Original Scinetific Paper

*Allocation of budget funds on agricultural loan programs: group consensus decision making in the Provincial Fund for Agricultural Development of Vojvodina Province in Serbia**

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Summary:
This paper presents a novel approach that could be used for scientifically verified group decision making for the allocation of budget funds on agricultural loan programs in the Provincial Fund for Agricultural Development of Vojvodina Province in Serbia. An approach is structured based on the Analytic Hierarchy Process, a recognized multi-criteria method suitable for supporting both individual and group decision making processes. The decision makers' weights in a group are derived in an objective manner and based on demonstrated individual consistency while assessing and evaluating elements within the decision-making framework. A real life application is used to demonstrate how the four key decision-makers can individually evaluate and rank agricultural loan programs and how their decisions are afterwards compiled into the final consensus based group decision.

Key words:
agricultural loan programs, Analytic Hierarchy Process, consensus, group decision making.

Rezime:
U radu je definisan pristup koji bi se mogao koristiti za naučno verifikovano grupno odlučivanje o raspodeli novčanih sredstava na kreditne linije u Pokrajinskom Fondu za razvoj poljoprivrede Vojvodine. Osnovu pristupa predstavlja metod višekriterijumske analize Analitički hijerarhijski proces, podjednako pogodan za podršku individualnih i grupnih procesa odlučivanja. Težine donosilaca odluka u grupi određuju se na osnovu demonstriranih individualnih konzistentnosti. Na realnom primeru je pokazano kako četiri ključna donosioca odluka mogu pojedinačno vrednovati i rangirati kreditne linije i kako se zatim njihove odluke objedinjuju u konačnu, konsenzus-odluku.

Ključne reči:
Analitički hijerarhijski proces, grupno odlučivanje, konsenzus, kreditne linije.

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1. INTRODUCTION

The Provincial Fund for Agricultural Development (hereafter reffered to as 'Fund') was founded by the Executive Council of Vojvodina Province in 2001 in order to stimulate balanced agriculture development and better employment in this economical branch. In addition, one of the goals of the foundation was promoting domestic agriculture in the surrounding region. The Fund is administrated by a Fund Council composed of the president and six members and represented by the Fund's director. One of the stimulations for agricultural development is pursued by providing budget funds for individual agricultural households, which are favorable and divided into nine loan programs. However, the Fund does not have an institutional framework for determining the mode of budget distribution on loan programs. The main reason for this is the possibility of budget transfers from one loan program to another, depending on the applicants' demands. Here we propose an approach that deals with the situation when there is interest for all loan programs that at the same time need to be acceptable for the Fund members' and/or for hired experts.

Taking into account the organization and employment structure of the Fund, this paper shows a possible way of building a new institutional mechanism of group decision making while reaching an objective consensus. Here is simulated the decision making process with three leading members of the Fund and an academic expert in economics of agriculture participating. The Analytic Hierarchy Process has been used in this paper as a multi-criteria method suitable for both individual and group decision making in different areas, including the financial sector [2, 9, 16, 18]. Decision makers individually and independently evaluated loan programs based on their personal knowledge and experience regarding agricultural problems and needs. They inevitably demonstrate their own affinities or implicitly present political and other types of interests according to their expertise background. The final decision is obtained by merging individual decisions regarding budget allocation on loan programs by applying an original consensus model. The group decision without reaching consensus is also provided. The model takes into account individual consistencies of the group members by assigning objective weights based on geometric consistency indexes (*GCI*), which are used for the logarithmic least squares (*LLS*) prioritization method.

The paper is organized as follows: a brief explanation of AHP and logarithmic least squares method is presented in Section 2, followed by the statement of the decision making problem (Section 3), a description of methodological steps used in developed approach for group decision

making without (Section 4) and with consensus (Section 5); Section 6 presents obtained results and the paper ends with the conclusions in Section 7.

