IOANA POPESCU

SUBMITTED BY;

GROUP NINE

DECISION SUPPORT SYSTEMS PROJECT REPORT

IHE DELFT INSTITUTE FOR WATER EDUCATION

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1. DEFINITION OF EACH BASIN GOALS AND POTENTIAL FOR AGREEMENT (ZHECHEN ZHANG, 1074448)

The Upper basin is the main runoff generation area of the whole basin and the landscape of the Upper basin is mainly with narrow and deep gorges. Thus, the topographical condition in the Upper basin is favorable for hydropower and not fit for navigation. And since the area of the Upper basin is only 24% of the total area and the terrain is steep and uneven, food production is also not very essential in the Upper basin. To sum up, the domain objective of the Upper basin is hydropower generation, the secondary goal is to develop food production, and the navigation is impossible in the Upper basin.

Combined with the above background, only three indicators totally meet the objectives of the Upper basin, overall energy generation, food production upstream, and (catchment) evaporation upstream. For the whole basin profit, some more indicators should be selected in the preliminary analysis for Upper basin. Three domain attributes are selected in order, the navigability of big vessels, wetland evaporation, and food production downstream. Because the indicators include the energy generation of the whole basin instead of the upstream energy generation, although the energy generation is more important than the food production in above objective analysis, the upstream food production will rank before the power generation of the whole basin in the separate preliminary analysis of the upstream. For optimizing the profit of the Upper basin, three indicators related to the Upper basin is before three indicators of the Lower basin. Thus, the final rank is as follows in order, food production upstream (1), overall energy generation (2), evaporation upstream (3), food production downstream (4), wetland evaporation (5), and navigability of big vessels (6).

Because the energy is the first objective for the Upper basin and also benefit for the whole basin, the aim of negotiations for the Upper basin group is to rank the overall energy generation as the first position. For arriving this aim, some feedback needs to be given to the Lower basin group, so the other indicators ranking, food production upstream and upstream evaporation doesn’t matter. The potential of agreement, which can be accepted by the Upper basin group, is ranking overall energy as the first position, and other two indicators as high as possible.

The Lower basin is endowed with fertile land and suitable for irrigation development, which costs cheaper than in any other part of the basin. And there is a protected wetland in the further downstream part of the Lower basin, which is the essential habitat for birds and rare fish. It is a great role for the local economy to navigate in the Lower basin. To sum up the above background, three objectives irrigation product, wetland ecology, and navigation economy, all are essential in the Lower basin. And when urbanization is improving, increased demand for electricity occurs, so energy generation is the fourth objective for the Lower basin.

The indicator food production downstream is reflected in the objective of irrigation. Three indicators of wetland evaporation, catchment evaporation, and bird habitat index are related to the objectives of wetland ecology. And the indicators of navigations are the navigability of big, medium, and small vessels separately. In the preliminary analysis, we leave two indicators of big and medium navigability to meet the navigation aim since navigability of bigger vessels can represent part of the capacity of smaller vessels (when bigger vessels can pass, smaller must be able to pass). Considering the importance and complexness of ecology, we leave all three ecology attributes in the preliminary analysis. Thus, there are totally seven indicators.

The rank of seven indicators is (1) navigability of big vessels, (2) wetland evaporation, (3) food production downstream, (4) catchment evaporation downstream, (5) overall energy generation, (6) navigability of medium vessels, and (7) bird habitat index. The reason is as follows. The first three indicators are the main indicators representing three domain objectives respectively. Large vessels can meet all the requirements of navigation, connecting cities, tourism, and transforming goods and the condition of big vessels navigation is stricter than medium vessels. Compared with three ecology indicators, navigation indexes are less selected, thus rank navigation in the first position. The second one is the most domain ecology indicator, which is selected as wetland evaporation by our group. The reason is that the bird index is the only unilateral influence of ecology not including fish and other species, and the wetland is the protected area from ecology perspective instead of the whole Lower basin. The third and fifth one is the indicator of the third and fourth objectives irrigation and energy generation respectively. To stand out the importance of ecology, we rank downstream evaporation, which is the second most important ecological indicator, ahead of electrical energy generation, and fourth overall. The remaining two indicators continue to be listed in the order of navigation and ecology.

The aim of negotiations for the Lower basin group is to keep the preliminary rank as much as possible. The rank of food production downstream must be ahead of food production upstream, because the Lower basin is the best area for irrigation in the whole basin. Predictably, overall energy generation will be the biggest issue during negotiation. Under the condition that the upstream can give some concessions in other indicators, appropriate forward adjustment of overall energy generation can be considered, which is after all profitable for the Lower basin. The order depends on what conditions are given by the upstream group.

