A Sustainability Approach for Planning and Design of Water Supply Scheme

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Abstract:
The most viable alternatives out of the various projects considered was evaluated using decision matrix methods based on a sustainability approach. The various possible alternatives projects based on water sources in Naharlagun area in Arunachal Pradesh were considered in the present study. After the preliminary survey, three alternatives projects based on the water sources available in the study area were identified. They were A1-Pachin river, A2-Dikrong river and A3-Niroch nallah. These alternatives are then evaluated for sustainability considering different factors. Technical soundness was observed as the most important decision factor in the Paired Comparison Technique. The project based on the Pachin river was found to be the most viable alternatives from the Alternatives Choice Coefficient (ACC) analysis.

Keywords: Sustainability, Alternatives, Comparison technique, Matrix, Source, Coefficient, Decision.

1. Introduction

To ensure the availability of sufficient quantity of good quality water, it becomes almost imperative in the modern society to plan and built suitable water supply schemes. The scheme should provide portable water to the various section of community in accordance with the demands and requirement. The provision of such a scheme shall ensure constants and reliable water supply to that section of the people to which it has been designed. The existence of water supply scheme shall further help in attracting industries and thereby helping in industrialization and modernization of the society, consequently reducing unemployment and ensuring better living standard. Such schemes shall, therefore help in promoting wealth and welfare to the entire humanity as a whole [Garg, 1977]. In planning a water supply scheme, it is essential to first search a source of water in the vicinity of the town or city which the scheme is to be designed. The source of water may be available nearby or sometimes far away. Further, it may be an underground well or it may be a river, stream or lake. Taking a final decision on a particular source considering various factors is a difficult task for the engineers as sometimes we can not foresee the future development in the area .A wrong selection of the sources will lead to the huge lost to the government and the entire community in particular. Thus, source selection has to be done carefully seeking out all possible ways and evaluate each in term of quantity, quality, environmental aspect, cost and more important is the sustainability of the project. In this paper, a sustainability concept is adopted to evaluate the most viable source for a Naharlagun (Arunachal Pradesh) water supply scheme.

2. Evaluation of alternatives

In present world the growing pollution is a major threat to the society. In order to overcome this problem a new approach is looked into, which will take care of the environmental as well as the technical aspects. Some of the environmental aspects that are considered in the evaluation of the alternatives are discussed here.

2.1 Concept of sustainability

The concept of sustainability development had been motivated by the tremendous environmental, social and political challenges faced by both developed and developing nations in the forging of future development policies and strategies. Such concept will greatly aid in advancing the underlying concept beyond the conceptual stage through to the development of practical approaches that engineers can use to sustainable plan, design and operate engineering projects. The majority of the work relating to the interface between engineering and sustainable development has been, till now very general. This will certainly change as more engineers become involved with developing approaches and techniques for incorporating sustainable development concepts into ongoing and new endeavors.

2.2 Development of new set of planning criteria

A first steps in sustainability approach is the development of a new set of planning criteria. The set of criteria, which are a synthesis and adaptation of existing suggested sustainability criteria could be used to evaluate technical alternatives from sustainability perspective. The synthesized criteria strongly related to aspects of natural ecosystems, which are inherently more sustainable than any human-oriented system [Canter, 1977].

To achieve a systematic approach to deciding among decision factors the comparison of a set of decision factors are chosen. The factors, which are generally considered for any such type of assessment are:

a) Success in meeting defined needs and identified objectives.
b) Economic efficiency
   - Benefits, costs
   - Excess benefits
   - Internal rate of return
   - Environmental cost-benefits analysis
c) Environmental impacts
   - Air quality
   - Surface-water quality, quantity
   - Soil quality and ground water quality, quantity
   - Noise
   - Ecosystem
   - Habitat quantity, quality
   - Threaten or endangered species
   - Historical-archeological resources
   - Socioeconomic characteristics
   - Human health risks
d) Public preference

2.3 Technique for assessment

There are several techniques, which can be used to assess the best possible alternatives of sources for water supply schemes. One such technique is the Paired-comparison technique (unranked and ranked) [David, 1998]. This technique is used for weighting important factors, which involved a series of comparison between decision factors and systematic tabulation of the numerical results of their comparison. The weighting techniques consist of considering each factors relative to every other factors. Thus, on a pair-wise basis and assigning a value of 1 to the factor considered being the more important and a value of 0 to the remaining factor. The 'dummy factor' is included so as to preclude the net assigning of a value of 0 to any of the basic factor i.e. the dummy factor is included as a 'place keeper' to avoid skewing the process. The 'dummy factor' is designed as that factor of each pair, deemed less important of the two. If two factors are considered to be equal importance than a value of 0.5 is assigned to each other in the pair. The individual weight assignments are assumed; and the factor-importance coefficient (FIC) [David, 1998] is calculated. FIC is equal to the sum value for an individual factor divided by the sum for all of the factors and is expressed as a decimal fraction. The total sum column should equal n(n-1)/2, where n is the number of factors included in the assignment of weight. The FIC column will indicate the best of the factors considered. The key fraction of rank pair wise comparison technique is that an initial rank ordering of all the decision factors is required.

