AHP- BASED SOCIAL VULNERABILITY INDEX FOR SMALL FISHERIES IN YUCATAN, MEXICO

ISAHP2020

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Laboratorio Nacional de Ciencias de la Sostenibilidad

AHP

Sensitivity analysis

Uncertainty analysis

Consensus

Social vulnerability

AHP

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Social vulnerability

Image from https://www.mobiusleadership.com/vulnerability-is-not-a-strength/

What does vulnerability mean?

Vulnerability is the state of people or places that are differentially affected by hazards.

(Eakin et al., 2011)

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The response to hazards depends on a combination of socio-institutional and environmental drivers, as well as the society's adaptive capacity.

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Vulnerability is the state of people or places that are differentially affected by hazards. The response to hazards depends on a combination of **socio-institutional** and environmental **drivers**, as well as the society's adaptive capacity.

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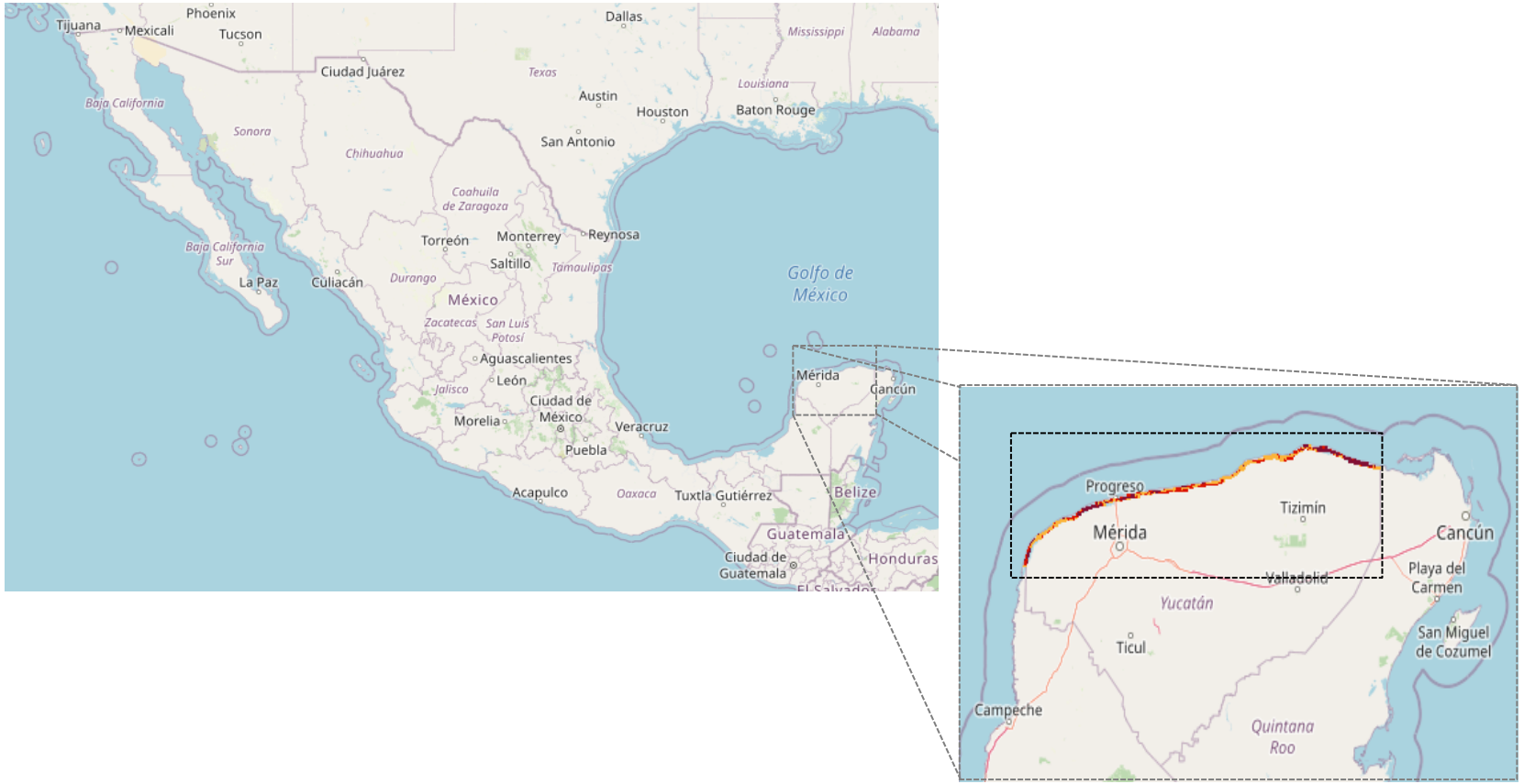
Case study



Images taken from https://www.openstreetmap.org/#map=5/25.245/-105.029; and http://sig.apps.lancis.ecologia.unam.mx/index.php/view/map/?repository=indices&project=Vulnerabilidad

Photo taken by Tonatiuh Alarcón. Instagram: @tonatiuh.alarcon

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Small fisheries

Complex

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Small fisheries

Complex

Multispecies

Photo taken by Tonatiuh Alarcón. Instagram: @tonatiuh.alarcon

Small fisheries

Complex

Multispecies

Multiscalar

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Small fisheries

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Multisectoral

Photo taken by Tonatiuh Alarcón. Instagram: @tonatiuh.alarcon

Small fisheries

Complex

Multispecies

Multiscalar

Multisectoral

Differential

Socio-institutional drivers

Image from https://www.synopsys.com/blogs/software-security/top-10-software-vulnerability-list-2019/

Adaptations

Image from https://www.synopsys.com/blogs/software-security/top-10-software-vulnerability-list-2019/

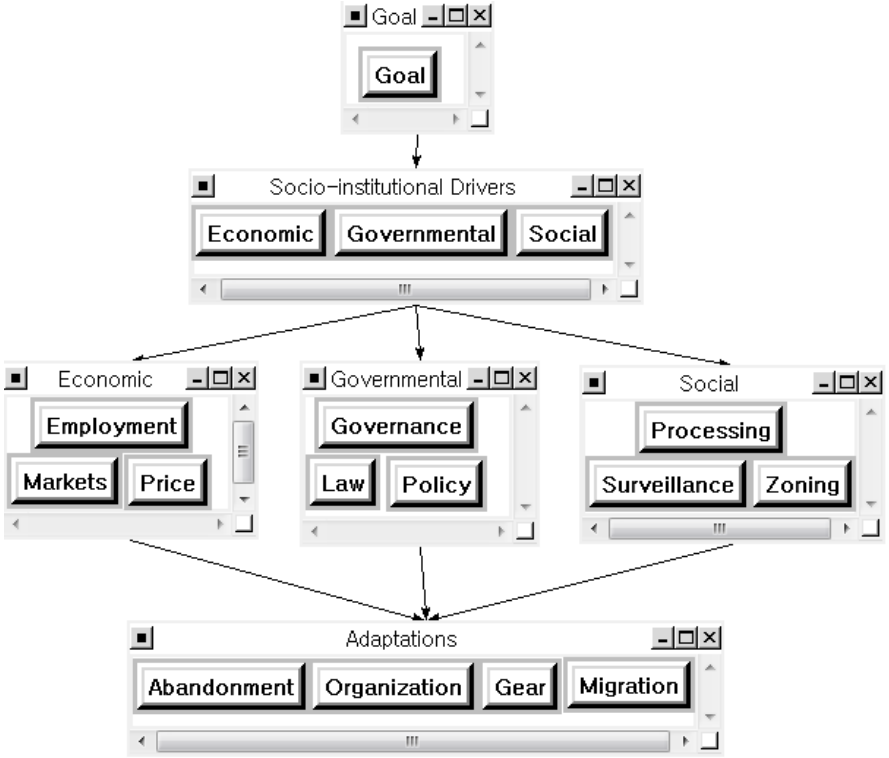
How can we measure vulnerability?

