Suggesting a New Scheme of 2nd Order Cybernetics to Integrate the Principle 'Think Globally, Act Locally' for Maximizing Sustainability

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Abstract: - This work deals with the integration of the original environmental Principle 'think globally, act locally' by incorporating its complement stating the inverse motto 'think locally, act globally', within a cyclic scheme (not a tradeoff). Such cyclic schemes, based on feedback loops, are a common characteristic in Cybernetics. Since human intervention is a *condicio sine qua non* for this cyclic integration, we may conclude that the suggested scheme belongs to 2nd order Cybernetics. A methodological framework, under the form of an algorithmic procedure, has been developed to achieve the objective of integration by maximizing system's sustainability. The functionality of certain stages of this procedure is proved through a case example referring to river pollution. A discussion is also presented, based on the interplay between decentralization and centralization, which forms the theoretical background of the integrated Principles.

Key-Words: - 'think globally, act locally', 'think locally, act globally', decentralization, centralization, 2nd order Cybernetics, river pollution

1 Introductory Analysis

The expression 'think globally, act locally' is frequently used as a slogan urging people to consider the health of the entire planet or a global/ total system and to take action in their own localities. The same expression is, also, a Principle in Environmental Management suggesting decentralization as a basic method for sustainable development. Nevertheless, the decentralization degree D should not exceed an optimal value D_{opt} if maximum benefit $B_{max}=(B_1+B_2)_{max}$ is to be achieved, where the partial benefits $B_1(D)$ and $B_2(D)$ represent development of skills/capabilities and coordination achievement, respectively, as functions of D. The former dependent variable, B_1, is an increasing function of D with a decreasing rate (i.e., $dB_1/dD>0$, $d^2B_1/dD^2<0$), because of the validity of the Law of diminishing (differential) returns (LDR). The latter dependent variable, B_2, is a decreasing function of D with a decreasing algebraic or an increasing absolute rate (i.e., $dB_2/dD>0$, $d^2B_2/dD^2<0$ or $d|dB_2/dD|/dD>0$), because of the validity of the LDR, too. Evidently, *Dopt* is the abscissa of the equilibrium point in the tradeoff between B_1 and B_2, where $d(B_1+B_2)/dD=0$, provided that the second order sufficient condition $d^2(B_1+B_2)/dD^2<0$ is confirmed for the D-value found by solving the equation representing the first order necessary condition; in economic terms, $MB_1=MB_2$, where $MB_1=dB_1/dD$ and $MB_2=|dB_2/dD|$ are the marginal benefits, respectively.

By introducing expert systems in order to use case/model/rules based reasoning (CBR, MBR, RBR, respectively), for further support of skills/ capabilities development, the B_1-curve will move upwards to its new position B'_1 becoming also steeper, since the higher difference in B_1-values will appear in the region of higher D-values, where the decline of the original curve is more expressed; as a result, D_{opt} is shifting to D'_{opt}, where $D'_{opt}>D_{opt}$ (Fig.1a). Similarly, by introducing a controlled vocabulary within an ontological scheme/network for further supporting coordination, the B_2-curve will move upwards to its new position B'_2 becoming, also, more flat, since the higher difference in B_2-values will appear in the region of higher D-values, where the need for better coordination is more intense; as a result, D_{opt} is shifting to D''_{opt}, where $D''_{opt}>D_{opt}$ (Fig.1b).

