What is a Critical Material?

Thomas E. Graedel
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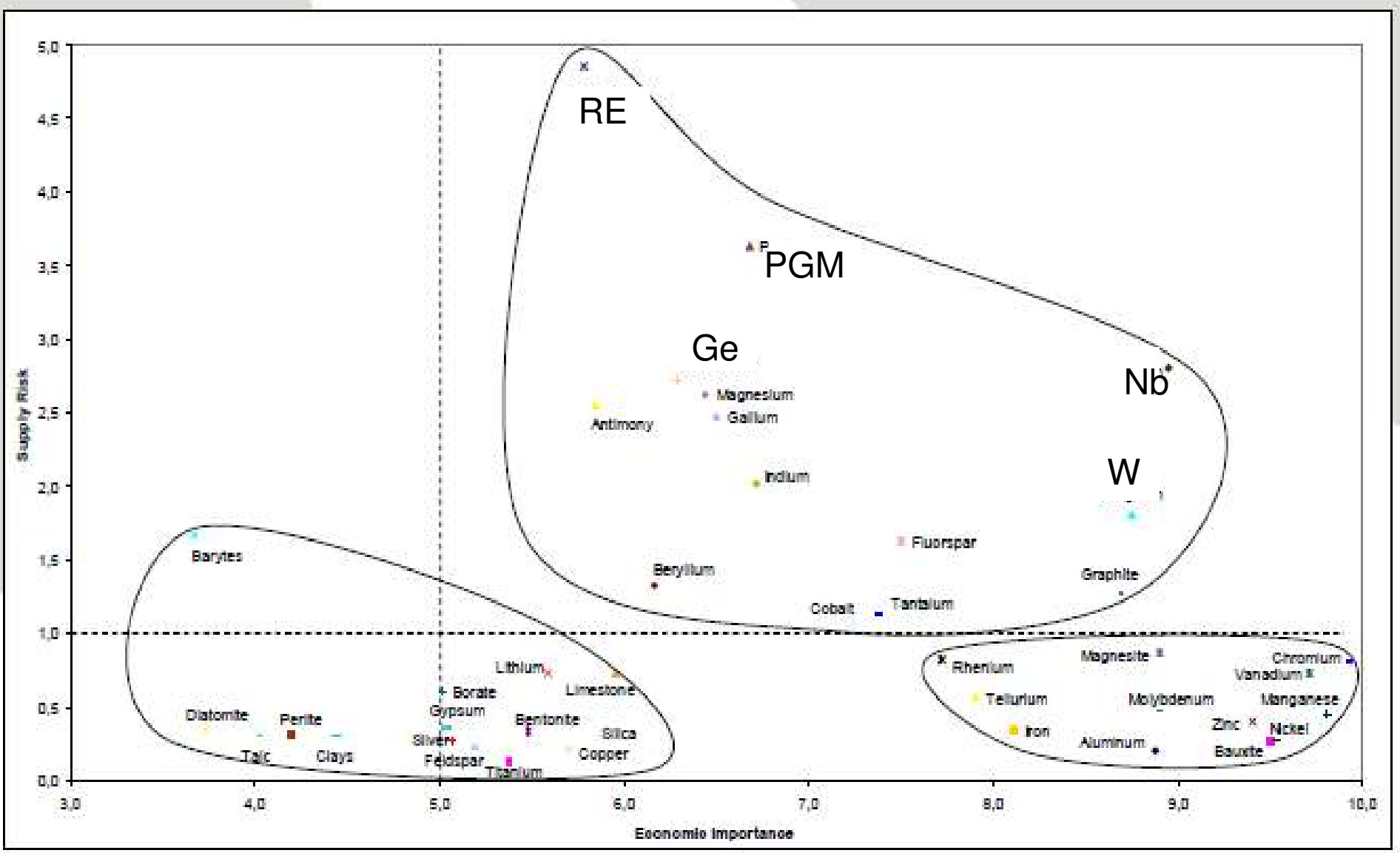
May 22, 2012

The European Commission Criticality Assessment, 2010



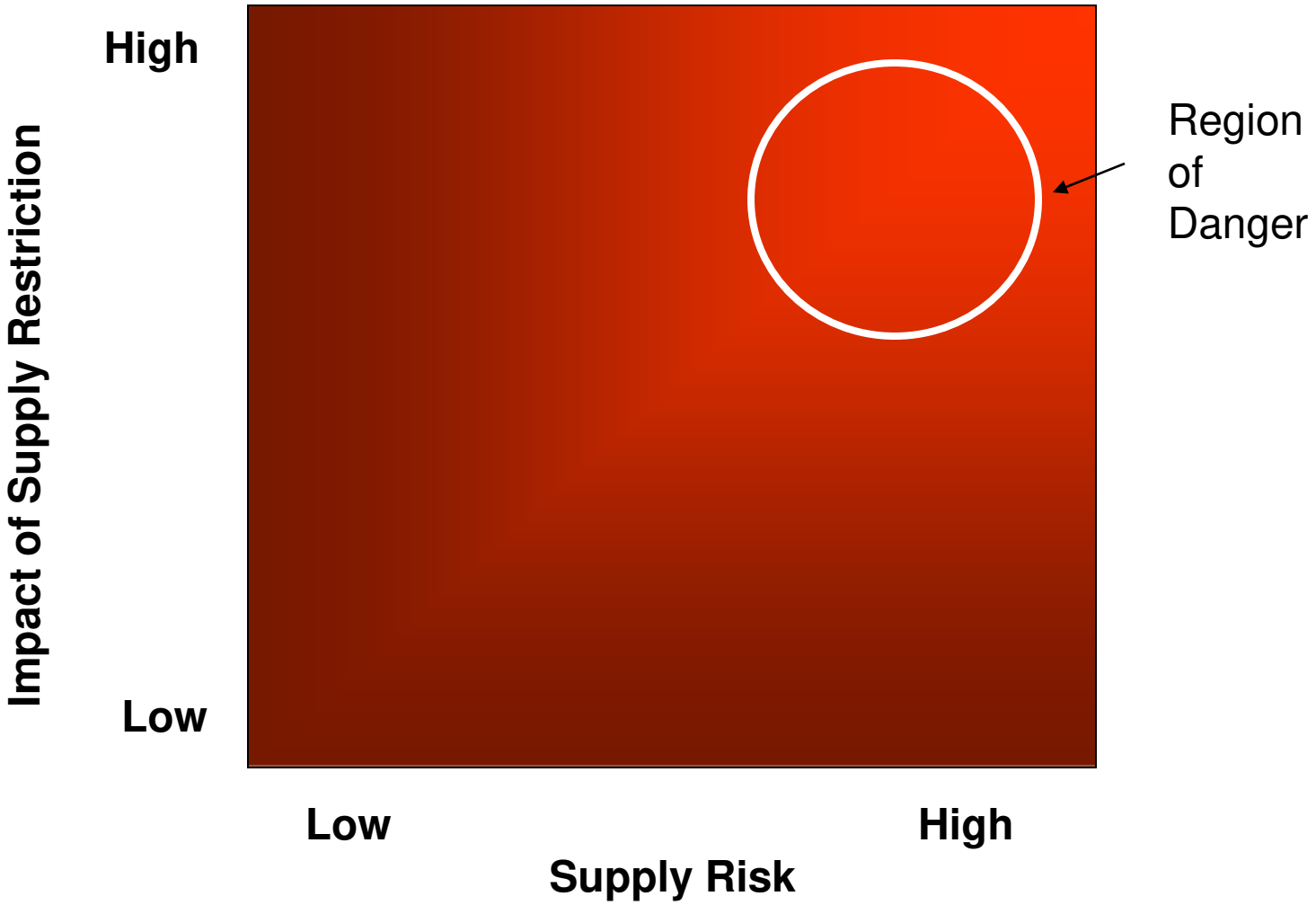
Random Results in Criticality Assessment