Social vulnerability index (SVI)

"The quantification stage is typically achieved by modeling social vulnerability through the construction of vulnerability indices …"

(Tate, 2013)

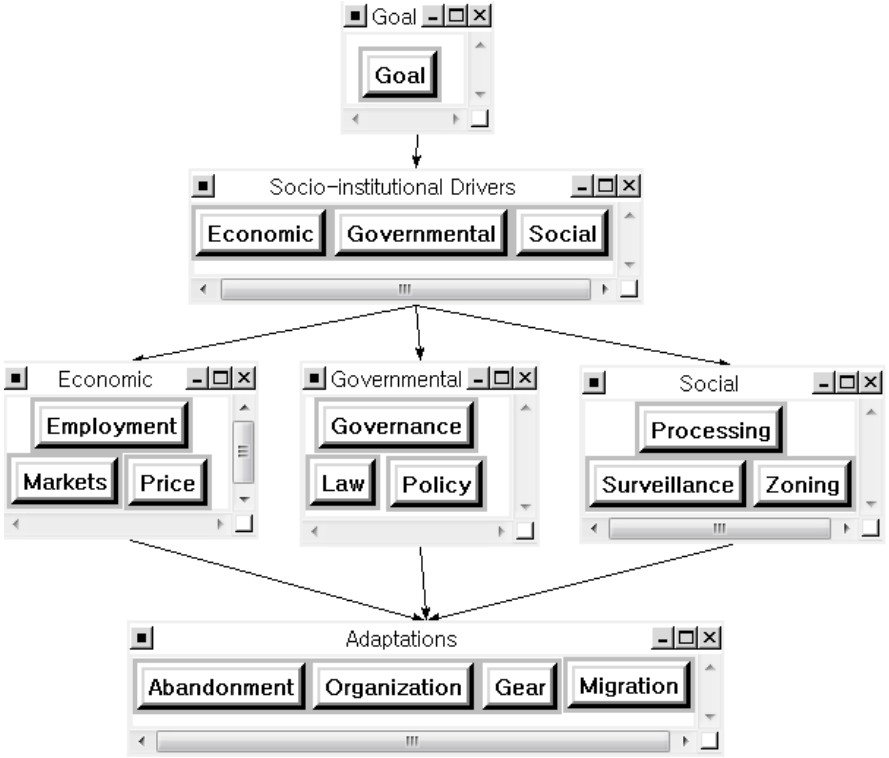
AHP-based SVI



Workshops

1. Political science

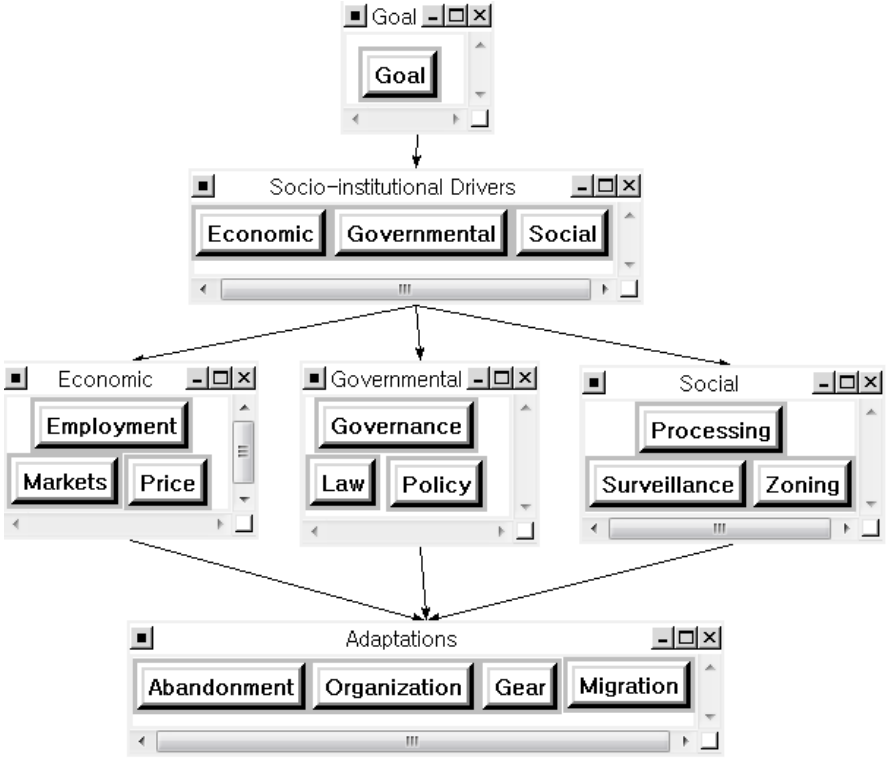
AHP-based SVI



Workshops

1. Political science
2. Fisheries biology

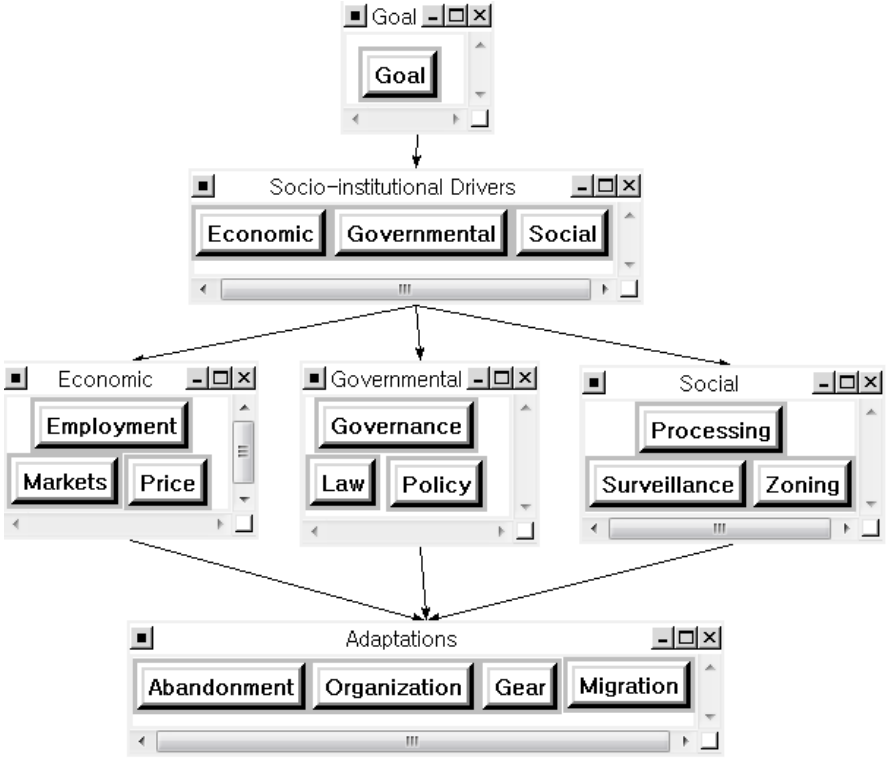
AHP-based SVI



Workshops

1. Political science
2. Fisheries biology
3. Coastal management

AHP-based SVI



Workshops

1. Political science
2. Fisheries biology
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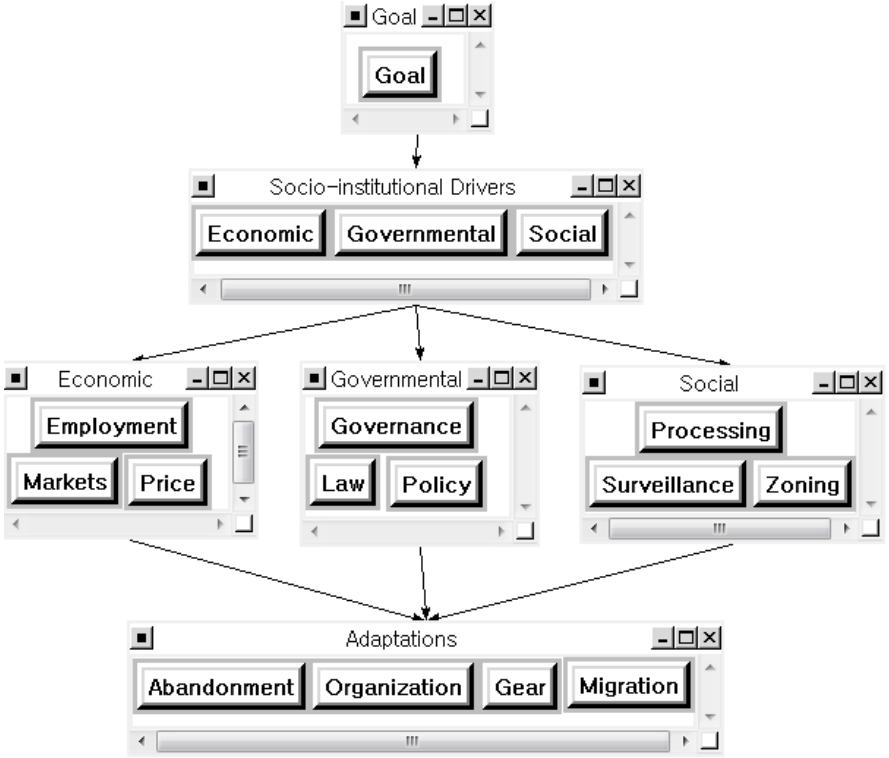

