Impact Assessment of Village Hydro Power Projects and Building of Game Theory Model

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Abstract -

This paper presents process of building a mathematical model, which represents the reorganization of villagers in order to optimize the benefit from village hydro projects, is the objective of our project. The main theory applied for the modelling was Game Theory.

In this assessment raw data collected from selected villages have being quantitatively and qualitatively analysed and prepared them in required format for the modelling. Fuzzy logic was used to model imprecise knowledge expressed in linguistic terms by villagers during the survey. During our survey we have being to 6 village hydro plants, which are located around Daraniyagala area.

I. Introduction

Our main objective was to model each and every possible relationship with a mathematical function. Therefore we applied theories of Game theory as well as other mathematical tools such as fuzzy logy.

In applying Game theory to our model we mainly believe the fact that each and every incident in the world can be identify as a game, where there are parties who involving the incident, the way they involve with it and outcome to them. The parties who participating in the activity is known as the players of the game, the way they participating is known as strategies and the benefits that they obtain as payoffs. That is the reason why we mainly focus on the Game theory where the village society can be treated as playing a game themselves for different achievements. So the objective is to achieve their achievements in the way reorganizing to obtain maximum benefits.

The other thing we focus on is that the village hydro plants are situated on very rural area and they can be treated as isolated units on some extend. So they are very much suitable in Game theory models since forcing factors of the game within the village and situation is not that much complex.

II. BEGINNING OF THE MODEL

During the studies we mainly focus on one model where there can be many models within the plant. The model is the game between villagers for energy consumption. So pay off is in maximum when they have enough power with high quality. High quality means no fluctuations of supply and no interruptions. Our model is a two player's game. Then how could it be modeled for lot of number of villagers? In our model what we did was defining one player as any arbitrary villager and his opponent is rest of the villagers. Then we have to accept following facts.

- Strategies are same
- The game is daily repeated
- Since we do not focus on specific villager and the game is daily repeated player 1 strategy becomes player 2 strategies. Thus, finally only the diagonal of the table can exists in an equilibrium situation.

So what we tried is finding out relationship (indeed a function or functions) between their strategies and pay off which is the basic mathematical work carried out on Game Theory Models.

A. *Basic model*

Pay off table of the game according to the strategy of the villagers and given in the figure 1.

St1 = Use very much lesser power than allowable limit

St2 = Use lesser power than allowable limit

St3 = Use approximately equal power to the allowable limit

St4 = Use much higher power than allowable limit

Player 1 \ Player 2	St1	St2	St3	St4
St1	(0,0)	(0,2)	(0,4)	(0,0)
St2	(2,0)	(2,2)	(2,4)	(0,0)
St3	(4,0)	(4,2)	(4,4)	(0,0)
St4	(6,0)	(6,2)	(6,3)	(0,0)

Fig. 1 Pay off table.

(4, 4) is the Nash equilibrium of the game.

B. Definition of Nash Equilibrium

If there is a set of strategies with the property that no player can benefit by changing her strategy while the other players keep their strategies unchanged, then that set of strategies and the corresponding payoffs constitute the Nash Equilibrium.

So Nash equilibrium is the ultimate objective of a game.

As we mentioned earlier the pay off is in maximum when they obtain high quality power, we should develop a function to fit with the pay off table when we have the data on actual energy consumption and the measure of quality. So we follow the following few steps.

C. Derivation Of Pay-Off Function

Po(Payoff) = k * [P ^ a + Q ^ b] (A)

k, a and b are the constants that should determine and afterwards pay off and the stage of the village is obtainable from po. So the four villages that we met is used to obtain the k, a and b.

TABLE I
HYDRO PLANTS WITH THEIR POWER CONSUMPTION, QUALITY AND PAYOFF

Plant	P	Q	P0
Kethiganaella	27%	80%	5
Kambili Oya	13%	95%	5
Veediyawaththa	14%	50%	3
Gederawaththa	2.6%	50%	1

Here values of p and q are obtained from the survey data. p means percentage energy consumption to the availability of the plant and q means percentage measure of the quality. Then we substitute from the table 1 to the above equation (1).

Here PayOff = 5 means the plant is in the Nash equilibrium. Actual situation of the Kethiganaella and Kambili Oya can be treated to be in Nash equilibrium where people satisfy their different requirements reorganizing the best way.

Kethiganaella

Expected payoff (po) = 5

[0.27^a * 0.9 ^b]k = 5

Taking log in both sides

a*[log 0.27] + b*[log 0.9] + log k = log5 (1)

Same way we obtain the other three equations and form that following equations can be obtained.

-0.569 * a -0.097 * b + log k = 0.699 (2)

-0.886 * a -0.022 * b + log k = 0.699 (3)

-0.854 * a -0.301 * b + log k = 0.477 (4)

-1.590 * a -0.301 * b + log k = 0 (5)

Form equation (2), (3), (4) and (5)

a = 0.65

b = 0.87

From here we deviated from the conventional calculations.