	EC	IDA	IW	NEDO	NRC	Oakd. Hollins	South Korea
Cu	No	No	Maybe	--	No	No	--
As	--	--	--	--	--	No	--
Se	--	--	Yes	No	--		No
Ag	No	No	Maybe	--	--	No	--
Te	No	No	--	No	--	Yes	No
Au	--	--	Maybe	--	--	No	--

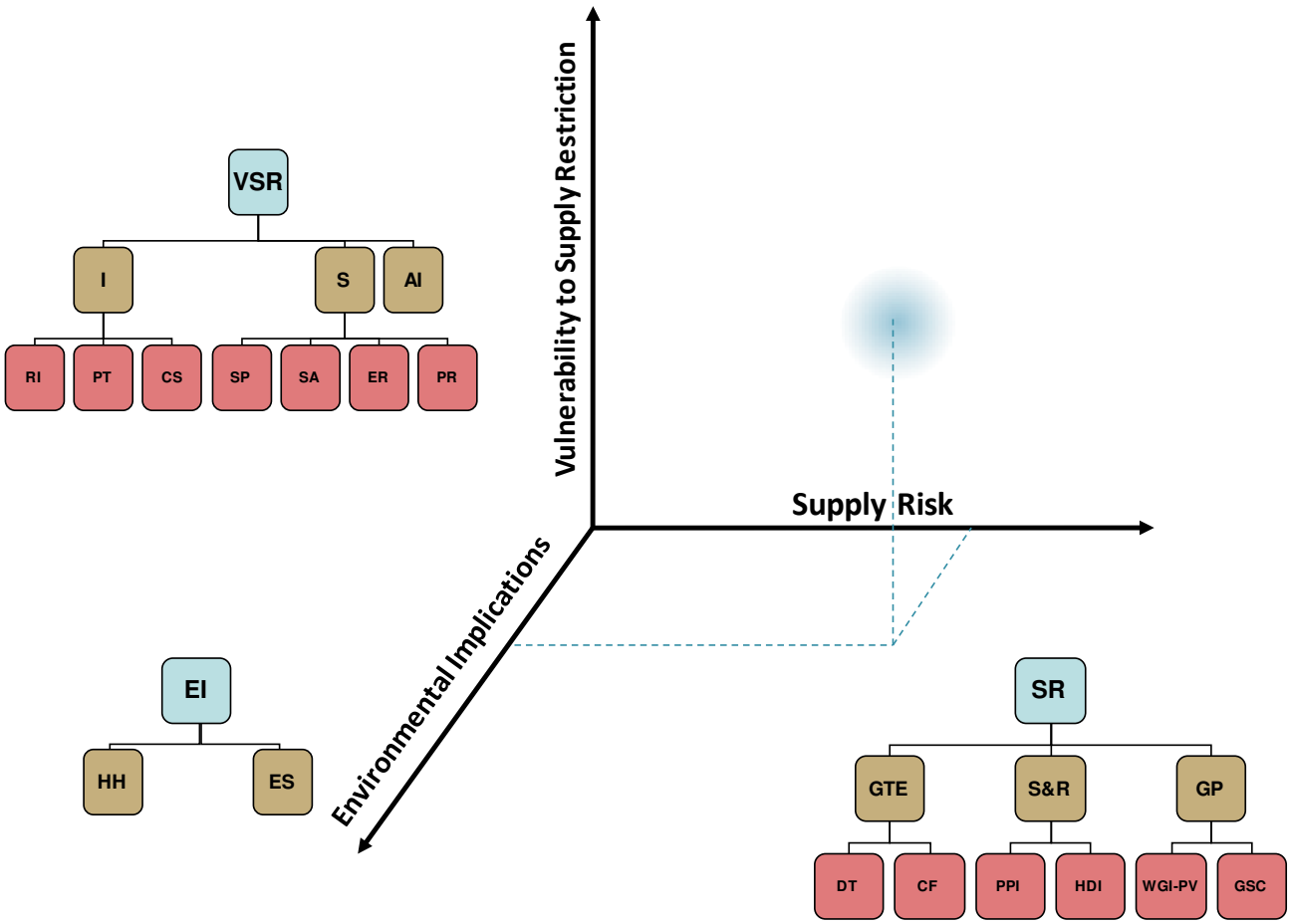
The Yale Approach

to Criticality

The Criticality Matrix and the "Region of Danger"