Workshops

1. Political science
2. Fisheries biology
3. Coastal management
4. Environmental policy

4 sets of pairwise comparisons

Pairwise comparison matrices

Expert	Driver								
	Economic			Governmental			Social		
		Employment	Markets		Law	Policy		Zoning	Surveillance
Political science	Price	1/2	1	Governance	2	1/4	Processing	1/3	5
	Employment		5	Law		1/5	Zoning		6
Fisheries biology	Price	1/5	1/5	Governance	1	5	Processing	2	1/2
	Employment		3	Law		5	Zoning		1/2
Coastal management	Price	1/3	1/2	Governance	4	3	Processing	3	3
	Employment		4	Law		1/3	Zoning		1
Environmental policy	Price	7	9	Governance	1/6	3	Processing	3	4
	Employment		3	Law		7	Zoning		1

Pairwise comparison matrices

Expert	Driver								
	Economic			Governmental			Social		
		Employment	Markets		Law	Policy		Zoning	Surveillance
Political science	Price	1/2	1	Governance	2	1/4	Processing	1/3	5
	Employment		5	Law		1/5	Zoning		6
Fisheries biology	Price	1/5	1/5	Governance	1	5	Processing	2	1/2
	Employment		3	Law		5	Zoning		1/2
Coastal management	Price	1/3	1/2	Governance	4	3	Processing	3	3
	Employment		4	Law		1/3	Zoning		1
Environmental policy	Price	7	9	Governance	1/6	3	Processing	3	4
	Employment		3	Law		7	Zoning		1

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Political science	Price	1/2	1	**Governance**	2	**1/4**	Processing	1/3	5
	Employment		5	**Law**		**1/5**	Zoning		6
Fisheries biology	Price	1/5	1/5	**Governance**	1	**5**	Processing	2	1/2
	Employment		3	**Law**		**5**	Zoning		1/2
Coastal management	Price	1/3	1/2	**Governance**	4	**3**	Processing	3	3
	Employment		4	**Law**		**1/3**	Zoning		1
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	Employment		3	**Law**		**7**	Zoning		1

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	Employment		3	Law		5	**Zoning**		**1/2**
Coastal management	Price	1/3	1/2	Governance	4	3	**Processing**	3	**3**
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Environmental policy	Price	7	9	Governance	1/6	3	**Processing**	3	**4**
	Employment		3	Law		7	**Zoning**		**1**

Whose pairwise comparisons affect the most?

Sensitivity analysis

Decision processes that require the aggregation of results obtained by several users, as it highlights which individuals most critically impact the aggregated group results.

(Ivanco et al., 2017)

Sensitivity analysis

Aggregated group weight

$$\bar{G}_r^{(i,j-1)} \sqrt[P]{A_r^1 A_r^2 \dots A_r^P}$$

C^{P_j} : pairwise comparison matrix
$\mathrm{P_j}$: expert

$A_r^{P_j}$: weight
r: criterion
i: level
under the criterion j_{i-1}

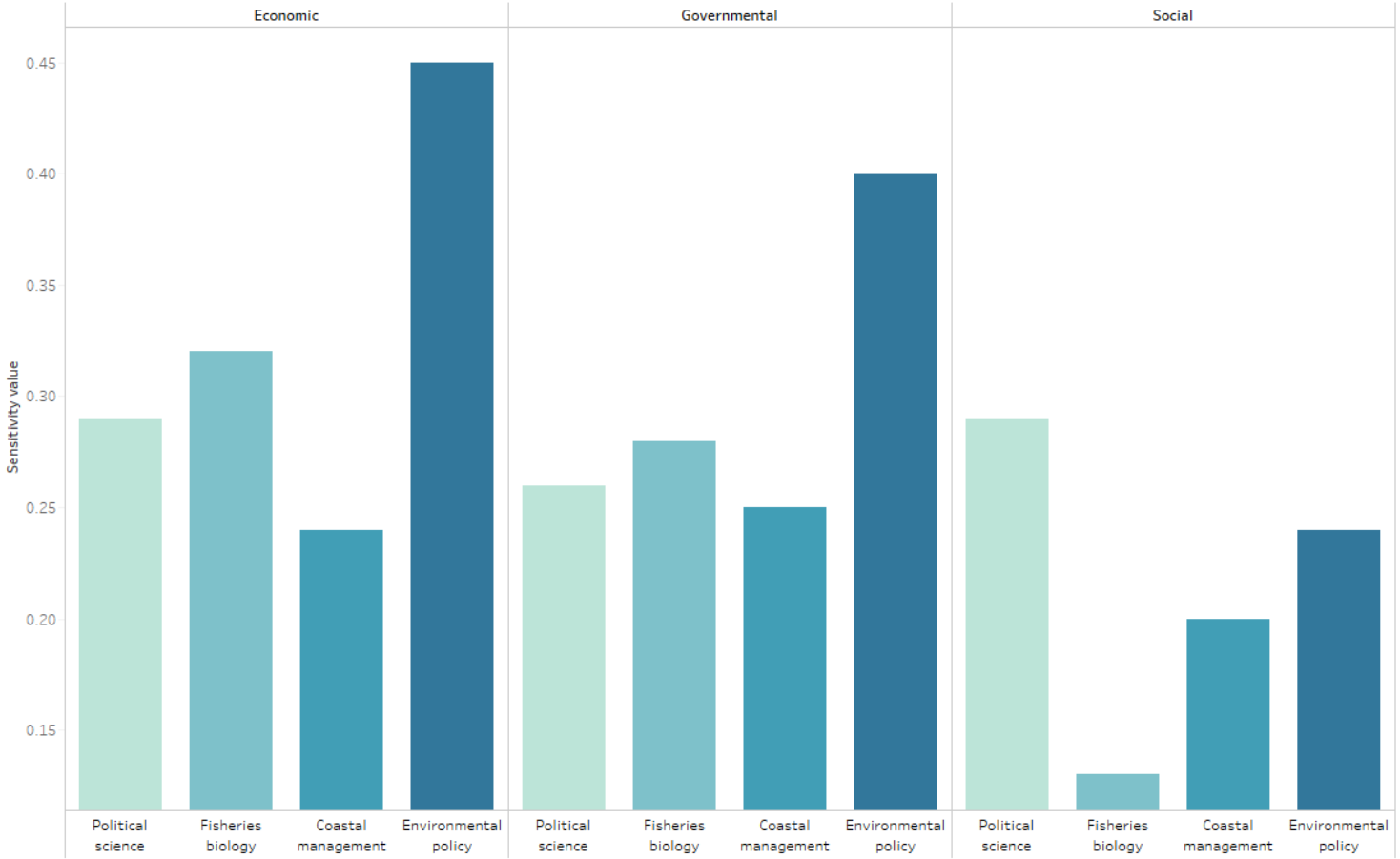
Change on normalized group weight

$$\frac{\partial G_r^{(i,j_{i-1})}}{\partial a_{k\ell}}$$

a_{kl}: element
k: row
l: column

Perturbation value of 1% of each pairwise comparison

(Ivanco, 2015)