That is we do not use any of the equations to calculate k. We use trial and error method to obtain k.

In this method we concentrate on following facts

- Function should be simple as possible
- Even though we use 5, 5, 3 and 1 in p0 column, they are just arbitrary values in the range of X > 4.0, X > 4.0, 3.5 > X> 2.5 and 0.5 > X > 1.5. (Where X is the arbitrary number.)

So after few trials, we obtain the following values for a, b, k, where they really fit on the equations.

a = 0.5

b = 1

k = 15

Our pay off function can simply say

Po(= 15 * [P ^ 0.5 + Q] (B)

III. METHODOLOGY

Main procedure followed on the program can be divided in two parts. This is described as programming part 1 and part2 in the following paragraphs. However, what basically happens in the program is obtain survey data through a graphical user interface and communicating with user with another two GUIs.

Programming part

A. First part

Obtaining the po is the beginning of the programming part. According to the po stage of the village is evaluated.

Mean while stages of the five forcing factors identified, are calculated. The five forcing factors are.

- Leadership
- Communication
- Income level
- Unity
- Thinking level

a. Leadership factors that influence to the success of the projects

Inputs from survey data

L1=positive leadership percentage,

L2=Negative leadership percentage

The values of L1 and L2 are obtained from the direct data from a surveys and averaging over the number of families.

L = (L1-L2)/100

L = Leadership

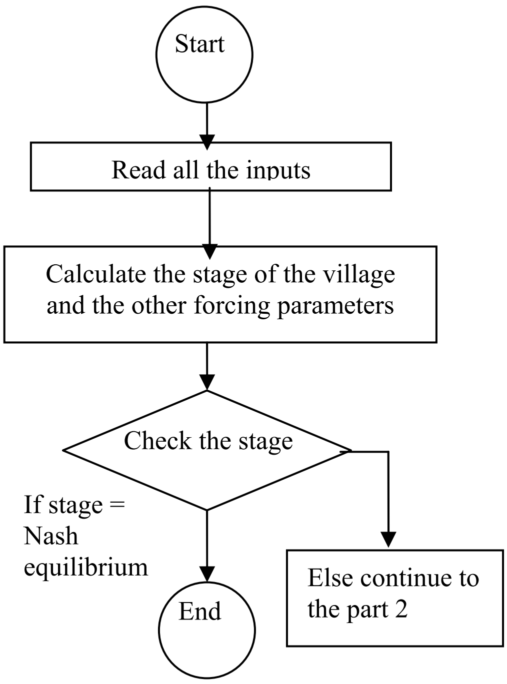

Fig. 2 Flow chart of programming part 1

Similar manner communication, income level, unity and thinking level can be calculated. Total description of the calculation of the forcing factors is in the Annex I. As we mentioned earlier the stage is derived from the po. It follows the following rules.

b. Rules of stages

Note: pij means the element of the ith row and jth column.

Rule one: The po is between 0 & 0.5.
And p is less than q
STAGE OF THE HYDRO PLANT = p11 = stg1
If q is less than p
STAGE OF THE HYDRO PLANT = p14, p24, p34 or p44.
Hear p14, p24, p34 and p44 are treated as same stages and = stg2.

Rule two: The payoff of the village is between 0.5 & 1.5
STAGE OF THE HYDRO PLANT = p12 or p21 = stg3

Rule three: The payoff of the village is between 1.5 & 2.5 and p is less than q
STAGE OF THE HYDRO PLANT = p22 = stg4
If q is less than p
STAGE OF THE HYDRO PLANT = p13, p41 or p31 = stg5

Rule four: The payoff of the village is between 2.5 & 3.5
STAGE OF THE HYDRO PLANT = p32 or p23 = stg6

Rule five: The payoff of the village is between 3.5 & 4 and p is less than q.
STAGE OF THE HYDRO PLANT = p42 = stg 7
If q is less than p
STAGE OF THE HYDRO PLANT = p43 = stg8

Rule six: The payoff of the village is greater than 4
STAGE OF THE HYDRO PLANT = p33
p33 is the Nash equilibrium.

Hereafter we have to consider one of the aspects of our game theory model. That is at the beginning we conclude that the equilibrium stage of the village should be in the diagonal of the pay off table. That means stage like stg2 or stg3 cannot remains long period of time and they will reach any of the diagonal stages such as stg1 or stg4.

B. Second part

If the village is in the Nash equilibrium it is fine. If not? During the second part of the program the village is testing on different stages of forcing factors when they cannot reach the Nash equilibrium.

