

A fuzzy AHP approach to assess preferences of La Tuque community towards wood based biorefinery

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on behalf of the research team

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IEA Bioenergy Inter-Task project: Measuring, governing and gaining support for sustainable bioenergy supply chains

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Contents:

- o Introduction
- o How to embed a specific bioenergy project to a specific community
- o Methodology of La Tuque wood based biorefinery project
- o Employing fuzzy AHP in assessing preferences
- o Conclusions

Introduction

- Decentralization of energy systems calls for a different approach in energy planning (Georgopoulou et al., 1998; Polatidis et al. 2006)
- If bioenergy share is to be increased in energy balances, a bioenergy project must meet
 - preferences of farmers and forest owners (supply chain)
 - **perceived** socio-economic-environmental aspects that „**the project**” will bring to „**the community**”.
 - local project implementation depends less on the technical performance (linked to the investor)

Bioenergy planning depends on stakeholders along the supply chain

- Bioenergy is too complex to be grasped at a glance by an „outsider” (decision-maker, NGO, a citizen...)
- Sustainable bioenergy is too complex issue even for a single bioenergy expert
- 3D of sustainability + dynamic variable:
 - environmental protection
 - economic feasibility and
 - social acceptance

Bioenergy projects interact with the community during the whole lifetime of the project.

How to embed a bioenergy project to a local community?

- o Involve community in early stages of planning of the project
 - Detect their expectations (preferences & fears)
 - **Ask them!**
 - Include those preferences in the project implementation so that the project transits from „the project” to „our project”



How to embed a bioenergy project to a local community?

(The other side of the coin)



- How much would the expectations inflate the project budget?
- **What if** detected expectations are
 - unrealistic?
 - conflicting between different stakeholders' groups?

It is necessary to include scientific methods in communication OR engage professional PR service (that would also use scientific methods in communication)

- o multi-criteria decision-making aid (MCDA) (analysis)
 - allows structure, unbiased results, transparent insight and scenario analysis
- o It is possible to involve most, if not all stakeholders
- o It grasps expectations of all stakeholders, not only the „loud ones”
- o It allows measurable contrasting of opposed/conflicting goals
- o It ranks expectations of the community in respect to the project.

How we have asked the community of La Tuque on wood-based biorefinery? (Methodology)

1. Identify the stakeholders groups along the supply chain
2. Semi-structured interviews with stakeholders' groups representatives
3. Identified expectations
4. Expectations transformed into a hierarchy
5. Hierarchy transformed into questionnaire
6. Surveyed n=85 stakeholders to evaluate expectations by
 1. Simple ranking (n=85)
 2. Fuzzy analytical hierarchical process (fAHP) (n=70)

Analytical Hierarchical Process (AHP)

- Th. Saaty, 1980
 - a decision-making tool that works well when the available data for the decision-makers are difficult to quantify OR
 - when it is necessary to rely on expert opinions OR preferences in some intangible aspects.

The objective of using AHP is to identify the preferred alternative and also determine a ranking of the alternatives when all the decision criteria are considered simultaneously.

- Widely used in various domains of renewable energies (Abu Taha& Daim, 2013)

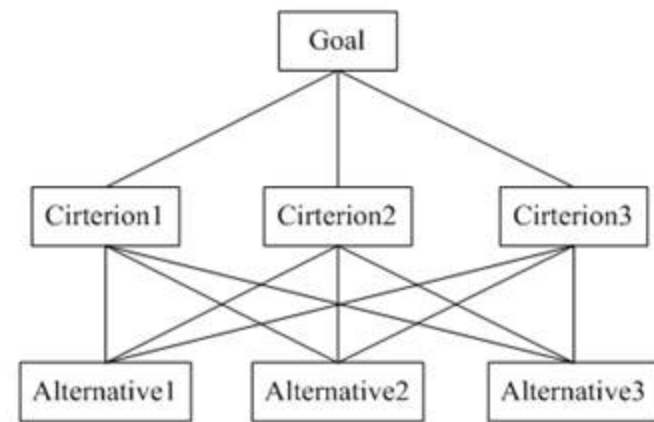
Table 1 Literature Review on MCDM Methods and Application to Renewable Energy Issues