Economic
Governmental
Social
Sensitivity value
0.45
0.40
0.35
0.30
0.25
0.20
0.15
Political science
Fisheries biology
Coastal management
Environmental policy
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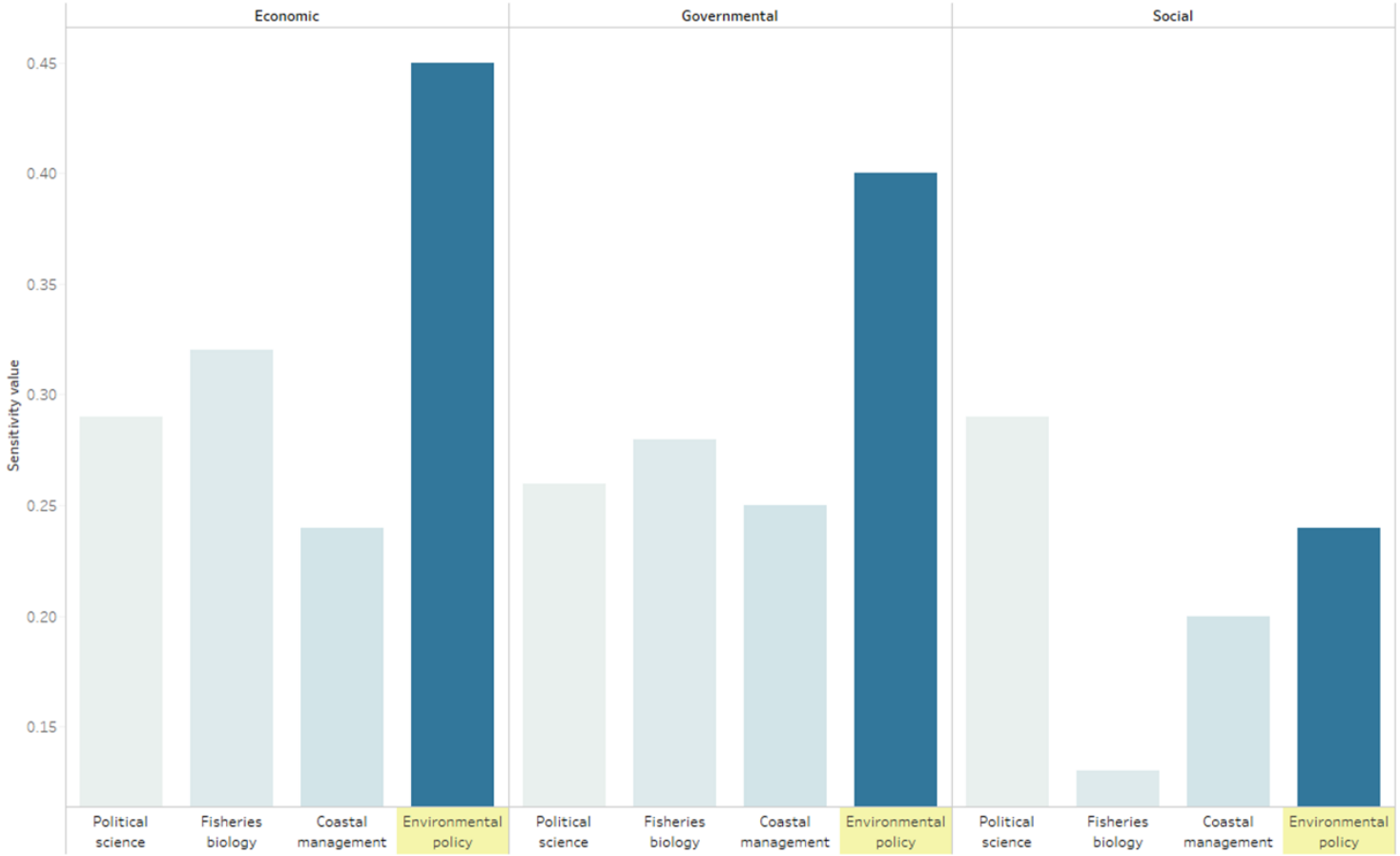
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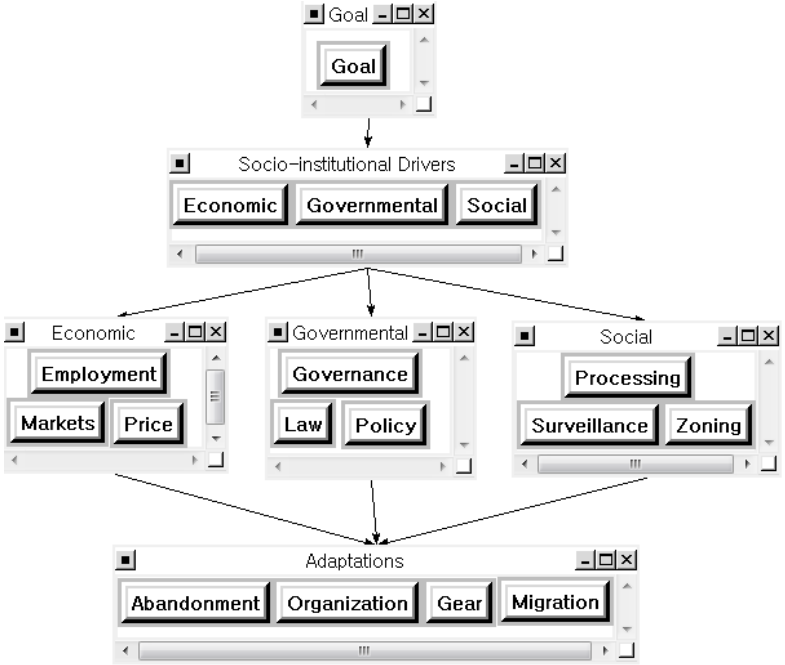
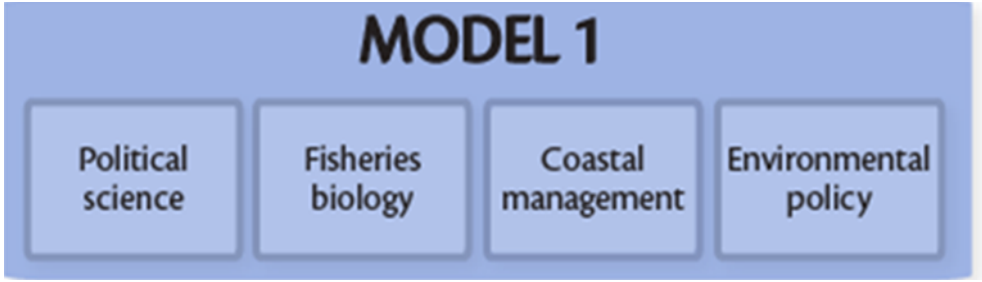
Generating two AHP versions





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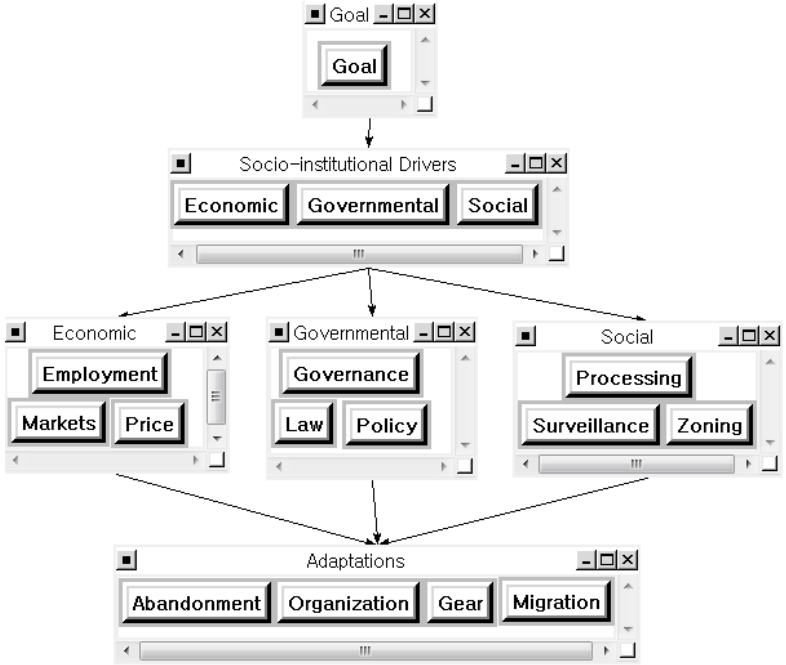

