Scandinavian SD – The SAFE Way

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Fuzzy Logic to cure the ill-defined concept of SD in Scandinavia
Fuzzy Logic to accurately measure SD.

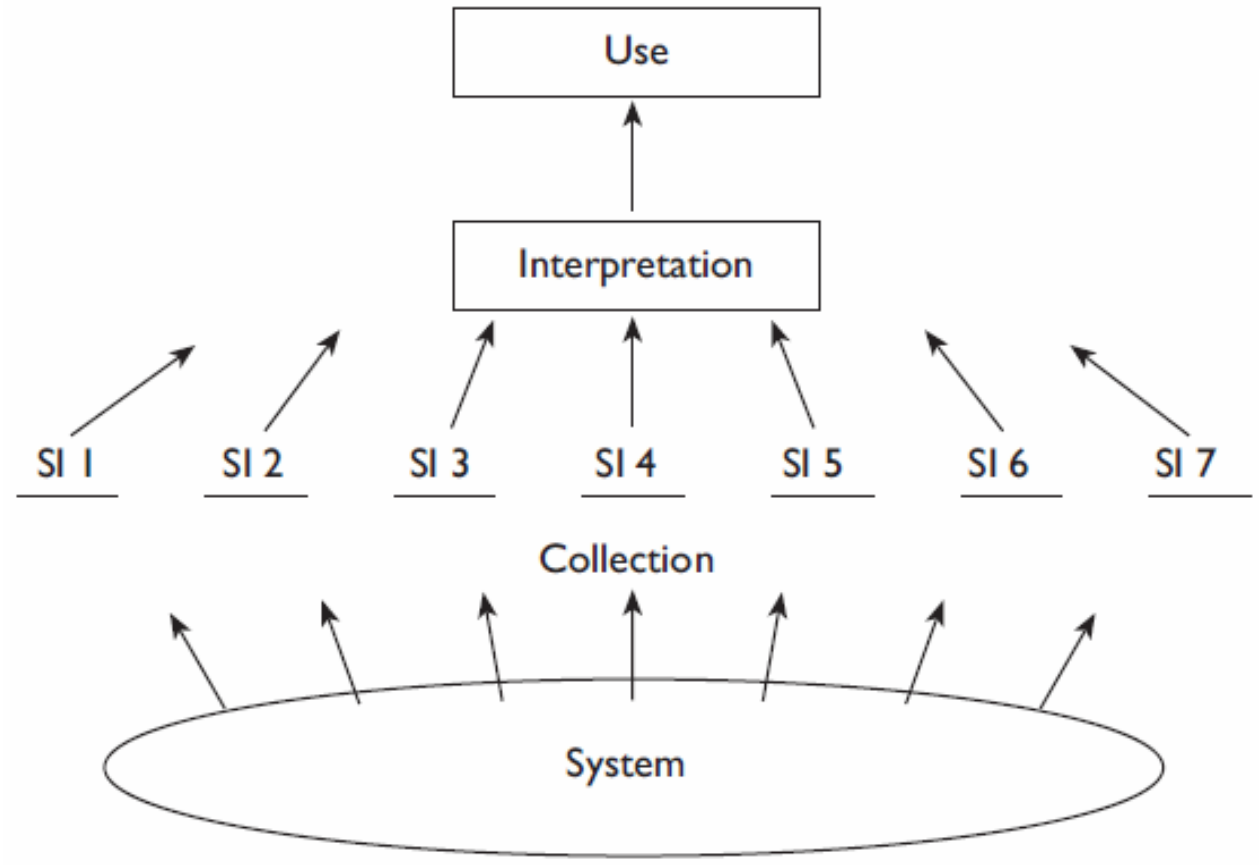
Agenda

1) Preamble
2) Sustainability Indicators
3) Why Fuzzy Logic?
4) The SAFE Model
5) Assessment Results
6) Sensitivity Analysis
7) Most Important Basic Indicators For Scandinavia

Preamble

Before: SD was not an issue - human actions were not a hazard.
Now: Humans have already exceeded the Earth's capacity to regenerate.
Thus we ask, how sustainable is our way of living?
To answer that, we need definitions, methods and indicators to assess SD.
Then comes this study...