Application area	AHP/ ANP	ELECTRE	PROMETHEE	Fuzzy sets	Others ^a	Sum
Renewable energy planning and policy	[24–30] ^b	[31, 32]	[33, 34]	[31, 35–37]	[3, 4, 12, 38–42]	23
Renewable energy evaluation	[43–47]	[48, 49]	[19, 50]	[49, 51, 52]	[47, 53–58]	19
Project selection	[1, 18, 59–62]	[23, 63]	[5, 63–65]	[60, 66–68]	[69–73]	24
Environmental	[74, 75]	[76]	[76]		[14, 21, 77–81]	11
Sum	20	7	9	11	26	

^a Others include: VIKOR, TOPSIS, SWA, SIMUS, UTADIS, value trees

^b Numbers in brackets refer to reference number

AHP in a nutshell



- o Reorganizes a problem to a hierarchy
- o Stakeholder is guided through a series of pair-wise comparison judgements to express relative strength or intensity of the elements in the hierarchy.

a_{ij} Value	Interpretation
1	Objectives i and j are of equal importance
3	Objective i is weakly more important than objective j
5	Experience and judgements indicate that objective i is strongly more important than objective j
7	Objective i is very strongly or demonstrably more important than objective j
9	Objective i is absolutely more important than objective j
2, 4, 6, 8	Intermediate values, for example, a value of 8 means that objective i is midway between strongly and absolutely more important than objective j

- o These judgements (numerical values) are synthesized in the use of eigen vectors to determine which variables have the highest priority

AHP criticism

- o inability to adequately accommodate the inherent uncertainty and imprecision associated with certain environments
- o it is difficult to subjectively scale a concrete quantitatively number to enable the pairwise comparison without losing some degree of accuracy
- o Bioenergy projects are full of uncertainties!

Fuzzy set theory and fuzzy logic

- o Zadeh, 1965
 - Evaluates expressions such as “not very clear”, “probably so”, “very likely”
 - allows some degree of uncertainty of human thought

The fuzzy theory has become a useful tool for automating human activities with uncertainty-based information.

Fuzzy logic has been employed to handle the concept of partial truth, where the truth value may range between completely true and completely false.



Fuzzy AHP

o Buckley, 1985

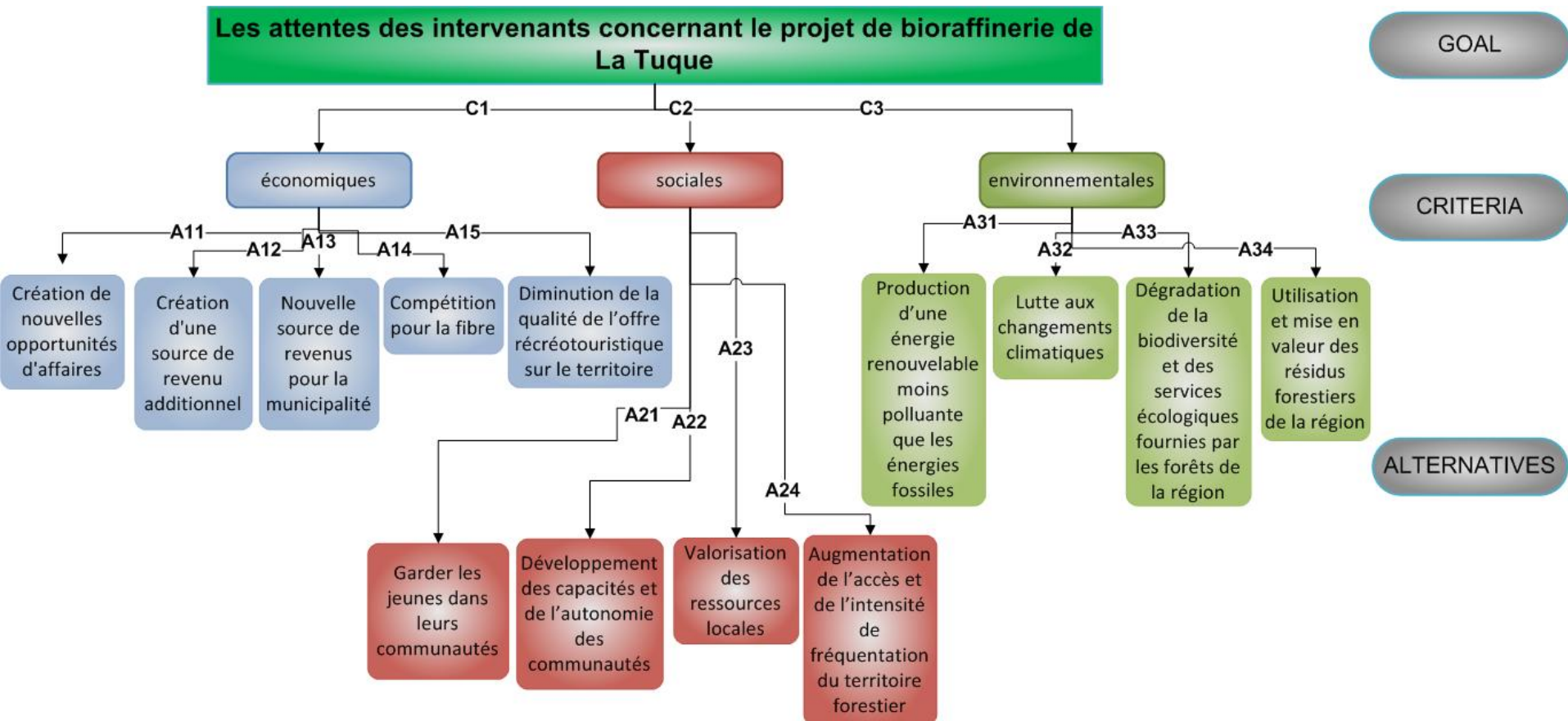
- uses linguistic terms associated with triangular fuzzy number instead of integer values