2. THE ANALYTIC HIERARCHY PROCESS

The Analytic Hierarchy Process (AHP) [13] is a method for supporting the process of decision making. It is based on forming a hierarchy of the problem and the original procedure for evaluating the elements on a given hierarchy level. During the evaluation, local weights of decision making elements are determined and the overall synthesis at the end provides weights of alternatives lying at the lowest level with the respect to the element on the highest level (overall goal). A decision maker (DM) compares hierarchy elements in pair wise manner with respect to all corresponding superior elements. In the standard AHP version elements are compared by assigning a linguistic (semantic) evaluation of relative importance with respect to the superior hierarchy element by using the fundamental scale presented in Table 1.

Table 1. Saaty's relative importance scale [13]

Definition	Assigned value
Equally important	1
Weak importance	3
Strong importance	5
Demonstrated importance	7
Absolute importance	9
Intermediate values	2,4,6,8

Remark: A two level hierarchy (like the one developed in this paper) implies the comparison of alternatives (other loan programs) only with respect to the goal here defined as 'determining the percentage share of available budget funds on each loan program according to the individual decision makers' preferences.'

When the decision maker on a certain hierarchy level evaluates *n* decision elements with respect to the superior element by using the scale shown in Table 1, its semantic evaluations belonging to the definitions from the left column are replaced by numbers from the right column and then inserted in the square matrix *A*. The matrix is positive and reciprocal (symmetrical with respect to the main diagonal), elements from the upper triangle are reciprocal to the elements from the lower triangle, while values of 1 are

posted on the main diagonal (a_{ij}=1/a_{ji}, for each *i* and *j*; a_{ii}=1 for each *i*).

$$A=\begin{bmatrix} a_{11} & a_{12} & . & . & a_{1n} \\ a_{21} & a_{22} & . & . & a_{2n} \\ . & & & & . \\ . & & & & . \\ a_{n1} & a_{n2} & . & . & a_{nn} \end{bmatrix} \quad (1)$$

Determining the weights of compared elements based on numerical values from matrix *A* is commonly referred to as prioritization. There are several prioritization methods [15] but here we used a logarithmic least squares method, relations (2)-(4).

$$\sum_{i=1}^{n}\sum_{j>i}^{n}[\ln a_{ij} - (\ln w_i - \ln w_j)]^2 \quad (2)$$

subject to: $w_i > 0$, $i = 1, 2, \ldots, n$; i (3)

$$\sum_{i=1}^{n} w_i = 1 \quad (4)$$

In relations (2)-(4) *n* is the dimension of matrix *A*, while w_i (*i* = 1,..., *n*) are unknown weights of compared elements. Crawford and Williams [3] have shown that the solution for problem (2)-(4) is unique and can be found as the geometric means of rows of matrix *A*:

$$w_i = \frac{\sqrt[n]{\prod_{j=1}^{n} a_{ij}}}{\sum_{i=1}^{n}(\sqrt[n]{\prod_{j=1}^{n} a_{ij}})} \quad (5)$$

For measuring decision makers' consistency, the same authors proposed geometric consistency index (*GCI*):

$$GCI(A) = \frac{2}{(n-1)(n-2)}\sum_{i<j}(\ln(a_{ij}) - \ln(w_i) + \ln(w_j))^2 \quad (6)$$

When *GCI*(*A*)=0, then the matrix *A* is fully consistent. According to authors [1], the matrix has acceptable inconsistency if: *GCI*<0.31 for *n*=3; *GCI*<0.35 for *n*=4; and *GCI*<0.37 for *n*>4.

3. PROBLEM STATEMENT

***Goal*:**

Allocate budget funds of Fund to the nine loan programs. Potential budget amount of 160.483.260 dinars for this purpose has been adopted according to the Activity report of The Provincial Fund for Agricultural Development for the year of 2010.