Sustainability Indicators

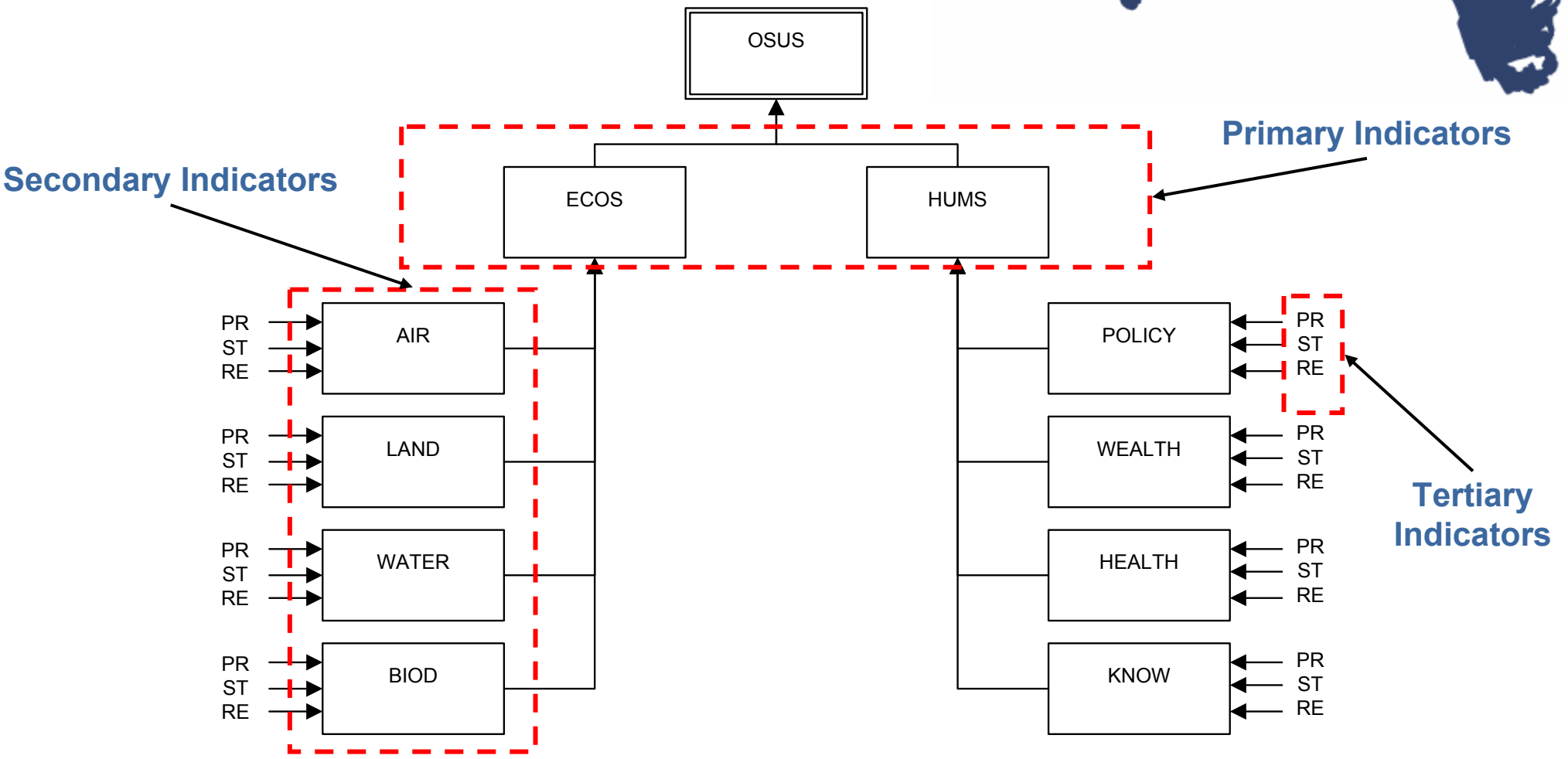


S. Bell and S. Morse, Sustainability Indicators: Measuring the Immeasurable?

Why Fuzzy Logic?