Table 1. Fuzzy scale of preferences

<i>Linguistic Variables</i>	<i>Crisp AHP Scale</i>	<i>Fuzzy AHP Scale</i>	
		<i>TFS</i>	<i>Reciprocal TFS</i>
<i>Equally Preferred (EqP)</i>	1	(1, 1, 1)	(1, 1, 1)
<i>Equally to Moderately Preferred (Eq-MP)</i>	2	(1, 2, 3)	(1/3, 1/2, 1)
<i>Moderately Preferred (MP)</i>	3	(2, 3, 4)	(1/4, 1/3, 1/2)
<i>Moderately to Strongly Preferred (M-SP)</i>	4	(3, 4, 5)	(1/5, 1/4, 1/3)
<i>Strongly Preferred (SP)</i>	5	(4, 5, 6)	(1/6, 1/5, 1/4)
<i>Strongly to Very Strongly Preferred (S-VSP)</i>	6	(5, 6, 7)	(1/7, 1/6, 1/5)
<i>Very Strongly Preferred (VSP)</i>	7	(6, 7, 8)	(1/8, 1/7, 1/6)
<i>Very Strongly to Extremely Preferred (VS-ExP)</i>	8	(7, 8, 9)	(1/9, 1/8, 1/7)
<i>Extremely Preferred (ExP)</i>	9	(8, 9, 9)	(1/9, 1/9, 1/8)

- Consistency of answers is examined.
- Geometric mean computed
- Defuzzification is performed (best non-fuzzy performance)
- The ranking is obtained

Organizing expectations of La Tuque community into a hierarchy with a goal, criteria and alternatives



How does fAHP work?

Attentes et perceptions envers le projet de bioraffinerie à La Tuque, Québec

Évaluation des attentes des intervenants concernant le projet de bioraffinerie de La Tuque (BELT)

1. Par rapport au projet de bioraffinerie devant être développé à La Tuque (Projet BELT), vos attentes sont reliées à des :

(Classez-les en fonction de leur importance selon votre opinion : 1 est le plus important et 3 le moins important)

- ☒ retombées économiques
- ☒ retombées sociales
- ☒ retombées environnementales

Notez qu'une retombée peut être soit positive (un bénéfice), ou négative (un risque)

2. Parmi les retombées possibles, selon vous, lesquelles sont les plus importantes, si vous suivez l'ordre ci-dessous? (Encerlez le mot qui rend la déclaration valide)