***Alternatives*:**

Alternatives are loan programs:

1. **AM** – purchase of agricultural machinery
2. **IR** – purchase of new irrigation equipment
3. **BE** – purchase of beehives and beekeeping equipment
4. **GH** – purchase of greenhouses
5. VC – planting of grapevines and purchase of viticulture equipment
6. **PF** – planting of fruit
7. **HN** – purchase of hail protective nets in fruit and vegetable plots
8. **SO** – construction of new grain storage objects (silos, floor stock)
9. **QC** – purchase of quality calves for fattening

Decision makers:

Four decision makers (DMs) participated in the decision making process: two of the employees most responsible for the Fund (DM1 – Director of the Fund, DM2 – Senior advisor of the Fund), one member of the Fund Council (DM3 – President of the Fund Council) and one external expert advisor in economy (DM4 – Professor of economics at the Faculty of Agriculture, Novi Sad). The Director and president of Fund Council are denominated by provincial authority, and hence their denominations have political implications.

4. DECISION MAKING WITHOUT CONSENSUS

AHP methodology for individual decision making was applied for each DM. Appendix A (Tables A.1-A.4) shows the evaluations of loan programs by using the scale from Table 1 and calculated weights of loan programs and individual geometric consistency indexes for all group members.

In order to derive a group decision, aggregation of individual AHP results requires defining the individual weights of decision makers in the group. This is a complex problem if there is no institutional framework for solving

this issue, as in the case of the Fund. There are several methods for determination the weights of DM [2, 6, 16, 17]. In this paper, weights of DM are determined directly and objectively, based on a consistency index that each decision maker demonstrated when evaluating the loan programs. A similar approach has been applied in [16] when the other consistency parameters were used: standard consistency ratio, generalized Euclidean distance, applicable when the eigenvector method is used as a prioritization method.

Proposed method for determining the weights of decision makers and deriving a group decision consisted of the following steps:

1. Calculating *GCI* for each DM, based on the corresponding comparison matrix.
2. Calculating the reciprocal values of *GCI* for each DM.
3. Performing the additive normalization (reciprocal *GCI* value for one DM is divided by the sum of reciprocal *GCI* values for all DMs). Then, the normalized value is accepted as a weight of DM when calculating the final weights of loan programs (group decision).
   The mathematical formulation of the procedure:

$$\alpha_k = (1/GCI_k) / \sum_{k=1}^{m} (1/GCI_k) \quad (m \text{ is the number of DM}) \tag{7}$$

   determines that the weight α_k for k-th DM depends only and directly on his consistency and that it is inversely proportional to the consistency parameter *GCI*. One the one hand, this calculation method makes each DM maker free to express his own preferences (which can significantly differ from the other decision makers' preferences) while his weight remains undiminished. On the other hand, the inconsistency is 'punished' because the higher inconsistency value decreases the decision maker's weight.

4. Aggregating the evaluations is performed on each position in matrix *A* by taking the values from individual matrices [5] in order to derive group matrix $A^{(c)}=(a_{ij}^{(c)})_{nxn}$, from which the 'group weights' of loan programs are calculated once again by applying *LLS* method. Aggregating the individual evaluations (corresponding elements $a_{ij}^{(k)}$ in matrices in Appendix A) is performed by relation:

$$a_{ij}^{(c)} = \prod_{k=1}^{m} (a_{ij}^{(k)})^{\alpha_k} \tag{8}$$

   subject to:

$$\sum_{k=1}^{m} \alpha_k = 1. \tag{9}$$

5. DECISION MAKING WITH CONSENSUS

Consensus models are used in various ways [8, 10, 12] in group decision making problems. Consensus is defined as the complete and unanimous agreement of all decision makers, the members of group, on weights and ranking of alternatives. However, some scientists believe that unanimous agreement is not necessary (and not reachable) in real life situations and that therefore the aim should be 'soft' consensus, based on measuring the deviation of each DM from the group decision [4, 7]. For example, in [4] consensus model is proposed when applying AHP and prioritization method *LLS*. The model is based on the iterative adjustment of individual evaluations of group members in individual matrices of comparison with a group matrix, i.e. diminishing the deviation of individual decisions from a group one. This model is applied on the decision-making problem in the Fund and it is presented as an algorithm consisting of five steps:

Step 1. Let $z = 0$ i $A_z^{(k)} = (a_{ijz}^{(k)})_{nxn} = (a_{ij}^{(k)})_{nxn}$.