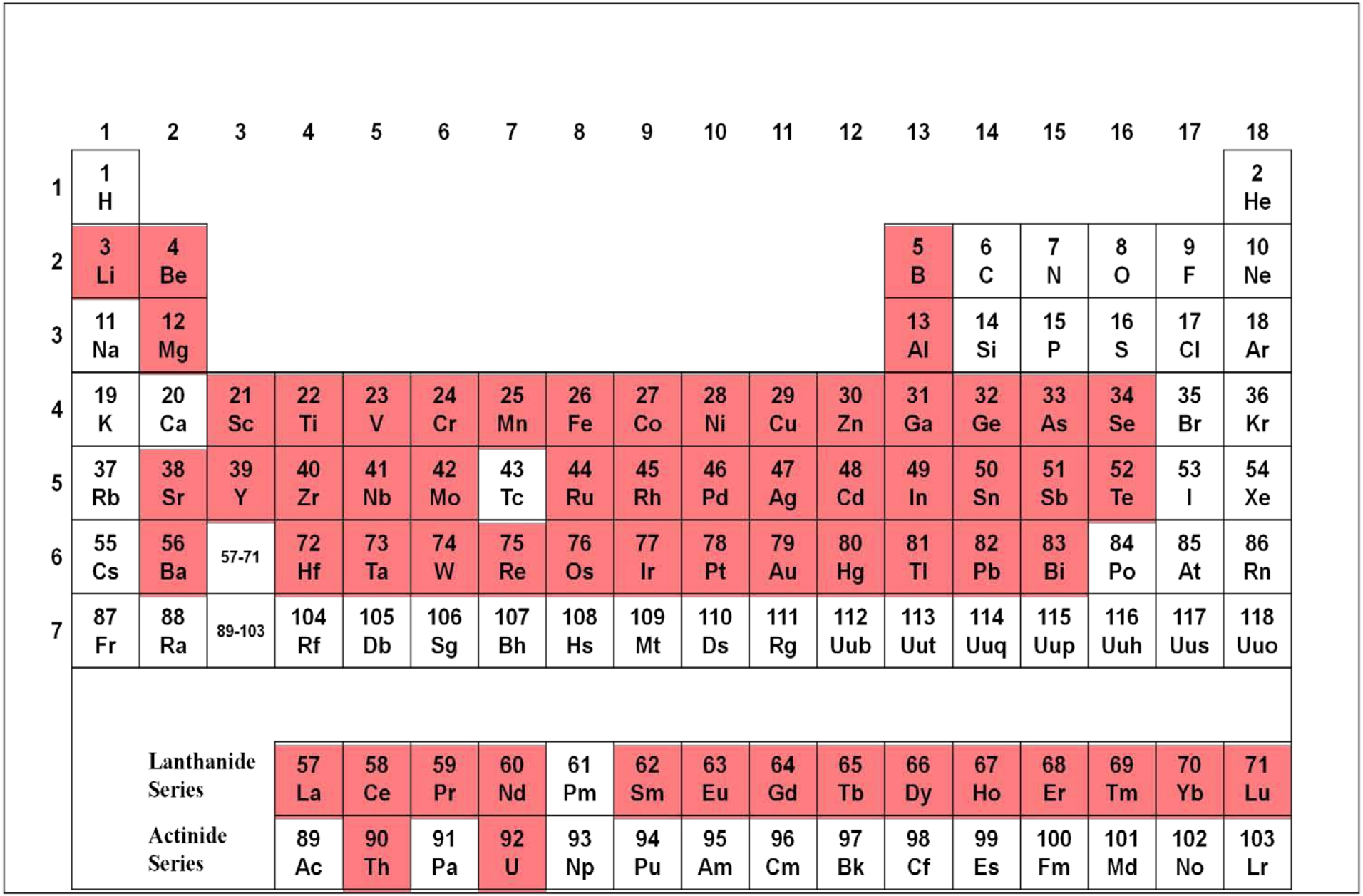


The Three-Axis Criticality Evaluation Concept

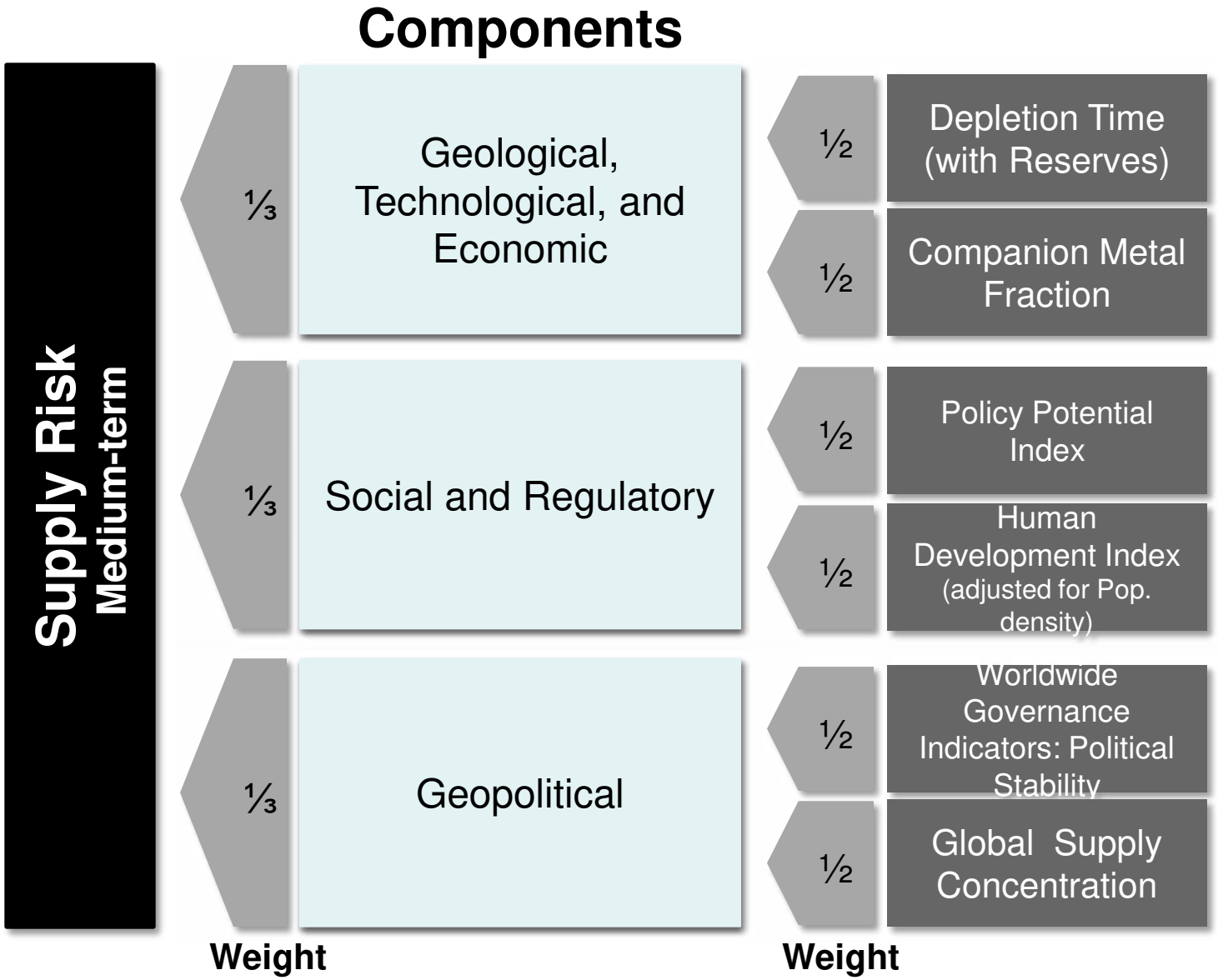


T. Graedel et al., *Env. Sci. Technol., 46,* 1063-1070, 2012.

Elements to be Analyzed in the Criticality Project



Supply Risk Axis – Corporate and National

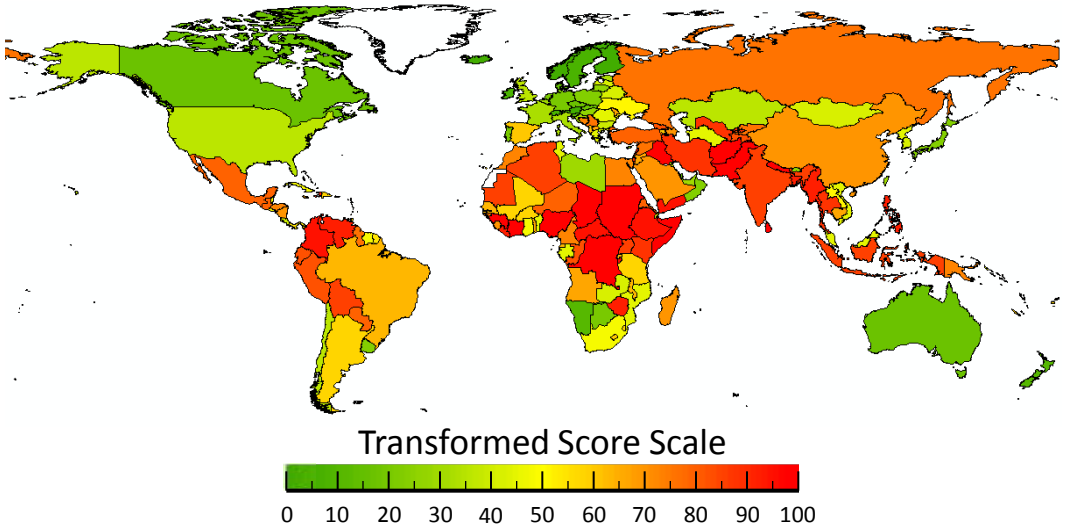


Politically unstable nations pose a higher risk of supply restriction

World Bank – WGI

- Measures perceptions of the likelihood that a government will be destabilized or overthrown by unconstitutional or violent means
- Encompasses social, economic, and political factors associated with underlying vulnerability and economic distress