2. PRELIMINARY MDSS ANALYSIS USING SAW FOR LOWER BASIN (ZHECHEN ZHANG, 1074448)

OPTIONS:	Score:	% (relative to 1st position)
A6.3	0.714	100%
A11.3	0.6785	95%
A7.3	0.6516	91%
A7.2	0.5345	74%
A6.2	0.517	72%
A11.2	0.4772	66%
A9	0.4416	61%
A7	0.4276	59%
A10	0.4059	56%
A6.1	0.3914	54%
A7.1	0.3774	52%
A8	0.3761	52%
A11.1	0.3545	49%
A12	0.3473	48%
A2	0.3461	48%
A4	0.3246	45%
A13	0.3072	43%
A3	0.2817	39%
A6	0.2815	39%
A5	0.2803	39%

P=0

OPTIONS:	Score:	% (relative to 1st position)
A6.3	0.797	100%
A11.3	0.7517	94%
A7.3	0.6706	84%
A6.2	0.5607	70%
A7.2	0.5358	67%
A11.2	0.5139	64%
A9	0.4231	53%
A6.1	0.4108	51%
A7	0.405	50%
A10	0.3822	47%
A11.1	0.3674	46%
A7.1	0.3495	43%
A8	0.348	43%
A12	0.2803	35%
A2	0.2766	34%
A6	0.2729	34%
A4	0.2526	31%
A11	0.2352	29%
A13	0.2309	28%
A3	0.2013	25%

P=0.5

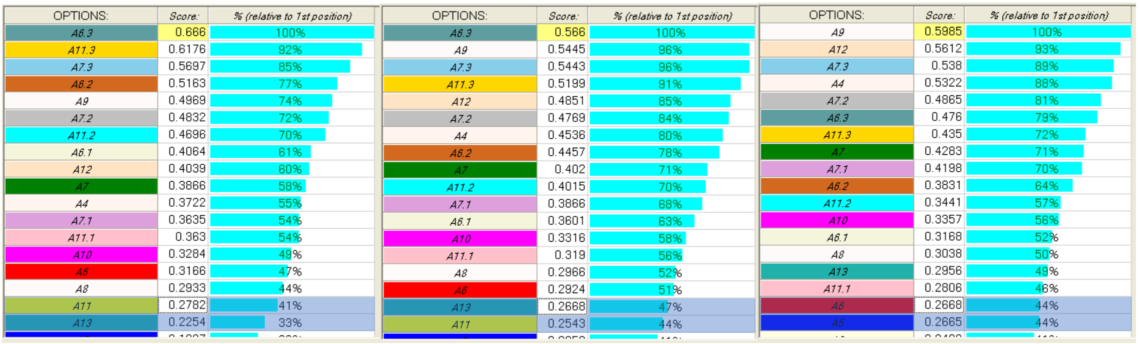
OPTIONS:	Score:	% (relative to 1st position)
A6.3	0.857	100%
A11.3	0.8062	94%
A7.3	0.6796	79%
A6.2	0.5971	69%
A11.2	0.5463	63%
A7.2	0.5336	62%
A6.1	0.4303	50%
A9	0.4077	47%
A7	0.388	45%
A11.1	0.383	44%
A10	0.3617	42%
A7.1	0.3273	38%
A8	0.3255	37%
A6	0.2747	32%
A11	0.2346	27%
A12	0.2345	27%
A2	0.2304	26%
A4	0.204	23%
A13	0.1756	20%
A3	0.1441	16%

P=1

Fig 1: Rank of options in preliminary analysis using SAW for Lower basin

Three best options are A6.3, A11.3, and A7.3, with whatever P value is in preliminary analysis using SAW for Lower basin. A6.3 is the combined option of extended irrigation downstream and 70% of water diverted bypass. A11.3 is the option of 70% water diverted bypass. A7.3 is the combined options of new dam base hydropower, extended irrigation upstream, and 70% of water diverted bypass. Three best options all have the project of the maximum bypass, which is most beneficial for our first rank indicator, the navigability of big vessels. Similar results indicate that the influence of distribution parameter P is not very large in the analysis of Lower basin by SAW method. In the conclusion of preliminary analysis, the desired project for the Upper basin is the bypass.

3. PRELIMINARY MDSS ANALYSIS USING SAW FOR UPPER BASIN (ZHECHEN ZHANG, 1074448)



OPTIONS:	Score:	% (relative to 1st position)
A6.3	0.666	100%
A11.3	0.6176	92%
A7.3	0.5697	85%
A6.2	0.5163	77%
A9	0.4969	74%
A7.2	0.4832	72%
A11.2	0.4696	70%
A6.1	0.4064	61%
A12	0.4039	60%
A7	0.3866	58%
A4	0.3722	55%
A7.1	0.3635	54%
A11.1	0.363	54%
A10	0.3284	49%
A6	0.3166	47%
A8	0.2933	44%
A11	0.2782	41%
A13	0.2254	33%

OPTIONS:	Score:	% (relative to 1st position)
A6.3	0.566	100%
A9	0.5445	96%
A7.3	0.5443	96%
A11.3	0.5199	91%
A12	0.4851	85%
A7.2	0.4769	84%
A4	0.4536	80%
A6.2	0.4457	78%
A7	0.402	71%
A11.2	0.4015	70%
A7.1	0.3866	68%
A6.1	0.3601	63%
A10	0.3316	58%
A11.1	0.319	56%
A8	0.2966	52%
A6	0.2924	51%
A13	0.2668	47%
A11	0.2543	44%