Step 2. Let $w_z^{(c)} = (w_{1,z}^{(c)}, w_{2,z}^{(c)}, ..., w_{n,z}^{(c)})$ be group priority vector derived from group matrix $A_z^{(c)} = (a_{ijz}^{(c)})_{nxn}$ by *LLS*. Elements of matrix are:

$$a_{ijz}^{(c)} = \prod_{k=1}^{m} (a_{ijz}^{(k)})^{\alpha_k} \tag{10}$$

where z is the number of iterations. The rest of denotations in (10) are the same, as they were so far.

Step 3. Calculate the cardinal consensus index for each matrix $A_z^{(k)}$:

$$GCCI(A_z^{(k)}) = \frac{2}{(n-1)(n-2)} \sum_{i<j} (\ln(a_{ij,z}^{(k)}) - \ln(w_{i,z}^{(c)}) + \ln(w_{j,z}^{(c)}))^2 \tag{11}$$

Remark: According to [4], for matrix sized 9x9 the recommended threshold is $GCCI_{max} = 0.37$.

Step 4. Pick the matrix with the highest *GCCI* (that matrix deviates the most from the group matrix). Correct the evaluation for respective (k-th) decision maker in a following way:

$$a_{ij,z+1}^{(k)} = (a_{ij,z}^{(k)})^{\theta} (\frac{w_{i,z}^{(c)}}{w_{j,z}^{(c)}})^{(1-\theta)} \tag{12}$$

where $0 < \theta < 1$. Then go back to Step 2.

Remark: As θ grows higher, more iterations will be needed in order to reach consensus (for higher values θ initial DM's evaluation will be less changed in every iteration, therefore more iterations will be needed to reach consensus). Here $\theta = 0.8$, as in [4].

Step 5. Algorithm outputs are corrected initial matrices for each DM whose cardinal consensus index was smaller than prescribed value ($GCCI_{max} = 0.37$), number of iterations (z) necessary to reach consensus, group matrix and its corresponding priority vector which represents the final – consensual solution.

6. RESULTS

6.1 Group decision without consensus

According to the results presented in Table 2, one can conclude that:

- DM1 (Director of the Fund) gave the highest weight to loan programs: QC (purchase of quality calves for fattening), AM (purchase of agricultural machinery) and PF (planting of fruit), respectively: 0.280, 0.231 and 0.162;
- DM2 (Senior advisor of the Fund) gave the highest weights to loan programs IR (purchase of new irrigation equipment) and GH (purchase of greenhouses), respectively: 0.307, 0.307 and 0.146;
- DM3 (President of the Fund Council) ranked the three leading loan programs as follows: AM (0.281), IR (0.220) and QC (0.185);
- DM4 (Professor of economics) evaluated as the most important loan programs QC, IR and HN (purchase of hail protective nets in perennial fruit and vegetable plots), with following weights: 0.409, 0.161 and 0.091.

Table 3 presents the calculated weights of decision makers (normalized on value 1) according to the demonstrated consistency (see relation 7). Since the DM4 was the most consistent ($GCI = 0.409$), his calculated weight was the highest and equal to 0.338. In other words, in the synthesis of and deriving a group decision, influence of his evaluation has approximately 1/3 of overall influence of the group members as a whole. Together with DM3, influence of this half of the group in deriving a final decision equals almost 2/3. DM1 demonstrated the highest inconsistency ($GCI = 0.917$) and accordingly got the lowest weight (0.151), this means that his influence on a group decision was two times smaller than the influence of DM4.