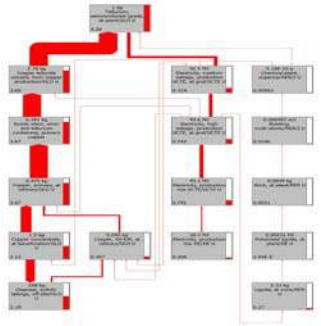
2008 Worldwide Governance Indicators – Political Stability & Absence of Violence/Terrorism



$$WGI\_PV_j^{Trans.} = 100 - WGI\_PV_j$$

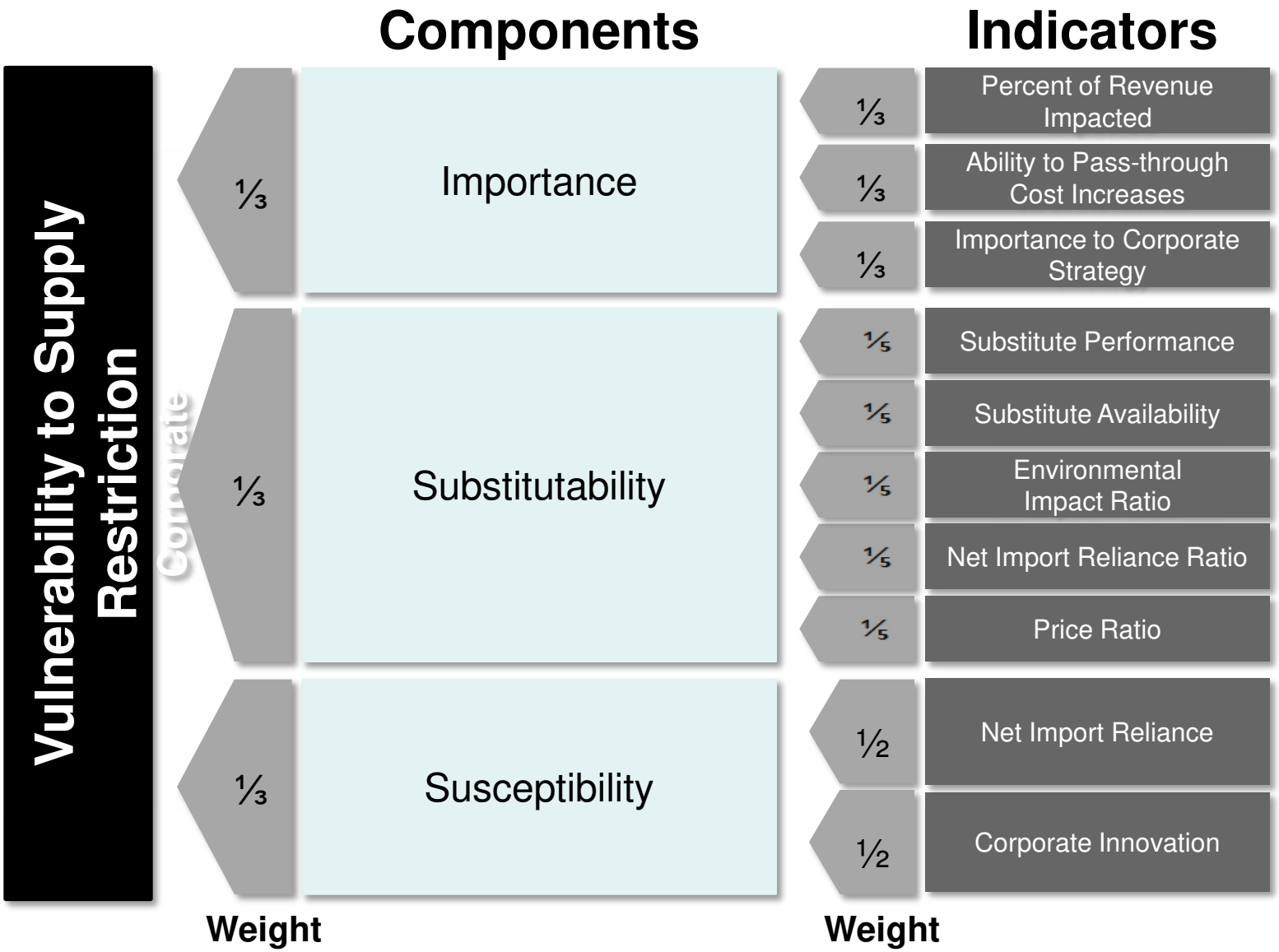
$$WGI\_PV_i = \sum w_{i,j} \times WGI\_PV_j^{Trans.}$$

Environmental Impact



- Evaluates the potential environmental impact of using a metal in modern society
- Based on Ecoinvent database, ReCiPe (H) Endpoint impact methodology (world average normalization)
- Using the following impact category only:
  - Ecosystems
- Result is a single score for a cradle-to-gate environmental impact assessment