2.1. Les retombées économiques sont **moins égales plus** importantes que les retombées sociales (encerlez une des réponses suivantes)

- Un peu moins / plus ou moins importantes
- Moins / **plus importantes**
- Significativement moins / plus **moins** importantes
- Extrêmement moins / plus importantes

(4,5,6)

2.2. Les retombées économiques sont **moins égales plus** importantes que les retombées environnementales (encerlez une des réponses suivantes)

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- Extrêmement moins / plus importantes

(2,3,4)

2.3. Les retombées sociales sont **moins égales plus** importantes que les retombées environnementales (encerlez une des réponses suivantes)

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Questionnaire2 middle value				
SURVEY RESULTS				
	C1	C2	C3	simple ranking
C1		1	5	3
C2	5		1	3
C3	3	3		1
total	9	9	7	
RECIPROCAL MATRIX				
	C1	C2	C3	
C1	1,00	5,00	3,00	
C2	0,20	1,00	3,00	
C3	0,33	0,33	1,00	
	1,53	6,33	7,00	
NORMALIZED RECIPROCAL				
	C1	C2	C3	sum
C1	0,65	0,79	0,43	1,87
C2	0,13	0,16	0,43	0,72
C3	0,22	0,05	0,14	0,41
Sum	1,00	1,00	1,00	
Average				
	EIGENVEC	lambda	Consistency measure	
C1	62%	3,43	lambda m	3,43
C2	24%		CI	0,22
C3	14%		PI	0,58
Sum			CR	37%
				<10%

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Notez qu'une retombée peut être soit positive (un bénéfice), ou négative (un risque)

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Questionnaire2

middle value

SURVEY RESULTS				
	C1	C2	C3	simple ranking
C1	1	5	3	1
C2	5	1	0,333333	3
C3	3	0,333333	1	2

upper value

	C1	C2	C3
C1	1,00	6,00	4,00
C2	6,00	1,00	0,50
C3	4,00	0,50	1,00
	11,00	7,50	5,50

RECIPROCAL MATRIX

	C1	C2	C3
C1	1,00	6,00	4,00
C2	0,17	1,00	0,50
C3	0,25	2,00	1,00
	1,42	9,00	5,50

NORMALIZED RECIPROCAL

	C1	C2	C3	sum	EIGENVEC	lambda	CR	lambda n	CI	RI	CR
C1	0,71	0,67	0,73	2,10	70%	3,01			3,01	7	
C2	0,12	0,11	0,09	0,32	11%				0,01	3	
C3	0,18	0,22	0,18	0,58	19%				0,58	8	
sum	1,00	1,00	1,00								1%

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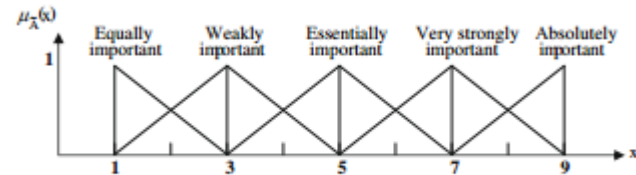


fig. 4. Membership functions of the linguistic variables for criteria comparisons.

	Qmin	Qmax	
Q	1,1648	0,9049	
	0,9625	0,9963	
	0,7530	1,3462	
	wkl*	wku*	
wkl	0,4769	0,8526	
	0,0799	0,1429	
	0,1962	0,3507	
	wl	wm	wu
E2	0,4769	0,6333	0,8526
	0,0799	0,1062	0,1429
	0,1962	0,2605	0,3507