OPTIONS:	Score:	% (relative to 1st position)
A9	0.5985	100%
A12	0.5612	93%
A7.3	0.538	89%
A4	0.5322	88%
A7.2	0.4865	81%
A6.3	0.476	79%
A11.3	0.435	72%
A7	0.4283	71%
A7.1	0.4198	70%
A6.2	0.3831	64%
A11.2	0.3441	57%
A10	0.3357	56%
A6.1	0.3168	52%
A8	0.3038	50%
A13	0.2956	49%
A11.1	0.2806	46%
A6	0.2668	44%
A5	0.2665	44%

P=0 *P=0.5* *P=1*

Fig 2: Rank of options in preliminary analysis using SAW for Upper basin

The best option is A6.3 (extended irrigation downstream and 70% of water diverted bypass), which is no benefit for the Upper basin, with P value of 0 and 0.5. As for P equal to 1, the best option is A9 (new dam base, new irrigation upstream, extended irrigation, and bypass). When P is equal to zero, the weights of indicators are the same. Thus, A6.3, which is totally not related to Upper basin, occupies the first position because of the contribution of the three downstream indicators. When P value increasing to 0.5, the best option is still A6.3. It is because of the influence of the indicator of upstream evaporation, which is a cost type indicator and persists to building a reservoir. When P is equal to 1, the weights of higher rank indicators are higher, and the best option is the option combined by all the projects. For the Upper basin group, the preliminary results indicate that the indicators overall energy generation and upstream evaporation effect options oppositely and base hydropower reservoir is more suitable for energy and irrigation indicators than peak hydropower reservoir, which is indicated by the results of P equal to 1.

4. NEGOTIATIONS ON INDICATORS（YINING ZANG, 1068605)

After negotiations between the upstream and downstream authorities, the seven important indicators were selected and ranked on the basis of the benefits of the entire basin and the respective demands of the upstream and downstream. In addition, the classification of Driving force, Pressure, State and Impact together with the categorization of ESE (environment, society and economy) were determined after the discussions. The results are shown in the Table 1.

Table 1: Ranking of selected indicators and the determination of DPSI and ESE

Ranking	Indicators	Unit	DPSI	ESE	P=0	P=0.5	P=1
1	Overall Energy Generation (the higher the better)	GWh/year	S	101	0.143	0.196	0.250
2	Navigability of Big Vessels (the higher the better)	days/year	P	101	0.143	0.182	0.214
3	Wetland Evaporation (the higher the worst)	m^3	I	100	0.143	0.166	0.179

4	Food Production Downstream (the higher the better)	tons/year	P	011	0.143	0.148	0.143
5	Food production Upstream (the higher the better)	tons/year	P	011	0.143	0.129	0.107
6	(Catchment)Evaporation (the higher the worse)	m3	I	100	0.143	0.105	0.071
7	Bird Habitat Index (the higher the better)	ND	I	100	0.143	0.074	0.036

A. ESE AND DPSI CLASSIFICATION

The construction of hydropower plant has effects on the local ecological environment and the economic development. Regarding its impact on environment, hydropower plant will cause hydrological changes in the basin, such as a decrease in the water level in the downstream or a decrease in sediment from the upstream or a large amount of evaporation of water reduce the total amount of downstream river water, which substantially reduces the water available for irrigation but the climate will be cooler and more stable, and the rainfall is reduced. Besides, it also has an effect on aquatic creatures due to changes in the upstream ecological environment, fish will be affected, leading to extinction or population reduction. However, it also brings many benefits to economic development. In addition to providing cheap electricity, it also has the following advantages: controlling flooding, providing irrigation water, improving river navigation, and related projects to improve the transportation, power supply and economy of the area, especially to develop tourism and aquaculture. Based on the impacts mentioned above, the state will change because of the hydropower plant installing, thus the overall energy generation indicator was classified to the State. The increased capacity of the navigability of big vessels can promote the trade and economy, while, the pollutants produced by shipping affect the water quality and the living environment of fish. In addition, building the proposed bypass for navigability also negatively contributes to the aquatic environment to a certain extent. According to these influences, this indicator was viewed as the environmental and economic aspects. Also, as a result of pollutants which do harm to the environment and cause environmental pressure, this indicator was regarded as the Pressure. In terms of food production of upstream and downstream, it is obvious that the lack of the food productivity will lead to lower farmers' employment status, at the meanwhile, inadequate food supply also can result in the instability and pressure of the society and economy of country. Hence, food productivity of both upstream and downstream were determined to the social and economic type. It was deemed to be the Pressure of the system. For wetland, catchment evaporation and bird habitat index only have impacts on the basin environment, so they were classified to the environmental type. Because these three indicators were affected by the hydropower plant and navigability of vessels as well as the food production of the basin, they were defined as the Impact in the system. In conclusion, the definition and classification of the indicators are relative in one system, they probably play a different role in different systems.