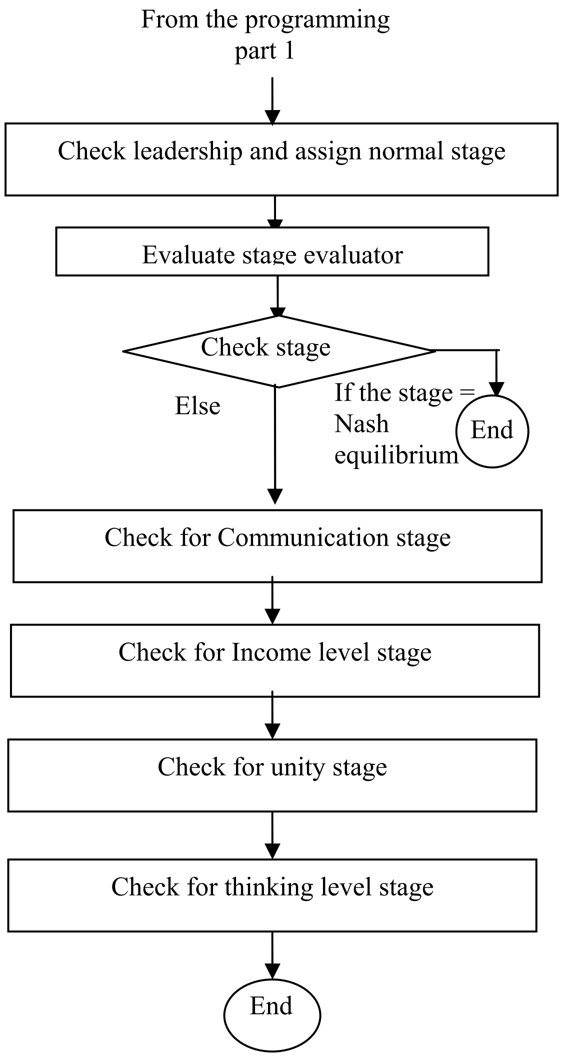

Fig.3 Flow chart of programming part 2

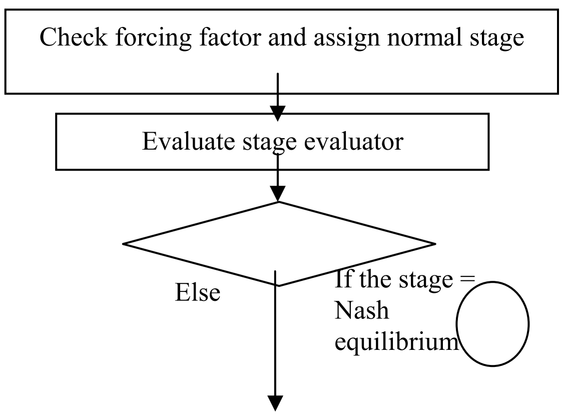

Fig. 4 Common check block of programming part 2

And the above blocks, check for communication etc. can be represented commonly in the figure 4.

a. Membership functions

During the second part we prepare to use fuzzy logy concepts since the linguistic terms that we use couldn't have sharp boundaries. For an example if we define Leadership > 0.5 is better then Leadership = 0.49 is treated as good which is not acceptable. So we define all the forcing factors as fuzzy sets. The membership functions of the all forcing factors are given in the figure 5 to figure 7.

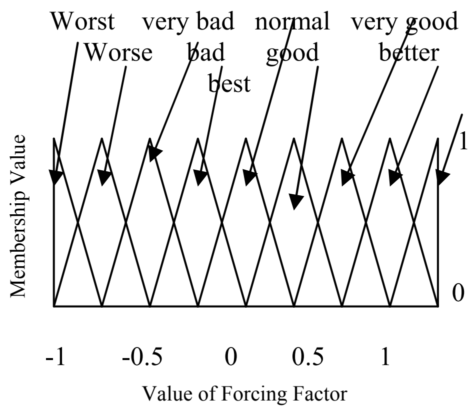

Fig. 5 Membership function of the leadership, communication, unity which has nine fuzzy sets

Note: Here we use two types of membership functions for leadership, communication, unity. This is due to the reason that if we use nine sets in evaluation of stage evaluator (RULE 9 to RULE 14) instead of 108 rules there should be 6561 rules. Since it is impractical we prepare to define two types of fuzzy sets for leadership, communication and unity.