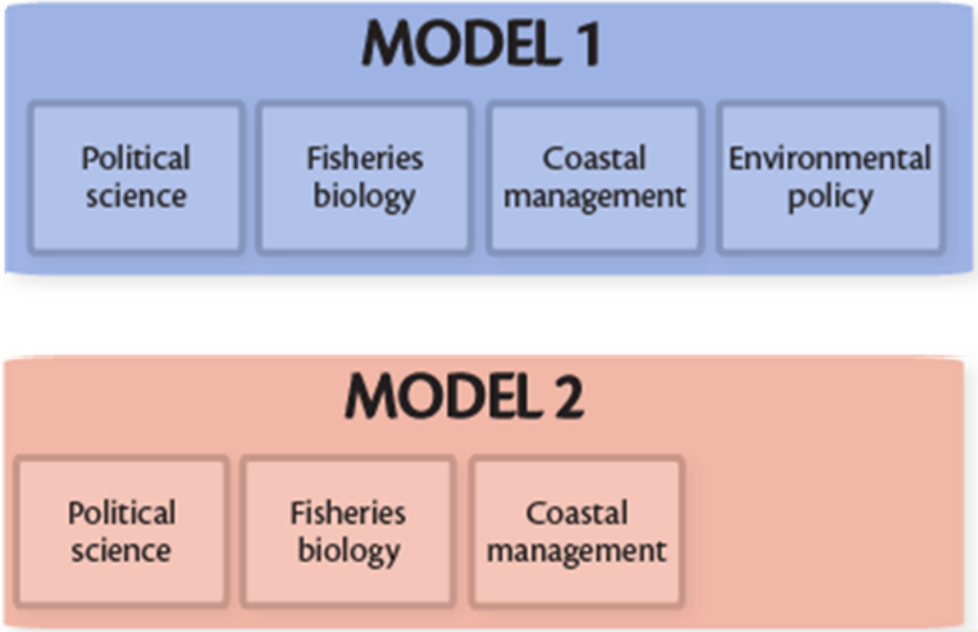

What is the probability of rank reversal?

Interval judgement analysis

Model		Economic driver	
		Employment	Markets
1	Price	[1/5,7]	[1/5,9]
	Employment		[3,5]
		Employment	Markets
2	Price	[1/5,1/2]	[1/5,1]
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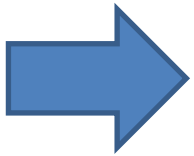

50,000 random matrices

Interval judgement analysis

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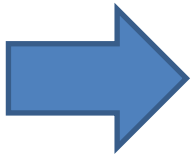

50,000 random matrices

Normalized weights

Interval judgement analysis

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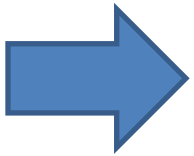


50,000 random matrices

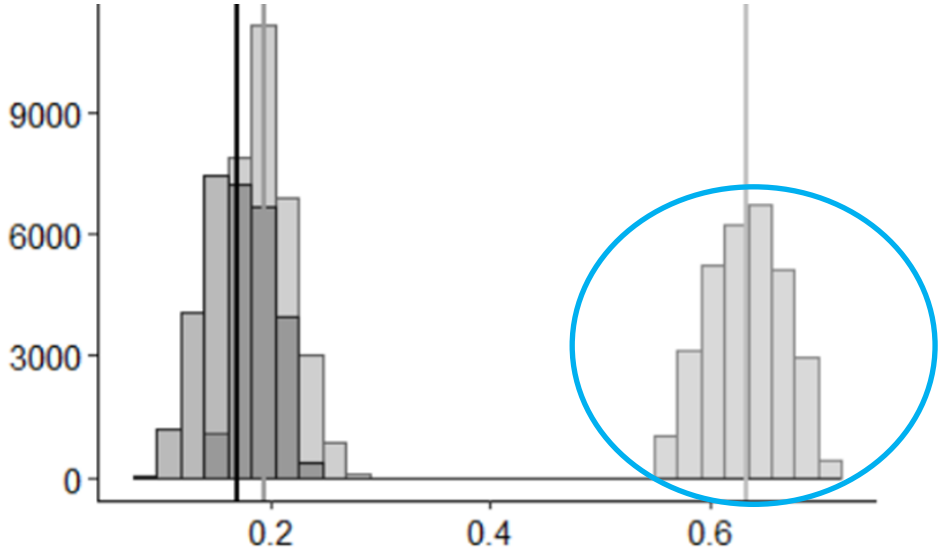
Normalized weights

C.I. < 0.1

Interval judgement analysis

Rank reversal probability

$$p_{ij} = \emptyset$$



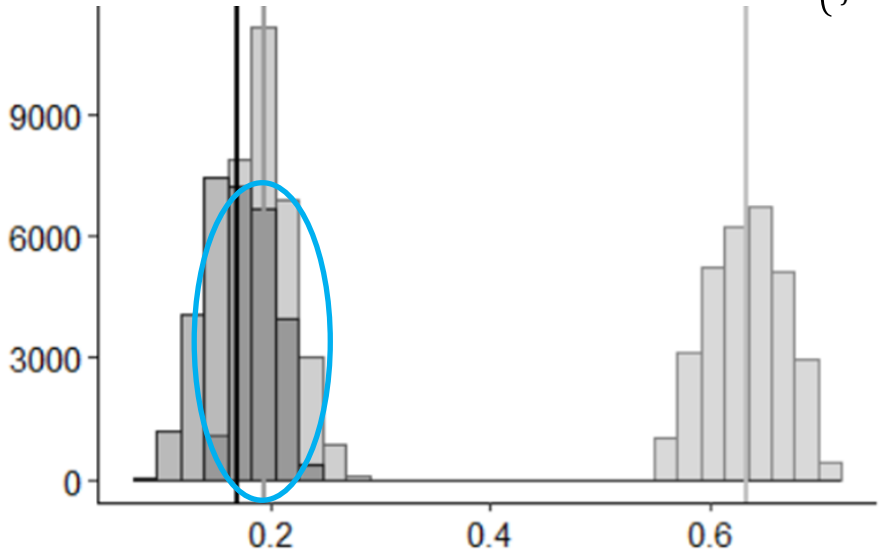
$$\left[\overline{w}_i \pm t_{\frac{\propto}{2},n-1}\, s_i\right] \qquad \left[\overline{w}_j \pm t_{\frac{\propto}{2},n-1}\, s_j\right]$$

(Saaty y Vargas 1987, pp.111)

Interval judgement analysis

Rank reversal probability

$$p_{ij} = \begin{cases} [F_i(w_i^U) - F_i(w_j^L)][F_j(w_i^U) - F_j(w_j^L)] \\ if \;\; w_i^L < w_j^L < w_i^U < w_j^U, \\ [F_i(w_j^U) - F_i(w_i^L)][F_j(w_j^U) - F_j(w_i^L)] \\ if \;\; w_j^L < w_i^L < w_j^U < w_i^U. \end{cases}$$