It is worthwhile noting that the vectors $(D'_{opt} - D_{opt})$ and $(D''_{opt} - D_{opt})$ have the same direction, denoting a tendency for increasing decentralization in environmental decision making and subsequent implementation of respective decision. In a similar

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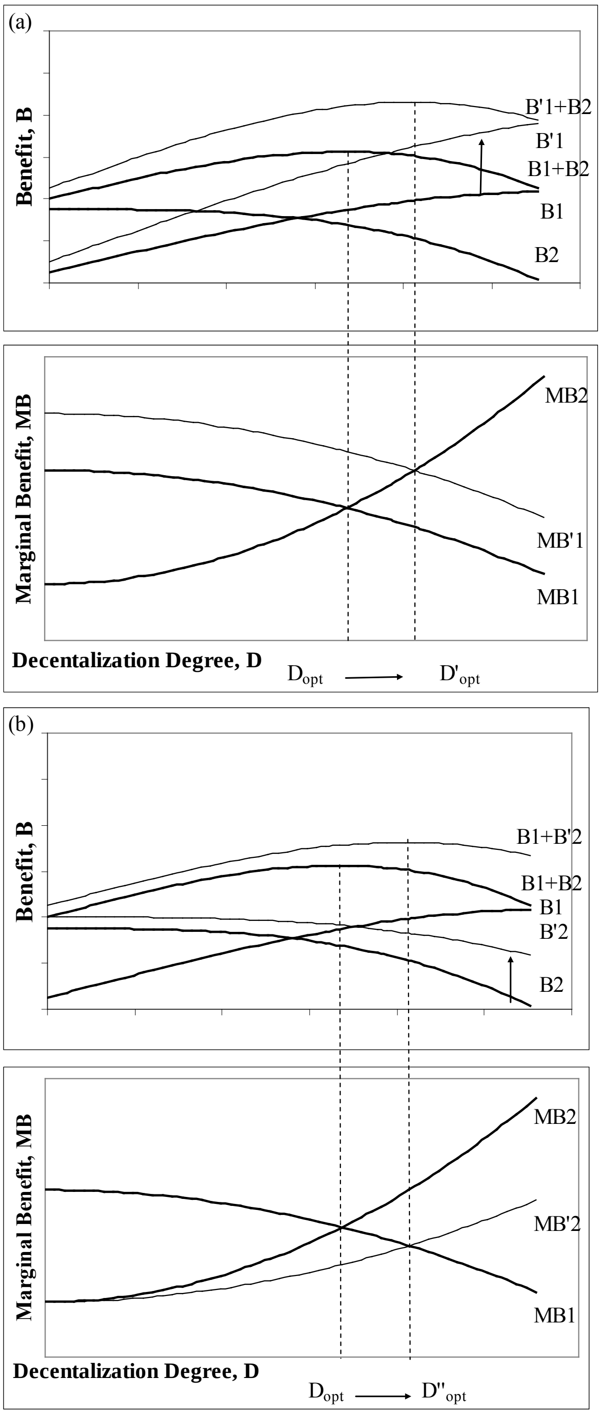

Figure 1. Dependence of partial benefits B_1 and B_2 on decentralization degree *D* and shifting of D_{opt} in case of introducing (a) expert systems in order to use CBR/MBR/RBR methods, and (b) a controlled vocabulary within an ontological scheme/network.

way we can reach an identical conclusion by setting the Centralization Degree *C*, as the independent variable, in order to find C_{opt} (see Fig. 4 in the Discussion section of the present work, where certain other factors are also examined). Therefore, the tendency to decentralization seems to be dominant.

Nevertheless, the continuous increase of decentralization changes the background that is assumed to be constant (known as *ceteris paribus* in Economics) for drawing the curves of Fig. 1. More specifically, the continually increasing demand for higher coordination at lower/ local level may lead to bureaucratic structure change and the need for decision making (including implementation by taking measures) at global/higher level. This means that the system under examination exhibits self-reorganization properties, indicating the possibility to be modeled as cybernetic scheme. Within such a scheme, 'autopoiesis' (a cybernetic term, coined by Maturana and Varela [1], to denote 'self-production' or 'self-organization', in accordance with its meaning in the Greek language that provided the original word) is the key to understand the transition from a decentralized scene to a new centralized system where decentralization begins again, after some time, following a cyclic process. This process, which is a main characteristic of most cybernetic schemes that include positive feedback loops, converts the Principle under consideration into its complementary 'think locally, act globally' and thereafter *vice versa*. Since 'autopoiesis' does not take place automatically but with human intervention, independent of whether the human factor is the modeler of the system or a user working on certain purpose, we should consider the situation as 2nd order cybernetics. It is this point of view that is suggested in the present study in order to improve system's sustainable development/growth.