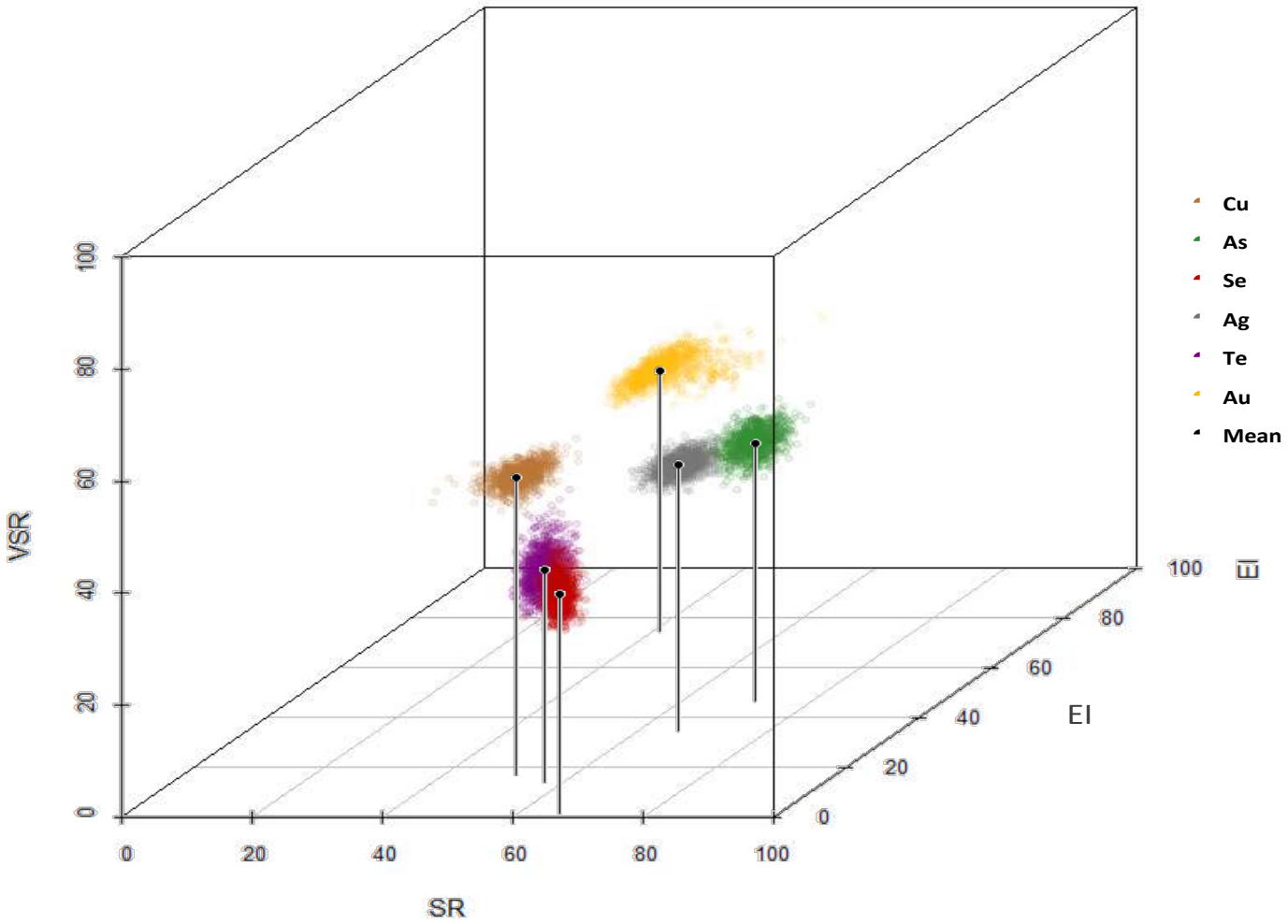
Vulnerability – Corporate Level



A Sampling of

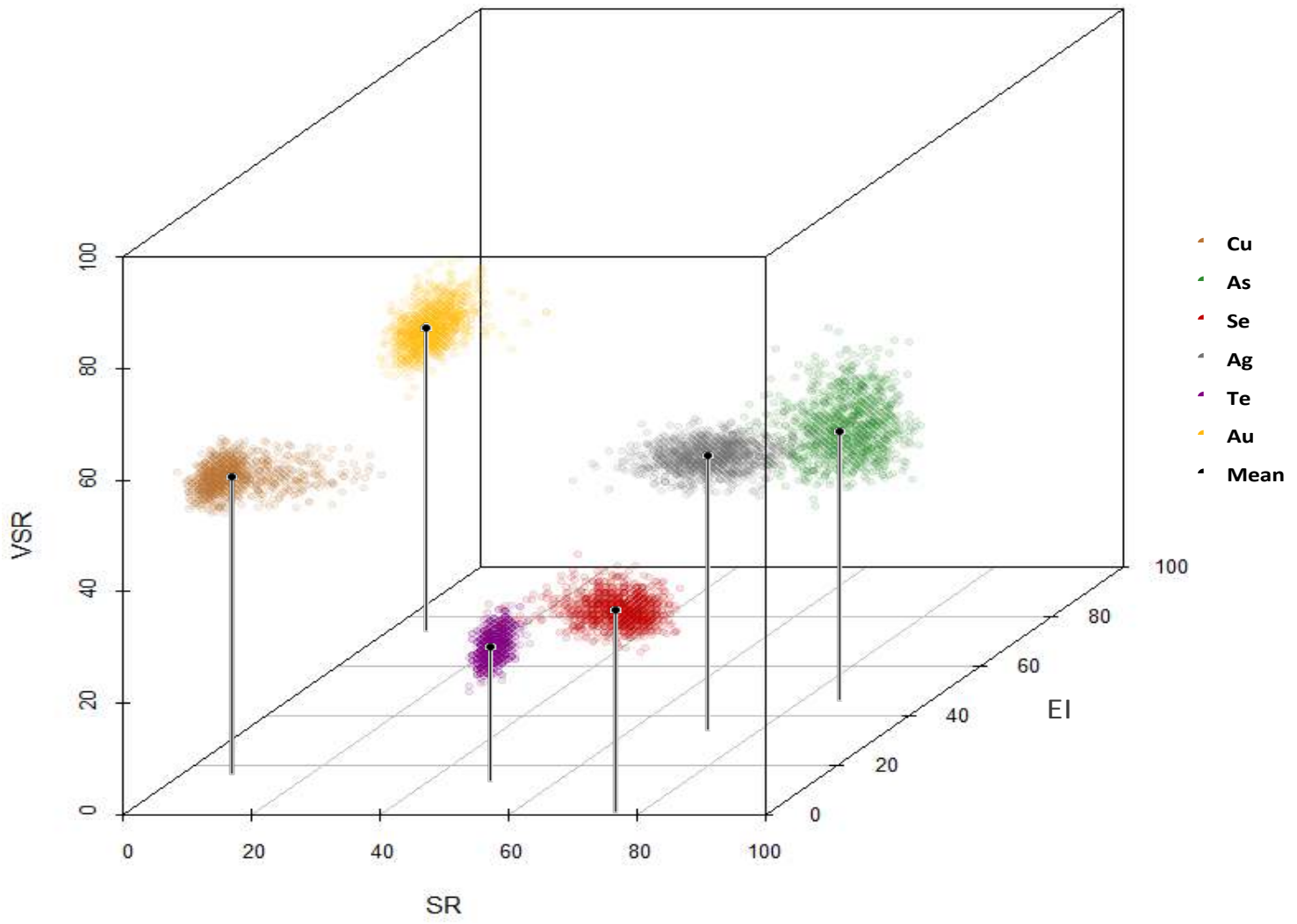
Criticality Results

Copper Family Criticality - US



N. Nassar et al., *Env. Sci. Technol.*, *46*, 1071-1078, 2012

Copper Family Criticality - Global



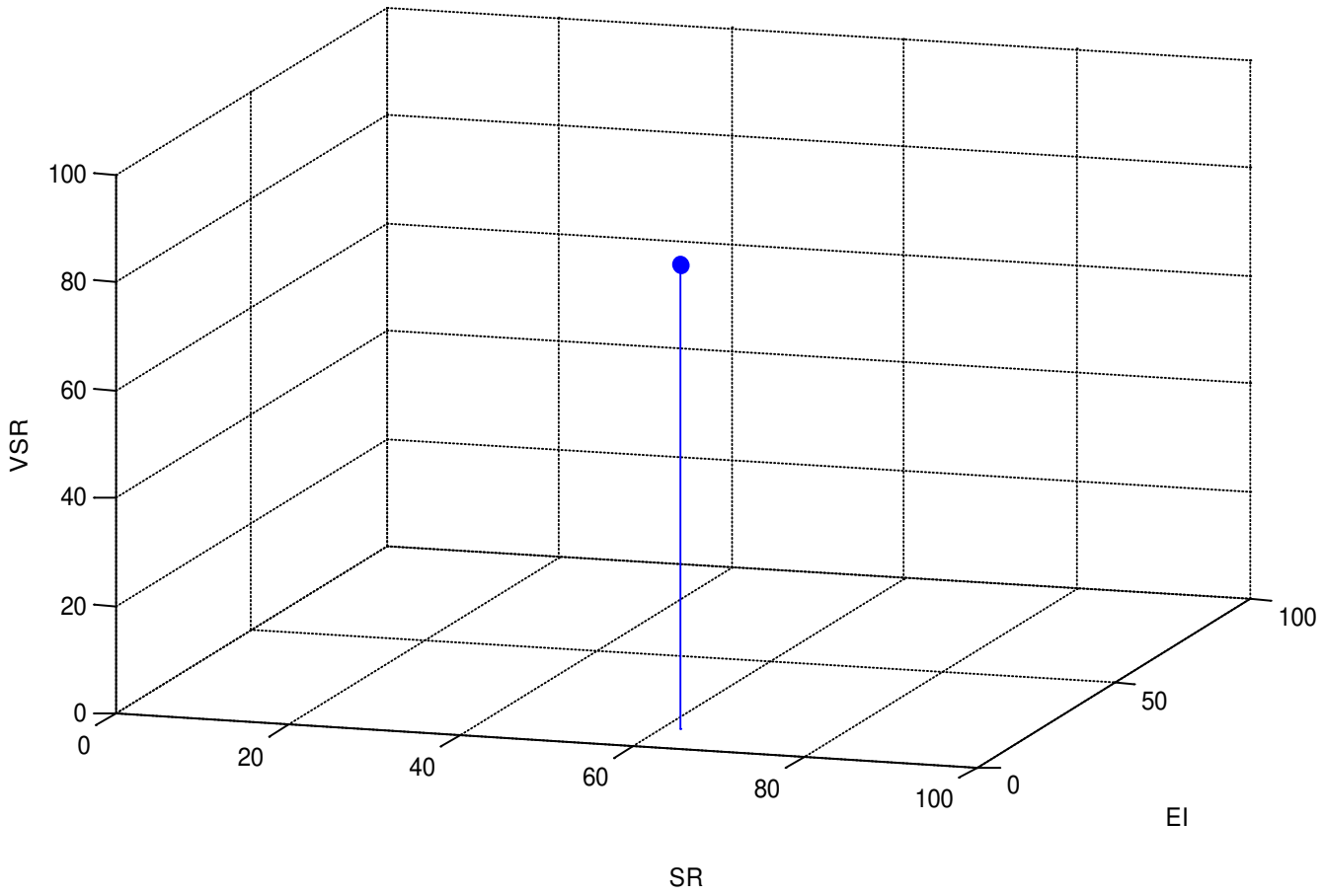
N. Nassar et al., *Env. Sci. Technol.*, *46*, 1071-1078, 2012

A Criticality Analysis for Tin

World Leading Countries in Tin Production

Country	***Mine production (tonnes)***	***% of global total***
China	115,000	44
Indonesia	60,000	23
Peru	38,000	15
Bolivia	16,000	6
Brazil	12,000	5
Total	261,000	100

Tin Criticality : Generic Methodology



Indicator Values

(utilizes generic substitutes for tin uses)

Supply Risk

Geological, Technological, and Economic			Social & Regulatory					Geopolitical					SR_M	SR_M alternative weighting*
DT_M	CF	GTE_M	PPI		HDI		S&R	WGI		GSC		GP		
91	0	46	Tin mining	60	Tin smelting	65	63	Tin mining	76	Tin mining	76	76	**62**	**87**

Vulnera-bility to Supply Restriction

Importance				Substitutability						Susceptibility			VSR_C
RI	PT	CS	I	SP	SA_M	ER	IRR	PR	S	IR	CI	SU	
87.50	62.50	87.50	79.17	43.75	42.23	12.05	62.50	7.00	32.26	100.00	62.5	81.3	59.2

Indicator Values

(assumes no suitable substitutes exist for tin uses)

Supply Risk

Geological, Technological, and Economic			Social & Regulatory					Geopolitical					SR_M	SR_M alternative weighting*
DT_M	CF	GTE_M	PPI		HDI		S&R	WGI		GSC		GP		
91	0	46	Tin mining	60	Tin smelting	65	63	Tin mining	76	Tin mining	76	76	**62**	**87**