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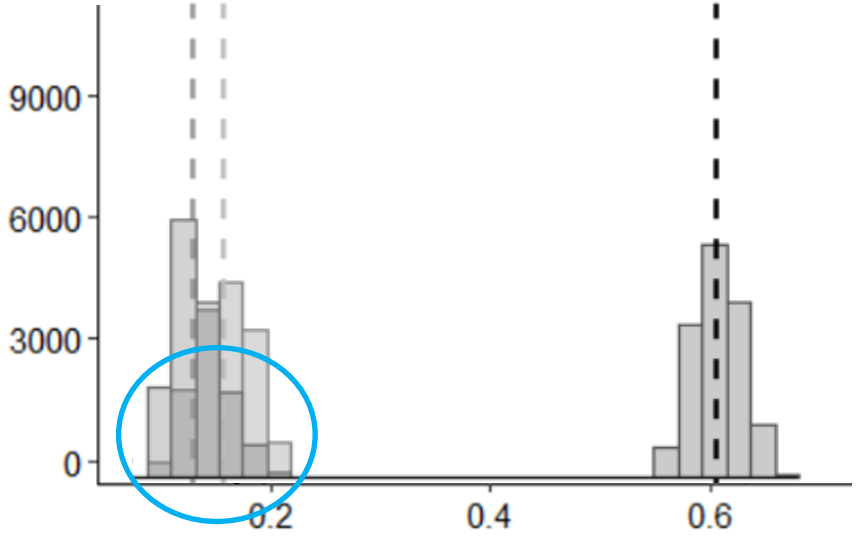
(Saaty y Vargas 1987, pp.111)

Interval judgement analysis

Rank reversal probability

$$p_{ij} = \begin{cases} F_j\left(w_i^U\right) - F_j\left(w_i^L\right) \; if \;\; I(w_i) \subseteq I(w_j), \\ F_i\left(w_j^U\right) - F_i\left(w_j^L\right) \; if \;\; I(w_j) \subseteq I(w_i). \end{cases}$$



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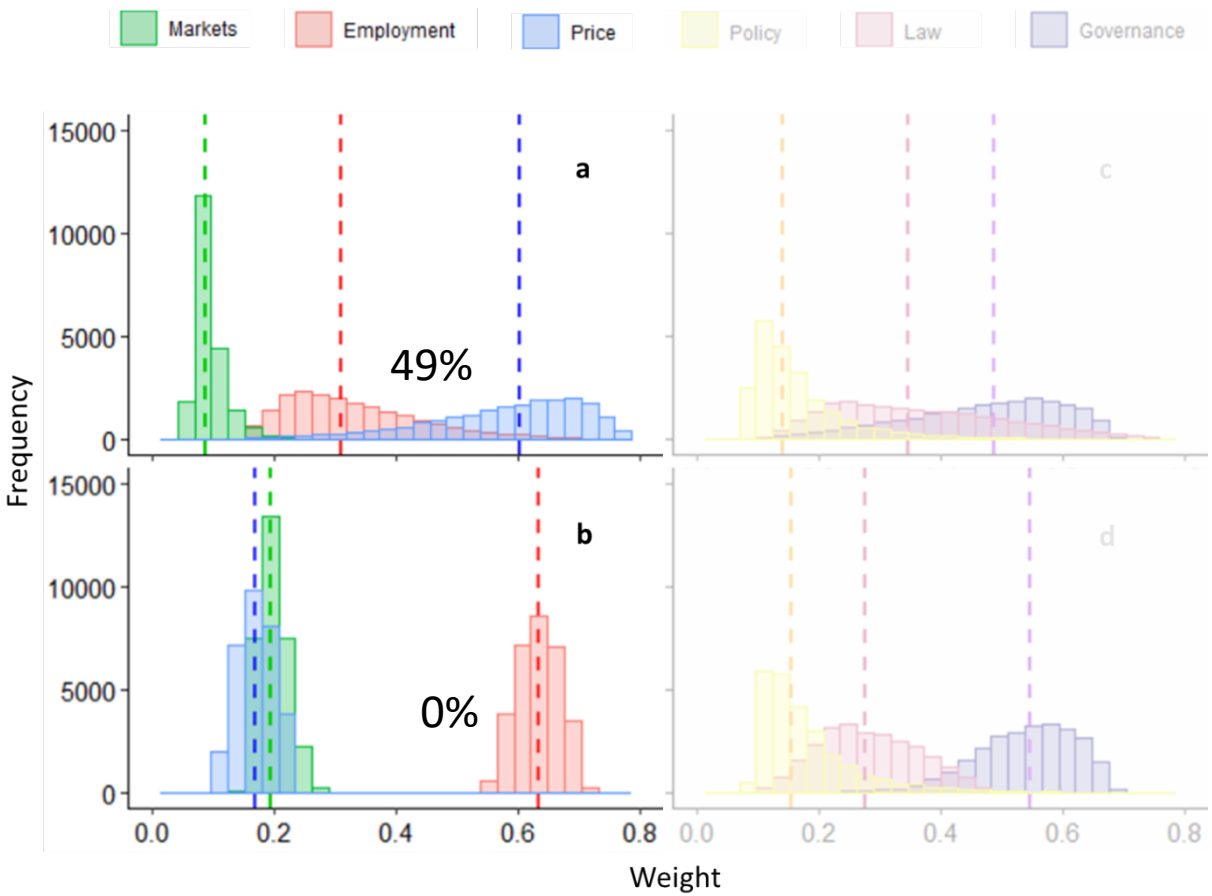
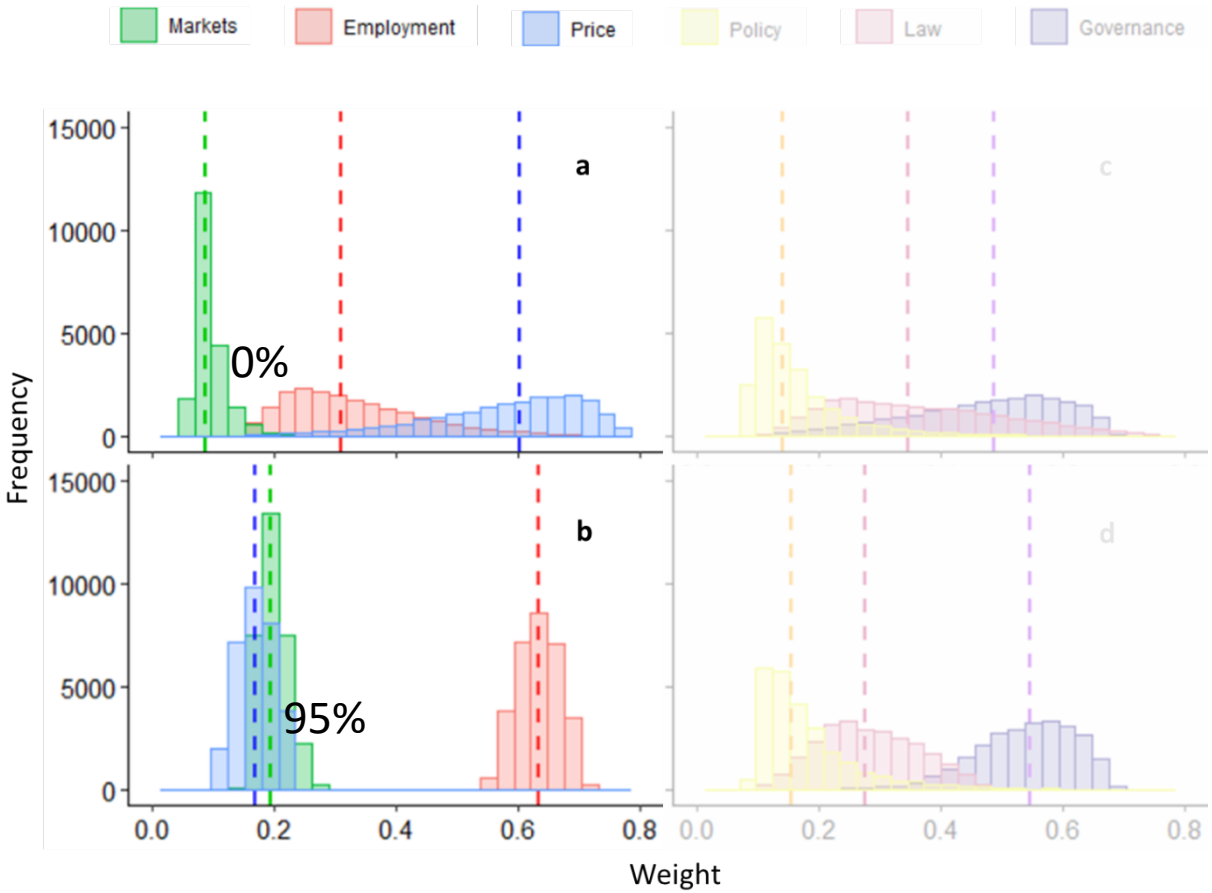