2 Methodology

For establishing the proposed new scheme of 2nd order Cybernetics to integrate the original and the complimentary Principles, we have developed a methodological framework under the form of the following algorithmic procedure, which includes 23 activity stages and 5 decision nodes (for their interconnection, see Fig. 2).

1. Description of the global/total system under consideration, as defined by the complementary Principle 'think locally, act globally'.
2. Decomposition into constituent subsystems representing quasi-autonomous entities at local level.
3. Examination of the initial/basic agreement and the recommended practices/guides/ standards issued for implementing this at

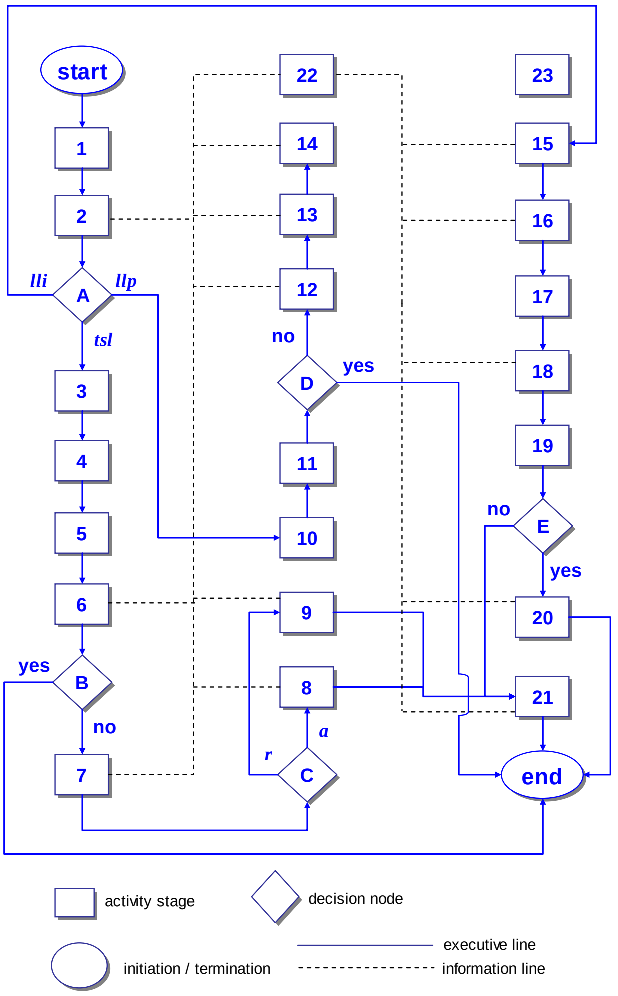

Figure 2. The methodological framework developed for suggesting a new scheme of 2nd order cybernetics to integrate the original Principle 'think globally, act locally' with its counterpart 'think locally, act globally'.

local level, according to the original Principle 'think globally, act locally'.