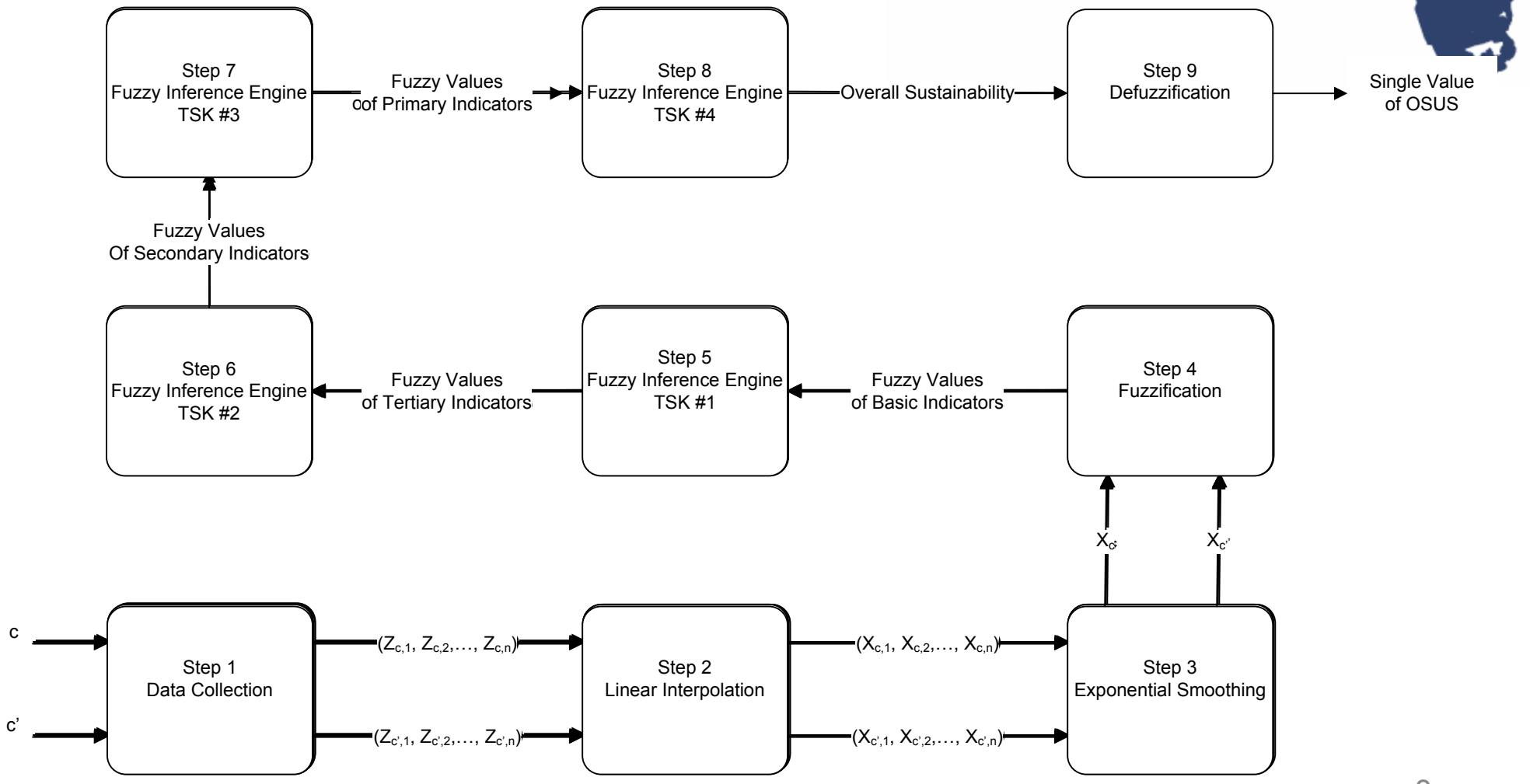
Sustainability is a composition of functions of several eco-variables.
Deterministic evaluation of these functions is not possible because sustainability is inherently a blurred concept.
Fuzzy Evaluation is applicable.

The SAFE Model



Y. Phillis and L. Andriantiatsaholiniaina, "Sustainability: an ill-defined concept and its assessment using fuzzy logic"

The SAFE Configuration



Linear Interpolation

value of c

Z_c minimum

normalized value of c

$$X_c = \begin{cases} 0 & Z_c \le v_c \\ \dfrac{Z_c - v_c}{\tau_c - v_c} & v_c < Z_c < \tau_c \\ 1 & \tau_c \le Z_c \le T_c \\ \dfrac{U_c - Z_c}{U_c - T_c} & T_c < Z_c < U_c \\ 0 & Z_c \ge U_c \end{cases}$$