B. RANKING OF INDICATORS

The seven indicators were selected from the preliminary analysis for respective upstream and downstream. The results are list in the Table 1. There are some changes comparing to the used indicators in preliminary analysis. Firstly, the catchment evaporation downstream was selected and evaporation of upper basin was ignored, that's mainly because the catchment evaporation downstream is more important due to that it affects largely the ecological environment of the wetland and irrigation for crops. Secondly, the navigability of the medium vessels was neglected because the big vessels can be viewed as the representative of navigability and medium vessels with lower ranking won't influence much.

For the determination of the ranking, the upstream authority insists on the overall energy generation in the first rank while the ranking of other indicators doesn't matter for the upper basin. The downstream authority hope the ranking of the indicators of downstream won't change. Therefore, there are only two arguments that the ranking of the overall energy generation and the food productivity of upstream and downstream. Firstly, though discuss, both sides reached a consensus that the first rank should be the overall energy generation because it benefits both basin. Secondly, the upstream authority agreed to rank the food productivity downstream ahead of the food productivity upstream. It is mainly because that the upstream has a steeper terrain and the downstream is flat, the downstream is more suitable for growing crops than the upstream. Thirdly, bird's habitat index was ranked after the food productivity, on the one hand, it is because food productivity is more important for the whole development of the basin, and on the other hand, the wetland evaporation as a representative of ecology has been ranked ahead already. In conclusion, the overall energy generation is ranked on the first position and food productivity downstream is ahead in the upstream, the ranking of other indicators is consistent with the downstream preliminary analysis.

5. OVERALL BASIN SAW ANALYSIS: RESULTS AND DISCUSSION (EUGEN BALILAJ, 1052768)

After the negotiations on indicators and their ranking based on the interests for both basins, the weights were calculated for 3 suggested p values. The indicators were grouped in the concept framework window of the MULINO software based on the classification as DPSI and ESE discussed in the Task 4. Before continuing with the SAW analysis, a decision needed to be taken for the alternatives with sub-categories such as the ones for A6, A7 and A11. From the given table of indicator values computed by Mike BASIN, it was noticed that for the 7 chosen indicators, alternatives A 6.3, A 7.3 and A 11.3 has better values. Only the Bird Habitat Index seems to be decreased (the higher the better) when the amount of the water diverted increased, however this indicator is ranked as the 7-th in our list and the other ones are to a greater interest. Furthermore, to support the decision about the chosen sub-alternatives the SAW analysis were carried first with all the alternatives and it was noticed that A 6.3, A 7.3 and A 11.3 outstands the other sub-alternatives. The analysis then continued with the defined alternatives and chosen indicators and the results for 3 p values are presented below:

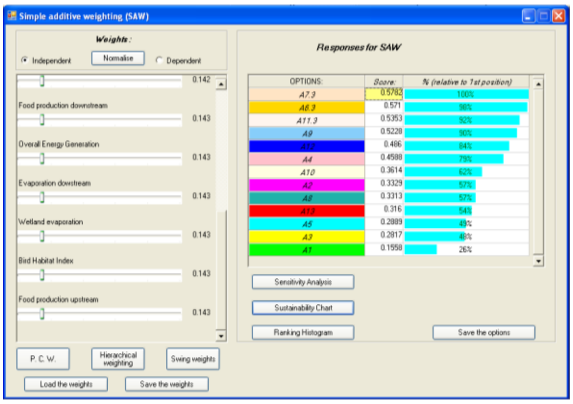


Fig.3: SAW analysis responses, p=0

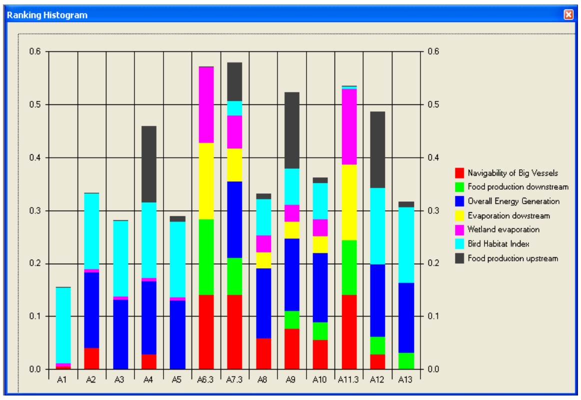


Fig.4: SAW analysis Ranking Histogram, p=0

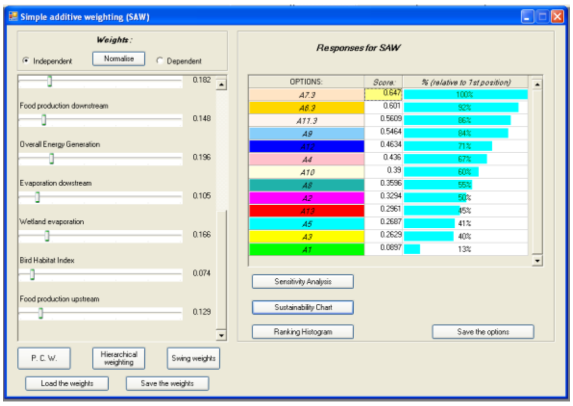


Fig.5 SAW analysis responses, p=0.5

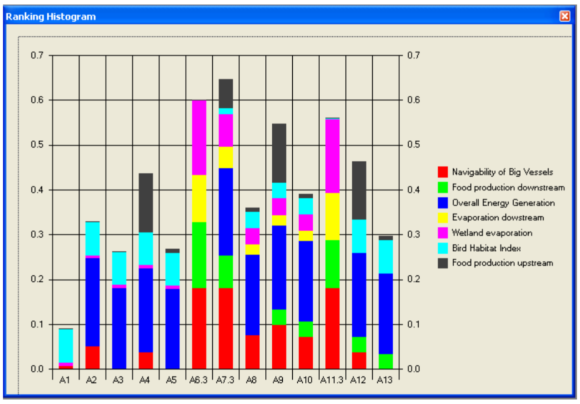


Fig.6 SAW analysis Ranking Histogram, p=0.5

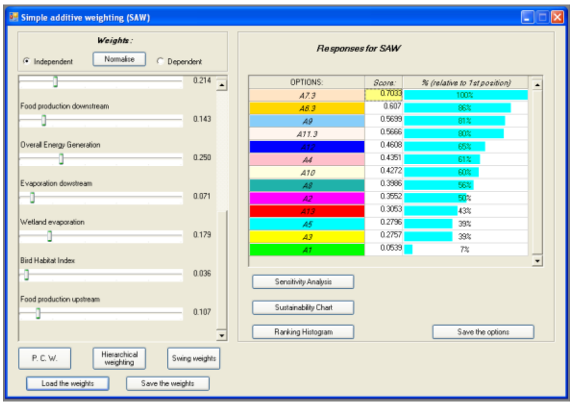


Fig.7 SAW analysis responses, p=1.0

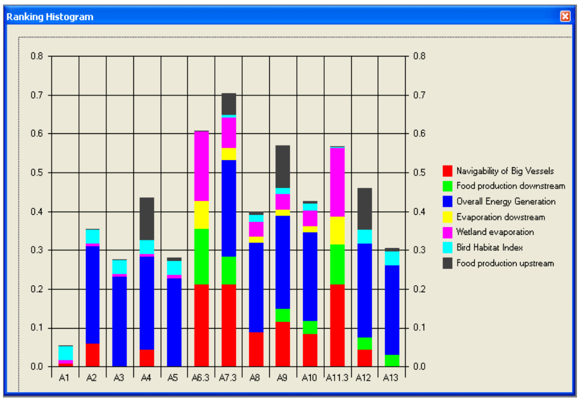


Fig.8 SAW analysis Ranking Histogram, p=1.0

In order to have a better and easily comparison the results from the SAW analysis are presented in a table as well:

Table 2: Overall results from SAW method

p	**0**		**0.5**		**1**	
Method	SAW		SAW		SAW	
Ranking	Alternatives	Score	Alternatives	Score	Alternatives	Score
1	A7.3	0.5782	A7.3	0.647	A7.3	0.7033
2	A6.3	0.571	A6.3	0.601	A6.3	0.607
3	A11.3	0.5353	A11.3	0.5609	A9	0.5699
4	A9	0.5228	A9	0.5464	A11.3	0.5666
5	A12	0.486	A12	0.4634	A12	0.4608
6	A4	0.4588	A4	0.436	A4	0.4351
7	A10	0.3614	A10	0.39	A10	0.4272
8	A2	0.3329	A8	0.3596	A8	0.3986
9	A8	0.3313	A2	0.3294	A2	0.3552
10	A13	0.316	A13	0.2961	A13	0.3053
11	A5	0.2889	A5	0.2687	A5	0.2796
12	A3	0.2817	A3	0.2629	A3	0.2757
13	A1	0.1558	A1	0.0897	A1	0.0539

From the above results, as the alternative with the highest scores for all 3 p values is alternative A 7.3. This project take into consideration the construction of the new dam upstream as base hydropower (1b), new irrigation upstream from the new dam (2) and the construction of the bypass downstream with a 40 % water diverted (4). The highest ranked indicators that we agreed upon was the Overall Energy Generation and the Navigability of Big Vessels and this alternative gives the best results in terms of both. Interestingly, from the ranking histograms for all 3 p values can be noticed that by increasing the p value the Overall Energy Generation (blue colour) and Navigability of Big Vessels (red colour) are increasing as well and this explains why for a p value of 1.0 alternative A 7.3 get the highest scores compare to the other p values. On the other hand from the same histograms the other indicators slightly decrease or remain the same. From the above table, another trend that can be observed is that for the alternatives which has in their implementation projects which corresponds with the ranked indicators (such as A 7.3, A 6.3, A 11.3 etc.) by increasing the p value the scores increases as well while for the other alternatives (such as A 12, A3, A1 etc.) the opposite happens, scores decreases by increasing p value. The ranking and the agreement on the indicators is to a great importance in this process as the interests and the projects are complementary to each other, this for example can be noticed for the food production downstream, even though the alternative A 7.3 does not take into consideration the project of Extending the Irrigation Downstream (3), as the result of the other project combinations especially the new dam upstream as base HP (regulates significantly the flow downstream) the food production downstream rises by approximately 1.000.000 tons/year compare to the situation as it is (A1).