2.4 Scaling, rating or ranking of alternatives

Scaling, rating or ranking of alternatives to each decision factors is the second major component in the use of the multiple-criterion or decision making approach. One of the most useful techniques is the unranked paired comparison. In this content, the unranked paired-comparison technique consists of considering each alternative to every other alternative relative to each decision factor and assigning to the more desirable of the pair of alternatives of a value of 1 or less desirable a value of 0. Here also a dummy alternative is included.

Following the assignment of the relative-desirability value to each alternative with the process based on the qualitative and quantitative information; the 'alternative choice coefficient' (ACC) [David, 1998] is determined. ACC is equal to the sum value for an individual alternatives divided by the sum for all the alternatives. The total of the sum column should be equal to m(m-1)/2, where m is equal to the numbers of the alternatives included in the assignment.

2.5 Development of the decision matrix

The final step in multiple-criterion making is to develop a decision matrix displaying the products of the importance weight (rank) and the alternatives scale (rating or rank). The final product matrix is calculated by summing of the product of the FIC and ACC [David, 1998 and Lockwood, 1998]. The numerical basis for the difference alternatives in the various alternatives is found out and the one having the highest numerical basis is chosen to be the best.

3. Evaluation Of Various Decision Factors

The set of criteria based on the preliminary survey of the sources considered are.

(a) Integration/synergy

Engineering projects that are sustainable should be well integrated within the natural environment to existing undertaking and to all aspects of society. The notion of synergy is also important to considered the benefits from the combination of two or more undertakings, which can be potentially greater than the benefits of the individual undertaking without integration.

(b) Simplicity

Simplicity is a relative term and certain technical alternatives may achieve multiple benefits through a relatively simple set of action.

(c) Input/output characteristics

From a sustainability perspective, alternatives with reduced such as energy resources, land resources and material resources are preferred. On the output side, the reuse or recycling of by-products to form closed-loop system is a desired goal and would emulate what occurs within natural ecosystems.

(d) Functionality

Alternatives that allow a wider variety of approaches to achieve a particular function are more sustainable and less concerned with a specific product or service.

(e) Technical soundness

Technical soundness of a project depends on the various technical parameters. Technical alternatives that are sustainable should also be adaptable to the range of projected changes for economic, social and natural/climatic environments.

(f) Susceptibility to pollution

It is also one of the factors which generally occurs due to the habitants nearby and if the pollution is less, then less treatment is required which indirectly saves the capital cost of the project.

(g) Carrying capacity

All natural systems have a limit or capacity on how much alteration can occur before the system is considerably affected. This motion of carrying capacity, from a social, ecological and economic perspective is of importance if development today will not compromise the need of future generations.

(h) Socio-economic

A sustainable alternative should be acceptable socially as well as economically. Socio-economic includes health impacts, recreational activities, aesthetic interest, land and housing values, job opportunity, community cohesion, lifestyles, governmental activities, well being, and behavioral response on the part of individuals, groups and communities. The basic impact area associated with predicting and assessing impacts on the socio-economic environment is called ‘region of influence’ (ROI).

The various decision factors considered for the sustainability approach are F1= Integrity, F2= Simplicity, F3= Input and output, F4= Functionality, F5= Technical soundness, F6= Susceptible to pollution, F7= Carrying capacity, F8= socio-economic and F9=Dummy factor.

4. Possible alternatives water sources for the study

In the presents study, three alternatives water sources in Naharlagun area (Arunachal Pradesh) are considered for the analysis.

(a) Pachin river as alternative 1 (A1)

The Pachin river originates in the hills, Soutwest of Itanagar. Various small rivulets and nallahs join the river. The Senkhi nallah is an important tributary of Pachin river joining it on the left bank. The river winds through both Itanagar and Naharlagun towns and it flows towards east and join Dikrong river at Nirjuli. Pachin river is at a relatively lower level than the town and water has to be pumped. It has a fairly discharge of about 3 cumecs at 45 m upstream of existing suspension bridge. Since, Senkhi is one of its tributaries joining it upstream. Thus, even in the winter months there is enough water.