Markets
Employment
Price
Policy
Law
Governance
a
b
c
d
49%
0%
Frequency
Weight
15000
10000
5000
0
0.0
0.2
0.4
0.6
0.8


Markets
Employment
Price
Policy
Law
Governance
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c
d
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Frequency
Weight
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10000
5000
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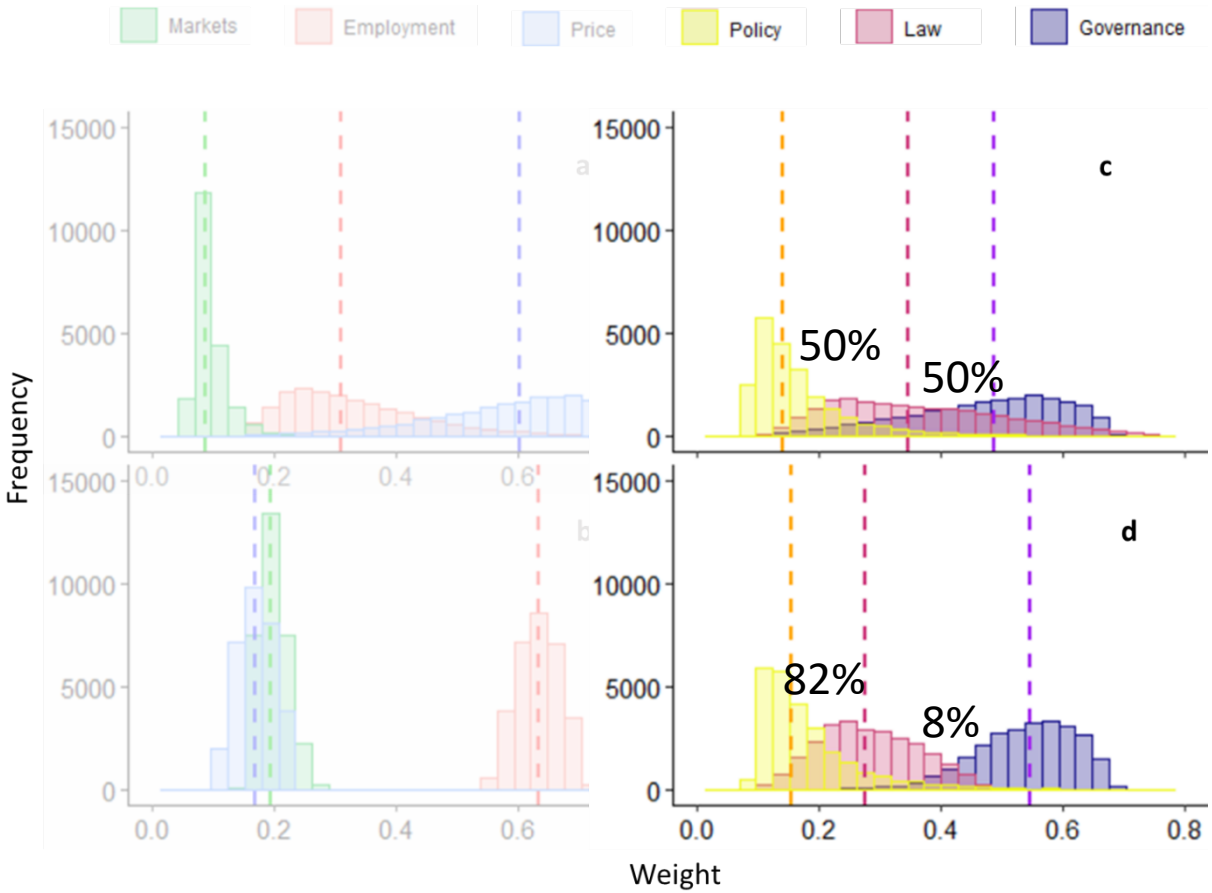
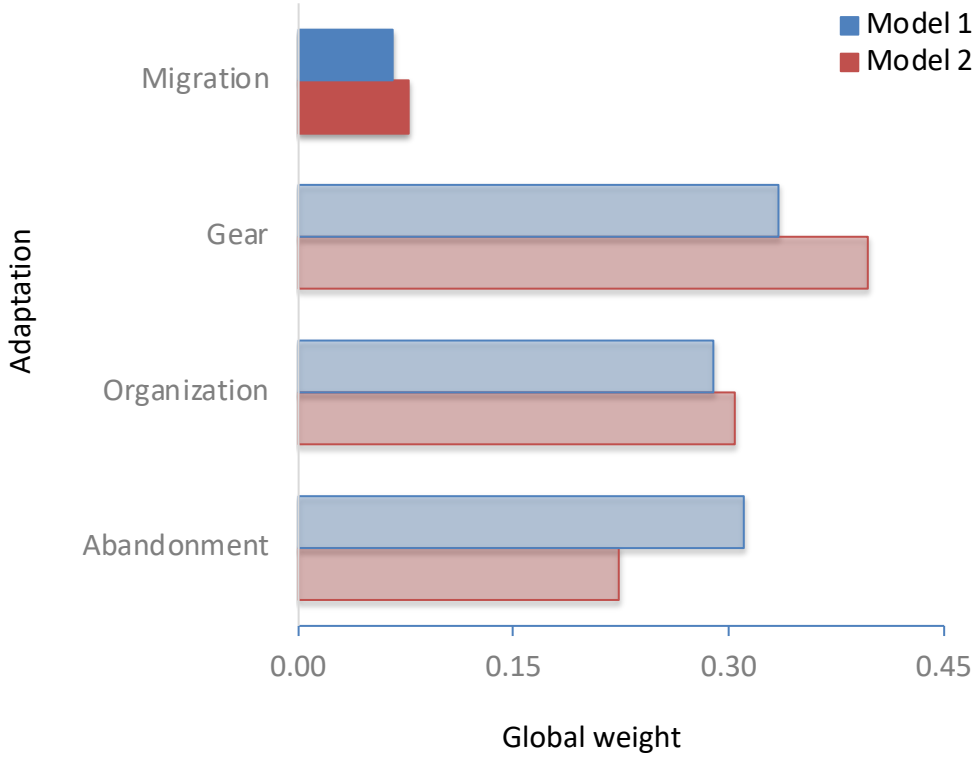
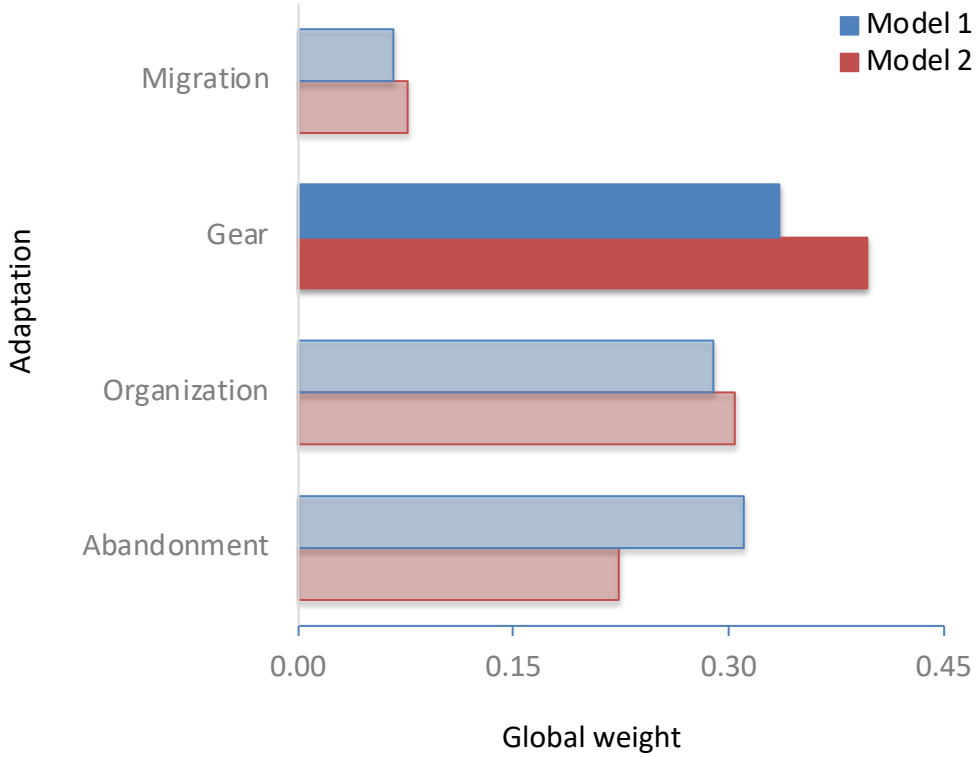
0.2
0.4
0.6
0.8