As final conclusion for the SAW analysis it can be said that alternative A 7.3 (for p=1.0, highest scores) meets all the objectives sets in the analysis which are identified through the ranked indicators. The last to be mentioned is that MULINO software provides several results in its analysis and another one is the sustainability chart, this is presented below for the p value of 1. All the alternatives lie in the same side and close to each other in this regard, however the chosen one (A 7.3) seems to be more sensitive in the economic and environmental terms and quite less considering the social one.

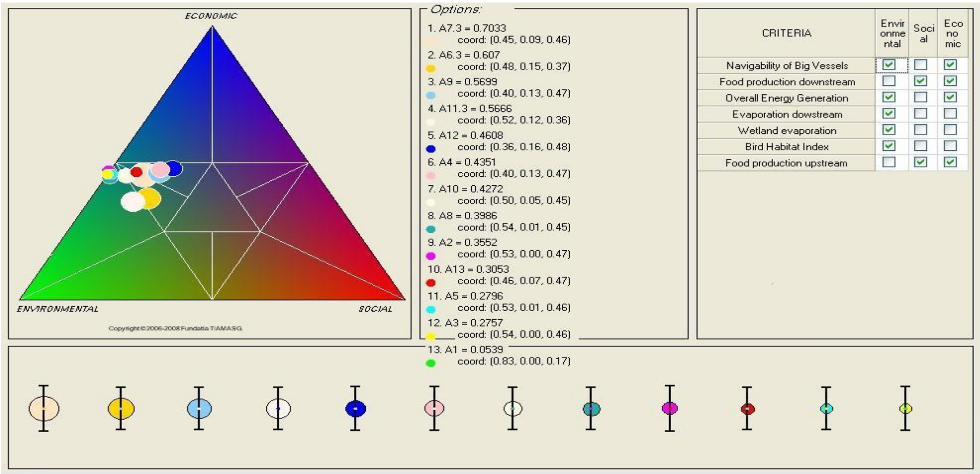


Fig.9: Sustainability chart, p=1.0

6. OVERALL BASIN TOPSIS ANALYSIS: RESULTS AND DISCUSSION (MARIO ALBERTO FUENTES MONJARAZ, 1069191)

A second Multi Attribute Decision Method (MADM) approach was taken in the project to assess the alternatives, and support the decision making process. This second approach was based on the same decision matrix, normalisation, rankings and weights of attributes, but differed in the computation of the outcome or scoring of each alternative. Instead of using the Simple Additive Weighting method (SAW), a Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was performed. As the name suggests, this techniques computes an ideal point based on the optimum values of each attribute, and determines the distance of the alternatives to this ideal point. At the same time, this method computes a negative ideal point based on the less optimum values of each attribute, and determines the distance of the alternatives to this negative ideal point. The best alternative is selected on the basis of closeness and separation to the positive and negative ideal point respectively. The optimal values of each attribute are defined as the values of the decision matrix which are maximum in benefit attributes and minimum in cost attributes.

The TOPSIS analysis was performed with *mDDS4 software* using the decision matrix and the weight assignation for different weights distribution parameters (p) already established in the SAW analysis. This task was easily achieved selecting the “Continue with TOPSIS” option in the advanced settings of the “Edit Analysis Matrix” tab. The weights were updated manually to get a TOPSIS weighted normalised matrix for different p values. The results of the alternatives scores using this method for different p values are shown in the next table.

Table 3: Summary of the scores of the alternatives for different p values

TOPSIS METHOD						
Parameter	p=0		p=0.5		p=1	
Ranking	Alternative	Score	Alternative	Score	Alternative	Score
1	A7.3	0.79	A7.3	0.82	A7.3	0.82
2	A5	0.28	A10	0.30	A10	0.38
3	A13	0.28	A8	0.30	A8	0.38
4	A6.3	0.26	A5	0.30	A5	0.37
5	A11.3	0.26	A13	0.30	A13	0.37
6	A2	0.25	A2	0.28	A9	0.36
7	A10	0.25	A9	0.28	A2	0.36
8	A8	0.25	A4	0.28	A4	0.35
9	A4	0.25	A6.3	0.28	A12	0.35
10	A12	0.25	A12	0.28	A3	0.34
11	A3	0.24	A11.3	0.27	A6.3	0.30
12	A9	0.22	A3	0.27	A11.3	0.29
13	A1	0.18	A1	0.11	A1	0.06

The results point out the option A7.3 as the best alternative for the management of the catchment. The project is related to the new dam with base HP, the new irrigation fields upstream and the bypass with 40%. Results are consistent even when changing p value. Even though the new irrigation field was considered in the negotiation process as a project with low economic and social impact given its location at hill areas, this project is integrated within the best alternative.