4. Registration and categorization of stakeholders who had contributed/pressed for signing the initial agreement at global level or its 'follow-up' papers at local level.
5. Examination of the procedures and their legal background.
6. Evaluation of results at local level.
7. Investigation of the causes of failure or deviation from target.
8. Proposals for supplementary agreement at global level and/or remedial action at local level (according to a bottom-up and/or a top-down approach, respectively).
9. Suggestion on a new cyclic scheme, according to 2nd order cybernetics.
10. Experimental design for estimating environmental degradation/damage at the predetermined site.
11. Performance of measurements.
12. Selection of the proper model of pollution transfer.
13. Determination of the polluting source by running the model, and identification by executing the respective measurements.
14. Confirmation of results under laboratory conditions, forecasting through accelerated testing, and suggestion of remedial proposals.
15. Mapping of pollution spatiotemporal distribution and its impact assessment.
16. Environmental cost estimation in monetary units.
17. Selection of cost sharing (between the stakeholders) methods.
18. Application of Experimental Economics techniques to estimate Willingness To Pay/ Accept (WTP/A), according to each environmental cost sharing model.
19. Negotiations for adopting a mutually accepted cost sharing scheme (see [1]).
20. Extension of negotiations results to form a permanent strategic plan for solving similar problems in the future, according to the original Principle 'think globally, act locally'.
21. Change of the rules valid so far by replacing them with a new agreement through a 'bottom-up' approach to be adopted by stakeholders, according to the complementary principle 'think locally, act globally'.
22. Development/operation/updating of an internal Knowledge Base (KB).
23. Searching in external KBs by means of an Intelligent Agent (IA), according to [2].

A. Is the examination taking place at total system level or at a pre-determined site (following a local level approach) or at the most negatively impacted (post-determined) point (denoted with *tsl*, *llp*, *lli* in Fig. 2, respectively)?
B. Are they satisfactory?
C. Is the failure due to flaws in the initial agreement or to false responses of stakeholders (denoted by *a* and *r* in Fig. 2, respectively)?
D. Are they satisfactory, according to pre-set limiting values?
E. Are these negotiations successful?

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3 Implementation

For implementing the main stages of the methodology described above, we use a case example of river pollution with wastewater containing organic load (e.g., a mixture of long-chain hydrocarbons). As a measure of environmental impact along a river representing the total system under consideration (denoted by *tsl* in decision node A in Fig. 2), we take the oxygen concentration deficit $F=C^*-C(X)$ that obtains its maximum value F_{max} at critical distance X_c downstream the discharge point (at X=0), according to the following pollution transfer model (see stage 12):

$$X_c = \frac{U}{k_2-(k_1+k_3)}\ln\left[\frac{k_2}{k_1+k_3}+\frac{k_2-(k_1+k_3)}{(k_1+k_3)L_0-L_a}\left(\frac{L_a}{k_1+k_3}-\frac{k_2F_0-S_R}{k_1}\right)\right]$$

where: $U=Q/A$, Q is the volumetric flow rate, $[L^3T^{-1}]$, A is the cross sectional area of the stream, $[L^3]$; X is the distance, downstream the point of wastewater discharge, [L]; k_2 is the re-aeration coefficient, $[T^{-1}]$; C^* is the dissolved-oxygen saturation concentration, $[ML^{-3}]$; k_1 is the deoxygenation constant, $[T^{-1}]$; S_R is the rate at which dissolved-oxygen concentration changes as a result of remaining sources and sinks in stream, $[ML^{-3}T^{-1}]$; k_3 is the rate constant for BOD removal through sedimentation and/or adsorption, $[T^{-1}]$; L_a is the rate of addition of BOD by local runoff or by re-suspension of organics from bottom sludge deposits, $[ML^{-3}T^{-1}]$; L_0 is the first-stage BOD at X=0, $[ML^{-3}]$; M, L, T, stand for the main dimensions Mass, Length, Time, respectively.

Evidently, any site along the river might be pre-determined (named *llp* in Fig, 2) for considering its environmental degradation while the *lli*-point coincides with X_c. The river users are the direct stakeholders while the habitants of the wider area are potential/indirect stakeholders. Each user should conform to the original Principle (as adapted for the case) 'think the whole river, act at the point you are discharging wastewater'. But for this thought to have a formal/legislative power, a consensus agreed *a priori* by the stakeholders should exist, as a result of exerting pressure through a 'bottom-up' approach, according to the complimentary Principle 'think locally, especially if you take water for agricultural or industrial use, act globally by supporting the health of the whole river/system, including the respective catchments and the corresponding network of streams'.