Markets
Employment
Price
Policy
Law
Governance
Frequency
Weight
a
b
c
d
50%
50%
82%
8%
15000
10000
5000
0
0.0
0.2
0.4
0.6
0.8

Aggregated results


Model 1
Model 2
Migration
Gear
Organization
Abandonment
Adaptation
0.00
0.15
0.30
0.45
Global weight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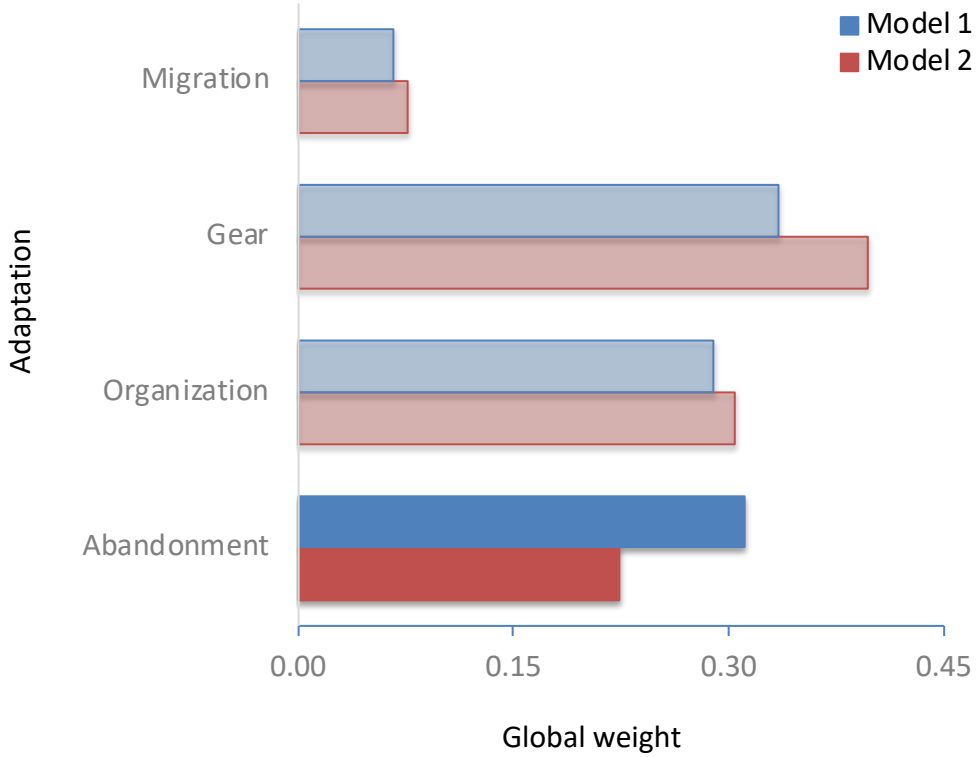
Model 1
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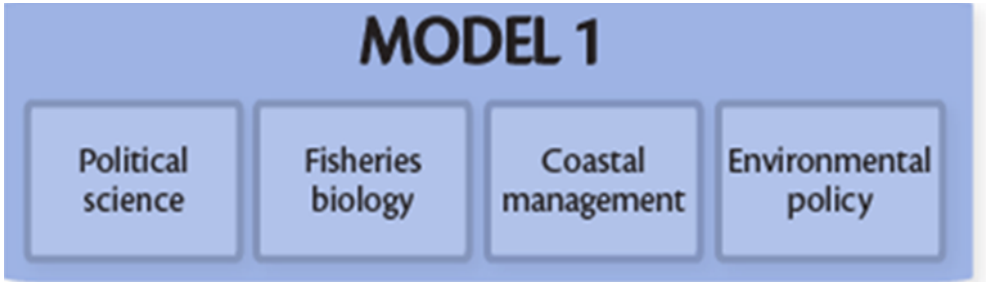
0.30
0.45
Global weight

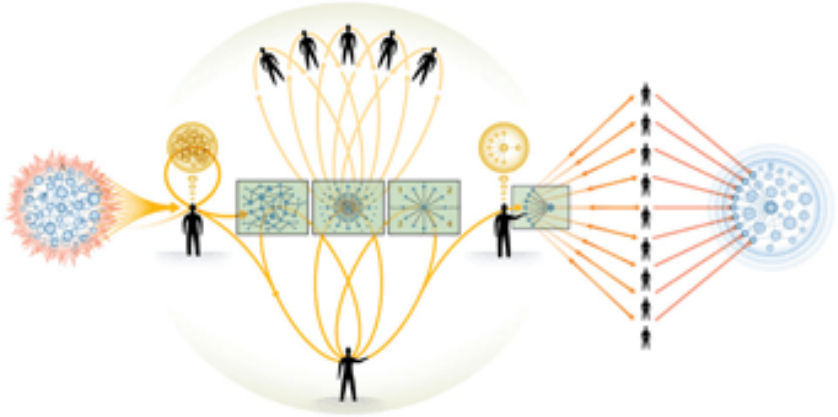
Implications

UNDERESTIMATION



Conclusions

Rigorous
Transparent



Images taken from https://www.lifehack.org/articles/communication/the-art-of-complex-problem-solving.html; and https://securityintelligence.com/six-month-old-vulnerability-exploit-attempt/

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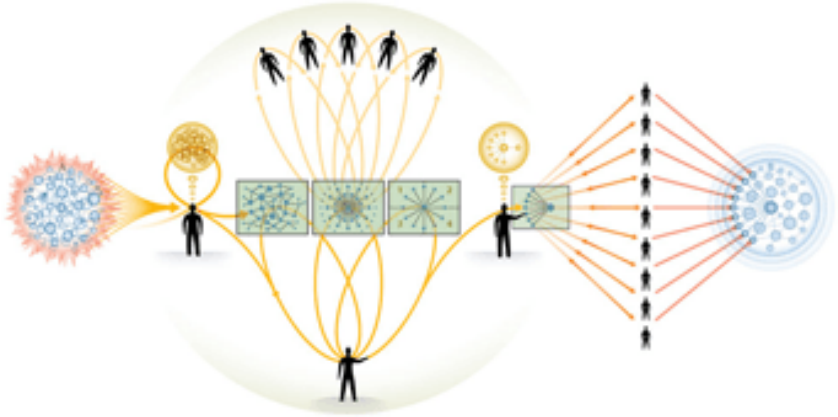
Transparent



BEST SVI

Image taken from https://www.lifehack.org/articles/communication/the-art-of-complex-problem-solving.html

THANK YOU.

References

Eakin, H., Bojórquez-Tapia, L. A., Monterde, R., Castellanos, E., & Haggar, J. (2011). Adaptive Capacity and Social-Environmental Change: Theoretical and Operational Modeling of Smallholder Coffee Systems Response in Mesoamerican Pacific Rim. Environmental Management, 47(3), 352-367.

Ivanco, M.L. (2015). Development of analytical sensitivity analysis for AHP applications. [Master of Science thesis, Old Dominion University].

Ivanco, M., Hou, G., & Michaeli, J. (2017). Sensitivity analysis method to address user disparities in the analytic hierarchy process. Expert Systems with Applications, 90, 111-126.

Saaty, T., & Vargas, L. (1987). Uncertainty and rank order in the analytic hierarchy process. European Journal of Operational Research, 32, 107-117.

Tate, E. (2013). Uncertainty Analysis for a Social Vulnerability Index. Annals of the Association of American Geographers, 103(3), 526-543.