Looking at other alternatives in the second and third position of the ranking, we find A5, A8, A10 and A13 options, which are mainly related to the dam with peak HP and irrigation fields downstream. These options might have not been only discarded for the simple fact that this types of dams are not useful for the regulation of water required for navigation, as discussed in the negotiation, but also because of the fact that their scores are rather low in comparison with those achieved by the alternative A7.3. Next figures show the percentages of each alternative relative to the 1st position for different p values. As observed in the figures, all the relative percentage are below 50%.

OPTIONS:	Score:	% (relative to 1st position)
A7.3	0.789	100%
A5	0.276	34%
A13	0.276	34%
A6.3	0.261	33%
A11.3	0.258	32%
A2	0.249	31%
A10	0.249	31%
A8	0.248	31%
A4	0.246	31%
A12	0.246	31%
A3	0.241	30%
A9	0.218	27%
A1	0.177	22%

OPTIONS:	Score:	% (relative to 1st position)
A7.3	0.815	100%
A10	0.303	37%
A8	0.302	37%
A5	0.299	36%
A13	0.299	36%
A2	0.282	34%
A9	0.277	33%
A4	0.275	33%
A6.3	0.275	33%
A12	0.275	33%
A11.3	0.271	33%
A3	0.268	32%
A1	0.106	13%

OPTIONS:	Score:	% (relative to 1st position)
A7.3	0.815	100%
A10	0.382	46%
A8	0.381	46%
A5	0.369	45%
A13	0.368	45%
A9	0.362	44%
A2	0.359	44%
A4	0.351	43%
A12	0.35	42%
A3	0.341	41%
A6.3	0.295	36%
A11.3	0.291	35%
A1	0.06	7%

Fig10: Percentage relative to the 1st position for different p=0 (upper), p=0.5 (middle) and p=1 (lower)

Results are rather convincing suggesting that alternative is A7.3 is the best solution based on the TOPSIS analysis results. In addition, the results fit with the main objectives of the catchment allowing infrastructure development in both upper and lower basins, giving more support to the alternative.

7. COMPARISON BETWEEN SAW AND TOPSIS (AYODEJI AKINTOMIDE OJO 1058373)

SIMPLE ADDITIVE WEIGHTING (SAW): The basic concept of the SAW method is to find the weighted sum of performance ratings on each alternative on all attributes. The SAW method requires the process of normalizing the decision matrix (X) to a scale comparable to all existing alternative ratings. SAW, also known as the weighted and simple weighted scoring method most commonly used for multiple decision attribute (MADM) tools. The difference between the SAW method and the other method lies in the factor of value. The value of SAW method is done simply by matching alternative condition to criterion (indicators and DSPIR elements). Another difference is also found in the determination factor of weight vector values. The determination of the priority value of the weighted vector is performed in accordance with the policy of the manager giving the value of the weight vector directly.

TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION (TOPSIS): TOPSIS was developed by Hwang and Yoon in 1981, the TOPSIS method for choosing alternatives that simultaneously had the shortest distance from the ideal solution and the furthest distance from the non-ideal solution (ideal ideal). A positive ideal solution maximizes the benefit criteria and minimizes the cost criteria, while the ideal negative solution maximizes the cost criteria and minimizes the benefit criteria. To apply this technique, attribute values must be numerical, monotonically increasing or decreasing, and having equivalent units. TOPSIS method is widely used in some models of Multiple Attribute Decision Making (MADM) because this method has several advantages namely:

1. The concept is simple and easy to understand.
2. Computing is efficient.
3. Have the ability to measure the relative performance of decision alternatives in simple mathematical form.

In this analysis, the indicators were used to evaluate the performance of the alternatives. The alternative with the highest performance (benefits) in terms of the objectives and the measuring indicators to both parties is taken as the ideal solution. In the case of SAW, the weight assigned to each indicator plays a significant role in choosing the alternative while TOPSIS measures the best (positive) alternative based on the distance to the ideal solution defined by the attributes or criteria.
The result from the analysis has been presented in *Fig11*. From the figure, it can be seen that both methods give the same alternative (A7.3) as the ideal solution but TOPSIS method has a clearer and more distinct score. Taking P_0 for illustration, the best alternative has a score of 0.79 and the next, 0.28 in TOPSIS while 0.58 and 0.57 respectively in SAW. Thus, it is much easier for the decision maker

to make fast and accurate decision based on TOPSIS result than SAW because the best alternative is very distinct and outstanding.