Table 2. Individual weights of loan programs and consistency indexes before applying consensus model

No.	Loan program	DM1	DM2	DM3	DM4
1	**AM**	0.231	0.307	0.281	0.035
2	**IR**	0.033	0.307	0.220	0.161
3	**BE**	0.033	0.030	0.016	0.021
4	**GH**	0.040	0.146	0.058	0.050
5	**VC**	0.055	0.048	0.031	0.080
6	**PF**	0.162	0.077	0.032	0.065
7	**HN**	0.080	0.013	0.054	0.091
8	**SO**	0.085	0.018	0.124	0.088
9	**QC**	0.280	0.055	0.185	0.409
	GCI	0.917	0.623	0.480	0.409
	GCCI	2.305	2.830	1.073	1.394

Table 3. Consistency measures and weights of decision makers

	GCI	***1/GCI***	α_k^*
DM1	0.917	1.091	**0.151**
DM2	0.623	1.605	**0.222**
DM3	0.480	2.083	**0.288**
DM4	0.409	2.445	**0.338**

*See relation (7)

Synthesis of individual evaluations as shown by relation (8) was resulting in deriving weighted group matrices from which weights of loan programs w_i were calculated as well as a group decision without consensus (Table 4). Loan program QC (purchase of quality calves for fattening) was assigned the highest weight (0.242), the second place goes to IR (purchase of new system and irrigation equipment) with assigned weight of 0.197, while third place is AM (purchase of agricultural machinery) weighted 0.169. The lowest weight of 0.027 was given to loan program BE (purchase of beehives and beekeeping equipment).

Table 4. The weights of loan programs (group decision without consensus)

	AM	**IR**	**BE**	**GH**	**VC**	**PF**	**HN**	**SO**	**QC**	w_i
AM		1.11	6.51	2.13	2.20	2.10	1.58	1.82	1.28	**0.169**
IR			8.37	2.23	3.17	2.79	2.42	2.99	0.96	**0.197**
BE				0.35	0.37	0.24	0.47	0.36	0.21	**0.027**
GH					1.48	1.54	1.16	0.57	0.30	**0.079**
VC						0.65	1.38	0.82	0.19	**0.063**
PF							1.24	1.04	0.25	**0.077**
HN								0.41	0.25	**0.061**
SO									0.17	**0.083**
QC										**0.242**

Multiplying the weights presented in Table 4 by 100 gives the percentage of budget allocation in loan programs as well as the correspondent currency amount for farmers' loan support (Table 5).

Table 5. The Fund's budget allocation on loan programs (without consensus)

Loan program	The Fund's budget allocation [%]	Amount of funds in dinars
AM	16.9	27.121.671
IR	19.7	31.615.202
BE	2.7	4.333.048
GH	7.9	12.678.178
VC	6.3	10.110.445
PF	7.7	12.357.211
HN	6.1	9.789.479
SO	8.3	13.320.111
QC	24.2	38.836.949
∑	99.8	160.162.293

6.2 Group decision with consensus

In order to derive a consensual decision, 17 iterations were needed (z =17); matrix of DM1 has been changed (adjusted) six times, matrix of DM2 five times, matrices of DM3 and DM4 have been changed three times each. The order of matrices' adjustments is shown in Appendix B (Table B.5). The results of applying the consensus model are corrected matrices for each DM and assigning weights of loan programs (Appendix B, Table B.1-B.4). Table 6 shows that after applying the consensus model, *GCCI* for all DMs was smaller than 0.37 and a consensus was reached successfully. Before applying consensus model *GCCI* exceeded the prescribed value of 0.37 and ranged from 1.073 (DM3) to 2.830 (DM2) (Table 2). The important conclusion is that decision makers' individual inconsistencies were significantly reduced comparing to the initial matrices, and were fitted into the proposed thresholds.

According to Table 7, which lists the group consensus matrix and calculated weights of loan programs, one can conclude that the highest weight belongs to loan program QC (0.261), the next one to IR (0.198) and on the third highest to AM with associated weights of 0.151. The lowest weight is assigned to the loan program BE (0.026).