Vulnerability to Supply Restriction

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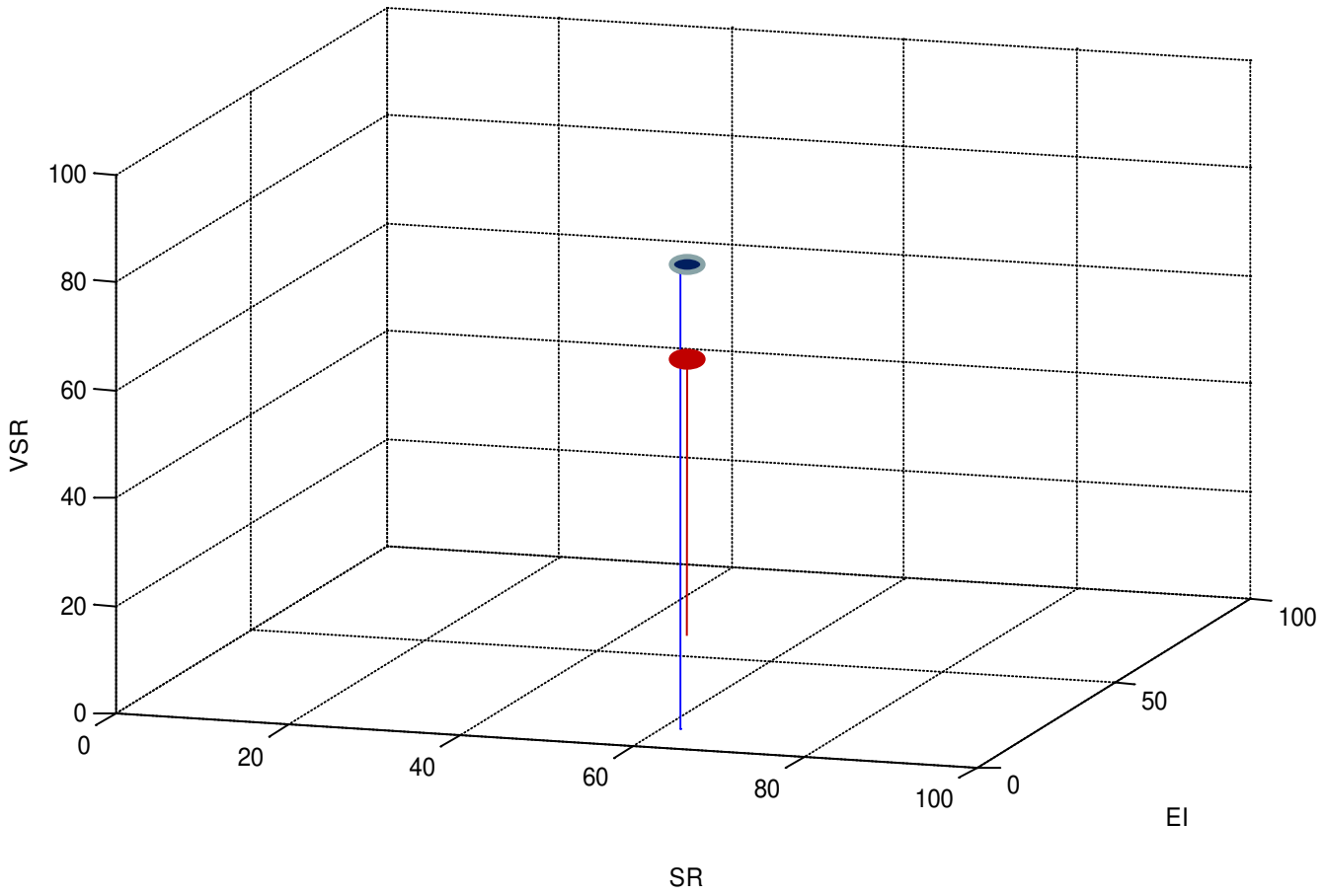
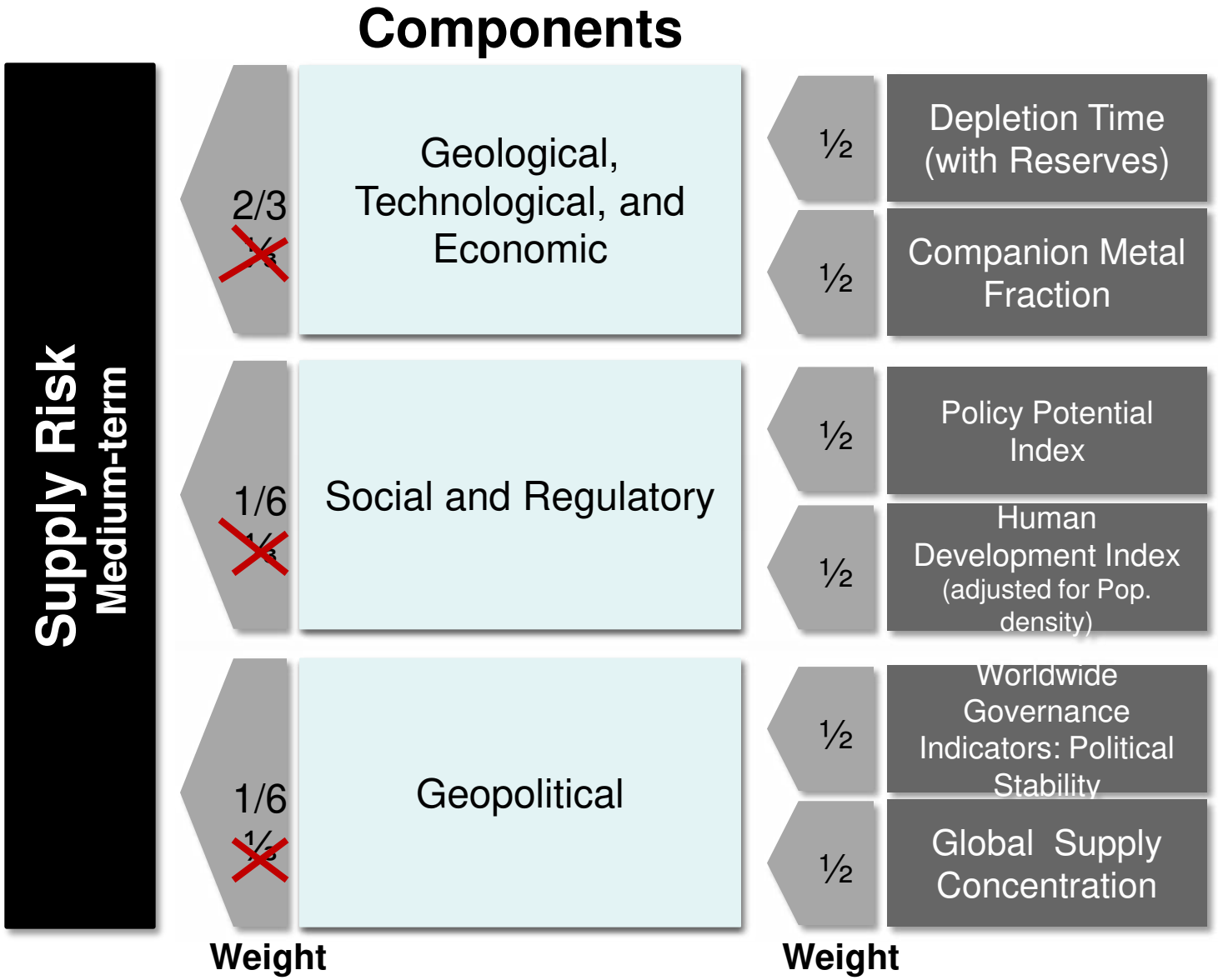
RI	PT	CS	I	SP	SA_M	ER	IRR	PR	S	IR	CI	SU	
87.50	62.50	87.50	79.17	100.00	100.00	100.00	100.00	100.00	100.00	100.0	62.5	81.3	85.8