(SAW method)						TOPSIS					
p=0		p=0.5		p=1.0		P=0		P=0.5		P=1	
Option	Score	Option	Score	Option	Score	Option	Score	Option	Score	Option	Score
A7.3	0.58	A7.3	0.65	A7.3	0.70	A7.3	0.79	A7.3	0.82	A7.3	0.82
A6.3	0.57	A6.3	0.60	A6.3	0.61	A5	0.28	A10	0.30	A10	0.38
A11.3	0.54	A11.3	0.56	A9	0.57	A13	0.28	A8	0.30	A8	0.38
A9	0.52	A9	0.55	A11.3	0.57	A6.3	0.26	A5	0.30	A5	0.37
A12	0.49	A12	0.46	A12	0.46	A11.3	0.26	A13	0.30	A13	0.37
A4	0.46	A4	0.44	A4	0.44	A2	0.25	A2	0.28	A9	0.36
A10	0.36	A10	0.39	A10	0.43	A10	0.25	A9	0.28	A2	0.36
A2	0.33	A8	0.36	A8	0.40	A8	0.25	A4	0.28	A4	0.35
A8	0.33	A2	0.33	A2	0.36	A4	0.25	A6.3	0.28	A12	0.35
A13	0.32	A13	0.30	A13	0.31	A12	0.25	A12	0.28	A3	0.34
A5	0.29	A5	0.27	A5	0.28	A3	0.24	A11.3	0.27	A6.3	0.30
A3	0.28	A3	0.26	A3	0.28	A9	0.22	A3	0.27	A11.3	0.29
A1	0.16	A1	0.09	A1	0.05	A1	0.18	A1	0.11	A1	0.06

Fig11: The result of the analysis from TOPSIS and SAW method showing the score of each alternative. The result was generated with mDSS software.

Table 4: Table showing comparison between SAW and TOPSIS method.

TOPSIS	SAW
The best alternative is measured on the basis of distance to the ideal solution	The best alternative is measured on basis of weights assigned to the indicators
The result is clearer and more accurate for decision making	The result can subject the decision maker to doubts and second thoughts
They both gave the same alternative (A7.3) as the best solution.	

Considering the needs of both parties (downstream and upstream) and the objectives of the negotiation, the solution provided by both methods is very ideal. A7.3 is an alternative that accounts for Dam with base HP, irrigation dam and bypass with water diversion of 40%. This alternative literarily satisfies the goals of both upstream and downstream basin. SAW and TOPSIS are very good methods for decision making.

8. RECOMMENDATION (VISHAL BALAJI DEVANAND, 1068322)

On analysing the results from both SAW and TOPSIS and with different p values, we could understand that the Alternative 7.3 holds the predominant ranking in all. It feels logically perfect as well because it satisfies most of our initial objectives, the demands of both the upper and lower basin.

The final recommendations as per our selected alternative **A7.3** are as follows:

Objective 1: The set-up of a new dam with facility to support hydroelectric power plant (base load type) in the Upper basin.
Objective 2: The Implementation of new irrigation scheme supported by our new dam.
Objective 4: Construction of Bypass with just 40% water diverted from flowing into the wetlands.

BENEFITS FOR THE BASIN AS A WHOLE

Since we have given first priority to maximize the benefit "Overall energy production" by giving the highest weightage compared to others, our final result supports it by enabling the production of Hydropower (Base load type) in the upper basin. This automatically upraises the overall energy production as it's the only scope for power production mentioned in our alternatives.

BENEFITS FOR UPPER BASIN

On further trying to understand the logic behind for selecting the base power and not the peak load type Hydropower is because, we have given higher weightage to the Indicator “Navigability of larger vessels”. We know that the Base load type hydropower plant does not require larger storing of water as needed for the peak types and this in-turn facilitates higher discharges to the lower basin thereby supporting the large vessels to commute comfortably in the lower basin for 295 days in a year. This decision also has an indirect effect on reduction of evaporation upstream because of the reduced storage in the reservoir of the new dam.

In terms of Food production upstream, Our decision also supports this pressure by allowing the establishment of a new irrigation system (NIRR) with the water source from the potential new dam which is going to be constructed for the purpose of hydropower.

BENEFITS FOR THE LOWER BASIN:

According to our final decision, we have the possibility to maintain the better navigability of the whole river in the lower basin, thanks to the compromise made by the Upper-basin Authority to go for Base-load type Hydropower instead of peak load.

In terms of Construction of Bypass channel, our decision was to bypass 40% of water from its stream so that we could have better connectivity for navigation in the downstream of the river. This would be really suitable, because we could contribute to new economic development by improving the navigability of the river and also with a lesser compromise on the environmental aspects by allowing 60% of water to keep flowing through the wetlands. Sixty percent of water would preserve the wetlands from getting dried thereby protecting the bird-habitat index, rare species of fishes and eco-tourism revenues and at the same time we could avoid excess flooding in the winter season.

CONCLUSION (VISHAL BALAJI DEVANAND, 1068322)

Thus we analysed the given set of **13 alternatives** of different combinations of **four development projects** which were considered viable based on the given characteristics of the Nile basin with the help of main **7 indicators** provided by the stakeholders, ranked on basis of our objectives using the Multi-criteria Analysis tool **mDSS**. At the end of the negotiations and analysis, we arrived at the best alternative A7.3 which is beneficial for both the Upper and Lower Basins.

Our recommendation to this analysis to become more effective, would be to consider including the **“Implementation and Management costs”** of these new development projects in our set of indicators for better assessment of the alternatives.

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