place:

- International Conference on Coordination and decentralization in Water Resource Management (October 1994, Israel).

Project Productivity

The project didn't accomplish all the goals proposed in the beginning since during research some aims have been changed. the main accent is the alternatives analysis and expert decision making and not comprehensive modeling of one of it as it was planned. The main reason is that the situation in Uzbekistan laboratories has changed. According the initiative of the Uzbek collaborators the direction of the research was changed to some extend.

There are several principle reasons that the alternatives analysis became more important and more actual:

- new data has been obtained (first of all ecological data);
- strong moving towards complex resolution of ecological crisis take place in Uzbekistan;
- relations with neighbor republics and political situation in them became more complex and unpredictable; this make it very important to find solutions less depended on the neighbor countries.

Future Work

The project will lead to future work in the direction covered by it. The rational for this is stated in the previous paragraph. More factors including irrigation water quality should be taken in consideration. Only 15% of the harmful matters come into humans with drinking water and some from 75 to 80 %% with food. And the influence of the irrigation water quality on the quality of vegetables and fruits is very strong. This makes it necessary to analyze some alternative irrigation methods. This means that drinking water supply schema should be investigated only as a part of a water system in whole.