Comparison of the results from Tables 4 and 7 shows the same order of the first three preferable loan programs, but with the different associated

weights. These differences resulted in different currency amounts (Tables 5 and Tables 8) to be allocated for supporting farmers. The percentage shares and amounts presented in Table 8 are preferable as the consensual ones.

Consensus increases the share of QC and IR and decreases the share of AM, which might affect the final budget allocation.

Table 6. Individual weights of loan programs and consistency indexes after applying consensus model

	DM1	DM2	DM3	DM4
AM	0.185	0.199	0.216	0.073
IR	0.114	0.240	0.212	0.183
BE	0.030	0.029	0.020	0.024
GH	0.063	0.096	0.066	0.062
VC	0.063	0.063	0.044	0.073
PF	0.099	0.079	0.047	0.069
HN	0.074	0.046	0.061	0.081
SO	0.093	0.063	0.110	0.093
QC	0.280	0.185	0.223	0.343
GCI	0.098	0.043	0.126	0.107
GCCI	0.261	0.252	0.282	0.316

Table 7. The weights of loan programs (group decision with consensus)

	AM	**IR**	**BE**	**GH**	**VC**	**PF**	**HN**	**SO**	**QC**	w_i
AM		0.86	6.21	2.05	2.19	1.98	1.75	1.56	0.72	**0.151**
IR			7.91	2.53	3.24	2.85	2.66	2.47	0.78	**0.198**
BE				0.33	0.41	0.31	0.38	0.28	0.13	**0.026**
GH					1.27	1.22	1.04	0.61	0.25	**0.074**
VC						0.85	1.04	0.67	0.21	**0.062**
PF							0.99	0.76	0.24	**0.070**
HN								0.59	0.25	**0.066**
SO									0.26	**0.091**
QC										**0.261**

GCI=0.020

Table 8. The Fund's budget allocation on loan programs (with consensus)

Loan program	The Fund's budget allocation [%]	Amount of funds in dinars
AM	15.1	24.232.972
IR	19.8	31.775.685
BE	2.6	4.172.564
GH	7.4	11.875.761
VC	6.2	9.949.962
PF	7.0	11.233.828
HN	6.6	10.591.895
SO	9.1	14.603.977
QC	26.1	41.886.131
∑	99.9	160.322.777

7. CONCLUSION

Agriculture, apart from in reindustrialization, plays a key role in the economic development of Serbia [11, 14]. Therefore, it is necessary that government bodies responsible for agricultural lending build a transparent mechanism of decision-making. The contemporary decision making process often includes more participants (politicians, experts and others) who have different preferences according to their position, interests, knowledge, etc. This paper presents an original procedure for possible group decision making of the allocation of budget funds on loan programs from The Provincial Fund for Agricultural Development of Vojvodina Province. The procedure was developed by taking into account that the Fund is a government body with a specific organization (the Council, the Fund employees). Evaluation of the loan programs is performed by four competent decision makers according to the methodology of the Analytic Hierarchy Process (AHP), a globally recognized method for supporting individual and group decision making processes. A group context was considered for two cases: decision making with consensus and without. Here we have proposed an objective method for assigning weights for each decision maker based on a demonstrated consistency in evaluating loan programs. For consensus reaching, we have applied one of the latest models from relevant world literature. The case example demonstrated how the four key decision makers evaluated nine different loan programs and how these evaluations were aggregated in a group decision with and without consensus.

The developed consensus approach is general because it allows the decision makers to search for the solution until the best one for the group is

found. Also, provided that everyone has a right to express their own preferences, individual decision maker domination during the process is reduced and the final decision is realistically expected to be supported by the whole group. This way, the decision has the legitimacy to be implemented.

The results of the applied procedure were presented to the involved decision makers. All of them found the results acceptable in the sense that the final (group) allocation of budget funds on loan programs suit their individual attitudes and anticipation of group context leading to the final decision. Further research will be focused on other contemporary consensus models designated for decision-making in AHP context.

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