The formal consensus should include the cost sharing scheme quoted in stages 19, 20, together with provision to arbitrate, so that disagreements can be settled within an *a priori* accepted mode. The Precautionary Principle might apply in such situations, dictating that if an activity has a potential risk of causing harm to the environment, in absence of scientific confirmation that this activity is harmful, the 'burden of proof' that it is not actually harmful falls on those exerting the activity. This means that if the river user discharging wastewater at X=0 and causing maximum deficit at $X=X_c$ cannot prove that his activity is harmless, then he has to decrease the polluting load in order to meet a well recognized environmental standard (Fig. 3).

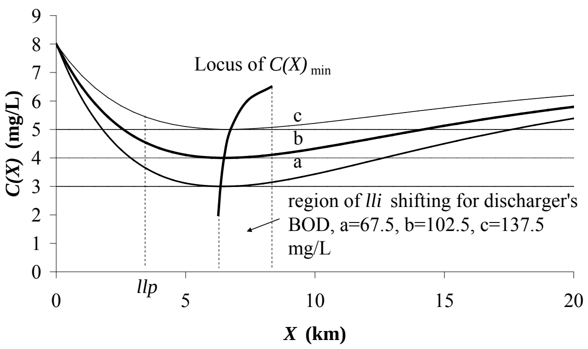

Figure 3. Dependence of oxygen concentration C(X) on distance X downstream the point of wastewater discharge in the river. In case that (i) the user cannot prove that his activity is harmless, and/or (ii) the environmental standards become stricter, he should decrease the loading index (e.g., BOD or COD).

3 Discussion and Conclusion

We can introduce additional factors to investigate the behavior of the system under investigation by setting Centralization Degree, C, as the independent variable and determining C_{opt} at $(B_1+B_2)_{max}$, where the partial benefits $B_1(C)$ and $B_2(C)$ represent coordination achievement and development of skills/capabilities, respectively. B_1 is an increasing function of C while B_2 is a decreasing function of C for the reasons quoted/explained in the Introduction section. In the time course, the coordination requirements generate excessive bureaucracy, pushing the B_1 curve downwards to its new position B'_1 with lower slopes (i.e., $dB_1/dC>0$, $d^2B_1/dC^2<0$), since the impact is more expressed in the region of higher C-values; as a result, C_{opt} is shifting to C'_{opt}, where $C'_{opt}<C_{opt}$ (Fig. 4a). In the same time course, there is an accumulation of empirical knowledge through 'learning by doing' which will move the B_2-curve upwards to its new position B'_2 with higher