Z_c maximum

[τ_c, T_c] equally desirable values of c

Linear Interpolation

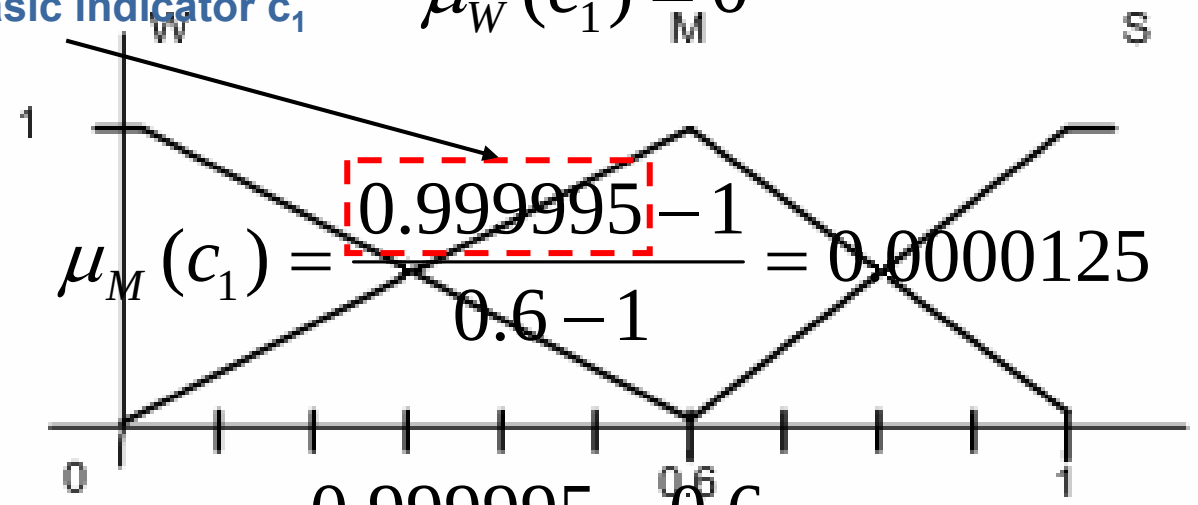
Basic Indicator	c_1 = Consumption of Ozone Depleting Substances (ODSs)		c2 = Greenhouse Gas (GHG) emissions per capita	
Target Value	$T_{c1} = 0$		$T_{c2} = 0.0000079$	
Least Desirable Value	$U_{c1} = 1.1301$		$U_{c2} = 0.0000262$	
Year	Original Value Z_{c1}	Normalized Value X_{c1}	Original Value Z_{c2}	Normalized Value X_{c2}
1990	0.000517	0.999542	0.0000117	0.792349
1991	0.000341	0.999698	0.0000111	0.825136
1992	0.000197	0.999825	0.0000107	0.846994
1993	0.000128	0.999886	0.0000111	0.825136
1994	0.000617	0.999454	0.0000115	0.803278
1995	0.000021	0.999981	0.0000114	0.808743
1996	0.000016	0.999985	0.0000120	0.775956
1997	0.000015	0.999986	0.0000119	0.781420
1998	0.000011	0.999990	0.0000119	0.781420
1999	0.00000033	0.999999	0.0000120	0.775956
2000	0.00000407	0.999996	0.0000118	0.786885

over [0, 1] → facilitates comparison

Fuzzification

exponentially smoothed value of the basic indicator c_1

$$\mu_W(c_1) = 0$$



$$\mu_M(c_1) = \frac{0.999995 - 1}{0.6 - 1} = 0.0000125$$

$$\mu_S(c_1) = \frac{0.999995 - 0.6}{1 - 0.6} = 0.9999875$$

Assessment Results

Country	ECOS	HUMS	OSUS
Sweden	0.7400	0.9370	0.8431
Finland	0.7412	0.9105	0.8301
Denmark	0.7458	0.8871	0.8145
Norway	0.7477	0.8752	0.8042

Sensitivity Analysis

1) Gauge OSUS.
2) Randomly choose a basic indicator, perturb its normalized value by a chosen amount.
3) Re-gauge OSUS.
4) Gauge OSUS gradient $\Delta = OSUS_{new} - OSUS_{old}$.
5) Repeat steps 2, 3 and 4 with all basic indicators.
6) Maximum gradient $\leftrightarrow$ the most important basic indicator.

Most Important Basic Indicators For Scandinavia

Those related to ecology or environment…

- Renewable energy production.
- Greenhouse gas emissions.
- Forest change.

Thank you!