(b) Dikrong river as alternative 2 (A2)

Dikrong river has a large discharge throughout the year. This river passes through the major towns like Doimukh, Sagali etc. and anumber of villages upstream of it. There is possibility of pollution taking place further rapid development. The gravity mains from the possible raw water intake point to the site of the water treatment plant on the right of the Dikrong will have to cross the river and various villages and also the treated water from the water treatment plant will be required to pumped to the ridge along Youth Hostel to serve the required area of Naharlagun. The length of the rising main in this sorce will be about 3 km.

(c) Niroch nallah as alternative 3 (A3)

Niroch nallah is a tributary of Pachin river meeting it on its left bank and is having a discharge of 0.8 cumecs at 13 km from Naharlagun. In between about 6 nallahs join Niroch thus increasing the discharge further. The probable taping in order to have gravity flow to water treatment plant near helipad will be about 1.5 km away from the location of the existing foot bridge on Doimukh road, where clear sparkling water is available. Besides there is no risk of pollution in future since no development is to take place in the foreseeable future. However, there is a feel that there may be possibility that the nallah mat dry out in the eventuality of development taking place in the area.

5. Information of the alternatives

The decision factors for set of criteria are linked to the information of the selected sources. Table 1 shows the various information collected from the sources considered based on the preliminary survey.

Table 1 Information of alternatives of sources

Decision factors	A1	A2	A3
F1	Having a single source	About six tributaries join the nallah	Different tributaries join this river
F2	Complex since pumping is required and several components also required	Simple since water flows under gravity, less component required	Simple since water flows under gravity but several components required
F3	Operational cost is high	Operational cost is low	Operational cost is moderate
F4	Treated water is available	Unacceptable turbidity due to many tributaries	Un acceptable turbidity due to many tributaries
F5	Technically sound	Technically not sound	Technically not sound
F6	Moderate pollution	Less pollution	High pollution
F7	Having high carrying capacity of about 3 cumecs	Having low carrying capacity of 0.8 cumecs	Having a moderate capacity of 1.8 cumecs
F8	More job opportunity, high water supply availability, improved water quality	Less job opportunity, low water supply availability, unpredictable water quality	Moderate job opportunity, moderate water supply availability, and unpredictable water quality.

6. Results And Discussion

The unranked paired-comparison technique consists of considering each alternative to every other alternative relative to each decision factor. The pair of alternatives of a value 1 represents the most desirable, while value 0 indicates a less desirable for the alternatives. Table 2 shows the assignment of weight 1 and 0 corresponding to the decision factors. From the assigned weight the FIC value is calculated. The FIC is equal to the sum value for an individual factor divided by the sum for all of the factors and is expressed as a decimal fraction. The FIC column will indicate the best of the factors considered. Following the assignment of the relative-desirability value to each alternative with the process based on the qualitative and quantitative information; the ACC is determined. ACC is equal to the sum value for an individual alternatives divided by the sum for all the alternatives. Table 3 to 10 shows the calculated ACC of all alternatives relative to a decision factors (F1to F8). It may be noted that a dummy alternative (A4) has also been included. The dummy factor is included so as to preclude the net assigning of a value of 0 to any of the basic factor. The calculated coefficient of FIC and ACC for various alternatives to a decision factors are furnished in Table 11. The final step in multiple-criterion making is to develop a decision matrix displaying the products of the importance weight (rank) and the alternatives scale (rating or rank). The final product matrix is calculated by summing of the product of the FIC and ACC. The numerical basis for the difference alternatives in the various alternatives is found out and the one having the highest numerical basis is chosen to be the best. Table 12 presents the detail calculation of product matrix for decision problem. It is seen from the table that alternative A1 having the highest numerical value of 0.449, which indicated the best possible sources for the scheme followed by A3 with 0.313 and least with alternatives A2 of 0.242.