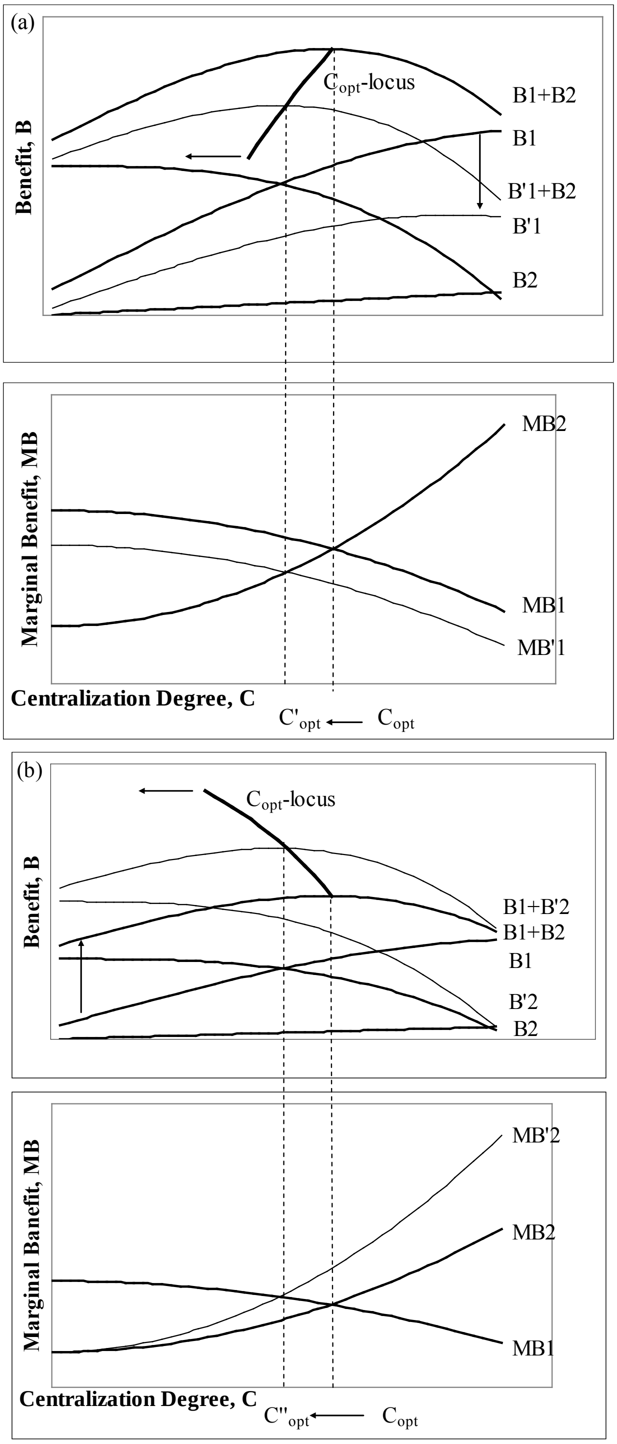

Figure 4. Dependence of partial benefits B_1 and B_2 on Centralization degree C and shifting of C_{opt} in the time course when (a) the coordination requirements generate excessive bureaucracy and (b) empirical knowledge is accumulated through 'learning by doing'; in each case, the locus of C_{opt} is shown.

slopes, since the impact is more expressed in the region at lower C-values; as a result, C_{opt} is shifting to C''_{opt}, where $C''_{opt}<C_{opt}$ (Fig. 4b). As a matter of fact, the vectors (C_{opt} - C'_{opt}) and (C_{opt} - C''_{opt}) have the same direction which coincides with the direction of the vectors shown in Fig.1, since centralization is the opposite of decentralization. Nevertheless, centralization does not take place in the same domain with the previously observed (and acting as a cause) decentralization, so that the expected cyclic process (see Introduction) corresponds to the projection of a spiral path on the basic plane. Consequently, this path represents the progress made by successive decentralization/ centralization stages in the considered time course.

Transferable Discharge Permit programs in water quality management may also produce environmental benefit, which closely achieves the same benefit through a command-and-control approach with comparatively lower costs [3]. The main question arisen in such a case is whether citizens should lobby the government to reduce pollution permit endowments or should they participate directly in the market by purchasing and retiring permits. Malueg and Yates [4] have addressed this question in a two-stage model: in the first stage firms and citizens may exert effort to influence the endowment of permits while in the second stage firms and probably citizens may participate in the permit market; even when citizens choose not to purchase permits, the possibility of doing so may affect the equilibrium.

It is worthwhile noting that the inverse problem, i.e., determining the wastewater treatment facility (installed at X=0) characteristics can be achieved by introducing stochastic/fuzzy methods as described in [5-8]. A more complicate situation may appear when the river crosses the borders between two countries, because of different legislation and asymmetric rights/information [9, 10].

In conclusion, we have proved the functionality of the methodological framework we developed for establishing a new scheme of 2nd order Cybernetics to integrate the Principle 'think globally, act locally', by analyzing a case example on river pollution. The counterpart of integration, namely 'think locally, act globally', provides the necessary basis for enabling cyclicity, a common characteristic of every cybernetic model due to feedback looping. The interplay between decentralization and centralization, which forms the theoretical background of the integrated Principles, also supports this functionality offering grounds for further applications.

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