

SOME (NECESSARY) FORMALIZATION ON SUSTAINABLE MINING AND INDICATORS OF SUSTAINABILITY FOR THE MINERALS EXTRACTION INDUSTRIES

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A) SUSTAINABLE DEVELOPMENT

A.1. Let

$$R \equiv \bigcup_0^n R_i$$

where

$R \equiv$ is the set of all resources as, for instance:

$R_1 \equiv$ natural resources

$R_2 \equiv$ environmental resources

$R_3 \equiv$ energy resources

$R_4 \equiv$ capital resources

$R_5 \equiv$ human resources

\vdots \vdots

$R_n \equiv$ any resource

and

$R_0 \equiv \phi$, i.e., no resources at all

A.2. Let W be a transform such as

$$W : R \rightarrow D$$

where

$W \equiv$ is the transform work

$D \equiv$ is the set of development stages

and W a surjective function, i.e. it links at least one argument to every possible image.

A. 3. Let:

$$S_i \equiv \bigcup_1^n \{ S_{i_1}, \dots, S_{i_n} \}$$

be the set of development hypothesis where n is the number of subsidiary hypothesis which characterizes S_i respectively to D^*

A.4. Now consider

$$S_d \equiv D \bigcup \{ S_{d_1} \cap S_{d_2} \cap S_{d_3} \cap S_{d_4} \cap S_{d_5} \}$$

where

$S_{d_1} \equiv$ set of minimal use of natural resources

$S_{d_2} \equiv$ set of optimal (or maximal) use of physical flow resources

$S_{d_3} \equiv$ set of minimal use of energy resources

$S_{d_4} \equiv$ set of minimal use of environmental resources

$S_{d_5} \equiv$ set of maximal social satisfaction states**

such as

$$s \in \bigcap S_d \leftrightarrow (\forall S_{d_i} \in S_d, s \in S_{d_i})$$

and S_d is a no empty set

$$S_d \neq \emptyset$$

* observe that $D \neq \bigcup_1^n S_i$, rather, S_i implies the acceptance of D !

** social satisfaction is the degree of societal acceptance of a given policy, or political agenda

A.5. Thus

S_d = set of sustainable development scenarios belonging to D and having as constraints

A.6. Then

$$\bigcap_1^5 S_{d_i}$$

represents the goals and targets of a political agreement*, a political agenda, and setting for the agreed states of sustainable development**.

B) SUSTAINABLE DEVELOPMENT INDICATORS

B.1. Having defined, formally, sustainable development, in order to measure it one needs an indicator or indicators.

B.2. Let define effort (T) as a function, or transform, that attributes a positive number to every productive operation (P) or process.

B.3. Thus

$$T : P \rightarrow \mathbb{R}^+$$

defined by

$$T(p) = r$$

for every $p \in P$ and $r \in \mathbb{R}^+$ and \mathbb{R}^+ is the set of real numbers

* In this regard sustainable development might be regarded as a *Weltanschauung* (meaning a “look onto the world” in German) rather than a full Khunian paradigm shift, i.e., that describes a process and result of a change in basic assumptions within the ruling theory of Science

** which, according Brundtland’s report is the essence of *environmental sustainable development*

B.4. Let define enhancement (E) as the benefit obtained by the person, or firm, x from y - also person, or firm - who performs or allows to perform the productive operation p

B.5. Let:

$$E : X \times Y \times P \rightarrow \mathbb{R}^+$$

such as :

$$E(x, y, p) - E(y, x, p) - T(p)$$

is the measure of agreement (A), indicator of agreement, when the enhancement $E(x, y, p)$ obtained by x from y through p , the disturbance $T(p)$ which the operation p causes to x , and $E(y, x, p)$ the enhancement obtained by y as retribution to x to performs or allows to perform operation p .

Thus:

$$A(x, y, p) = E(x, y, p) - E(y, x, p) - T(p)$$

B.6. If

$$A(x, y, p) = 0$$

it implies a mutual enhancement or benefit for x and y

$$A(x, y, p) < 0$$

$x \in X$, loses

$$A(x, y, p) > 0$$

$y \in Y$, loses.

B.7. for a community or nation or any social group , G , where $X \subset G$ and $Y \subset G$:

$$A(x, y, p) = \sum_{x \in G} E(x, y, p) - \sum_{y \in G} E(y, x, p) - \sum_1^n T(p)$$

where n is the number of productive operations considered involving x and y .

B.8. If

$A(x, y, p)$ is a sustainable indicator , A_s

Then

$$A_s = S_d \cup \{A_1, \dots, A_n\}$$

where

A_i = is the set of agreements obtained under prevailing S_d conditions

C. SUSTAINABLE ORE BODY

C.1. Let :

$$R_{S_i} = R \bigcup_1^5 \{S_d_1, S_d_2, S_d_3, S_d_4, S_d_5\}$$

be the set of sustainable resources

C.2. a sustainable are body (O_s) is such that

$$O_{S_i} = R_{S_i} \cup A_{S_i}$$

$$m \in \bigcap O_{S_i} \leftrightarrow (\forall A_{S_i} \in O_{S_i}, m \in A_{S_i})$$

where m is ore mineral reserve.

D. SUSTAINABLE MINE

D.1. applying the transform **W** :

$$\mathbf{W}: \mathbf{O}_s \rightarrow \mathbf{M}$$

where

M = Sustainable Mine Development