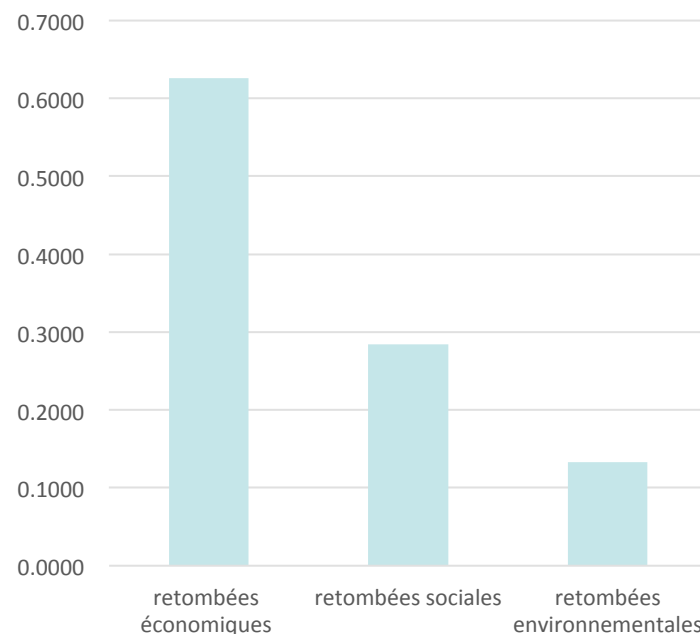
Simple ranking vs. fuzzy AHP ranking (example on Criteria)

Simple ranking

1. retombées économiques
2. retombées sociales
3. retombées environnementales

Includes any answer

fAHP



Includes only consistent answers

How does fAHP work?

- o After inserting all questionnaires, aggregation of consistent answers is made by each criteria and alternative(s)
- o The fuzzy matrix per each level of hierarchy is defuzzified to the best non-fuzzy number
- o Weighted ranking is obtained.

Simple ranking vs. fuzzy AHP ranking - 11 alternatives

Simple ranking

Preference	Rank
C1-A3	1
C3-A1	2
C1-A1	3
C1-A4	4
C1-A2	5
C2-A3	6
C2-A2	7
C3-A3	8
C2-A1	9
C3-A2	10
C3-A4	11

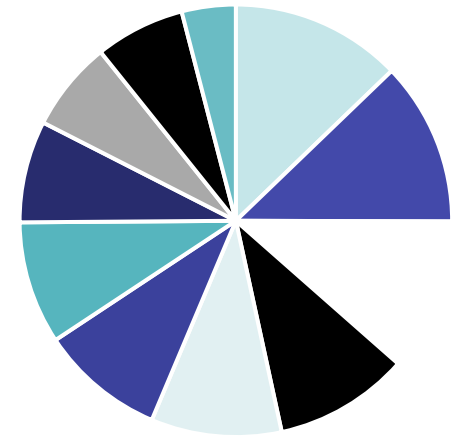
Includes any answer
N=70

fAHP

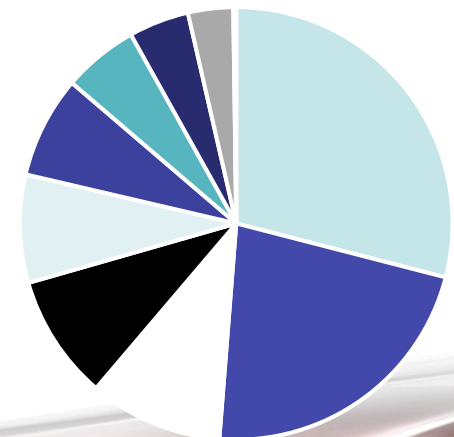
Preference	Rank	Weight a	Weight b
C1-A3	1	0,1158	0,2624
C3-A1	2	0,1107	0,2011
C1-A1	3	0,1035	0,0902
C1-A4	4	0,0914	0,0845
C1-A2	5	0,0883	0,0731
C2-A3	6	0,0845	0,0689
C2-A2	7	0,0831	0,0510
C3-A3	8	0,0689	0,0407
C2-A1	9	0,0610	0,0305
C3-A2	10	0,0607	0,0010
C3-A4	11	0,0365	0,0010

Includes only consistent answers
n<70

Weight A



Weight B



Conclusions

- o Performing a fAHP can focus the efforts of the project developer to the set of preferences that were weighted the most.
- o fAHP can provide a basis for dialogue and prevent negative consequences of the projects (whether it is about too high or unrealistic expectations or some small but important local issue)
- o All stakeholders are included and the interpretation of results are transparent.
- o Ranking of preferences gives also idea to the stakeholders how much a specific agenda/preference is supported.

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IEA Bioenergy Task 43 NTL for Croatia

A decorative graphic at the bottom of the slide features flowing, wavy lines in shades of red and white, creating a sense of movement and energy.