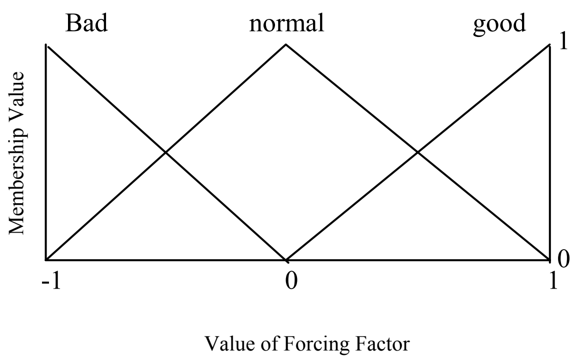

Fig.6 Membership function of the leadership, communication, unity, which has three fuzzy sets and used in RULE 1 to 9

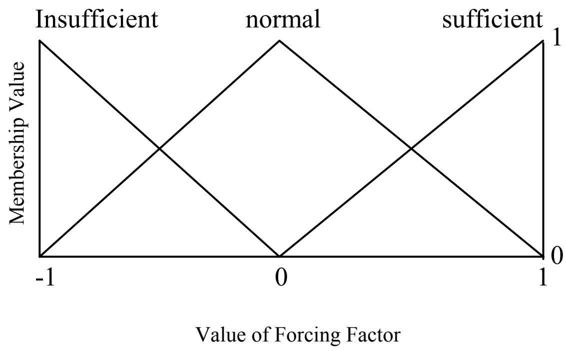

Fig. 7 Membership function of the income level and thinking level, which has three fuzzy sets and used in RULE 1 to 9

During the programming part if leadership, communication or unity is worst, worse, very bad or bad, it is changed to normal and calculates special parameter called stage evaluator.

b. Stage Evaluator

According to the fuzzy rules which we have defined stage evaluator can be weak, normal, strong or very strong. For an example RULE 12 is one of the rule that are used to evaluate the stage evaluator.

RULE 12

If leadership good and communication, income level and unity are bad and thinking level is normal then stage evaluator is weak

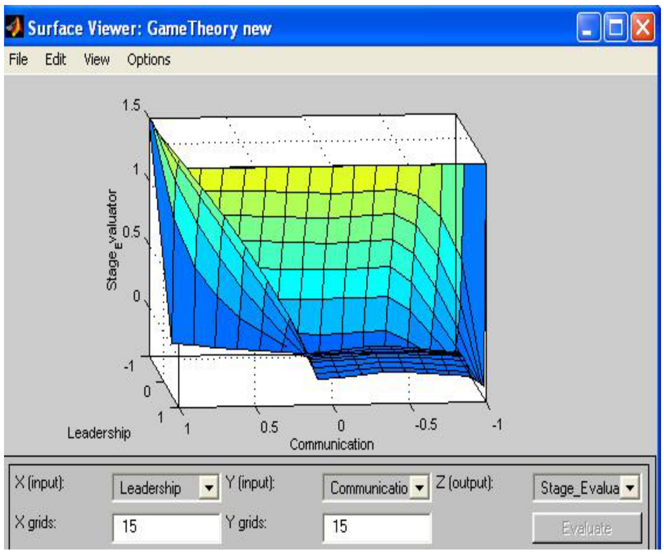

Fig. 8 surface print of the stage evaluator for different stages of the forcing factors.

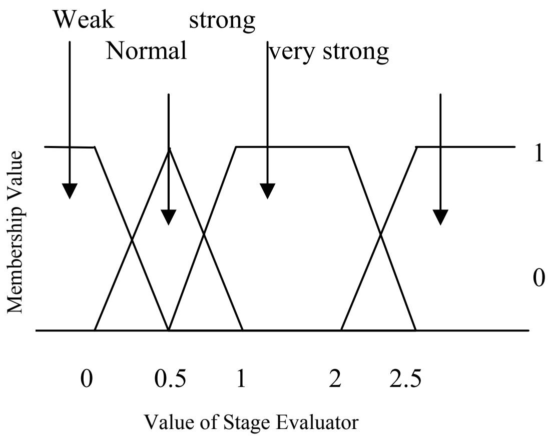

Fig. 9 Membership function of stage evaluator

According to the position of the stage evaluator, stage of the village can follow different paths, which is happening to be according to the defined rules. After the stage evaluator position evaluated the stage of the plant can be determined. Fuzzy rules are applying hear. For an example RULE A2 is one of the rule that are used to evaluate the stage evaluator.

RULE A2

If stage evaluator strong and stage p11 then stage = p22.

According to the above rules the final stage of the village after the all the adjustments is reachable.

C. Results.

The program terminates when the village becomes Nash equilibrium or when it cannot reach the Nash equilibrium and showing why it cannot reach it.

Programming language used

During the programming parts we use the matlab to obtain the all the results. We think matlab is the most suitable software package for our mathematical model, which is one of the most advance engineering software.

IV. CONCLUSION

The success of the projects are not solely depends on the technology. There are some other external factors, which have major impact on them. Those factors were identified and mathematically analyzed in the implemented model.

By using this model we can find out reasons for unsuccessful projects and the way in which they can be overcome.

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[1] Jhon F. Nash Jr, "Essays On Game Theory," : Edward Elgar Publishing Company, 1996.