Table 2 Weight assignment

Decision Factors	Assignment of weights																																					Sum	FIC
F1	1	1	0	0	1	0	1	1																														5	0.139
F2	0								1	0	0	1	0	0	1																							3	0.083
F3		0							0							0	0	1	0	0	0	1																2	0.06
F4			1							1						1							0.5	1	0.5	1	1											7	0.194
F5				1							1						1						0.5					1	1	1	1							7.5	0.208
F6					0							0						0						0				0				0	0	1				1	0.028
F7						1							1						1						0.5				0			1			1	1		6.5	0.181
F8							0							1						1						0				0			1		0		1	4	0.111
F9								0							0						0						0				0			0		0	0	0	0.000
	Total																																					36	1.000

Table 3 Scaling/Rating /Ranking of Alternatives Relative to decision factor F1

Alternatives	Assignment of desirability						Sum	ACC
A1	1	1	1				3	0.500
A2	0			0	1		1	0.167
A3		0		1		1	2	0.333
A4 (dummy)			0		0	0	0	0.000
	Total						6	1.000

Table 4 Scaling/Rating /Ranking of Alternatives Relative to decision factor F2

Alternatives	Assignment of desirability						Sum	ACC
A1	0	0	1				1	0.167
A2	1			1	1		3	0.500
A3		1		0		1	2	0.333
A4 (dummy)			0		0	0	0	0.000
	Total						6	1.000

Table 5 Scaling/Rating /Ranking of Alternatives Relative to decision factor F3

Alternatives	Assignment of desirability						Sum	ACC
A1	0	0	1				1	0.167
A2	1			1	1		3	0.500
A3		1		0		1	2	0.333
A4 (dummy)			0		0	0	0	0.000
	Total						6	1.000

Table 6 Scaling/Rating /Ranking of Alternatives Relative to decision factor F4

Alternatives	Assignment of desirability						Sum	ACC
A1	1	1	1				3	0.500
A2	0			0	1		1	0.167
A3		0		1		1	2	0.333
A4			0		0	0	0	0.000
	Total						6	1.000

Table 7 Scaling/Rating /Ranking of Alternatives Relative to decision factor F5

Alternatives	Assignment of desirability						Sum	ACC
A1	1	1	1				3	0.500
A2	0			0.5	1		1.5	0.250
A3		0		0.5		1	1.5	0250
A4 (dummy)			0		0	0	0	0.000
	Total						6	1.000

Table 8 Scaling/Rating /Ranking of Alternatives Relative to decision factor F6

Alternatives	Assignment of desirability						Sum	ACC
A1	0	1	1				2	0.333
A2	1			1	1		3	0.500
A3		0		0		1	1	0.167
A4 (dummy)			0		0	0	0	0.000
	Total						6	1.000

Table 9 Scaling/Rating /Ranking of Alternatives Relative to decision factor F7

Alternatives	**Assignment of desirability**						**Sum**	**ACC**
A1	1	1	1				3	0.500
A2	0			0	1		1	0.167
A3		0		1		1	2	0.333
A4 (dummy)			0		0	0	0	0.000
	Total						6	1.000

Table 10 Scaling/Rating /Ranking of Alternatives Relative to decision factor F8

Alternatives	**Assignment of desirability**						**Sum**	**ACC**
A1	1	1	1				3	0.500
A2	0			0	1		1	0.167
A3		0		1		1	2	0.333
A4 (dummy)			0		0	0	0	0.000
	Total						6	1.000

Table 11 FIC and ACC values for decision problem

Decision factors	**FIC value**	**ACC value**		
		A1	**A2**	**A3**
F1	0.139	0.500	0.167	0.333
F2	0.083	0.167	0.500	0.333
F3	0.06	0.167	0.500	0.333
F4	0.194	0.500	0.167	0.333
F5	0.208	0.500	0.250	0.250
F6	0.028	0.333	0.500	0.167
F7	0.181	0.500	0.167	0.333
F8	0.111	0.500	0.167	0.333

Table 12 Product matrix for decision problem

Decision factors	**FIC x ACC**		
	A1	**A2**	**A3**
F1	0.070	0.023	0.046
F2	0.014	0.042	0.027
F3	0.010	0.030	0.020
F4	0.097	0.032	0.065
F5	0.104	0.052	0.052
F6	0.009	0.014	0.005
F7	0.091	0.030	0.060
F8	0.055	0.019	0.037
Total	**0.449**	**0.242**	**0.313**

7. Conclusions

Three alternatives projects based on the water sources available in the Naharlagun area in Arunachal Pradesh were identified. They are A1-Pachin river, A2-Dikrong river and A3-Niroch nallah. The most viable alternatives were evaluated using decision matrix methods based on a sustainability approach considering different factors. Unranked Paired Comparison Technique was used to assess the best possible alternatives projects. The project based on the Pachin river was found to have more weightage as compared to the other two project sources. This method of comparisons provides a complete assessment of the project from all points of view.

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