Tin Criticality as a Function of Substitutability

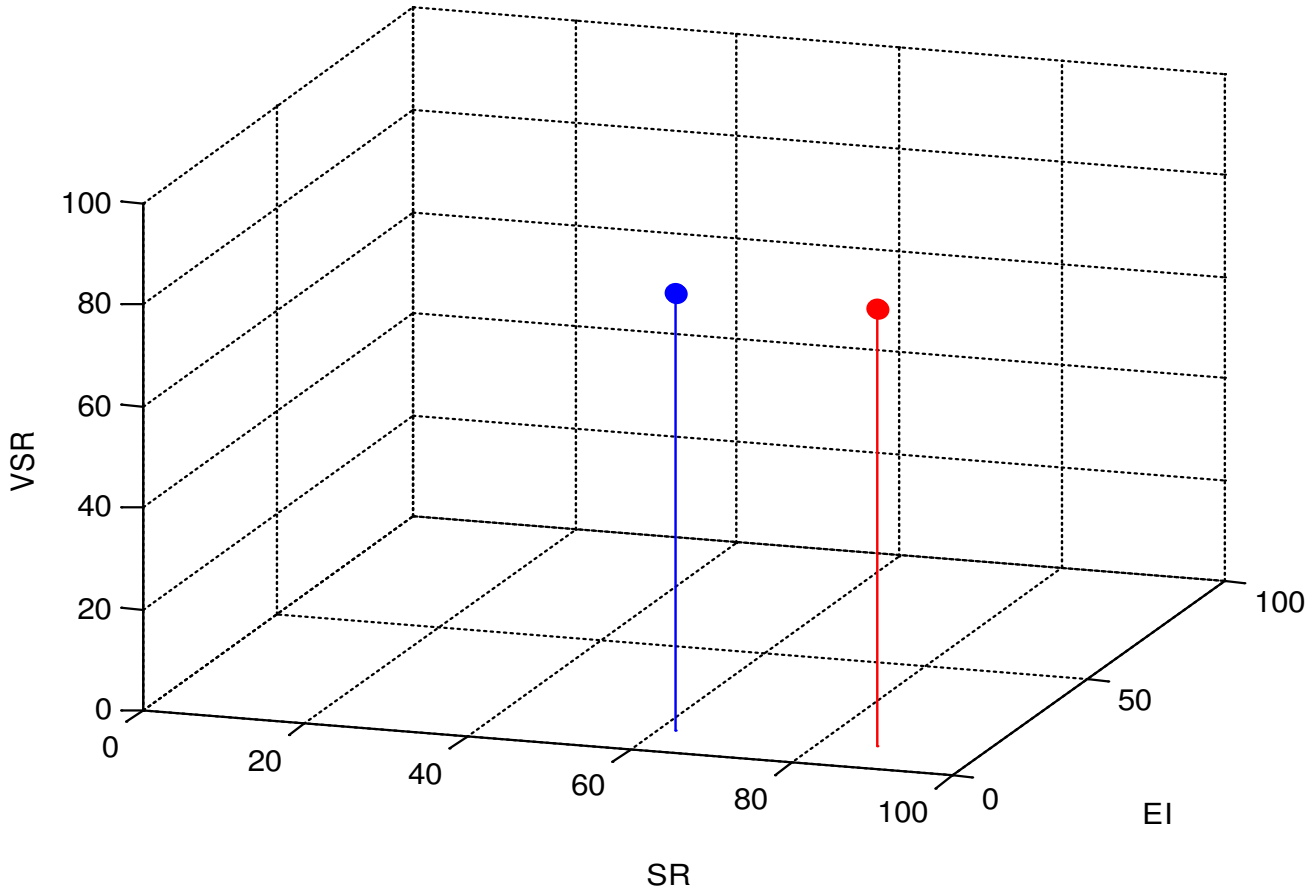


Red: generic substitutes; blue: no suitable substitutes

Supply Risk Axis – Corporate and National

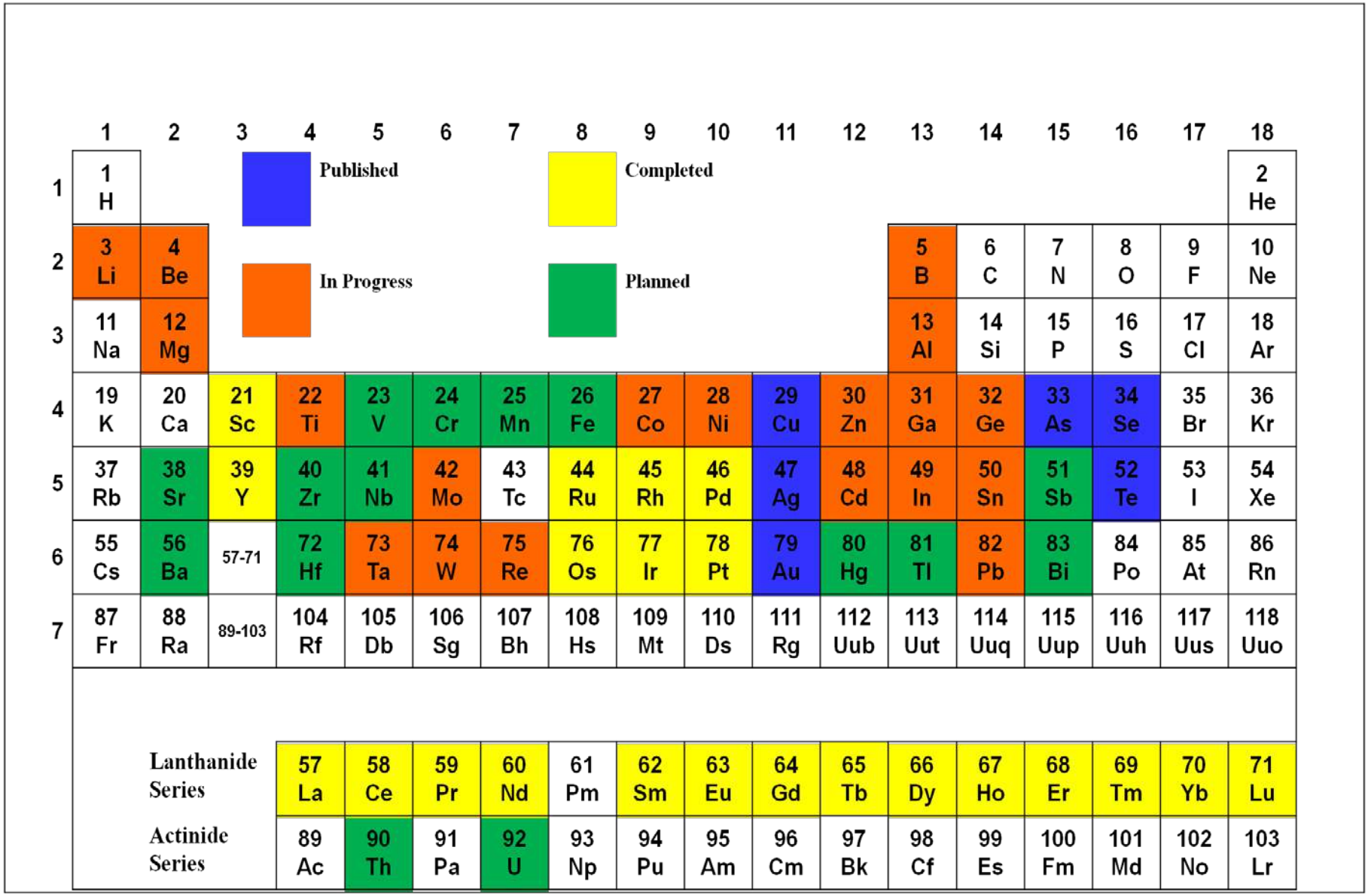


Tin Criticality – Alternative Weighting of Supply Risk Components



Blue: no weighting; Red: weighting GP 2/3, GTE 1/6, SR 1/6

Criticality Project Plan – May, 2012



Evaluating Criticality: A Summary

- What is critical to one organization may not be critical to another, and methodologies must take this into account

- Criticality is best regarded as an attribute of degree rather than as a state, and the important information is *why* a metal's criticality is what it is, not *whether* the metal is "critical" or not

- The Yale comprehensive critical metals assessment will be complete by the end of 2012